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EXECUTIVE SUMMARY

BACKGROUND AND PROJECT DESCRIPTION

Eskom Holdings (SOC) Limited has applied, in accordance with the regulations R.927 (regulations on licensing of sites for new nuclear installations), for a nuclear installation site licence (NISL) for the Thyspunt site. The purpose of the NISL application is to licence Thyspunt as a nuclear site for a new nuclear installation(s).

The NISL application is equivalent to an early site permit (ESP) application (Safety Evaluation Report review leg) in the United States, through which a site may be licensed, independent of a specific nuclear power plant design, as suitable for the construction and operation of a nuclear power plant.

This Public Information Document (PID) serves to provide members of the public with information on the analyses and assessments that support the Eskom NISL application.

The specifics of the nuclear installation design does not form part of the NISL application. It is Eskom's plan to subsequently apply for nuclear installation licences to construct and operate multiple nuclear installations on the site, at which time Eskom will be required to provide detail on the installation's design and layout. However, to show compliance with NNR requirements, on among others, radiological dose and risk, preliminary design and operation information was used in the Thyspunt Site Safety Report (TSSR). Since the TSSR is based on site-specific data in conjunction with preliminary enveloping data on the proposed nuclear installation, the conclusions of the TSSR will be confirmed by definitive safety analyses performed in support of the application for subsequent nuclear installation licences.

SITE DESCRIPTION

The Thyspunt site is located on the South African south coast approximately 4 km east of Oyster Bay, 12 km west of St. Francis Bay and 17,3 km south of Humansdorp (distances measured from the site centroid to the nearest town boundary).

There are no highways that traverse the site. The main access road to the site is by an unsurfaced secondary road to Oyster Bay. An alternative route is via an unsurfaced branch road from the tarred R330 road from Humansdorp to St. Francis Bay.

The airfields in the region are predominantly small civil airfields and emergency landing strips located on farms. Most are unregistered facilities used for private purposes with no structures or buildings. The Port Elizabeth International Airport, located 85 km to the east of the site is the nearest major airport to the site. There are no military facilities within 80 km of the site.

There are no railway lines that traverse the site.

The Port Elizabeth and Ngqura (Coega) harbours, located beyond 80 km from the site, are the largest commercial harbours in the broader region. A small craft harbour at Cape St. Francis, located 13,9 km to the east, consists of a breakwater with an inside basin for commercial fishing vessels, with mooring at concrete jetties and a section with a slipway facility for small recreational vessels.

SAFETY JUSTIFICATION

The Thyspunt site has been extensively investigated with regard to all the site characteristics that could have an impact of the safety on the proposed nuclear installation(s). In addition, the potential impact of radiological events in normal operational states and in accident conditions was also evaluated.

Appropriate methods following international codes and standards and safety were adopted and applied throughout, for example, a state-of-the-art methodology, the senior seismic hazard analysis committee (SSHAC) Level 3 approach was followed to determine the seismic hazard for the site.

Based on the studies performed it is concluded that the natural and human-induced external events associated with the Thyspunt site does not preclude the site from the establishment of a nuclear installation. External events were either:

- Screened out from being considered further as a design bases;
- Screened out conditionally on the basis that the status be confirmed when the specific design is selected; or
- Will be compensated for by means of:
  - Design features of the envisaged nuclear installation; or
  - Site protection measures.

In the evaluation of the site to determine its potential radiological impact on the region for normal operational states and accident conditions, appropriate estimates of expected or potential releases of radioactive material were derived, with account taken of the enveloping characteristics of proposed facilities to be constructed on the site and its safety features.

The direct and indirect pathways by which radioactive material could reach and affect people and the environment were investigated and evaluated, taking into account specific regional and site characteristics.

The radiological dose assessment indicates that the annual effective dose to the hypothetical critical group associated with normal operation and minor occurrences is less than 72 μSv/a. This confirms that the site is suitable to locate a new nuclear installation(s) and that the annual dose to the public will be within the National Nuclear Regulator dose constraint requirement of 250 μSv/a.

The assessment of emergency preparedness and response concluded that there are no significant impediments that could affect the feasibility of developing and implementing an emergency plan. Furthermore, to ensure the viability of the site and the feasibility of developing an emergency plan, it is recommended that regulatory control and/or monitoring of development within the emergency planning zones surrounding the site be implemented.

CONCLUSION

Detail on the analyses and assessments performed to assess the suitability of the Thyspunt site are documented in the Thyspunt Site Safety Report. The comprehensive nature of the studies and the diligence with which they were performed forms the justification for Eskom's NISL application. Care was taken to ensure that all hazards that could result in ionising radiation have been identified and that their associated radiological impact can be kept as low as reasonably achievable. It can therefore be concluded that:

- The radiological dose to the public will be acceptably low and within regulatory limits.
- No significant impediments to the development of an emergency plan have been identified.
- All identified hazards were assessed and either screened out or can be dealt with in the nuclear installation(s) design.
- Adequate security measures can be put in place.
- No anomalous or critical data or trends were detected.

CONTENTS

FIGURES

TABLES

ABBREVIATIONS AND ACRONYMS

Abbreviation / Acronym	Description
AADQ	Annual Allowable Discharge Quantity
AC	Alternating Current
ADS	Automatic Depressurisation System
ALARA	As Low As Reasonably Achievable
APC	Airplane Crash
ASME	American Society of Mechanical Engineers
BLEVE	Boiling Liquid Expanding Vapour Explosion
CAA	Civil Aviation Authority
CCWS	Component Cooling Water System
CED	Committed Effective Dose
CFR	Code of Federal Regulations
CHRS	Containment Heat Removal System
CISF	Central Interim Storage Facility
COL	Combined Operating Licence
CP	Construction Permit
CSS	Containment Spray System
CVCS	Chemical and Volume Control System
DSA	Deterministic Safety Analysis
EA	Environmental Authorisation
EAD	Environment Agency – Abu Dhabi
EFWS	Emergency Feed Water System
EIA	Environmental Impact Assessment
EIR	Environmental Impact Report
ENEC	Emirates Nuclear Energy Corporation
EP	Emergency Planning
EPD	Electronic Personal Dosimeter (EPD)
EPR	European Pressurised Water Reactor
EPRI	Electric Power Research Institute
EPZ	Emergency Planning Zone
ESP	Early Site Permit
EUR	European Utility Requirements
EZ	Exclusion Zone
FANR	Federal Authority for Nuclear Regulation

Abbreviation / Acronym	Description
FAR	Federal Aviation Regulatory
FB	Fuel Building
FPCPS	Fuel Pool Cooling and Purification System
GAL	Generic Action Level
GIL	Generic Intervention Level
GMC	Ground Motion Characterisation
GMRS	Ground Motion Response Spectrum
GWh	Gigawatt hour
HLW	High Level Waste (Heat generating radioactive waste with high long- and short-lived radionuclide concentration)
HV	High Voltage
HVAC	Heat, Ventilation, and Air Conditioning
I&C	Instrumentation and Control (System)
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
IDLH	Immediately Dangerous to Life or Health
ILW	Intermediate Level Waste
INSAG	International Nuclear Safety Advisory Group
IRP	Integrated Resource Plan
IRWST	In-Containment Refuelling Water Storage Tank
ISI	In-Service Inspection
ISO	International Organisation for Standardisation
IST	In-Service Testing
JPC	Joint Planning Committee
kA	Kiloampere
KNPS	Koeberg Nuclear Power Station
kV	Kilovolt
LCR	Licence Change Request
LFL	Lower Flammable Limit
LLW	Low Level Waste
LNT	Linear No-Threshold Model
LOCA	Loss of Coolant Accident
LOOP	Loss Of Offsite Power
LPZ	Long-Term Protective Action Zone
LRF	Large Release Fraction

Abbreviation / Acronym	Description
LWR	Light Water Reactor
MeV	Mega electron Volts
MOX	Mixed Oxide
mSv	Millisievert
MTU	Megaton of Uranium
MW	Megawatt
MWe	Megawatt (electrical)
MWh	Megawatt hour
MWth	Megawatt (thermal)
NAB	Nuclear Auxiliary Building
NECSA	The South African Nuclear Energy Corporation
NEMA	National Environmental Management Act
NISL	Nuclear Installation Site Licence
NKP	National Key Point
NIL	Nuclear Installation Licence
NM	Nautical Miles
NNR	National Nuclear Regulator
NPP	Nuclear Power Plant
NPS	Nuclear Power Station
OSP	Operational Support Development Programme
OTS	Operating Technical Specifications
PCCS	Passive Containment Cooling System
PEIA	Port Elizabeth International Airport
PID	Public Information Document
PP	Position Paper
PPE	Plant Parameter Envelope
PRA	Probabilistic Risk Assessment
PSA	Probabilistic Safety Assessment
PSHA	Probabilistic Seismic Hazard Analysis
PSM	Power Station Manager
PWR	Pressurised Water Reactor
QRA	Quantitative Risk Assessment
RAP	Representative Animal and Plant
RB	Reactor Building
RCCA	Rod Cluster Control Assembly

Abbreviation / Acronym	Description
RCP	Reactor Coolant Pump
RCS	Reactor Coolant System
RD	Regulatory Requirements Documents
RF	Radio Frequency
RG	Regulatory Guide
RP	Radiation Protection
RPC	Radiation Protection Certificate
RPP	Radiation Protection Programme
SAB	Safeguard Auxiliary Building
SABS	South African Bureau of Standards
SAMSA	South African Maritime Safety Authority
SANS	South African National Standards
SAR	Safety Analysis Report
SBO	Station Blackout
SC	Safety Case
SG	Steam Generator
SIS	Safety Injection System
SSA	State Security Agency
SSHAC	Senior Seismic Hazard Analysis Committee
SSR	Site Safety Report
STP	Sewerage Treatment Plant
TCA	Terminal Control Area
TEDE	Total Effective Dose Equivalent
TLD	Thermoluminescent Detector
TMI	Three Mile Island
TRITON	Transport Rigor Implemented with Time-Dependent Operation for Neutronic Depletion.
TSSR	Thyspunt Site Safety Report
UAE	United Arab Emirates
UFP	Used Fuel Pool
USA	United States of America
USNRC	United States Nuclear Regulatory Commission
UV	Ultraviolet
VEGP	Vogtle Electric Generating Plant
W-C	Wolff-Chaikoff
WHO	World Health Organisation

COMPOUND SYMBOLS

Compound	Description
KI	Potassium Iodide
KIO_3	Potassium Iodate
NIS	Sodium-iodide symporter
CO_2	Carbon dioxide
UO_2	Uranium dioxide

DEFINITIONS

Term	Definition
Burn-up	The total heat energy extracted per unit weight of fuel, preferably expressed in Megawatt-hour per kilogram of Uranium (MWh/kgU) or Megawatt-day per megaton of uranium (MWD/MTU). (Note: MWh is thermal energy not electrical energy.)
Committed effective dose (CED)	The quantity $E(\tau)$ is defined as: $E(\tau) = \sum_T w_T \times H_T(\tau)$ .... Eqn 1 Where: $H_T(\tau)$ is is the committed equivalent dose to tissue or organ T over the integrated time τ that elapsed after an intake of radioactive substance. W_T is the tissue weighting factor for tissue or organ T. When τ is not specified it is taken to be 50 years for adults and the duration of intake for children to be 70 years.
Constraint	A prospective and source related value of individual dose (dose constraint) or of individual risk (risk constraint) that is used in planned exposure situations as a parameter for the optimization of protection and safety for the source, and that serves as a boundary in defining the range of options in optimization. i) For occupational exposure, a constraint on individual dose to workers established and used by registrants and licensees to set the range of options in optimizing protection and safety for the source. ii) For public exposure, the dose constraint is a source related value established or approved by the government or the regulatory body, with account taken of the doses from planned operations of all sources under control. iii) The dose constraint for each particular source is intended, among other things, to ensure that the sum of doses from planned operations for all sources under control remains within the dose limit. iv) For medical exposure, the dose constraint is a source related value used in optimizing the protection of carers and comforters of patients undergoing radiological procedures, and the protection of volunteers subject to exposure as part of a programme of biomedical research. v) The risk constraint is a source related value that provides a basic level of protection for the individuals most at risk from a source. This risk is a function of the probability of an

Term	Definition
	unintended event causing a dose and the probability of the detriment due to such a dose. Risk constraints correspond to dose constraints but apply to potential exposure.
Dose	A measure of the energy deposited by radiation in a target.
Effective dose	The quantity E, which defined as a summation of the tissue or organ equivalent doses, each multiplied by the appropriate tissue weighting factor: $E = \sum_T w_T \times H_T$ ....Eqn 2 Where: H_T is the equivalent dose in tissue or organ T and, w_T is the tissue weighting for tissue or organ T.
Enrichment	Any process that artificially increases the fraction of U-235 in a mixture of Uranium Isotopes to levels higher than what is found in nature, given that in nature U-238 constitutes about 99,274% and U-235 about 0,720%. There are other isotopes such as U-234 and U-236, but these only make up a small fraction e.g. U-234 only constitutes 0,005%. The balance is made up of U-232, U-233, and U-236.
Irradiated fuel	Nuclear fuel that has been exposed to neutron radiation in a nuclear reactor, but not necessarily to design burnup.
Nuclear fission	Nuclear fission occurs when a nucleus of an atom breaks into two or more nuclei.
Nuclear installation site licence (NISL)	A nuclear authorisation for a nuclear site that is earmarked for the siting, construction, and operation of one or multiple nuclear facilities. Individual nuclear licences are required for each nuclear facility being constructed on the nuclear site.
Probability	The likelihood of an event occurring.
Probabilistic risk assessment (PRA)	A qualitative and quantitative assessment of the risk associated with plant or facility operation and maintenance that is measured in terms of frequency of occurrence of risk metrics, such as release category frequency and its effects on the health of the public [also referred to as a probabilistic safety assessment (PSA) or quantitative risk assessment (QRA)].
Projected dose	The dose that would be expected to be received if planned protective actions were not taken.
Reference accident	A selected accident that envelops the set of accidents that can reasonably be foreseen in the safety analysis (refer to RG-0011).
Reference animal or plant (RAP)	A hypothetical entity with the assumed basic biological characteristics of a particular type of animal or plant (as described to the generality of the taxonomic level of family) with defined anatomical, physiological and life history properties. A RAP can be used for the purposes of relating exposure to dose and dose to effects, for that type of living organism.
Representative person	An individual, who will almost always be a hypothetical construct, receives a dose that is representative of the more highly exposed individuals in the population. The representative person is equivalent to, and replaces, the average number of the critical group.

Term	Definition
Risk	Refers to the frequency and consequences of an event, as expressed by the "risk triplet" that answers the following three questions: • *What* can go wrong? • How *likely* is it? And • What are the *consequences* if it occurs?
Spent or used fuel	Nuclear fuel that has been irradiated in a nuclear reactor to the point where the fuel is no longer useful in sustaining a nuclear reaction. The fuel is removed from the reactor core and stored underwater in storage racks in spent fuel pools.
Stochastic effects	Those effects for which the probability of occurrence increases with dose, for which there is no threshold where they will occur.
Source term	The fractions defining the portion of the radionuclide inventory in the reactor at the start of an accident that is released to the environment. Also included in the source term are the initial elevation, energy, and timing of the release.

1 PURPOSE AND SCOPE

The purpose of this document is to provide members of the public with information regarding the nature of the nuclear installation site licence (NISL) application for the Thyspunt site. The document provides a broad overview of the project, a description of the hazards that could result from exposure to ionising radiation, high level detail on the technology type that could be located on the site, site specific parameters considered in characterising the site, a description of the site and justification for its suitability, supporting safety case elements, an assessment of the feasibility of developing and implementing an emergency plan, information regarding waste management and decommissioning, a description of transport actions and provisions for safe transport of radioactive material.

A NISL application is limited to the evaluation of the suitability of a site for new nuclear installations and this is done in accordance with regulations on licensing of sites for new nuclear installations (Regulation R.927). The process makes provision for the applicant to request authorisation in the absence of a specific design selection by considering an envelope of nuclear installation that are most likely to be located at the site (also known as the Plant Parameter Envelope approach). This approach is used to provide finality on siting issues upfront where a decision on a specific reactor design is still outstanding. As part of the application, compliance must be demonstrated to the NNR that the relevant siting factors have been appropriately characterised and assessed to address safety issues and that the risk to the public from all nuclear installations will be as low as reasonably achievable (ALARA).

A nuclear installation licence (NIL) represents the primary authorisation for the construction, operation, maintenance, decontamination, and decommissioning of the nuclear installation based on a specific design. The associated PID for a specific NIL application will be developed once an application for an NIL is made.

2 BACKGROUND

In many countries, including South Africa, economic growth and social needs are resulting in substantially greater energy demands, in spite of accelerated energy efficiency advancements. As a result, the increase in demand for power must be met by installing new capacity. Eskom is South Africa's primary power producer and supplier.

Eskom has applied for an NISL in accordance with the nuclear energy policy of 2008, which requires the owner and operator of nuclear plants, to ensure that sites to build future nuclear plants on are available, secured, protected and authorised before development pressures makes them unsuitable or create major safety and emergency planning difficulties.

This NISL application is a precursor for an NIL to construct and operate a nuclear power station at the Thyspunt site.

2.1 SIMILAR NUCLEAR SITING PROJECTS WORLDWIDE

Siting of a nuclear installation is a crucial process since it can significantly affect the costs, public acceptance, and safety of the installation over its operating lifetime.

The nuclear siting process is a well-defined process. Various countries which have embarked on siting processes, take guidance from publications by the International Atomic Energy (IAEA) such as IAEA's SSG-35 (*Site Survey and Selection*), NG-T-3.7 (*Managing Siting Activities for Nuclear Power Plants*), SSR-1 (Site Evaluation for Nuclear Installations), the Electric Power Research Institute's (EPRI) siting guide and the United States Nuclear Regulatory Commission's (USNRC) 10 CFR Part 100; 10 CFR Part 51; 10 CFR Part 52, and others.

In terms of siting and site evaluation, these countries display similar approaches at a high level in terms of policy or process but vary considerably at the detail level. Site selection is approved by one means or another, though not always by the nuclear safety regulator and not always formally. Consideration of alternative sites is sometimes required.

Site evaluation and preparation activities are generally defined and controlled by the nuclear safety regulator. In general, site evaluation factors in IAEA SSR-1 are considered in all countries, though commonly through local interpretation. It is also common practice to perform an environmental assessment to address the impact of the power station on the surrounding area and the impact of the site and the surrounding area on the power station.

Two case studies, one for a brownfield site (an existing site with plant infrastructure) and one for a greenfield site (new site with no plant infrastructure) on the execution of siting projects worldwide, are discussed below.

2.1.1 Vogtle Electric Generating Plant (VEGP) Site (Brown Field)

The Southern Nuclear Operating Company, Inc. (Southern) submitted an application on 14 August 2006 for an early site permit (ESP), the equivalent to a nuclear installation site licence (NISL) in South Africa, to the USNRC for a site within the VEGP site, adjacent to the existing VEGP units 1 and 2 in accordance with the requirements of Title 10 of the Code of Federal Regulations, Part 52, (10 CFR 52) Subpart A, Early Site Permits. On 16 August 2007, a supplement to Southern's ESP application was made to the USNRC expanding the scope of the application to include a request for the approval to perform selected construction activities, generally labelled limited work authorisation. The Vogtle site ESP and limited work authorisation was issued by the USNRC on 26 August 2009.

The Vogtle site is located in Burke County, Georgia, approximately 42 km southeast of Augusta, Georgia. An ESP is a USNRC approval of a site for one or more nuclear power facilities and is separate from the filing of an application for a construction permit (CP) or combined licence (COL) for such a facility. The purpose of the ESP application was for the USNRC to determine whether the VEGP site is suitable for the proposed two new units (VEGP units 3 and 4) by resolving certain safety and environmental issues before Southern incurs the substantial additional time and expense of designing and seeking approval to construct such a facility at the site. Part 52 of CFR Title 10 describes an ESP as a "partial construction permit". An applicant for a CP or COL for a nuclear power plant(s) to be located at the site for which an ESP was issued can reference the ESP, thus eliminating the review of siting issues at that stage of the licensing process.

The review and approval of a site for the construction and operation of a nuclear power plant (NPP) is conducted by the USNRC with a focus on radiological safety; numerous approvals from other local, state, tribal, and federal agencies may also be needed.

Safety reviews for the ESP relate to site safety and emergency planning. Factors considered include:

- description of the site
- an assessment of the site features affecting facility design, including an analysis of major systems, structures and components that bear significantly on site acceptability;
- Physical characteristics of the site that might impede the development and implementation of a suitable emergency plan,
- seismic, meteorological, geological, and hydrological characteristics of the site

Site characterisation, vendor processes, and quality assurance are subject to the USNRC's inspection programme. A Site Safety Analysis Report taking into account Site Characteristics, is submitted as part of the ESP application for review and acceptance by the regulator.

An environmental review that complements the safety review discloses the physical, ecological, social, and radiological effects of constructing and operating the proposed facility at the proposed location.

2.1.2 Barakah Nuclear Power Plant site (Green Field)

In the United Arab Emirates (UAE), the Federal Authority for Nuclear Regulation (FANR) regulates the selection of sites and site preparation for nuclear activities. The UAE Federal Law by Decree No. 6 of 2009 gives FANR authority to regulate the “Nuclear Sector”. Article (25) describes the selection of a site, preparation of a site, and construction of nuclear facility as regulated activities for which a licence is required from FANR.

The FANR regulations for the siting include:

- FANR Reg-01: Management Systems for Nuclear Facilities;
- FANR Reg-02: Siting of Nuclear Facilities.

Once the site has been assessed, the operator requires a further licence to prepare the selected site. Once the licence is issued to the operator, the regulator will oversee the site preparation.

In February 2010, a site selection licence was issued by the Federal Authority for Nuclear Regulation (FANR) to the Emirates Nuclear Energy Corporation (ENEC). This licence authorised ENEC to select a site. The site selection licence authorised the following activities:

- Regional analysis and identification of potential sites;
- Screening of potential sites and identification of candidate sites;
- Evaluation of candidate sites so as to characterise fully the site specific conditions pertinent to the safety and security of a nuclear facility.

The selection process was executed in adherence to best practices and standards from the FANR, the EPRI, the USNRC, and the IAEA.

Barakah site, situated at Barakah in the Al Dhafra region of Abu Dhabi, approximately 5 km west-southwest of the city of Ruwais, was selected as the site for the UAE’s first nuclear power plant (NPP) following a comprehensive analysis that lasted 12 months and involved the evaluation of multiple locations across the UAE, while considering the following factors:

- History of seismic activity;
- Distance from large population centres;
- Proximity to large supplies of water;
- Proximity to existing electrical power;
- Proximity to infrastructure;
- Favourable construction, security, and evacuation route conditions;
- Environmental considerations.

Following the selection process, site characterisation studies for the two highest ranked sites, of which Barakah was one, were performed. These activities included the following:

- **Field investigations**: An onshore boring programme provided geotechnical and geo-hydrological information to identify and mitigate ground risks, while an offshore boring programme provided onshore and offshore geophysics and geotechnical measurements, oceanographic bathymetric survey, and a laboratory programme findings according to the USNRC, Regulatory Guide 1.138.
- **Data collection**: Monitoring well networks and ongoing (monthly) measurements, water quality sampling (ground- and seawater), sediment and soil sampling, robust baseline marine and terrestrial baseline surveys (seasonal).
- **Geography and demography**: Describing the location and boundaries of the site, the site exclusion area, and the distribution of the population within 80 km of the site, including projections for the duration of the operating licence.
- **Nearby industrial, transportation, and military facilities**: Describing the nature of relevant facilities within 8 km of the site, descriptions of potentially hazardous materials stored or transported, and an evaluation of potential accidents at the facilities, including air transport.
- **Meteorology**: Describing the regional, local, and onsite meteorological conditions including several years of onsite meteorological data collection taken from a mast with data collection instruments at 10-metre and 20-metre altitudes.
- **Hydrological engineering**: Describing the local surface water and groundwater hydrology, including normal and extreme conditions; extensive field studies including the installation of surface water and groundwater monitoring systems, data collection, and modelling; coastal flooding analysis (i.e. tsunami, storm surge, winds); wind-wave effects; wave run-up analysis; and evaluating dispersion of radioactive materials through surface and groundwater. The results of these analysis provided hazard data and projections as input to the determination of a safe and conservative site grade elevation.
- **Geology, seismology, and geotechnical**: Investigations were conducted to describe the site geological setting and perform a detailed evaluation of the seismic conditions, including a probabilistic seismic hazard analysis (PSHA), which potentially affects the design of foundations and structures. An extensive field work programme (borings, geophysical testing, and laboratory testing) and analysis was required to support siting of the plant and its related safety structures and components.
- **Strategic environmental assessment / environmental impact assessment (EIA)**: Oceanography studies were conducted (i.e. effluent and thermal dispersion and recirculation) and completed in accordance with the USNRC, UAE, and EIA preparation requirements. Complete baseline studies of the terrestrial environment were completed, including seasonal surveys.

All work was completed in accordance with a quality assurance programme in compliance with 10 CFR 50, Appendix B, and American Society of Mechanical Engineers (ASME) NQA-1-1994.

Following FANR's review of ENEC's submission in support of a licence for the preparation of a site for the construction of a nuclear facility, FANR and the environment agency Abu Dhabi (EAD), issued a site preparation licence to ENEC in July 2010. This licence allowed ENEC to start the installation of site infrastructure not directly related to the nuclear reactors, such as roads, telecommunication networks, and site administration buildings. After issuance of this licence, FANR performed oversight over the site preparation activities.

3 APPLICANT INFORMATION

The applicant's full name	Eskom Holdings SOC Limited
Physical address	Megawatt Park Maxwell Drive Sunninghill 2157
Company registration number	2002/015527/30
Date of incorporation	2002
Registered address	P.O. Box 1091, Johannesburg, 2000
The address of the proposed nuclear installation	The site is situated in the Eastern Cape between the towns of Humansdorp (north 17,3 km), St. Francis Bay (12 km east) and Oyster Bay (4 km west), bounded to the south by the Indian Ocean, with the site centroid having the following coordinates: X (m): –27522,999806; Y (m): –3784463; Latitude: 34°10'60″ S; Longitude: 24°43'00″ E. Because there is no site physical address, the GPS coordinates have been used.
Details of any holding or subsidiary companies	Eskom Holdings SOC Limited is wholly owned by the state.
Details of any foreign involvement or control of nuclear installation by foreign corporations/governments	N/A

4 PROJECT DESCRIPTION

4.1 PROPOSED PLANT

Eskom has not made a decision on the specific design of the reactor to be located at the Thyspunt site, however, a pressurised water reactor (PWR) technology (refer Figure 1) was chosen by Eskom as the reactor type to be used. A PWR uses light water as a coolant and moderator. Eskom has been using this type of a reactor safely for over 35 years at Koeberg Nuclear Power Station (KNPS) and is therefore familiar with this technology. The PWR technology used at KNPS was based on a design by Westinghouse of the USA and built by Framatome, a French company.

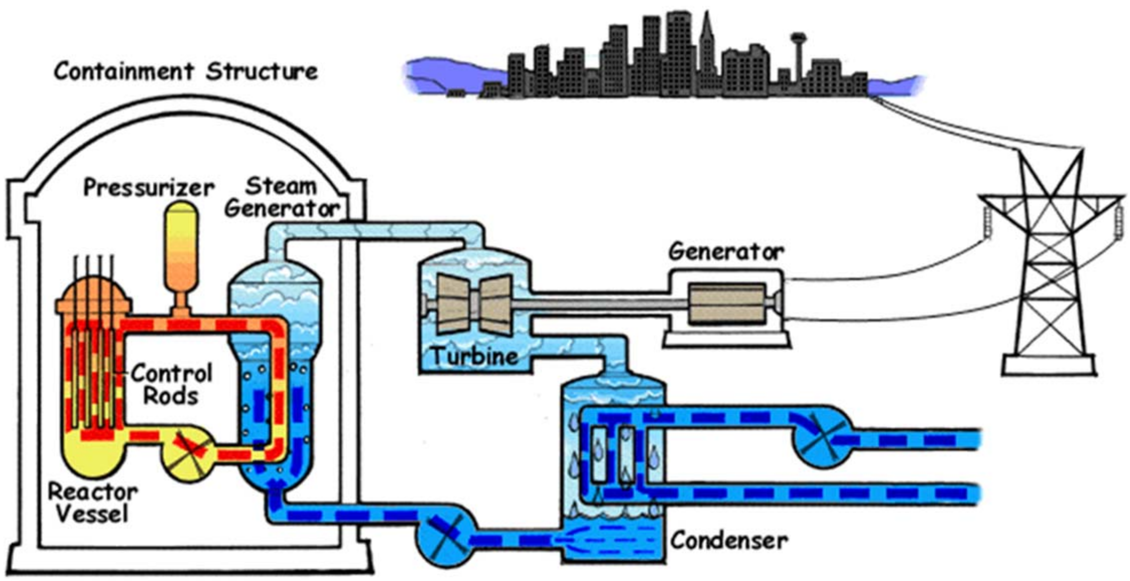

Figure 1: Typical pressurised water reactor schematic

A typical PWR is made up of a three-loop system in which the systems are separated from each other as shown in Figure 2 with minimal mixing between cooling water of adjacent systems.

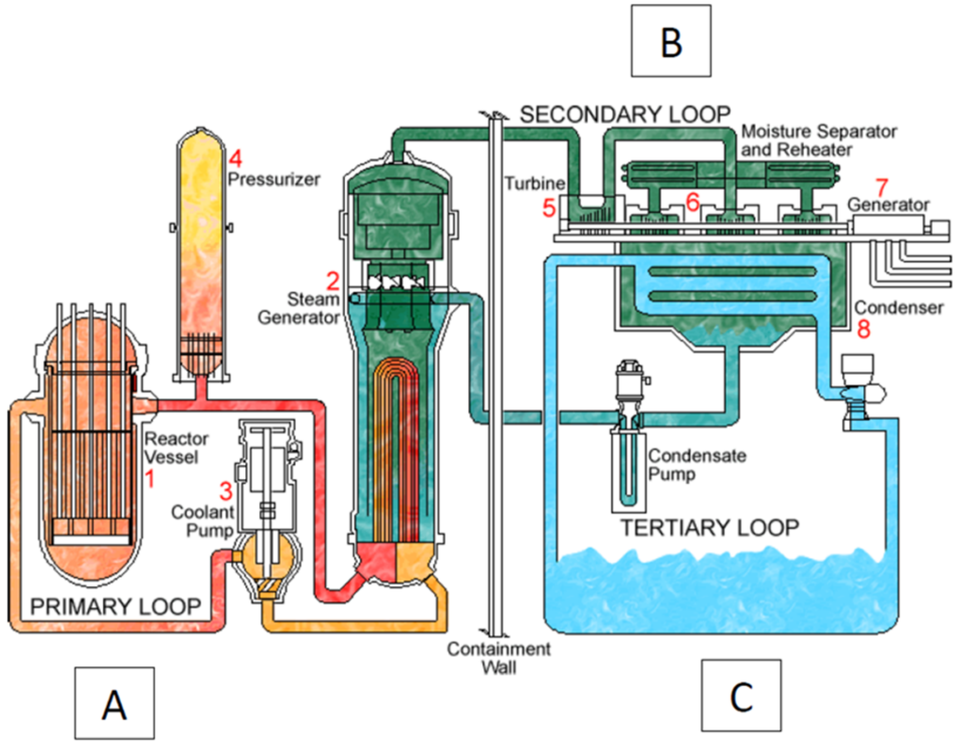

Figure 2: Configuration of the systems of the PWR

Each reactor unit comprises a nuclear island, a turbine island, water intake and discharge structures and, in some cases, a cooling tower. The main parts of the nuclear island are:

- the reactor building (RB), also referred to as the containment: contains the reactor and all the pressurised coolant loops as well as part of the loops and systems required for reactor operation and safety; is a leak tight, pressure retaining building that both retains radioactivity released by the core in the unlikely event of an accident and protects the reactor system from external events. During normal operation the RB is kept under a negative pressure.
- fuel building (FB), which houses the facilities for storing and handling new fuel (pending its loading into the reactor), and used fuel (coming out from the reactor)**Error! Reference source not found.**. The fuel building also contains the equipment for the fuel pool cooling and purification system (FPCPS) and, for units in operation, the equipment for the steam generator emergency feedwater system (EFWS),
- a safeguard auxiliary building (SAB) with electrical equipment rooms. These are split into four trains (divisions), depending on the technology, each containing a series of emergency systems with electrical support systems and each train geographically and functionally separate.
- The electrical equipment rooms contain all the means for controlling the unit (the control room and operations facilities, electric power supplies, and the instrumentation and control [I&C] system).

- a nuclear auxiliary building (NAB) housing the auxiliary systems required for normal reactor operation. This building houses the equipment of the chemical and volume control system (CVCS), the gaseous waste processing system, the reactor coolant effluent processing system, and the boron recycle system;
- two geographically separate buildings, each housing a diesel generator (emergency power supply).

Eskom has not decided on a preferred supplier for the nuclear build programme and therefore detailed descriptions of the proposed plant are not yet available. However, salient features of the design that Eskom may seek to procure when a decision is made to build a new nuclear installation, are:

- A standardised design for the type of plant to expedite licensing, reduce capital cost, and reduce construction time;
- A simple and robust design, making the plant easier to operate and less vulnerable to operational upsets;
- High availability and longer operating life than current operating reactors – typically in excess of 60 years;
- Reduced possibility of core melt accidents;
- Higher containment integrity;
- Minimal effect on the environment;
- Higher burn-up to optimise fuel use and reduce the amount of waste; and
- Burnable absorbers to extend fuel operating cycle.

These features are characteristic of current PWR technologies (also known as Generation 3 and 3+ designs).

4.2 GENERATION 3 / 3+ PWR DESIGNS

Generation 3 and 3+ reactors have utilised industry experience over the past few decades, and several improvements have been incorporated in their designs. These designs incorporate improved fuel technology, have superior thermal efficiency, significantly enhanced safety systems (including passive nuclear safety) and have standardised designs for reduced maintenance. All reactor types meeting the above requirements would be considered should the nuclear procurement be given the go-ahead in future. Generation 3 and 3+ designs currently understood to be in the market include (but are not limited to) the Westinghouse AP1000, Korean APR1400, Framatome's EPR and Rosatom's VVER1000. Key differences between these plants and the Koeberg Nuclear Power Station are given in Table 1 and a brief description of each technology is given below:

Table 1: Comparison of Key Characteristics of Known PWR Designs

Characteristic	**Koeberg (reference)**	**AP 1000**	**APR1400**	**EPR**	**VVER1200**
Developer	Framatome	Westinghouse/ Mitsubishi	Dosam (KHNP)	Framatome	Rosatom (ASE)
Core thermal power (MWth)	2 775	3 400	3 983	4 250	3 200
NSS thermal power (MWth)	2 790	3 415	4 000	4 500	3 212
Net electrical power output (MWe)	900	1 117	1 400	1 600 – 1 700	1 082
Plant efficiency (%)	32	35,6	35	37	34.5
Plant design life (years)	40	60	60	60	60
No of loops	3	2 hot legs/4 cold legs	4	4	4
Fuel assembly pin array	17x17	17x17 square	16x16 square	17x17 square	Hexagonal
No of fuel assemblies per core	157	157	241	241	163
Enrichment limits (%)	4,95	4,80	3,80	5 or MOX	4,69
No. of steam generators per reactor	3	2 with triangular pitch	2 with a triangular pitch	3 with a triangular pitch	4 corridor arrangement
Layout of steam generators	Vertical	Vertical	Vertical	Vertical	Horizontal
Reactor coolant pumps	3	4	4	4	4

4.2.1 AP1000

The AP1000 is an advanced passive PWR designed by Westinghouse Electric Company. It is a larger version of the AP600 design which was reviewed and certified by the US NRC in 2005 with the first AP1000 design beginning operations in China at Sanmen Nuclear Power Station in 2018.

It is a two loop plant with the reactor coolant system (RCS) consisting of two heat transfer circuits, each with a steam generator, two reactor coolant pumps installed directly onto the steam generator, hence eliminating piping between pumps and the steam generator, a single hot leg and two cold legs for circulating reactor coolant. A simplified support structure for the primary systems reduces in-service inspections and improves accessibility for maintenance.

The AP1000 has a severe accident mitigation goal which is to ensure the continued functioning of the containment in the event of an accident that results in significant structural degradation of the reactor core. Reactor safety functions are achieved using passive processes only, no active pumps, no alternating current (AC) power, cooling water, HVAC (heating, ventilation and air conditioning) and instrumentation and control (I&C).

Specific design features have been incorporated for the retention and stabilisation of the molten core inside the containment as well as for the mitigation of environmental effects that can compromise its fission product retention capability. These design features provide redundant and diverse mitigation of challenging phenomena in the unlikely event of a severe accident. These features include the reactor coolant automatic depressurisation system (ADS), the ability to flood the reactor vessel cavity, hydrogen igniters in the large dry containment, and the passive containment cooling system (PCCS). These design features act to maintain RCS integrity, prevent containment over-pressurisation from hydrogen detonation or deflagration, and remove heat from the containment. These mitigation features maintain a very low potential for fission product release from the AP1000 containment.

The AP1000 is designed with environmental consideration as a priority. The safety of the public, power plant workers, and the impact to the environment has been addressed as follows:

- Operational releases have been minimised by design features.
- Aggressive goals for worker radiation exposure have been set and satisfied.
- Total radioactive waste volumes have been minimised.
- Other hazardous waste (non-radioactive) has been minimised.

4.2.2 APR1400

The Advanced Power Reactor 1400 (APR1400) is a standard evolutionary advanced light water reactor developed by the Koreans in 2002. The design is based on the experience that has been accumulated through the development, construction, and operation of the OPR1000, Optimum Power Reactor 1000 MWe, the first standard pressurised water reactor plant in Korea.

APR1400 has several advanced features such as direct vessel injection from the safety injection system, passive flow regulation device in the safety injection tank, in-containment refuelling water supply system, advanced safety depressurisation system, and systems for severe accident mitigation and management. Another design improvement is the advanced main control room, designed with the consideration of human factors engineering, with full-digital I&C systems.

4.2.3 European Pressurised Reactor (EPR)

The EPR is a PWR designed by Framatome and EDF (France) and Siemens (Germany) with the first operational EPR unit commissioned in China (Taishan 1) in 2018.

It is a four-loop plant. Each loop is made up of a steam generator and a RCP, all connected to the reactor. The entire primary system has only one pressuriser connected to the hot leg of the reactor as shown in Figure 3.

The EPR safety design is based primarily on deterministic analyses complemented by probabilistic analyses. The deterministic approach is based on the defence-in-depth concept, which comprises four levels, the objectives of which are:

- To compensate for potential human and component failures;
- To maintain the effectiveness of the barriers by averting damage to the plant and to the barriers themselves;
- To protect the public and the environment from harm in the event that these barriers are not fully effective.

Thus based on this, the top priority of the defence-in-depth principle is prevention of accidents, and if this fails, to limit their potential consequences and prevent any evolution to a more serious condition. It uses active safety systems (such as AC power) to protect the plant.

The overall mean large release fraction (LRF) of radioactive materials released to the environment from a core damage event will be less than 10^{-6}/reactor-year. Some of the most important safety features of the EPR as illustrated in Figure 4.

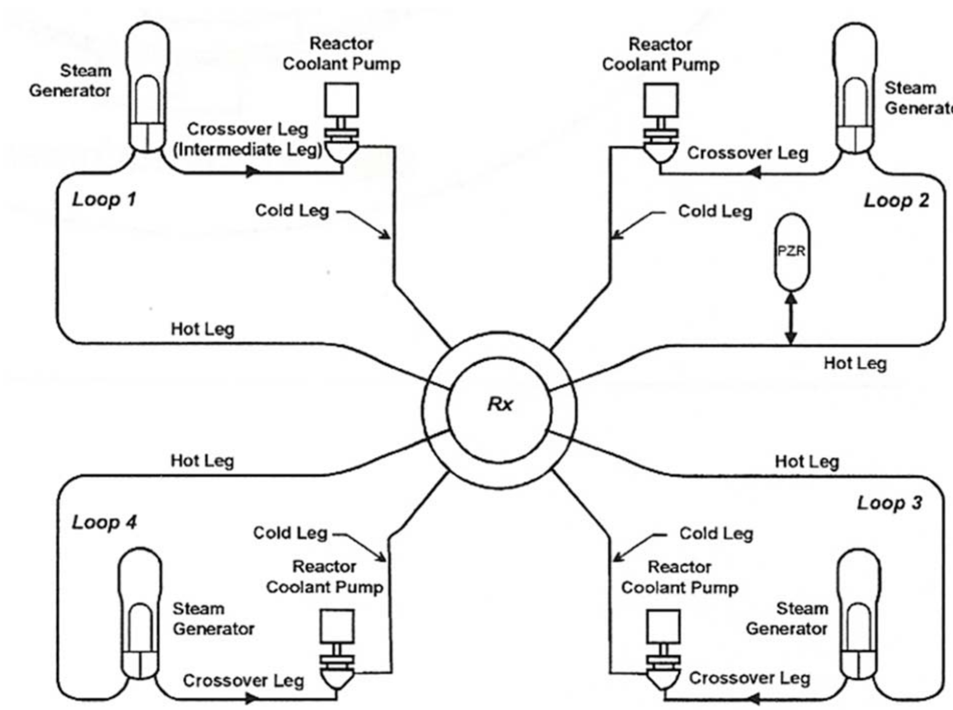

Figure 3: Illustration of generic arrangement of SSCs in a four-loop nuclear plant

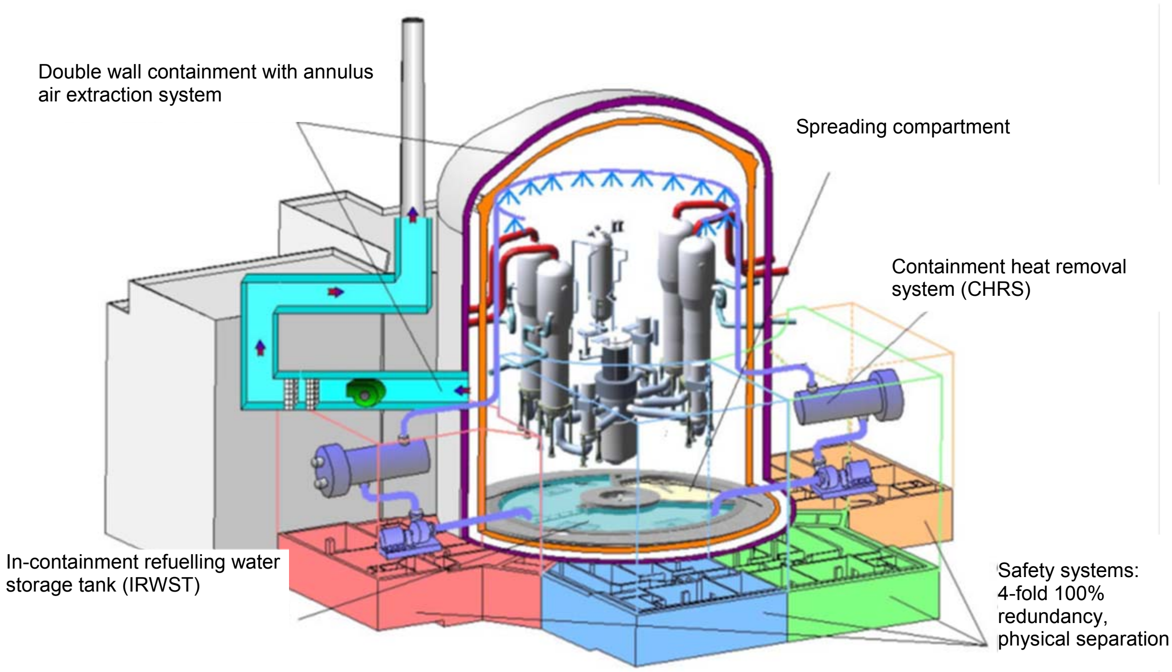

Figure 4: Main safety features of an EPR PR

4.2.4 VVER1200

The VVER-1200 (AES-2006) is a standardized Russian nuclear power plant design that satisfies Generation 3+ design features and strives to attain up-to-date safety and reliability characteristics with the optimization of construction costs. VVER stands for 'water-water energy reactor' (i.e. water-cooled water-moderated energy reactor). VVERs are mostly installed in Russia but also in China, Finland, Germany, Slovakia, Bulgaria, India, and Iran.

The main distinguishing features of the VVER compared to other PWRs are:

- Horizontal steam generators
- Hexagonal fuel assemblies
- No bottom penetrations in the pressure vessel
- High-capacity pressurisers providing a large reactor coolant inventory.

The water in the primary circuits is kept under a constant elevated pressure to avoid its boiling. Since the water transfers all the heat from the core and is irradiated, the integrity of this circuit is crucial.

To provide for the continued cooling of the reactor core in emergency situations the primary cooling is designed with redundancy.

4.3 ELECTRICITY GENERATION FROM NUCLEAR POWER PLANTS

4.3.1 Nuclear fission

Nuclear power relies on low enriched uranium and/or mixed oxide (MOX) as a source of fuel to produce heat. The heat generated during nuclear reactions result from a process called 'fission'. Fission entails the splitting of nuclei of atoms by smaller particles, called neutrons. When a relatively large fissile atomic nucleus is struck by a neutron, it splits into two or more smaller nuclei as fission products and emits particles and ionising photons in the process. Thereafter the free neutrons trigger further fission and the fission process continues in a chain reaction. The splitting of the atoms and the subsequent release of energy is called nuclear fission.

The process is controlled within the reactor and the energy released heats up water excessively. To prevent the temperature from increasing beyond the limits it can withstand, cooling water is circulated through the primary system to maintain the temperature within design limits. The hot water leaves the reactor through the hot leg of the reactor and flows into the steam generator (SG) and exits the SG through the cross-over leg of the SG into the inlet of the reactor coolant pump (RCP) and is then pumped back into the reactor via the cold leg of the reactor. In the case where the loop has a pressuriser as in loop 2 of Figure 3, the hot water will leave the reactor via the hot leg and pass through the pressuriser and into the SG, and exit the SG via the cross-over leg of the SG. From there, the water is pumped back into the reactor by the RCP via the cold leg, where it is heated up again by the energy released from the nuclear fission process.

In the process, heat is transferred between the primary and the secondary systems, and in the secondary system, water is heated even further and converted into steam. This steam is then used to drive the turbine which in turn drives the generator which generates (produces) electricity.

The PWR technology generally operates using three separate water systems. The purpose of separating the three systems is to ensure that the water from the primary system, which is radioactive and in a closed system, does not leak into secondary systems and therefore should not contaminate the water in these systems. KNPS uses a three-loop system (primary loop, secondary loop, and tertiary loop). The primary loop is kept under pressure by a pressuriser hence the name pressurised water reactor.

4.3.2 Radioactive material to be used

A nuclear reactor produces and controls the release of energy through a fission process (i.e. splitting of atoms) using Uranium-235 (U-235) isotopes in the form of uranium oxide (UO_2) pellets, as fuel. Several hundred fuel assemblies containing thousands of small pellets of ceramic uranium oxide fuel make up the core of a reactor. In the reactor core the U-235 isotope fissions or splits, producing a lot of heat in a continuous process called a chain reaction. Usually the UO_2 pellets are stacked in tubes to form fuel rods, which are loaded into the reactor core as fuel assemblies. A neutron source is usually needed to start the fission reaction (usually beryllium mixed with polonium, radium or other alpha-emitter) in the new fuel in a new reactor; however, restarting a reactor with some used fuel may not require activation as there may be enough neutrons to achieve criticality. In a fission reaction, most of the neutrons are released promptly, but some are delayed. These are crucial in enabling a chain reacting system (or reactor) to be controllable and to be able to be held precisely critical. Water is typically used as a moderator to slow down the neutrons released from fission process so that they can cause more fission, whereas control rods and dissolved boron in the primary coolant are used to control the rate of reaction within the reactor core.

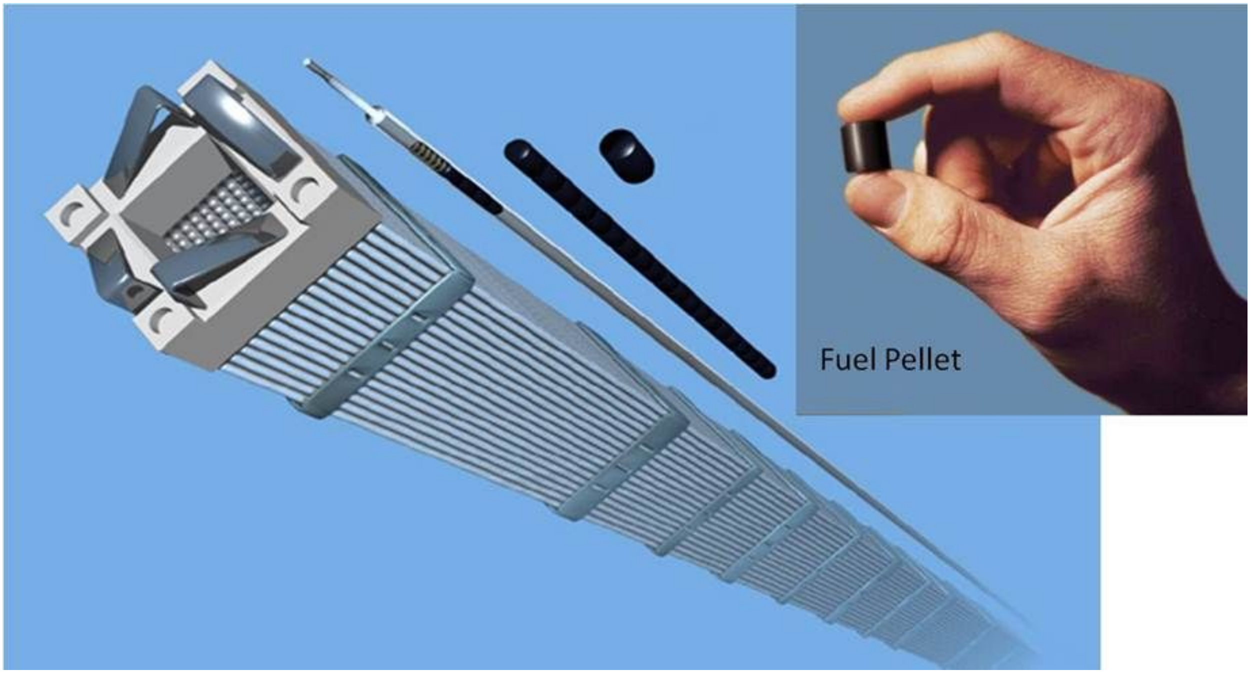

Figure 5: Illustration of a typical PWR fuel assembly, with the fuel rod, control rod and fuel pellet elements shown separately. (insert: photo of an unirradiated fuel pellet)

The type of nuclear reactors that are most likely to be located at the Thyspunt site are designed to sustain an ongoing fission chain reaction of enriched uranium, contained in specially designed nuclear fuel assemblies.

As an example, AP1000 fuel assemblies are similar to other PWR fuel such as the 17x17 robust fuel assembly and 17x17 XL robust fuel assemblies, for which substantial operating experience exist. AP1000 fuel assemblies have an active fuel length of approximately 4,2 m and consist of 264 fuel rods in a 17x17 square array. The fuel rods consist of uranium, enriched to a maximum of 5 wt% U-235, in the form of cylindrical pellets of uranium dioxide, contained in ZIRLO™ tubing. The tubing is plugged and seal welded at the ends to encapsulate the fuel. Fuel rods are pressurized internally with helium during fabrication to reduce clad creep down during operation and thereby prevent clad flattening. The fuel rods in the AP1000 fuel assemblies contain additional gas space below the fuel pellets, compared to previous fuel assembly designs, to allow for increased fission gas production due to high fuel burnups. Fuel rods may also contain burnable absorbers in the form of boride-coated fuel pellets or uranium oxide fuel pellets mixed with gadolinium oxide, or a combination, for reactivity control in the core

The centre position in an AP1000 fuel assembly has a guide thimble that is reserved for in-core instrumentation. The remaining 24 positions in the fuel assembly have guide thimbles, joined to the top and bottom nozzles of the fuel assembly to provide the supporting structure for the fuel grids. The AP1000 fuel assemblies have three intermediate flow mixing grids in the top mixing vane grid.

A number of proven design features have been incorporated in the AP1000 fuel assembly design, such as low pressure drop intermediate grids, intermediate flow mixing grids, a reconstitutable Westinghouse integral nozzle, and extended burnup capability. The bottom nozzle is a debris filter bottom nozzle that minimizes the potential for fuel damage due to debris in the reactor coolant. The AP1000 fuel assembly design also includes a protective grid for enhanced debris resistance.

The EPR core can accommodate different fuel assembly designs such as the AFA 3GL or HTP type. The EPR fuel assembly has an active length of approximately 4,2 m and consists of 265 fuel rods that are arranged in a 17 × 17 matrix. The assembly also contains 24 guide thimbles which are used as locations for rod cluster control assemblies (RCCAs) and for in-core movable instrumentation.

The EPR fuel assembly rods are made of highly corrosion-resistant and low-growth M5™ alloy tubing. These rods contain UO_2 ceramic pellets, with an initial enrichment of less than or equal to 5 wt% U-235. The fuel rods are mechanically restrained axially and radially in the fuel assembly structure by eight M5™ intermediate grids and two end spacer grids. The pellets contain Gd_2O_3 as integral burnable poison in which the Gd concentration may vary between 2 wt% and 8 wt% to suppress high excess reactivity in the core. Depending on the amount of burnable poison required to meet the design or safety requirements, the number of Gd_2O_3 rods in the fuel assembly may be varied from 8 to 20.

For the fuel designs discussed here the concentration of fission products and heavy elements will increase during operation, to the point where it is no longer feasible to continue to use the fuel. Thus after 12-24 months the used fuel assemblies are removed from the reactor. When removed from a reactor, the used fuel will continue to emit both radiation and heat.

From the reactor core, the used fuel assemblies are placed in a used fuel pool to allow for heat and the radiation to decrease to acceptable levels before they are transferred into used fuel casks. In the used fuel pool, the water above the fuel provides shielding against radiation and absorbs the heat being emitted by the fuel. The used fuel assemblies are kept in spent fuel pools for a number of years to allow for cooling and depending on availability of space in the spent fuel pool.

4.4 RADIATION

Radiation is the emission or transmission of energy in the form of waves or particles through space or through a material medium. This includes:

- electromagnetic radiation such as radio waves, visible light, and x-rays;
- particle radiation such as alpha, beta and neutron radiation.

There are two types of radiation, ionising and non-ionising radiation.

4.4.1 Ionising Radiation

Ionising radiation is radiation with enough energy so that during interaction with an atom, it can remove tightly bound electrons from the orbit of an atom, causing the atom to become charged or ionised. The removed electron may have sufficient kinetic energy to produce further ionisation in the irradiated matter. Ionising radiation can be divided into low linear energy transfer radiation and high linear energy transfer radiation or into strongly penetrating radiation and weakly penetrating radiation.

Typical types of ionising radiation include α-particles, β-particles, and γ-rays. The radiation types with electrically charged particles are directly ionising; others such as X-, γ- and neutron rays are indirectly ionising. Research in radiobiology has shown that exposure to high levels of ionisation is the major cause of biological effects on human tissues.

The main types of ionising radiation are:

- **Alpha (**α**) radiation** consists of heavy, positively charged particles emitted by atoms of elements such as uranium and radium. Alpha radiation can be stopped completely by a sheet of paper or by the thin surface layer of our skin (epidermis). However, if alpha-emitting materials are taken into the body by breathing, eating, or drinking, they can expose internal tissues directly and may, therefore, cause biological damage.
- **Beta (**β**) radiation** consists of electrons. They are more penetrating than alpha particles and can pass through 1-2 centimetres of water. In general, a sheet of aluminium a few millimetres thick will stop beta radiation.
- **Gamma (**γ**) rays** are electromagnetic radiation similar to X-rays, light, and radio waves. Gamma rays, depending on their energy, can pass right through the human body, but can be stopped by thick walls of concrete or lead.
- **Neutrons** are uncharged particles and do not produce ionisation directly. But, their interaction with the atoms of matter can give rise to alpha, beta, gamma, or X-rays which then produce ionisation. Neutrons are penetrating and can be stopped only by thick masses of concrete, water, or paraffin.

To reduce the harmful effects of radiation, various shielding materials are used to protect the public from undue radiation exposure, depending on the type of radiation that shielding is required for as shown in Figure 6.

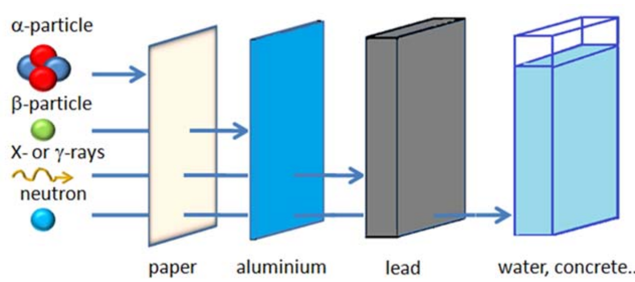

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Figure 6: Types of ionising radiation together with their respective shielding materials

Hazards associated with radiation exposure depend on the type of radiation, duration over which it is delivered, and the amount of energy deposited in the material. Acute health effects such as skin burns or acute radiation syndrome can occur when doses of radiation exceed certain levels. Low doses of ionising radiation can increase the risk of longer-term effects such as cancer. Known effects include direct damage to the cells (DNA strand in a chromosome), chromosomal mutation, genetic disorders, heritable effects, organ dysfunction, cancer, and in some instances, death.

4.4.2 Non-Ionising Radiation

Non-ionising radiation on the other hand, consists of waves of electric and magnetic energy moving together (radiating) through space. Radio waves and microwaves released by transmitting antennas are one form of electromagnetic energy. Often the terms “electromagnetic field” or “radiofrequency (RF) field” are used to indicate the presence of electromagnetic or RF energy. Non-ionising radiation therefore means that the radiation does not have sufficient energy to knock electrons out of atoms and cause the types of health effects (such as damage to DNA) that the various forms of ionising radiation such as neutrons and gamma rays can produce.

4.4.3 Public Exposure to Radiation

Radioactivity is part of the earth. People are exposed to natural radiation sources (including materials found in soil, water, and air) as well as human-made sources on a daily basis. Another source of radiation that people are also exposed to include natural radiation from cosmic rays, particularly at high altitudes, for example, on ultra-long-haul flights at high altitudes, such as a Boeing 747 flying between London and Tokyo, the effective dose rate at cruising altitude is around 5 microSieverts (μSv)/h.

Sources of radiation that poses the greatest risk of radiation exposure to the general public are natural sources and artificial sources. Considering natural radiation sources, radon, a naturally-occurring gas is the most common source, and originates from certain types of rocks and soil. Members of the public may experience high radiation dose levels if they live in areas where the rocks or soils release radon. Among the artificial sources, the largest contributor to exposure from artificial sources is the use of radiation in medicine worldwide.

Radiation exposure may be internal or external, and can be acquired through various exposure pathways, e.g. inhalation, ingestion, or direct (refer to Figure 7). Internal exposure occurs when a radionuclide is inhaled, ingested, or injected whereas external exposure may occur when an individual is immersed in an airborne radioactive cloud, also known as cloud shine.

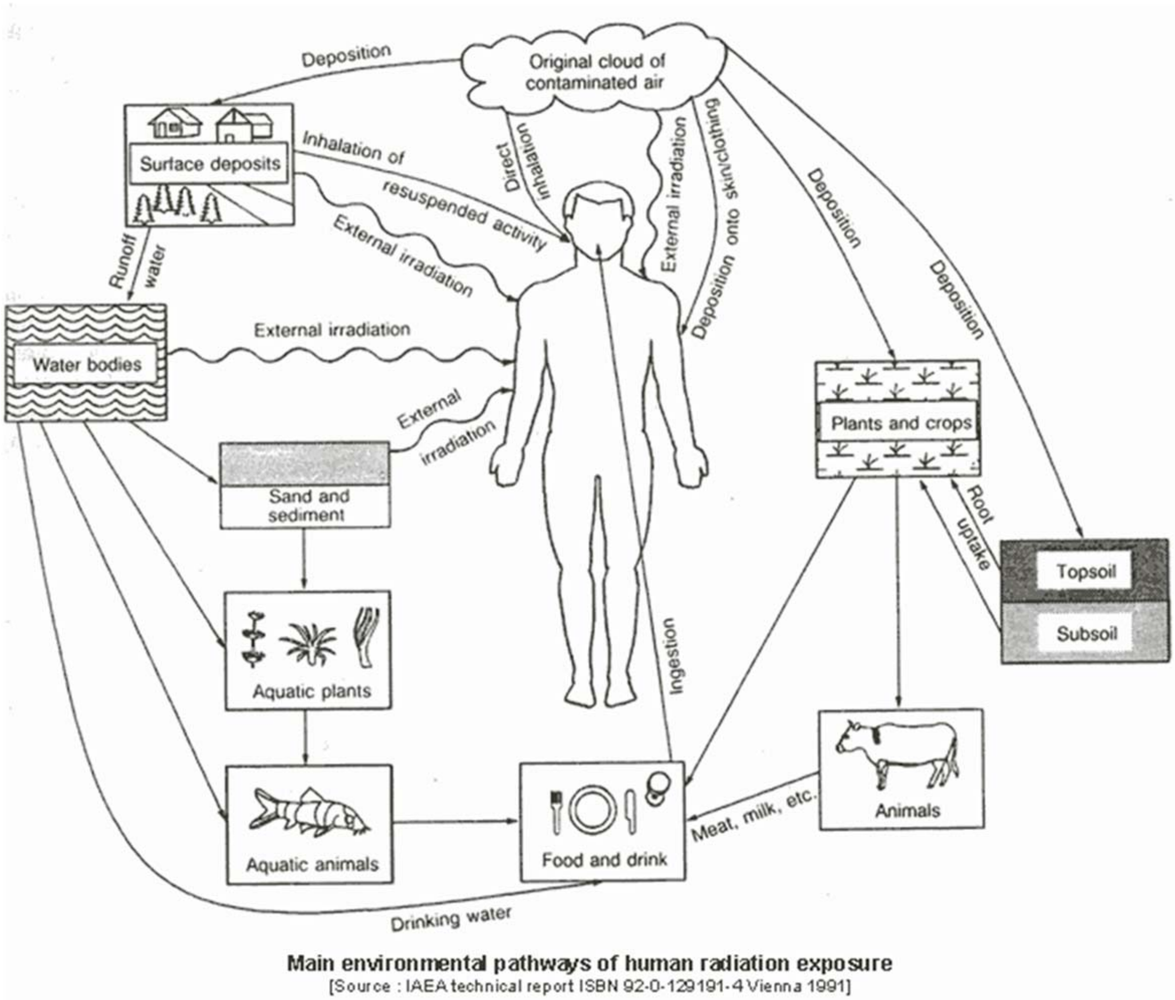

Figure 7: Exposure pathways

Exposure can be categorised into occupational exposure (exposure of workers incurred as a result of their work), medical exposure (exposure of patients as part of their diagnosis or treatment), and public exposure (exposure of members of the public to radiation as a result of being exposed to all kinds of sources of radiation, man-made or natural). Exposure from natural sources includes being exposed to high background radiation which may be found in some areas as a result of the soil or rock types in those areas and also other man-made activities such as a nuclear accident.

Exposure can be classified into three exposure situations, i.e. planned exposure situation, existing exposures, and emergency exposure situation:

- **Planned exposure situations** result from deliberate introduction and operation of radiation sources with a specific purpose (e.g. medical use of radiation for diagnostic or treatment purposes).

- **Existing exposure situations** are those exposure situations that already exist when a decision on control has to be taken, such as those caused by natural background radiation.
- **Emergency exposure situations** are those unexpected situations such as those that may occur during the operation of a planned situation, or from a malicious act, requiring urgent attention.

The risk of public exposure as a result of the radiation released to the environment is controlled through the implementation of the system radiation protection (RP) and shielding at a nuclear power station or in industries that emit radiation. The system provides an appropriate level of protection from harmful effects of ionising radiation for both human and non-human species (i.e. the *representative animals and plants* (RAPs)). For human beings, the system is used to prevent harmful effects that are, in principle, preventable and to reduce the risk of cancer and heritable effects to the extent reasonably achievable. For the environment, the system is used to ensure that the impact on the environment is negligible so as to maintain biological diversity, conservation of species, and the health and status of natural habitats, communities, and ecosystems. The significance of such radiation exposure is determined by calculating the resulting radiation dose from the source.

For public exposure, dose is not obtained by direct measurement of individual exposures as is the case with occupational exposure. The annual effective dose to members of the public is estimated by calculating the sum of the effective dose obtained within a period of one year from external exposure and the committed effective dose from radionuclides incorporated within that year. This is coupled by data obtained from effluent discharges, environmental measurements, and habit data and modelling.

For planned exposure situations, dose limits and dose constraints are used as a measure of protection to the public. For potential exposures, the corresponding concept is risk constraint. For emergency and existing exposure situations, the source related restriction is the reference level and for non-human species, a screening value is used to quantify the environmental risk.

For public exposure, in planned exposure situation, a dose limit of 1 mSv per annum is applied. The NNR specifies the dose constraint of 250 µSv per annum for the average of the critical group (also known as the representative person).

For each planned activity, it is expected that the dose to the public and the environment is assessed taking into account all exposure pathways. The work performed to assess the radiological impact on the public considers liquid discharges into the marine environment, marine dispersions (aquatic food ingestion, sea spray inhalation), sedimentation (external radiation), and airborne discharges taking into account dispersion (external radiation, plume inhalation) and deposition (external radiation, suspension, and terrestrial food) as reflected in Figure 7. The radiological impact on the public and the environment is also assessed for emergency situations so that appropriate measures can be put in place to protect the public and the environment.

As part of its normal operations, a nuclear power station discharges both liquid and gaseous effluent to the environment under controlled and monitored conditions to ensure that the risk to the public are kept as low as reasonably achievable (ALARA). The liquid and gaseous releases are required to conform to the Annual Allowable Discharge Quantities (AADQs) limits, which complies with the maximum annual effective dose limit of 250 µSv/a (also known as dose constraints) to a member of the critical group within the exposed population as set out by the NNR in terms of the National Nuclear Regulator Act no. 47 of 1999 (NNRA). Prior to locating the proposed nuclear installation at the Thyspunt site, detailed safety assessments will be performed to demonstrate adequate fulfilment of safety functions by the design of the nuclear installation, and assurance that barriers designed to ensure that the release of radioactive material will prevent an uncontrolled release that could lead to exposure to the public and the environment for all plant states.

For the 2014 calendar year, the public exposure to radiation as a result of KNPS' operations is well below the dose constraint of 250 µSv/a (see Figure 8).

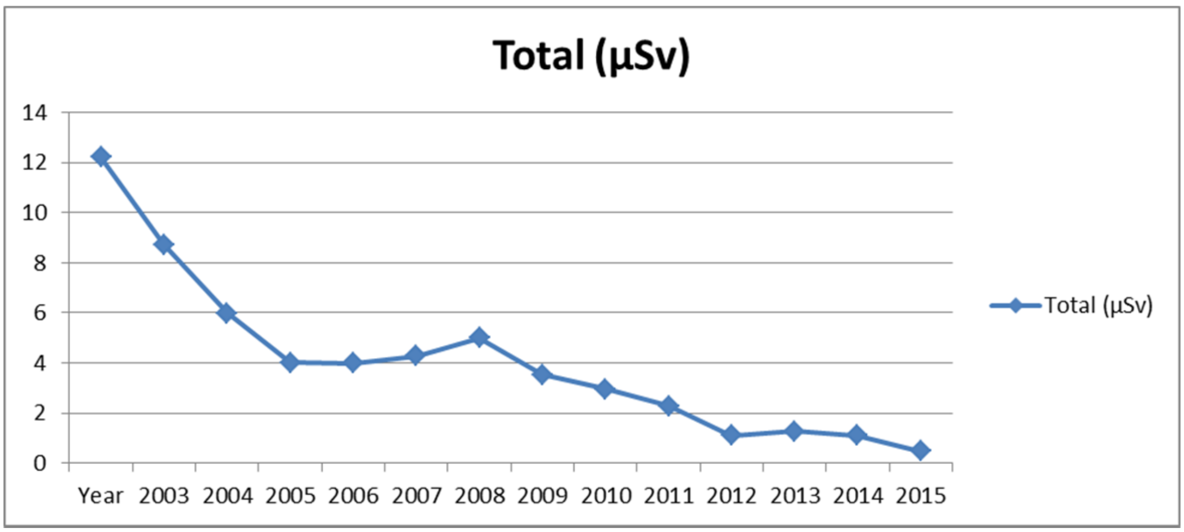

Figure 8: Public exposure as a result of operation of Koeberg

It is expected that any of the reactor designs that Eskom acquires will not exceed the dose constraint of 250 µSv/a.

4.4.4 Occupational Exposure to Radiation

Employees who are recruited to work for Eskom as radiation workers undergo extensive medical examination to determine whether they are fit to work in a radiation environment. Prior to working in the radiation zone, employees are trained and certified as radiation workers. This enables the employee to learn and understand the risk associated with exposure to high levels of radioactivity as well as to know measures that are in place to protect them. Radiation workers are issued with an electronic personal dosimeter (EPD) and the thermo-luminescent detector

(TLD) indicated in Figure 9 and Figure 10 respectively which they wear all the time to monitor their exposure levels when working in controlled zones.

Figure 9: Electronic personal dosimeters

Figure 10: Thermo-luminescent dosimeter

Radiation workers who perform work in a controlled zone (an area where radiation levels are high), are also issued with personal protective equipment commensurate with the protection required for that contamination level.

To minimise the harmful effects of radiation when handling radiation sources the “time, distance, and shielding” principle of radiation protection is applied which may be explained as follows:

- The longer the time (duration) one spends in the vicinity of a radiation source/radioactive material, the higher the potential of health risk associated with radiation.
- The shorter the distance between radiation source and the person handling it, the higher the potential of health risk associated with radiation.
- The thicker the shielding material one uses for a given type of radiation, the better the protection is from the harmful effects of radiation.

For occupational exposure in planned exposure situations, the recommended dose limit is 20 mSv per annum averaged over a defined 5-year period (100 mSv in 5 years), with a provision that the effective dose does not exceed 50 mSv in any single year.

5 SITE DEVELOPMENT CONSIDERATIONS

5.1 NUCLEAR DEVELOPMENTAL STAGES

The site will be developed in various stages in accordance with the NNR Position Paper 0009 (PP-0009) (refer to Table 2).

Table 2: NNR Licensing Stages

Stage	Activity	Nuclear Authorisation
1(a)	Site establishment	Permit
1(b)	Early site activities	NISL / NIL to site
1(c)	Early construction activities	NIL to site via Licence Change Request (LCR)
2(a)	Design (Optional)	Authorisation to Design/Design Certification
2(b)	Manufacturing (Long Lead Items)	Authorisation to Manufacture
3(a)	Construction	NIL to Construct a Nuclear Installation LCR
3(b)	Fuel to/on Site	NIL via LCR
3(c)	Fuel Loading and Commissioning	NIL via LCR
4	Plant Operation	NIL via LCR
5	Decontamination and Decommissioning	NIL via LCR

Figure 11 illustrates approximate time intervals for various site lifecycle phases.

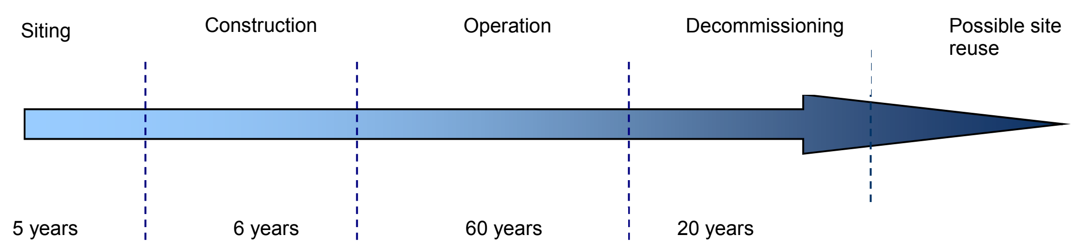

Figure 11: Theoretical Planned Site Lifecycle Phases

Most existing nuclear power plants were initially licensed for 40 years. The design that Eskom seeks to procure has a lifespan of 60 years which can be extended to ~ 80 years. The number and design of the reactors to be built are still to be determined, but they will be of the Pressurised Water Reactor type.

5.2 DEVELOPMENTAL CONSTRAINTS

On the basis of the available information about the site characteristics and preliminary design considerations, a provisional enveloping footprint area has been selected (shown in Figure 13). This is the area within which the reactor and other buildings will be established. As no vendor has as yet been appointed detailed design of the site layout as well as the number and dimensions of plant facilities remain preliminary and conceptual.

Nonetheless information exists, assumptions can be made and principles stated with respect to site specific developmental constraints and the principles that will inform the development of the site. These are described in the subsequent sections. It should be noted that these may change due to changes in site data, regulatory requirements or shifts in international practice.

5.2.1 Environmental Constraints

The Nuclear-1 EIA process is yet to be concluded. Based on the specialist studies performed and the public participation process, environmental constraints identified will be managed in accordance with the Environmental Management Plan in accordance with the National Environmental Management Act requirements.

5.2.2 Physical Constraints

The following physical constraints will need to be taken into account when defining the nuclear power plant terraces.

- The terraces supporting NPPs should be located in that part of the environmental footprint which has the lowest dunes. This in turn, results in the smallest quantity of sand which needs to be excavated and removed. Any changes in this position will have severe consequences with respect to excavation of the NPP foundations.
- The volumes of sand and rock which will need to be excavated, stockpiled, backfilled and spoiled will vary depending on the exact terrace location, dimensions and the below grade level of the selected power plant design.
- At the NPP terrace locations the upper section of the bedrock will be weathered and will need to be prepared such that a competent load bearing bedrock is exposed. Once competent rock is exposed, the foundation may need to be built up with a soil cement sub-foundation to the underside of the nuclear island, as in the case of KNPS.
- The oceanography studies undertaken to date suggest a maximum design basis wave height in the order of +13,5 m amsl at a recurrence interval of 1:1 000 000 years. This elevation results from a combination of tide and storm conditions, run-up, climate change and tsunami. In order to provide a margin against the design basis tsunami, the terrace elevation for NPPs should be greater than +15 m amsl.

- The water table mirrors the site topography, steadily rising towards the north-west. The NPP terraces should be located such that there is a minimum margin of at least 2,0 m between top of terrace and the water table. This depth to groundwater will be greater than 2,0 m over most of the site with only the north eastern corner experiencing the minimum depth.
- As the elevation of the terrace increases so does the power demand for pumping cooling water through the turbines. Hence, it is desirable to optimise as far as possible the terrace elevation against the electrical house load. It is anticipated that the cooling water requirement will be in the order of 184 m^3/s for 4 000 MWe, and 76 m^3/s is required for 1 650 MWe) and this volume will need to be pumped over the 60 year life of the NPP(s). This in turn, implies a loss of power output and a portion of the capital expenditure which cannot be recovered.

5.3 CONCEPTS ADOPTED FOR SITE DEVELOPMENT

The concepts discussed in this section are preliminary and conceptual, and will be influenced by the licensing and regulatory requirements that will need to be adhered to, as well as the site development and contracting approaches to be adopted by Eskom.

5.3.1 Access Roads

On receipt of an Environment Authorisation (EA) and when a decision is made to build, the identified access roads will be constructed in accordance with NEMA requirements and constraints identified during the EIA.

Major roads located within the 35 km radius of the Thyspunt site (refer to Figure 12**Error! Reference source not found.**) are described below.

The N2 highway, 21,5 km north of the site, serves as an east-west national distributor, being the primary road linkage between Port Elizabeth and Cape Town. There are four grade-separated interchanges along the N2 situated within the 35 km radius. These are as follows:

- The link to the R102 at Mondplaas
- The turnoff to Jeffrey's Bay
- The link to the R330 north of Humansdorp
- The link to the R62 at Trifolia.

The R102 road, is a two-lane surfaced road running more or less parallel to the N2, and used to be the main road linkage between Port Elizabeth and Cape Town prior to the construction of the N2. Currently it functions as a rural access road.

The R62 road, 19,7 km northwest, is a two-lane surfaced road, providing access to Langkloof and beyond. It is classified as a regional distributor but can also be used as an alternative route to the Western Cape.

The R330 road, 11,3 km east northeast, serves as a north-south regional linkage between the towns of Hankey, Humansdorp and Cape St. Francis, and is the major road within the vicinity of the Thyspunt site.

The R332 road is an unsurfaced rural access road and connects to the R330, approximately 6,0 km north of Humansdorp.

5.3.1.1 Roads to Access Site

Two roads are considered as access points to the Thyspunt site to reduce traffic volumes that would prevail on a single route and would potentially halve the disturbance to communities close to the site. These are the western access (via the Oyster Bay road) and eastern access (via the R330) (refer to Figure 16).

5.3.1.2 Emergency Evacuation Routes

Two access roads are also required for the safe and quick evacuation of all personnel in the unlikely event of an emergency. Further arrangements with regard to emergency evacuation will be put in place with the local authorities and disaster management structures once a firm decision is made to build the nuclear power station.

5.3.1.3 Transportation of Abnormal/Heavy Haul Loads

Most major components for a nuclear power plant are manufactured overseas and imported by sea, and many of these components are abnormally large in comparison to normal road freight. Delivery to the site by abnormal load vehicles will therefore be required. Most of the heavy equipment from abroad will therefore be transported by ship to the Port Elizabeth harbour as it is the closest harbour to Thyspunt that has the capacity for heavy loads. From there, it will be transported to Thyspunt by road transport via the N2. From the N2, a tarred feeder road leads to Humansdorp to St. Francis Bay (refer to Figure 15). The eastern access route was recommended as the primary route for supply of heavy haul/abnormal loads to the site. The upgrades and changes to these routes for the construction phase will be permanent and available for use during the operational phase.

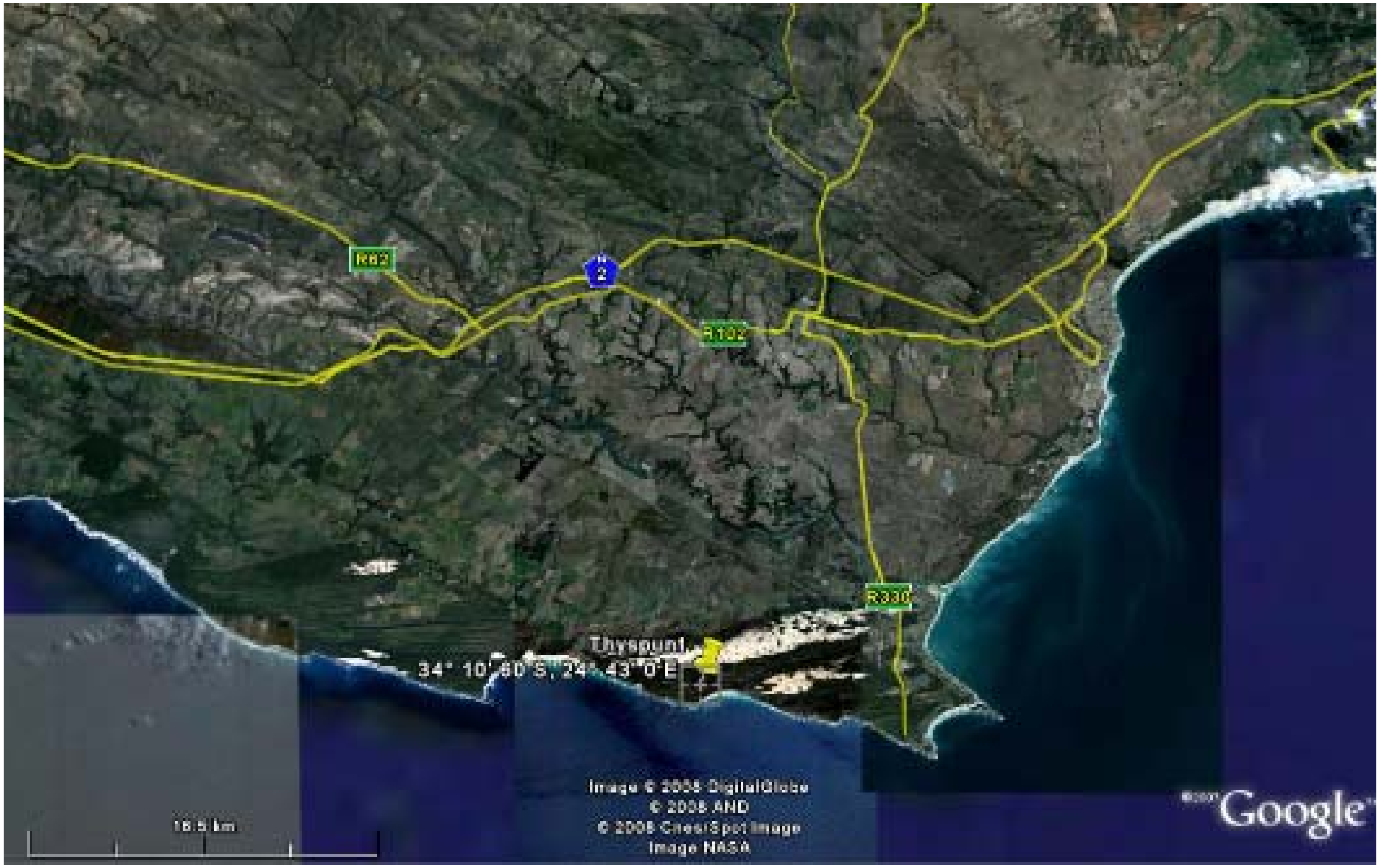

Figure 12: Major roads located within the 35 km radius of the Thyspunt site

5.3.2 Bulk Earthworks

Once the earthmoving machinery has been transported to the site, small scale earthworks will be undertaken to provide platforms for temporary Eskom Offices, Visitors' Centre, Fitness for Duty Building, temporary desalination plant, potable water storage tanks, portable toilets, central conservancy tanks for waste water, parking and a contractor's yard.

Areas will be identified for

- a mulch stockpile
- a helipad
- a topsoil stockpile

Thereafter, earthworks will proceed on the NPP terrace as well as terraces for other buildings. Excavated material will be used for compacted fill in other terraces. Once the NPP terrace has been prepared to its finished elevation, preparatory work for the excavation can begin. These works will include some form of dewatering which may not affect the wetlands. These works are likely to extend for a period in the order of 8 months prior to the start of excavation.

Contractors' yards will be constructed from the sands on the site with the aim of achieving a balanced cut and fill and so limit as far as possible the need for disposal of spoil.

The elevations of the NPP terraces should be located at elevations which achieve a balance between mitigating against flooding from the sea, achieving at least 2 m height above the ground water table, minimising the quantity of sand spoil and the cooling water pumping requirements over the life of the power station.

A wearing course of imported material will be constructed on all terraces which will accommodate construction traffic and support an applied pressure of 150 KPa for laydown areas. The terraces will be profiled to ensure that rainwater will flow to the stormwater drainage system which will be installed as part of the earthworks. Primary access roads will be provided on the terraces but access to the contractors' yards from the primary roads will be provided by the vendor. Note should be taken that there will be some weathering of the surface during construction and this will be monitored and repaired where necessary by the vendor. Also included in the construction of the terraces will be the potable and fire water ring mains, electrical ring main which feeds inter alia, the site lighting, stormwater and sewer networks.

Edges of terraces will be indicated properly for safety, including if necessary railings or fences. A site security fence will surround the construction site and will be constructed once the earthworks are completed.

Rock which is removed from the cooling water inlet tunnel and the excavation for the Nuclear and Conventional Islands may be used as fill material or transported to the local quarry for crushing and use in other applications.

5.3.3 Potable Water Ring Main

A potable water ring main will be established. During the initial stages of construction the potable water requirements are envisaged to be 1,05 l/s. This water can be supplied from a number of sources as construction proceeds. Initially potable water will be supplied from existing boreholes on site but this water may need to be treated. The water will be stored in elevated water tanks. As the site readiness activities increase so the water demand will be satisfied by increased numbers of water storage tanks located on relatively high parts of the construction site. The tanks will supply sufficient pressure for drinking water, the filling of toilet systems and other low pressure requirements to temporary and permanent buildings as these are developed. Where required, pressurised pump systems can be added for additional pressure.

As the bulk earthworks for the various terraces are completed, water ring mains will be installed. Water will be supplied from the desalination plant (which will have been completed by this time) to storage reservoirs which in turn, feed the ring mains. Draw-off points will be provided in the ring main as required on site.

Water will be stored at various locations around the construction site to meet balancing requirements and cater for emergencies (e.g. firefighting) or planned shut-downs. The balancing volume is required to cater for peak outflows; while a near constant inlet flow is being received. A storage capacity of 48 hours of annual average daily demand is suggested, although there may be situations where 24 hours will suffice.

The nominal capacity for elevated storage, based on a typical period involved in power failures, will be based on 2 to 4 hours of instantaneous peak demand. The nominal capacity of the duty pump should be equivalent to the sum of the instantaneous peak demands.

5.3.4 Stormwater System

As noted under the bulk earthworks, the stormwater systems for the terraces will be included in the terrace construction.

The rain water will be collected via a system of roads, stormwater pipes, and open channels. Open channels are the preferred option primarily from construction cost and maintenance perspectives.

Prior to discharge into the environment, the stormwater will pass through environmental ponds / sediment collection structures designed to collect all types of solid material conveyed in the water and oil/grease traps should pollution be a possibility. Thereafter, it will be discharged into the open vegetation from the various terraces with energy dissipation structures being used to prevent erosion at the exit points.

Stormwater will be considered for discharge into the cooling water intake basin once operating.

Research indicates that the extended duration flows typically experienced in retention ponds negatively impact receiving streams / wetlands, particularly when the streams and wetlands are subject to erosive flows for long periods. Standing water also serves as a habitat for mosquitoes associated with diseases. Hence, the use of retention ponds will need special attention if they are considered for use on the site.

5.3.5 Sewer System

During the initial stages of the construction use will be made of chemical toilets provided and serviced by an independent service provider. Conservancy tanks will be provided as central collection points for sewerage. From these tanks the sewerage will be transported to the local municipality for treatment.

Once the temporary sewerage treatment plant (STP) has been commissioned and the sewer piping network installed, treatment of the waste will be done on the site. The temporary STP may need to be moved into its final position once the terrace construction has been completed. The STP will be modular to cater for variations in flow rate over the life of the NPP. The STP will not interface with the nuclear island and all waste generated which is potentially contaminated will be treated separately inside the nuclear island.

There may be more than one collection point for the sewer system but these will be limited as far as possible to limit the number of pump stations constructed. These pumps will then pump sewerage to the STP.

5.3.6 Electrical Ring Main

The construction supply system will consist of a 11 kV cable network fed from a substation / switching station. The substation will initially be fed by a 22 kV line from the existing reticulation network in the area. The supply will be supplemented with a 132 kV line during the course of the construction period. The 132 kV supply will be stepped down to 11 kV.

The 11 kV cable network will be used to supply mini-substations located at various supply points on the site. The 11 kV will be stepped down to supply 400 V 3-phase to the vendor.

400 V is the South African standard voltage for 3 phase industrial supplies. The 11 kV cable network can also supply 11 kV directly to the vendor if required.

The location of plant, for example sub-switching stations, mini-substations shall be decided upon considering the following factors:

- Vehicular and pedestrian traffic.
- Environmental impact.
- Water run-off.
- Pollution.
- Accessibility for ease of operation and maintenance, and
- Location of other underground services, for example telecoms lines, water etc.

5.3.7 External Lighting

During pre-construction the main areas of concern for lighting are the Eastern Access Road, Contractors Facility, Electrical Substation Yard and Eskom Site Office Facilities.

Most of the exterior luminaries whether or not they are pole-mounted or surface-mounted onto buildings shall have photocell lighting control, which means that the lamps stay on from dusk till dawn for security purposes.

The smaller roads and building facades around the site shall be adequately lit to enable cars and pedestrians to manoeuvre around the site. Lighting levels shall not be excessive. Extensive use of floodlights and surface mounted bulkhead lights with sharp cut-off angles and excessive upward light distribution shall not be encouraged.

High-mast lighting is provisionally envisaged at various locations on the site.

5.3.8 Telecommunications

The systems, buildings and towers to accommodate the site telecommunications will be constructed and commissioned as the earthworks are completed for the terraces.

6 SITE DESCRIPTION AND JUSTIFICATION

In accordance with local regulatory requirements, in particular RG-0011 (*Interim Guidance on the Siting of Nuclear Facilities*) and Regulation R.927 (*Regulation on Licensing of Sites for New Nuclear Installations*), an application for a nuclear site licence must consider the following aspects in the evaluation of the suitability of a site for a nuclear facility:

a) Effects of external events occurring in the region of the particular site (natural and human induced);

b) Characteristics of the site and its environment which could influence the transfer of released radioactive material to persons; and

c) Population density and distribution, as well as other characteristics in relation to the possibility of implementing emergency measures and the need to evaluate risk to individuals and the population.

The site is deemed unsuitable if it has serious deficiencies that cannot be compensated for by means of:

- Design features;
- Site protection measures; or
- Administrative procedures.

A brief site description is provided below.

6.1 THYSPUNT SITE DESCRIPTION

The Thyspunt site falls within the Sarah Baartman district municipality, which covers an area of almost 60 000 km^2 in the western portion of the Eastern Cape Province. It falls within the Kouga local municipal area. All places and infrastructure discussed below are shown in Figure 15. The site is located on the south coast 4 km east of Oyster Bay, 12 km west of St. Francis Bay and 17,3 km south of Humansdorp (distances measured from the site centroid to nearest town boundary). The site centroid is defined by the coordinates X: -27 522,999 806 and Y: -3 784 463 (Figure 13). The large urban areas of Port Elizabeth and Uitenhage are located partly within the 80 km radius of the site.

There are no highways that traverse the site. The N2 highway runs in an east-west direction approximately 22 km to the north of the site. A tarred feeder road leads to Humansdorp and then the main existing access route to the site is by an unsurfaced secondary road in moderate condition to Oyster Bay. An alternative route is via an unsurfaced branch road from the tarred R330 road from Humansdorp to St. Francis Bay. The following access routes are currently under consideration (refer to Figure 15 and Figure 16);

- Existing Oyster Bay road but bypassing Oyster Bay and approaching the site from the west;

- R330 with a turn-off near Sea Vista and approaching the site from the east;
- R330 and then via the existing route that needs to be upgraded and linked to the Oyster Bay Road.

There is significant and extensive agricultural activity in the area, with the closest being dairy pastures within 3 km and centre-pivot irrigated crops at a distance of 5 km from the site centroid. The site is situated between two rivers, the Krom River to the northeast and the Slang River to the west in quaternary catchment K80F. There are no rivers on the site itself but there are ecologically important wetlands and springs, the former in the vegetated and mobile dune area and the latter along the coast.

The site is bounded to the south by the Indian Ocean. The rocky shoreline is oriented almost west-northwest and east-southeast and comprises a wave-cut platform. The landform inland for a distance of approximately 3 km comprises a prominent dune field having crests trending east-northeast as a result of the prevailing winds. The coastal dune belt is vegetated while there is a narrow inland belt of non-vegetated, mobile dunes that extends from Oyster Bay towards St. Francis Bay. These dunes are labelled as shifting sand dunes.

The highest portion of the dune field is approximately 2 km from the coastline and has an average elevation of about 100 m, with high points of 111 m and 122 m. The undulating vegetated dunes between this zone and the coastline are approximately 70 to 80 m high dropping to a terrace 20 m above the rocky shore. Further inland from the dune field the topography rises evenly to a low hill that has its long axis oriented northwest-southeast with a high point of 170 m. This elongated hill is about 6 km inland.

The airfields within the region are predominantly small civil airfields and emergency landing strips located on farms. Most are unregistered facilities used for private purposes with no structures or buildings. The nearest major airport to the site is Port Elizabeth International Airport, which is located 85 km to the east. Only one active commercial airport occurs within 16 km of the site, the St. Francis airfield (10,8 km east). The airfield has one grass runway 10/28, measuring 1 000 × 23 m. It operates daily and has no control tower, but has landing lights and accommodates 13 hangers for storage and maintenance of small private planes. No aviation fuel or other hazardous chemicals are stored on this site. General aircraft, i.e. propeller type, helicopters, and Lear jets (< 5,7 t as defined by the ICAO) use this airfield and approximately 100 movements per year have been recorded. At present there are no plans for future extension of this airfield. There are no military facilities within 80 km of the site.

There are no railway lines that traverse the site. A section of the Port Elizabeth-Avontuur narrow gauge, non-electrified, railway line is located 21,3 km north of the site. Rail traffic consists of about three diesel-electric freight trains per week, hauling pulpwood from Assegaaibosch to Port Elizabeth. The line is also used by the Apple Express, a local tourist train. No future development of the rail infrastructure is planned within the 16 km of the site.

Port Elizabeth and Ngqura (Coega) harbours are the largest commercial harbours in the broader region and are located beyond 80 km from the site. The Port St. Francis small craft harbour is located 13,9 km to the east. It consists of a breakwater with an inside basin for commercial fishing vessels, with mooring at concrete jetties, and a section (within the harbour) with a slipway facility for small recreational vessels. Entry to the port is access-controlled and a harbour master is employed to manage the facility.

These issues, i.e. harbours, airfield etc. constitute part of the site characteristics which must be seen in the context of:

a) constituting a potential external hazard to the nuclear power station (NPS) which may be a risk to the NPS, for example an aircraft crashing in the NPS thus resulting in radiological/nuclear emergency;

b) the mode of transport available in the area which may be used in delivering goods to the NPS. For example, the Port Elizabeth harbour is the largest harbour in the region and will be used for the receipt and despatch of equipment to the NPS during the construction phase and for fuel assemblies during the operational phase.

The site falls within the Fish-Tsitsikamma water management area. However, large quantities of water are imported from the upper Orange River water management area via the Sundays River. The various water storage and transfer systems that supply the local area and the Nelson Mandela Bay Municipality (NMBM) are called the Algoa water supply system. The NMBM supplies water to the population at Humansdorp and St. Francis Bay via the Churchill pipeline from the Churchill and Impofu (formerly Elandsjacht) dams with capacities of 26,3 and 32,1 million m^3 respectively. This pipeline runs in an east-west direction to the south of the N2 freeway from these dams to Port Elizabeth, with an offshoot to St. Francis Bay linking up with the Humansdorp-St. Francis Bay tarred road (R330) just before the Krom River bridge. The local towns obtain a portion of their water supply from groundwater sources.

A 22 kV line passes 0,4 km to the north of the site, which can provide a supply of approximately 8 MVA. A new 66 kV line will be required from the St. Francis Bay substation to the site and it is anticipated that this line will follow the planned eastern access road from St. Francis Bay to the site. A new 132 kV line needs to be provided from the Melkhout sub-station (approximately 3 km north of Humansdorp) to the HV yard across the dunes in order to provide 30 MVA to the site.

From a regional perspective, land use change in the site region is expected to be concentrated in and around existing settlements. Any significant growth that would occur would be concentrated in the NMBM and more specifically towards the Coega industrial development zone. The agricultural and irrigation pattern is expected to remain constant. Coastal resort towns are expected to grow in keeping with tourism development in the region. Although some growth is expected to occur within the smaller settlements in the region, the focus is envisaged to be in coastal resort areas, where no significant industrial development, other than the nuclear installation at the site is planned for the future.

6.2 PROPOSED BUILDINGS AND SITE LAYOUT

The proposed power station complex as shown in Figure 13 will include inter alia, the nuclear reactors and their auxiliaries such as:

During construction:

- A temporary spoil pipeline into the ocean for construction; and
- Laydown areas and other areas to be cleared during construction.

During operation:

- Reactor building
- Nuclear auxiliary buildings
- Turbine halls;
- Used or spent fuel and nuclear fuel storage facilities;
- Hydrogen plant
- Diesel and gas turbine generators
- Waste handling and storage facilities;
- Waste water treatment works;
- Intake and outfall structures into the ocean required to obtain/release water used to cool the process;
- Desalinisation plant;
- 132 kV and 400 kV transmission and distribution lines from the power station to the high-voltage yard;
- Roads;
- 400 kV and 132 kV high-voltage yard (HV yard);
- Transmission lines between the power station and the HV yard (only at the Thyspunt site); and
- Other auxiliary service infrastructure.

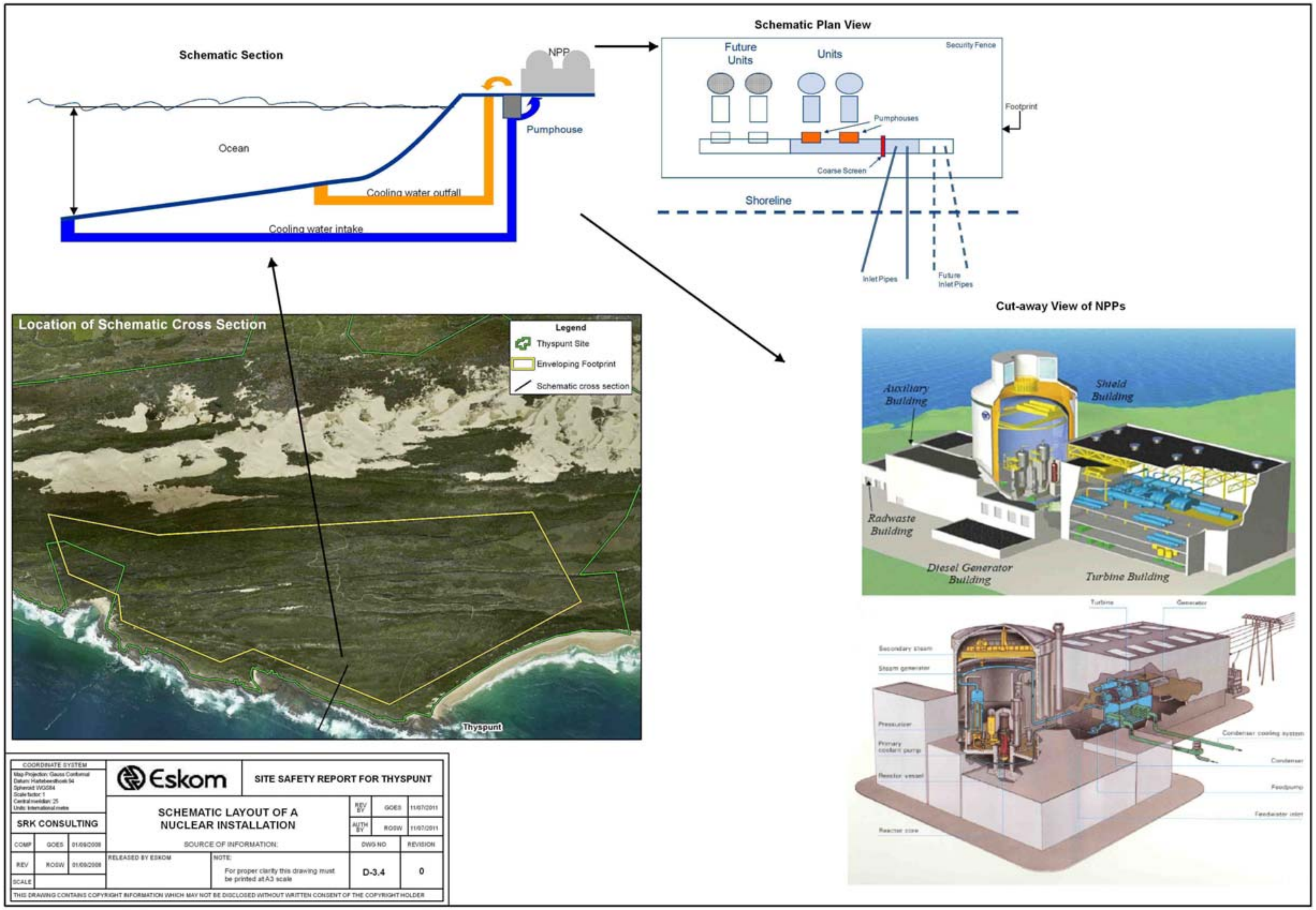

Figure 13: Schematic layout of a nuclear installation

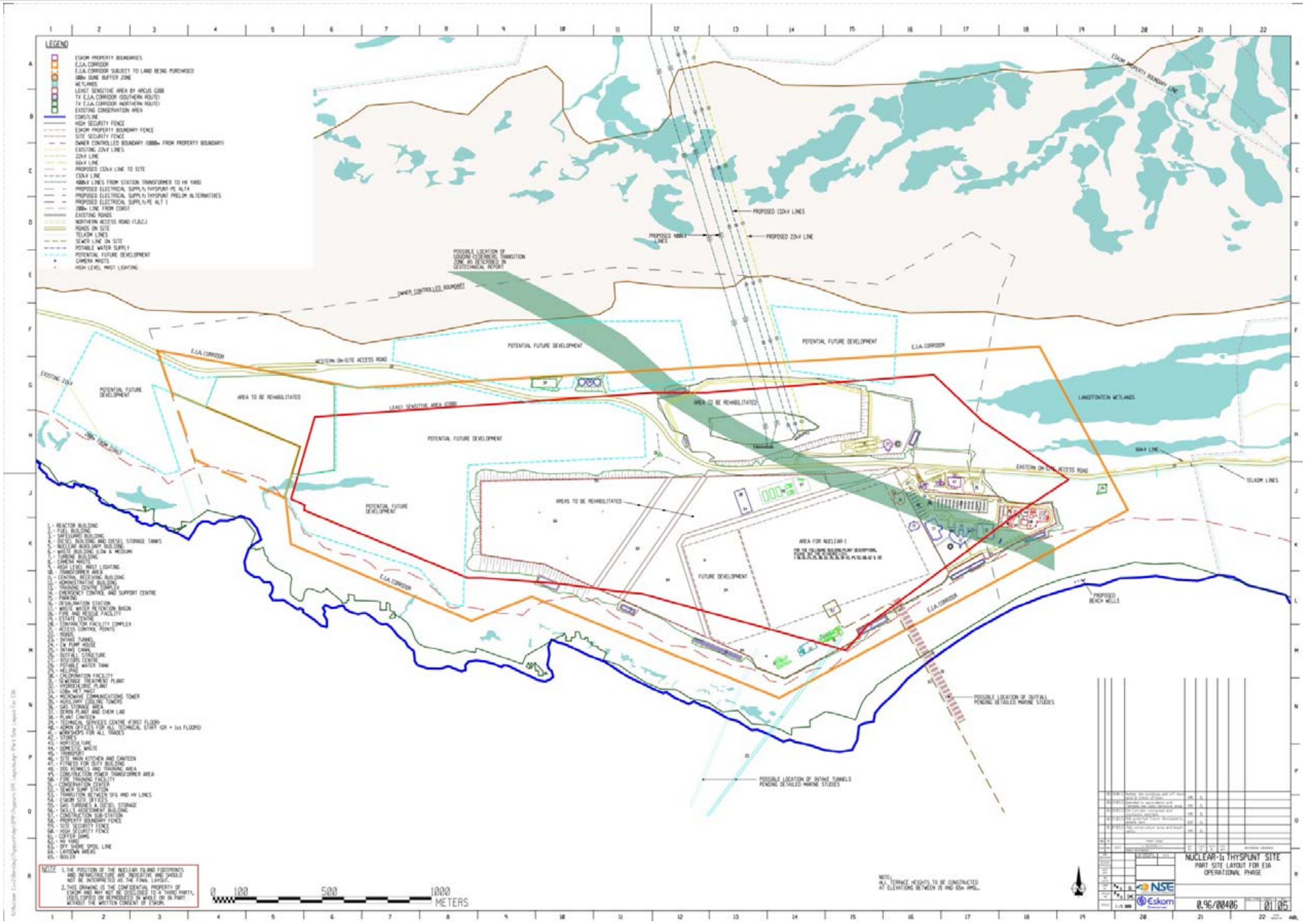

Figure 14: Thyspunt site layout

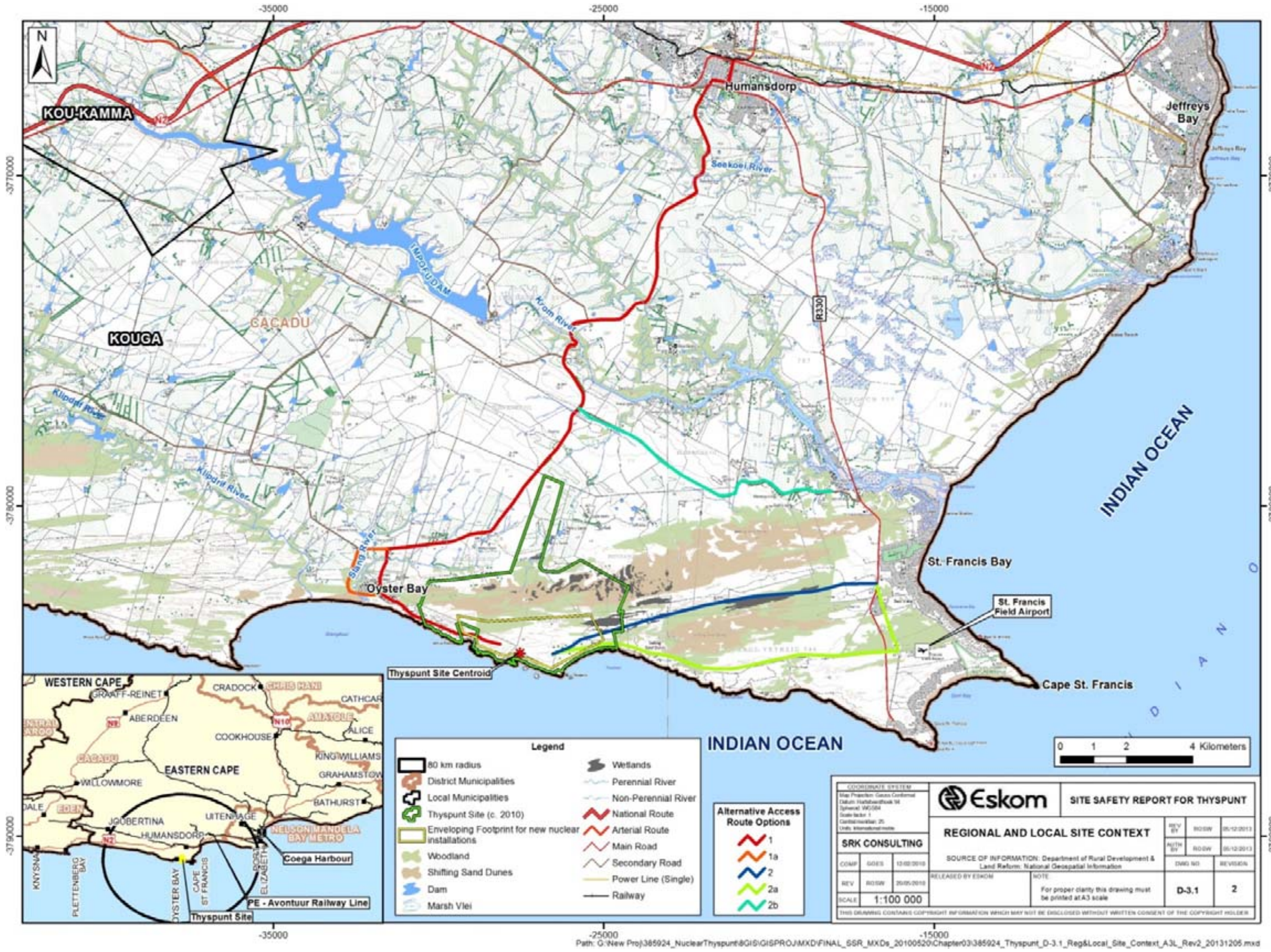

Figure 15: Thyspunt regional and local site context

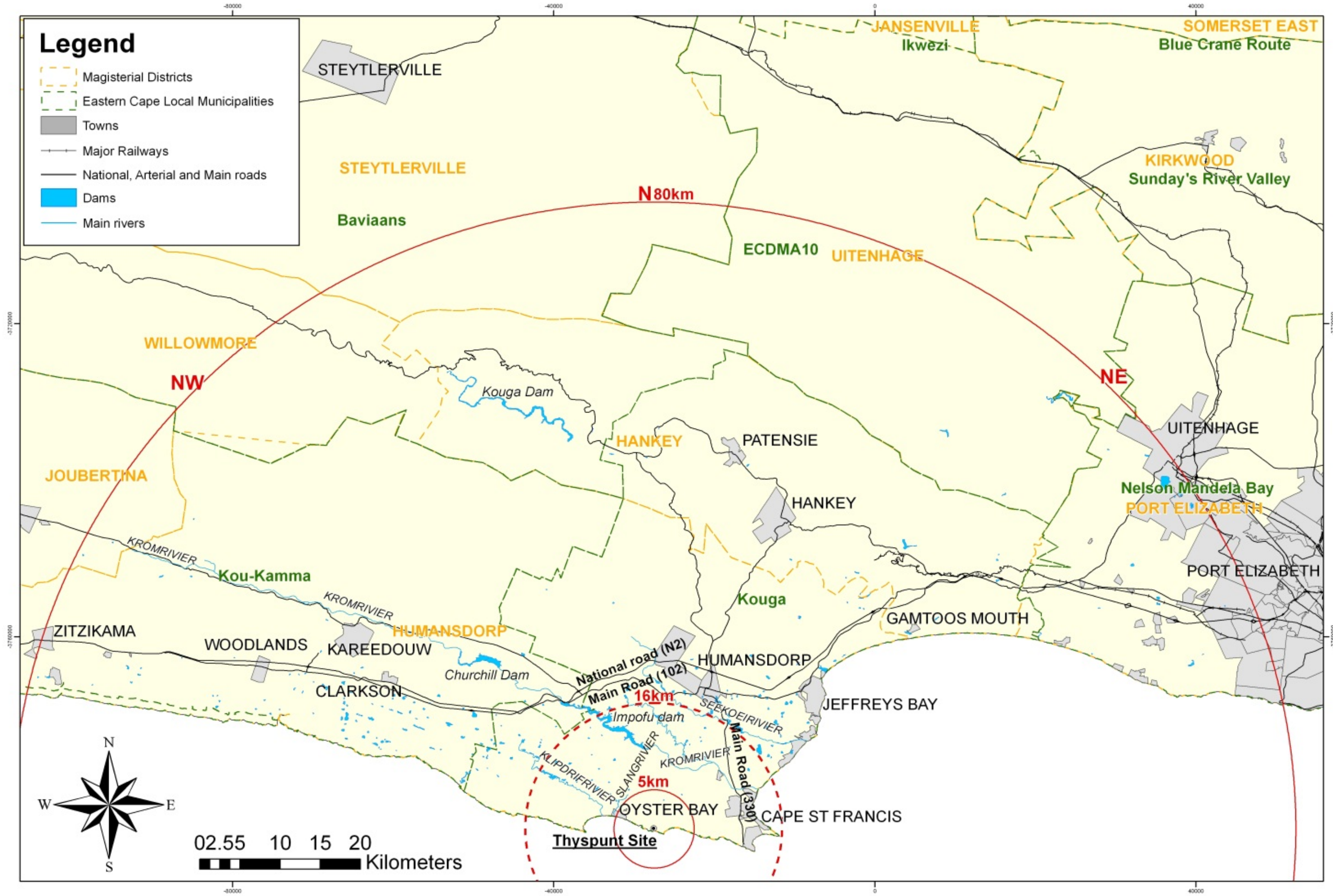

Figure 16: Main road network within the Thyspunt region (80 km)

6.3 SITE JUSTIFICATION

Detailed investigations were performed to confirm the suitability of the Thyspunt site, taking into account all factors relevant to the site (i.e. natural and human-induced external events, potential radiological impact to the public and the environment, feasibility of developing and implementing an emergency plan as well as security arrangements required for the site).

6.3.1 Evaluation of External Events

Events external to a nuclear installation(s) which could challenge nuclear safety were identified and evaluated for the site. The site location and engineered safety features of the proposed nuclear installation(s) must ensure compliance with regulatory safety criteria. The two main categories of external events are:

- Events of natural origin, e.g. extreme weather-induced flooding of the site;
- Events of human-induced origin, e.g. accidental aircraft crashes.

The current regulatory requirements relevant for the evaluation of external events during site characterisation for new nuclear installations are stipulated in the following two documents:

- R.388 (*Safety Standards and Regulatory Practices*); and
- R.927 (*Regulations on Licensing of Sites for New Nuclear Installations*).

The regulations in R.927 that make reference to external events are:

> *"4(2) The proposed nuclear installation design(s), and the characteristics specific to the site: New nuclear installation(s) must reflect through their design, construction and operation an acceptably low probability of postulated events that could result in release of quantities of radioactive material."*
>
> *"4(3) The site location and the engineered safety features of all nuclear installations, included as safety measures against the hazardous consequences of postulated events, must ensure an acceptably low risk of public exposure."*
>
> *"4(4) The site must be such that radiological doses and risks from normal operation and postulated events associated with all nuclear installations in the vicinity will be acceptably low."*
>
> *"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;"

"5(4) A source term analysis that is representative of the overall potential hazards posed to the public and the environment owing to the new nuclear installation(s). A representative scope of internal and external events enveloping the new nuclear installation(s) must be taken into consideration.'

6.3.2 Natural Hazards

Events are evaluated by analysis of available monitoring data for the site and determining event frequencies statistics. These statistics are return periods and annual probabilities of exceedance of parameter values characteristic of the event severity.

6.3.2.1 Geological hazards

Geological investigations for the Thyspunt site have been conducted for more than 25 years. These studies have included geological mapping, on- and offshore geophysical studies, geochronological analyses, geomorphic studies, paleoseismic studies, and geotechnical investigations.

These studies were conducted as part of early screening studies to evaluate multiple nuclear sites, specific studies conducted for the Thyspunt site, and geological investigations conducted specifically to address key issues of importance to seismic hazard analysis. Consistent with NNR guidance and international regulatory guidance and standards, the full range of methods and tools were applied and the investigations included the recommended increasing levels of specificity ranging from the site region, site vicinity, and the site area, to the site location. As is recommended in the existing regulatory guidance, the results of the investigations conducted for the site were integrated with studies conducted by a large number of investigators within the geological community and published in the professional literature.

The net result of integrating all the geological studies conducted with the interpretations offered by members of the community in technical publications is a strong, complete geological knowledge base for the site region, site vicinity, site area, and site location.

The on- and offshore regional geology and tectonics at the site are well understood. The shoreline and coastal plain at the site area and location represent an old and stable landscape. From an erosional point of view, the resistant rocks that establish this rugged coastline provide a stable base for the construction of nuclear installations. Significant changes in the geological environment are therefore extremely unlikely. Given the silica-rich (sandstones and siltstones) nature of the Palaeozoic-age bedrock underlying the site location, there is no risk of solution cavities forming beneath the site.

1. Slope instability

The site and its vicinity were evaluated to determine the potential for slope instability (such as land and rock slides) that could affect the safety of the nuclear installation(s).

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 nuclear installation. It could also hinder emergency response.

The site geotechnical profile consists of bedrock overlain by predominantly cohesionless Aeolian sands that range in thickness from 0 m at sea level to a maximum of 65 m under the dune peaks inland (about 700 m inland from the sea) There is also an intergranular aquifer found at (or near) surface at sea level and as deep as 60 m from surface under the dune peaks inland.

Slope instability will be catered for by civil engineering design requirements.

2. Collapse, subsidence, or uplift of the site surface

Geological maps and other appropriate information for the region were examined for the existence of natural features such as caverns, karstic formations, and human-made features such as mines, quarries, and wells. The potential for collapse, subsidence, or uplift of the site surface was evaluated.

The site is underlain by Table Mountain Group (TMG) sandstone dominated by the Skurweberg (near the sea) and the Goudini (further inland) formations. These formations do not possess any physical attributes that could result in the development of subsurface voids (e.g. caves) and karst features (which develop in limestone/dolomite). Extensive drilling programmes carried out on the site have not encountered any voids or karst features that could pose external hazards to the site.

The following features are considered hazardous to a nuclear installation:

- 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; and non-conformities in soluble rocks;
- Zones of weakness or discontinuities in crystalline rocks.

Information gathered to date from historical and extensive intrusive investigations on site, indicate that no features that could be potentially hazardous to a nuclear installation are present on the site. In addition, as the nuclear installation is planned to be founded on (or in) bedrock, no subsidence, collapse, or uplift is anticipated at the site during the lifetime of the facility.

Mining activities within 16 km of the site were considered to identify the potential sources of human-induced events. The site evaluation concluded that there are no mining activities within the 16 km radius of the site that could affect surface stability.

A limited number of quarries, sand mines, and brickfields found in the site area are directly related to the construction industry and occur in areas close to existing towns where most new construction takes place.

Production boreholes/wells would have to be sited close to the nuclear installation to have any possible effects due to drawdown of groundwater levels based on yield testing carried out on the site.

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

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

3. Soil liquefaction

The liquefaction potential of the subsurface materials of the proposed site was evaluated by using parameters and values for the site specific ground motion. The evaluation included the use of accepted methods of soil investigation and analytical methods to determine the hazards. Significant damage can occur to civil structures supported on soils that liquefy.

The site is underlain by an intergranular aquifer dominated by poorly graded Aeolian sand that exhibits erratic soil consistency in places. At sufficiently high peak ground acceleration, an unacceptably high liquefaction potential exists.

Liquefaction risks will be dealt with in the design of the installation, e.g. through founding the plant basemat on bedrock.

4. Volcanism

Volcanic events can present significant hazards to a nuclear installation during its lifetime. As a general guide, volcanoes that have erupted during the last 10 000 years are usually considered active. Information on the assessment of the potential volcanism in the site region indicate that volcanism occurred in the region more than 10 million years ago which means that they can be considered inactive.

5. Behaviour of foundation materials

The geotechnical characteristics of the subsurface materials, including uncertainties, were investigated and a soil profile for the site in a form suitable for design purposes was determined. The stability of the foundation material under static and seismic loading was assessed. The groundwater regime and the chemical properties of the groundwater were also studied.

Extensive investigation of the site bedrock through field and laboratory investigations revealed that the site is underlain by hard quartzitic (sandstone dominated) Skurweberg formation rocks in the south and less hard (quartzitic sandstone dominated) Goudini formation rocks in the central and northern parts of the site.

These rocks have been extensively sheared and deformed due to past tectonic activity and the site itself is located on the southern limb of an anticline. The Table Mountain Group (TMG) rocks underlying the site dip at approximately 50° to the south. Being of sedimentary origin, it is apparent that the weathering profile of these rocks varies considerably across the site and this weathering is influenced by depositional characteristics and discontinuities in the deformed rocks.

The Skurweberg and Goudini formation rocks appear to have varying characteristics related to uniaxial compressive strength (UCS). In essence, the Skurweberg formation rocks tend to have a higher average UCS than the Goudini formation rocks. The distribution of UCS in the Skurweberg rocks envelops the distribution of UCS in the Goudini rocks.

Comparison of the general foundation soil characteristics requirements for a nuclear installation(s) and the currently available data for the site indicate no impediment to building the nuclear installation foundations on (or in) the site bedrock.

6.3.2.2 Seismic hazard and surface faulting

In conducting the Thyspunt probabilistic seismic hazard analysis (PSHA), the USNRC endorsed the “Senior Seismic Hazard Analysis Committee (SSHAC) Level 3” process that was followed to provide a high degree of assurance that uncertainties have been identified and characterised. Care was taken to ensure that the hazard study was extensively documented in all regards, and subjected to rigorous quality assurance.

The earthquake catalogue is the basis for modelling the recurrence rate for future earthquakes, which are the drivers of the hazard estimates. Unfortunately, the period covered by instrumental recordings is short and the South African seismographic network is sparse in terms of spacing between instruments. In order to expand the earthquake catalogue, historical investigations of archives and newspapers (seeking both reports and ‘negative evidence’) were conducted to confirm whether absence of evidence was evidence for absence of earthquakes in the site region. The historical earthquake investigations were complemented by the collection of intensity data from earthquakes for which instrumental solutions are available, which were used to calibrate the relationships employed to assign locations and magnitudes to historical earthquakes.

After establishing the tectonic and geological framework for the southern part of South Africa, investigations were conducted for evidence of geologically-recent movements on known faults. These investigations consisted principally of fault corridor investigations, especially for the Kango fault which has been re-activated in the Quaternary, where trenching was conducted.

Marine terrace studies provided constraint on movements of onshore and offshore faults. In the absence of a database of strong ground-motion recordings from earthquakes in South Africa, use was made of weak-motion recordings and the intensity database to obtain insights into the nature and amplitude of ground motions in this region. There are no published ground-motion prediction equations (GMPEs) for South Africa, but care was taken to select state-of-the-art GMPEs for this application and then to adjust these to the target region and site.

Extensive in situ measurements of shear-wave velocity were made at the Thyspunt site itself. In all regards, an extensive database was assembled for the Thyspunt PSHA and rigorously analysed. The technical bases were further enriched through structured interactions with resource and proponent experts at formal workshops conducted in accordance with the specifications for an SSHAC Level 3 process. A participatory review panel (PPRP), consisting of prominent international experts, was appointed, and undertook rigorous review of both the process followed and the technical bases for the hazard input model, interacting with the project on numerous occasions and conducting a detailed review of the final documentation. The PPRP has expressed unqualified endorsement both that the SSHAC Level 3 process was adhered to throughout and that the final hazard assessment meets all of the requirements, including capturing the “Centre, Body, and Range” of “Technically Defensible Interpretations”.

1. **Seismic hazard analysis**

The most important potential hazard at the site is seismic hazard, vibratory ground motion hazard, and surface faulting hazard. A probabilistic seismic hazard analysis (PSHA) was conducted using latest internationally recognised methodologies. The PSHA methodology accounts for the uncertainties that are associated with the evaluation of seismic hazards.

The input to the PSHA consisted of a seismic source characterisation model and a ground motion characterisation (GMC) model. (The seismic source characterisation model defines the location and average rates of all potential future earthquakes of different magnitudes and uses information collected and documented on pre-historical, historical, and instrumentally recorded earthquakes in the region. The GMC model predicts the expected distribution of spectral accelerations at a site due to a particular earthquake scenario.)

The resulting ground motions from all possible earthquake scenarios were calculated and by sampling, the full distribution of ground motion amplitude estimates were obtained of the total rate at which each level of acceleration is expected to be exceeded at the site. A ground motion response spectrum (GMRS) was determined which is the basis for seismic design of any nuclear installation to be constructed on the site.

The Thyspunt GMRS indicates that the Thyspunt site is located in an area of very low seismic activity. The shape of the Thyspunt GMRS is similar to those obtained for hard rock sites in Eastern United States. The low amplitude of the design basis spectrum for the Thyspunt site, notwithstanding that it is based on the mean hazard from an analysis that incorporated wide margins of epistemic uncertainty is the consequence of the absence of a highly active seismic source in close proximity to the site.

2. **Surface faulting**

The potential for surface faulting (i.e. the fault capability) was assessed for the site. The methods used and the investigations made were sufficiently detailed to determine that there is no capable fault on the site. The investigation indicates that there is no evidence for capable tectonic deformation at the site location and that the potential for tectonic deformation is negligible. This is based on the geological investigations which demonstrated that mapped faults within the site area are not capable faults. Bedrock mapping in the site vicinity found no evidence for surface faulting or deformation that would suggest capable faults in the site area. The basis for this conclusion is the absence of geomorphic features, indicative of Quaternary deformation.

6.3.2.3 Meteorological events

The meteorological and climatological characteristics for the region around the site were investigated and evaluated in support of the identification of external events and potential hazards to the nuclear installation on the site. The atmospheric structure required for enabling atmospheric dispersion predictions necessary for the assessment of potential radiological impact on the public and the environment and the feasibility of emergency planning is also developed. In accordance with local and international recommendations, 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.

In order to evaluate their possible extreme values, the following meteorological phenomena were investigated: hurricane-force wind (including windblown dust storms), thunderstorms, precipitation (including hail), air temperature (dry bulb and wet bulb), atmospheric pressure, and storm surges. Uncertainties in the data and the potential effects of climate change were taken into account in this evaluation.

1. **Meteorological measurement**

On-site meteorological data has only been accumulated for a period of three years. Data accumulated over longer periods are required for long-term statistical analysis. To allow the establishment of historical trends, the NNR and IAEA consider it acceptable to collect meteorological information from nearby weather stations. Since the conditions at Cape St. Francis most closely represent the meteorological conditions at the site, the site data was augmented by long-term meteorological data collected by a weather station of the South African Weather Service (SAWS) at Cape St. Francis, approximately 12 km east of the site. Longer-term data (30 years and more) were sourced from monitoring stations in Humansdorp and Port Elizabeth, which are located further away.

The meteorological station on site consists of a 10 m tall mast, fully equipped with instrumentation to measure the required parameters. An automatic data logger is used to record meteorological data. The data is retrieved remotely via telephone dial-up modem or downloaded onsite, using a data transfer connection cable and personal computer.

Corrosivity of the local atmosphere was measured using a coupon-based method (CLIMAT) and the ISO Standard 9223 methodology. The CLIMAT method involves the exposure of metallic coupons to the environment and subsequently classifying the resultant corrosion. The ISO Standard 9223 methodology uses the measured temperature and relative humidity from the local weather station together with the deposition rate of sulphur dioxide and airborne salinity to determine the corrosivity rate.

Meteorological measurement at higher levels will be initiated at least one year prior to the start of the nuclear installation construction.

2. Meteorological parameters

i) Wind speed and direction

The historical data set produced by Eskom (1987 to 1988) indicates that the most dominant wind direction in the site region is from the west-northwest to northwest. More frequent stronger winds were recorded from a west-northwest to northwest direction.

On-site observations carried out during the period 2008 to 2011, shows that westerly winds dominate with approximately 20,88% occurrences. The westerly wind direction also experiences a high frequency of strong winds (0,33% above 12 m/s). The second highest frequency (0,30%) of strong winds comes from the east, followed by west-southwesterly (0,19%) and east-northeasterly (0,17%) winds.

Significantly more westerly and easterly winds were observed at Cape St. Francis than at the site during the summer season. Significantly more frequent east-northeasterly and west-northwesterly winds were observed at the site than at Cape St. Francis.

The highest hourly average and wind gusts recorded at the site during the 2008 to 2011 period are presented in Table 3 below. Most of the gusts occurred during westerly winds, followed by east-northeasterlies.

Table 3: Monthly maximum hourly average and wind gusts (m/s) at Cape St. Francis and Thyspunt

Month	**Cape St. Francis (June 2004 – March 2011)**		**Thyspunt (January 2008 – March 2011)**	
	Average	**Highest Gust**	**Average**	**Highest Gust**
January	16,7	24,0	14,2	22,8
February	16,4	25,0	13,5	30,7
March	19,5	28,0	13,5	22,9
April	16,4	24,9	14,1	22,4
May	19,5	33,7	15,1	31,6
June	23,2	36,4	17,9	28,4
July	19,9	34,2	18,2	24,6
August	21,1	35,3	16,4	27,6
September	18,8	29,9	14,9	30,6
October	18,5	27,7	17,9	30,4
November	16,2	24,3	13,8	23,4
December	19,7	28,9	16,6	24,2
Annual	23,2	36,4	18,2	31,6

ii) Ambient air temperature

The mean daily maximums for the site and Cape St. Francis were 20,9°C and 19,6°C, respectively. The mean daily minimums for the site and Cape St. Francis were 14,6°C and 14,5°C, respectively.

The most extreme hourly average temperatures over the 1920 to 1984 period were recorded on 2 January 1963 (42,8°C) and 3 May 1934 (0,8°C). These extremes were not observed at Cape St. Francis during the 2004 – 2011 period (37,2°C on 19 March 2008 and 5,0°C on 19 August 2005) or at the site (38,2°C on 13 April 2010 and 6,7°C on 20 August 2010).

iii) Precipitation

The rainfall season for the site area is all year round. The mean annual precipitation (MAP) is expected to be between 600 mm and 800 mm. The limited three-year monitoring (2008 to 2011) at the site resulted in a MAP of 589,6 mm, i.e. 515,3 mm during 2008, 595,1 mm during 2009, and 657,3 mm during 2010.

Long-term rainfall observations made at the SAWS station at Cape St. Francis over the period 1878 to 2001 recorded a MAP of 664 mm. The MAP calculated for the period 2005 to 2010, excluding 2008, at the new weather station erected at Cape St. Francis in 2004 is 530,2 mm.

A comparison of the three year's observation at the site was made to the SAWS's long-term statistical analysis for Cape St. Francis.

Normal monthly rainfall is well distributed throughout the year with:

- The highest monthly averages of 75 mm and 72 mm occurring in August and May, respectively;
- The lowest monthly averages of 32 mm in January.

The highest monthly rainfall of 366 mm occurred in September 1932, and the lowest monthly rainfall of 0 mm occurred in January 1906 and June 1949.

The recorded highest 24-hour rainfall at Cape St. Francis (old station) of 130 mm occurred on 27 May 1944, followed by 120 mm on 25 March 1981. A new record high 24-hour rainfall of 157,8 mm was recorded on 5 March 2007 at the new SAWS station. The highest hourly rainfall of 35,4 mm was also recorded on this day. The highest hourly rainfall at the site of 51,9 mm was recorded on 17 March 2011.

iv) Thunder, hail, snow, and fog

The SAWS climate data for Cape St. Francis (1881-1984) were used to determine the average number of days that thunder, hail, snow, and fog occur. The results of the data analysis are presented in Table 4.

Table 4: Average number of days with thunder, hail, snow, and fog at Cape St. Francis (1881-1984)

Month	Thunder	Hail	Snow	Fog
January	0,6	0,0	0,0	2,0
February	0,7	0,0	0,0	4,0
March	1,0	0,0	0,0	4,8
April	0,8	0,0	0,0	2,8
May	0,7	0,2	0,0	1,1
June	0,3	0,1	0,0	0,2
July	0,3	0,2	0,0	0,5
August	0,4	0,2	0,0	0,8
September	0,5	0,0	0,0	1,0
October	0,8	0,1	0,0	2,4
November	0,6	0,0	0,0	2,1
December	0,5	0,0	0,0	2,6
Annual	7,2	0,8	0,0	24,3

v) Atmospheric moisture

Measurements of relative humidity were performed for the period January 2008 to March 2011 at the site.

At the site, the highest daily average relative humidity of 84,9% occurred in January followed by a slightly lower value in February (84,5%). The highest daily maximum humidity values at the Cape St. Francis station also occurred in January and February, i.e. 84,4% and 85,1% respectively.

The lowest daily average relative humidity at the site was for July (69,9%) followed by June (72,3%). The annual average maximum and minimum relative humidity recorded at the site were 94,6% and 55,9% respectively.

The annual average maximum and minimum relative humidity recorded at the Cape St. Francis station were 91,4% and 62,3% respectively.

vi) Atmospheric stability

The southern and western coastal areas experience a persistent low-level subsidence inversion, termed the sub-escarpment layer, with its base at approximately 500 m and a depth of about 600 m. This layer is due to the predominance of the South Atlantic high-pressure (HP) system, and represents the boundary between the dry, subsided upper air and the moist influx of maritime air. The height of this layer is related to the depth of the sea breeze system and intensity of subsidence in the upper air. The strength of inversion has been shown to vary between an average of 7°C in summer and 5,2°C in winter. The sub-escarpment inversion is stronger and occurs more frequently during the summer (51%) due to the South Atlantic HP reaching its most easterly position during December. The inversion occurs for approximately 30% of the time during winter months. Surface inversions occur 50 to 60% of nights over the year, being most prevalent during winter months with a 70% frequency of occurrence.

The most prevalent atmospheric condition observed at the site is neutral (stability class D), followed by unstable conditions (stability class C).

3. Severe and rare phenomena

Rare meteorological phenomena are defined as phenomena that occur infrequently. Thus, at any particular weather 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.

i) Severe weather

The southern coast of South Africa is subjected to large synoptic scale systems that drive the local weather conditions at any given area. These local weather conditions are normally characterised as low-level stratus clouds and not by towering convective storms that produce hail and thunder showers. Severe weather is more closely associated with severe wind conditions. Four main wind producing systems have been identified, namely coastal low buster, cut-off lows, shallow south-easterlies, and mid-latitude lows.

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 Eastern Cape are compound, producing various combinations of hail, wind, tornado, lightning, and flash flooding. Damaging winds associated with severe thunderstorms include tornadoes, downbursts (macrobursts or microbursts)[1], straight-line winds[2], gust fronts, and derechoes[3].

ii) Tropical cyclones

The potential for tropical cyclones in the site region was investigated. The Thyspunt 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 34°S and is therefore not subjected to tropical cyclones.

iii) Tornadoes

A tornado is a violent rotating column of air extending from a thunderstorm. The potential for the occurrence of tornadoes in the region of Thyspunt was assessed on the basis of detailed historical and instrumentally recorded data for the region. The hazards associated with tornadoes were derived and expressed in terms of parameters such as rotational wind speed, translational

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[1] A downburst is created by an area of significantly rain-cooled air that, after hitting ground level, spreads out in all directions producing strong winds. Microbursts and macrobursts are downbursts at very small and larger scales, respectively. Most downbursts are less than 4 km in extent: these are called microbursts. Downbursts larger than 4 km in extent are sometimes called macrobursts.

[2] Straight-line winds are common with the gust front of a thunderstorm or originate with a downburst from a thunderstorm. If these winds meet or exceed 93 km/h then the storm is classified as severe.

[3] 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.

wind speed, radius of maximum rotational wind speed, pressure differentials, and rate of change of pressure. In the assessment of the hazard, missiles that could be associated with tornadoes and other strong winds were considered.

There have been three reports of tornadoes at Port Elizabeth (16 March 1956, 10 October 1978, and 2 November 2000), but no evidence of tornadoes could be found for the site and its surrounding area. On the basis of the available tornado occurrences an estimate of tornado frequency for the site was made by analysing the available tornado recordings. This included tornadoes witnessed up to a maximum distance of about 320 km from the site (East London). Figure 17 depicts the tornado occurrences over the period 1905 to 1997.

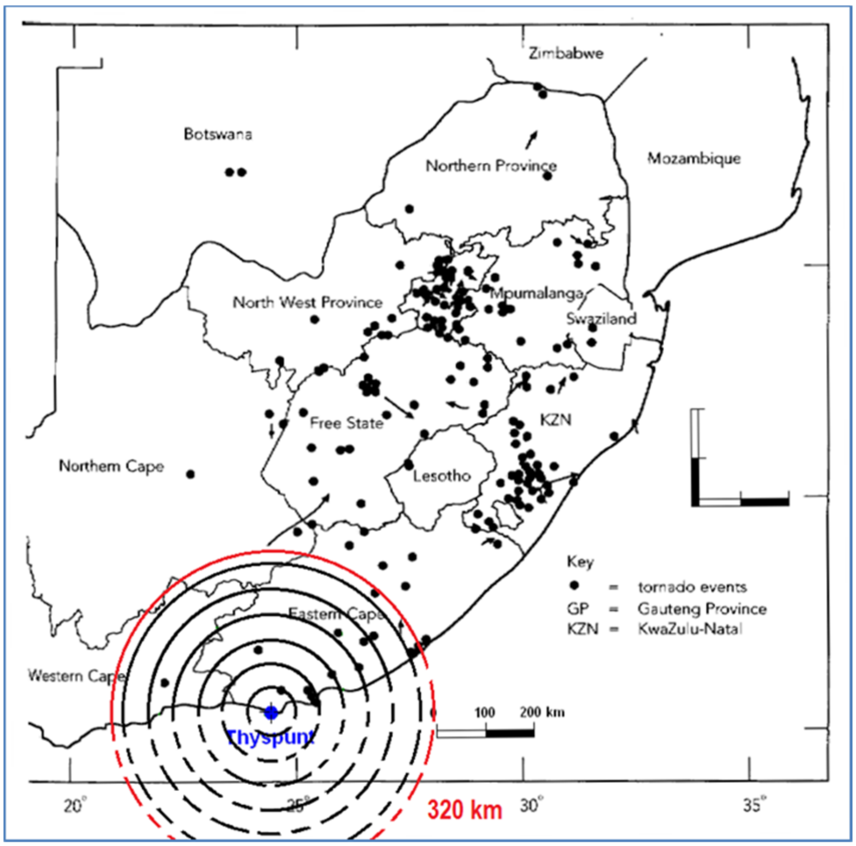

Figure 17: Distribution of tornado events over the eastern parts of South Africa in the period 1905 - 1997

iv) Lightning

The potential for the occurrence and the frequency and severity of lightning and the potential for electromagnetic interference were evaluated for the site. The analysis of data shows that the site experiences less than 1 lightning flash per year per km^2. The highest peak current recorded during the period was 166 kA (kiloampere) with an average of 25 kA

v) Wind-borne missiles

A meteorological event that is of particular importance is the potential impact of wind-borne missiles on structures, systems, and components.

Wind velocities in excess of 34 m/s are capable of generating missiles from objects lying within the path of tornadoes and from debris of nearby damaged structures. The estimated 10^{-7}/a tornado rotational wind speed is 90 m/s. The design-basis missiles are based on the highest wind speed category developed by the USNRC, which gives the design-basis tornado missile spectrum and maximum horizontal speed as follows:

- schedule 40 pipe:
  - size: 0,168 m diameter by 4,58 m long;
  - mass: 130 kg;
  - maximum horizontal speed: 34 m/s;
- automobile:
  - size: 5,0 m by 2,0 m by 1,3 m;
  - mass: 1 810 kg;
  - maximum horizontal speed: 34 m/s;
- solid steel sphere:
  - size: 0,025 4 m diameter;
  - mass: 0,0669 kg;
  - maximum horizontal speed: 7 m/s.

4. Other extreme meteorological events

Extreme events such as tropical cyclones, ice and ice cover, blizzards, and drought are screened out because of the meteorological data presented above and the fact that the sea serves as a heat sink. Ice is not anticipated to form in the sea at the site.

The potential abrasive effect of the windblown sands has not been quantified. The vegetation found on the site, however, acts as a natural mitigation measure, apart from the area of headland by-pass dunes north of the site footprint.

6.3.2.4 Hydrological events

The site region was assessed to determine the potential for flooding due to one or more natural causes that may affect the safety of the nuclear installation such as high tide, storm surge, seiche, and wind waves. All pertinent data, including historical data, both meteorological and hydrological, was collected and critically examined.

A suitable meteorological and hydrological model was developed with account taken of the limits on the accuracy and quantity of the data, the length of the historical period over which the data were accumulated, and all known past changes in relevant characteristics of the region.

The possible combinations of the effects of several causes were also examined. For example the potential for flooding by a combination of high tide, wind effects on bodies of water, and wave actions were assessed and taken into account in the hazard model.

The hazards for the site due to flooding were derived from the model. The parameters used to characterise the hazards due to flooding included the height of the water, the height and period of the waves, the warning time for the flood, and the duration of the flood and flow conditions. Values for extreme high sea water levels and the annual probabilities of exceedance were identified which include the potential effects of climate change. Extreme low sea water levels were also analysed and quantified.

The potential for instability of the coastal area due to erosion or sedimentation was investigated.

The region was also investigated to determine the potential for tsunamis or seiches that could affect the safety of nuclear installation(s) on the site.

1. **Flooding from the sea**

   The following hydrographic parameters have been analysed and quantified in order to calculate their combined flooding level from the sea:

   - Tides;
   - Storm surge;
   - Wave set-up and run-up;
   - Long waves (including meteo-tsunamis);
   - Tsunami;
   - Seiche (found not to be relevant at the site).

   Flooding from the sea was identified as a significant hazard that will need to be taken into account in the design of the nuclear installation, i.e. the terrace will need to be positioned above the design-basis flood level, or a protective revetment will need to be designed in front of the terrace.

2. **External flooding from other sources**

   Other flooding scenarios that have to be considered for a nuclear installation on the site are those that could induce a transient in water level at the site resulting in static effects (water weight) and dynamic loads on the nuclear installation. 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. The provisions for such events are mostly design related.

3. **Floods and waves caused by failure of water retaining structures**

   The hazards associated with the failure of water control structures (e.g. dams) were investigated. The risks from changes in the natural channel for rivers were also investigated. There is a large dam (Impofu) situated on the Krom River approximately 10 km north of the site. It however falls in a different watershed and therefore does not drain towards the nuclear installation and hence poses no hazard to the installations at the site.

   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 approximately 4 to 5 km north of the site. Failure of a dam upstream of the site is not considered a hazard to the nuclear installation since these dams are small with approximate dam wall heights not more than 5 m.

   Due to the extensive temporary ponding areas, low flows, and velocities, there is minimal erosion potential which may affect the safety of the nuclear installation. Any potential flooding due to sedimentation within a watercourse is negligible and will not affect the safety of the nuclear installation.

   Hence, from a site safety perspective, the nuclear installation will not be located along any major watercourses which could potentially affect the site during an extreme flood event. The flood levels are controlled by the extreme downstream water levels from the ocean rather than water levels generated by surface water run-off from the minor catchments.

6.3.2.5 External fires

External fires were investigated with appropriate considerations for the safety of the facility (e.g. access to the site, availability of power, ventilation, etc.) with special emphasis on the unavailability of power or any threat to operator action owing to the release of smoke and toxic gases. External fires are fires occurring outside the site boundary, e.g. forest/veld fires and oil spills at sea. Potential hazards are loss of off-site power (LOOP), forced isolation of a nuclear installation's ventilation, and the impact on control room habitability. Protection of the nuclear installation against fires is to be achieved by minimising the probability of a fire and providing barriers against external fires.

Protection of the nuclear installation against external fires is achieved by minimising the probability of a fire and providing barriers against external fires.

On-site fires are prevented with the establishment and management of fire breaks and alien vegetation eradication in accordance with an approved environmental management plan. Land use around the nuclear installation will be managed so that an external fire does not propagate toward the plant.

6.3.3 External Human-Induced Events

Human-induced events are considered accidental events (e.g. oil spills and hazardous material explosions). Potential stationary and mobile sources of human-induced hazards that were investigated are:

- The potential for aircraft crashes on the site, with account taken to the extent practicable of characteristics of future air traffic and aircraft. Airfields and airports within the site vicinity and region are investigated because aircraft crashes from civilian and military aircraft onto the proposed Thyspunt power station has the potential to result in severe consequences to both works and the nearby public. Most of the air crashes occur during take-off and landing phases of flight hence the existence of airports and airfields in the site vicinity and region increases the potential of aircraft crash hazard on the plant.
- Activities in the region that involve the handling, processing, transport and storage of chemicals having a potential for explosions or for the production of gas clouds capable of deflagration or detonation. The region is investigated for facilities (including facilities within the site boundary) in which flammable, explosive, asphyxiant, toxic, corrosive, or radioactive materials are stored, processed, transported, or otherwise dealt with which, if released under normal or accidental conditions, could jeopardise the safety of the nuclear installation(s).
- Facilities that may give rise to missiles of any type that could affect the safety of the nuclear installation(s).
- Potential sources (stationary and mobile) of hazards, including external fire.

The ultimate purpose of the investigation is to identify transportation, civil, industrial, and military facilities outside of the owner-controlled boundary that may affect the feasibility of implementing emergency plans or potentially hazardous activities that may pose a threat to the nuclear installation(s) on the site and to identify sources of external hazards inside and/or outside the owner-controlled boundary in order to ensure the safety of the nuclear installation(s) against external human-induced events.

6.3.3.1 Aircraft crashes

The NNR requires a design-specific assessment of the effects on the nuclear installation of the impact of a large commercial or military aircraft. A nuclear installation has to be designed to withstand the impact of a design-basis aircraft crash without the loss of any safety function. The potential for aircraft crashes on the site was assessed with account taken to the extent practicable, of characteristics of future air traffic and aircraft (both military and commercial). Double containment and layout of advanced nuclear installation designs to reduce aboveground vertical profiles offer advantages in the resistance to malevolent human-induced external events which cannot be probabilistically defined. Key relevant information on airports and airways can be summarised as follows:

- St. Francis airfield (10,8 km east) is the only airfield within 16 km of the site and it does not accommodate routine, commercial, or public traffic. No aircraft accidents have occurred at the airfield according to records kept by the Civil Aviation Authority (CAA) for the period 1 January 1998 to 10 May 2008.
- There is no evidence of a planned airport upgrade, and given the existing use and infrastructure, the risk analysis increased the average movements of 100 per annum to 400 per annum to accommodate the uncertainties related to possible peaks.
- The only airport outside the 16 km radius of any significance is Port Elizabeth International Airport (PEIA) (85 km east-northeast), which controls all domestic flights for the south-eastern region of South Africa. Two aircraft accidents have occurred at the airport in the period January 1997 to May 2008 according to records kept by the Civil Aviation Authority.

Aircraft movement operations at PEIA are significantly less than a screening distance value criterion of $1\,000 \times d^2$. The parameter d is the distance in kilometres from a large airport to a site. The risk analysis conducted indicates that the airport will experience future growth in air traffic but this growth will be in the northerly direction of Johannesburg and Europe. The study indicates that an increase in flights to and from Cape Town would not influence frequencies calculated to determine risk as:

- PEIA is sufficiently far from the site to exclude airport related accidents; and
- In-flight crash frequencies are based on historical crash data over the South African mainland over the last 10 years. There is no indication that an increase in air traffic would result in a high crash zone having a higher crash frequency than for other parts of the country.

Airspace falls under the control of PEIA. The only major airport route in the vicinity of the site is for scheduled flights between PEIA and Cape Town. The analysis indicates that OKSET[4] needs

[4]OKSET refers to a marker beacon used by pilots when approaching the airport. It is a unique identifier related to the approach/holding pattern at PEIA, which forms part of the flight path to Cape Town and not an abbreviation.

to be further investigated for acceptability of distance from a flight path, as IAEA recommendations indicate a screening distance value of 4 km from the site for airways.

Crash frequencies were determined for airport and in-flight related operations. In-flight crashes per km^2 for the South African mainland were determined from historical aircraft accidents for the various sub-categories. Crash rates, based on the available data at the time of the risk analysis are summarised in Table 5.

Table 5: In-flight aircraft crashes

Aircraft Category	Sub-Category	In-Flight Crash Rate/km^2 (50% Confidence Interval)
Commercial	Air carrier	$1{,}31 \times 10^{-7}$
	Air taxi	$1{,}31 \times 10^{-7}$
General Aviation	Fixed wing	$1{,}20 \times 10^{-6}$
	Helicopter	$2{,}18 \times 10^{-6}$
Military	Large aircraft	$3{,}00 \times 10^{-8}$
	Small aircraft	$9{,}00 \times 10^{-7}$
	Helicopter	$5{,}00 \times 10^{-7}$

The frequency of aircraft crashes onto a building (nuclear installation) is determined by the sum of the in-flight and airport crashes and is depicted in the Table 6.

Table 6: Total crash frequencies for building areas

Aircraft Category	Sub-category	Total Crash Frequency/Year	Total Crash Frequency/Year	Total Crash Frequency/Year
		Area of 2 487 ha	**Area of 100 ha**	**Area of 10 ha**
Commercial	Air carrier	$2{,}30 \times 10^{-6}$	$1{,}37 \times 10^{-7}$	$3{,}84 \times 10^{-8}$
	Air taxi	$2{,}29 \times 10^{-6}$	$1{,}35 \times 10^{-7}$	$3{,}72 \times 10^{-8}$
General Aviation	Fixed wing	$4{,}09 \times 10^{-5}$	$1{,}73 \times 10^{-6}$	$3{,}83 \times 10^{-7}$
	Helicopter	$3{,}34 \times 10^{-5}$	$1{,}37 \times 10^{-6}$	$1{,}54 \times 10^{-7}$
Military	Large aircraft	$5{,}05 \times 10^{-7}$	$2{,}71 \times 10^{-8}$	$6{,}89 \times 10^{-9}$
	Small aircraft	$1{,}46 \times 10^{-5}$	$6{,}91 \times 10^{-7}$	$1{,}81 \times 10^{-7}$
	Helicopter	$7{,}77 \times 10^{-6}$	$3{,}18 \times 10^{-7}$	$3{,}58 \times 10^{-8}$
Total Crash Frequency for All Aircraft Categories		$1{,}02 \times 10^{-4}$	$4{,}40 \times 10^{-6}$	$8{,}37 \times 10^{-7}$

It is important to note that aircraft crash is included as a standard event with specific load functions in the design basis of the reference nuclear installations (designs with known parameters used in analyses to assess compliance with regulatory requirements), irrespective of aircraft crash frequency considerations. Both the Westinghouse AP1000 and the Framatome EPR reactors, have designs that are certified as being able to withstand the impact of a large commercial aircraft and include the following safety features:

- Performing the cooling function with reduced use of operator action;
- Intact containment (i) will not be perforated by the impact of a large commercial aircraft, and (ii) will maintain ultimate pressure capability, given the core damage event until effective mitigation strategies can be implemented. Effective mitigation strategies are those that provide, for an indefinite period, sufficient cooling to the damaged core or containment to limit temperature and pressure challenges below the ultimate pressure capability of the containment.
- Used fuel pool (UFP) integrity: The impact of a large commercial aircraft on the UFP wall or support structures would not result in leakage through the UFP liner below the required minimum water level of the pool.

6.3.3.2 Explosions and asphyxiant/corrosive/toxic gas releases

Activities in the region that involve the handling, processing, transport, and storage of chemicals and explosives having a potential for safety concerns, such as explosions and asphyxiant/toxic gas releases, were investigated. Consequences from external events involving hazardous substances would either damage nuclear installation structures, systems, and components or incapacitate operating personnel as a result of toxic gases, thermal radiation, and/or explosion overpressures. The limiting hazard parameter values where the consequences would be considered ‘safe’ and not pose a threat to life because of events, e.g. failures of structures, are given in Table 7.

Table 7: Limiting values for external events associated with hazardous material

Hazard	Hazard Parameter	Screening Value
Pool fire	Thermal radiation (1)	2,9 kW/m^2
Jet fire	Thermal radiation	2,9 kW/m^2
Flash fire	Flammable limits	½ LFL(2)
Boiling liquid expanding vapour explosion (BLEVE)	Thermal radiation[5]	2,9 kW/m^2
Explosion	Overpressure	2 kPa
Toxic cloud	Concentration	IDLH(3)

[5] The screening value of 2,9 kW/m^2 has been adjusted for the maximum daily solar radiation value of 1,1 kW/m^2; IDLH: Immediately Dangerous to Life or Health IDLH) and refers to the maximum concentration to which a healthy person may be exposed for 30 minutes and escape without suffering irreversible health effects or symptoms that impair escape (ranging from runny eyes that temporarily impair eyesight to a coma).

6.3.4 Assessment of Potential Impact of the Nuclear Facility in the Site Region

6.3.4.1 Demography (population growth and distribution)

The current and future population characteristics in the site region and vicinity were investigated in order to assist in assessing the potential effects of the proposed nuclear installation on the public in the region. Data on the population around the site were obtained from Statistics South Africa, South African Tourism, local and district authorities, or by means of specific field surveys. Spatial development plans and frameworks have also been utilised to assist in the estimation of the projected population in the region (i.e. estimated growth rates and envisaged development nodes). Projections were made on the basis of population growth rates and plans for possible development in the region. The projected figures for the two categories of permanent population and temporary population were extrapolated separately according to the data available. Critical groups of the population with particular dietary habits and specific locations for particular types of activity in the region have also been considered.

1. Current population distribution

i) Permanent population

a) Population

The analysis showed that a population of approximately 294 700 persons resided within 80 km of the site in 2001. The largest population numbers are in west-northwest, northwest, north, north-northeast, northeast, and east-northeast directions from the site (refer to Figure 18). The main settlements are presented in Table 8.

Table 8: Main settlements within the 80 km zone (2001)

Settlement	Distance (km)	Direction	Number of Persons (2001)
Oyster Bay, Umzamowethu	5	W/NW	340
Cape St. Francis, St. Francis Bay, Sea Vista	10 to 15	E/ENE	2 432
Humansdorp, Kruisfontein	15 to 25	N/NNE	17 584
Jeffreys Bay, Pellsrus, Ashton Bay, Paradise Beach	25 to 30	NE	16256
Hankey, Patensie	35 to 45	NNE	15 608
Kareedouw	40 to 50	WNW/NW	3 880
Thornhill	45 to 55	NE	1 667
Woodlands	50 to 55	WNW	1 514
Sanddrif, Nompumelelo Village	65 to 75	WNW	3 019
Portion of the Nelson Mandela Bay Municipality	55 to 80	ENE/NE	207 747

b) Population centres/density

In accordance with international recommendations, population centres of about 25 000 should not be closer than approximately 6,5 km from the reactor site, as a density of approximately 200 persons per square kilometre within this distance would yield a population of approximately 25 000 persons (approximately 16 km for 100 000 persons, 35 km for 500 000 persons, and 50 km for 1 000 000 persons) (Figure 19).

The 2001 census data indicate that the site complies with this guideline.

2. Temporary population

Transient population groups that were analysed for the Thyspunt region are those members of the public who reside for a short period (days or weeks) in a location (such as a camping ground) that can be identified in advance. This does not include members of the public who may be travelling through the area.

3. Tourist population

Data related to both domestic and international tourists visiting the Thyspunt region were obtained from South African Tourism and the Department of Environmental Affairs and Tourism. The results of the tourist population are presented below:

The tourist population for the Eastern Cape Province was estimated on the total international arrivals in South Africa for 2002 to 2006 and the provincial penetration rates as published by South African Tourism. Based on the results of the investigation, the total estimate for all the settlements depicted in Table 9 is 25 644 tourists/holidaymakers during December 2008.

Table 9: Tourists/holidaymakers in settlements in the Kouga municipal area on a typical day during December 2008[6]

Name of Settlement	Number of Permanent Residents (2008)	Total Number of Tourists	Tourist / Permanent Population Ratio
Oyster Bay	464	1 172	2,53
Cape St. Francis, St. Francis Bay, Sea Vista	3 061	2 563	0,84
Jeffreys Bay, Pellsrus, Aston Bay, Paradise Beach	19 967	12 067	0,60
Coastal towns: Sub-total	23 492	15 802	0,67

[6] Estimate by Planning Partners (2008)

Name of Settlement	Number of Permanent Residents (2008)	Total Number of Tourists	Tourist / Permanent Population Ratio
Humansdorp, Kruisfontein	27 094	1 374	0,05
Hankey, Patensie	24 323	7 146	0,29
Loerieheuwel	3 154	0	0,00
Thornhill	2 018	1 322	0,66
Inland towns: Sub-total	**56 589**	**9 842**	**0,17**
Total	**80 081**	**25 644**	**0,32**

The total estimate for all the above settlements shows that 25 644 tourists/holidaymakers visited the settlements in the Kouga municipal area during December 2008. This equates to:

- An average of 0,67 tourists per 1 permanent resident for coastal towns;
- An average of 0,17 tourists per 1 permanent resident for inland towns.

4. Projected population distribution

ii) Permanent population

a) Projected population

In accordance with the relevant regulations on the development of a nuclear installation, population projections need to be undertaken for the life expectancy of the installation. For this reason, population growth within the 80 km radius around the site was projected to 2086.

The total resident population within the 6,5 km zone is estimated to be approximately 1 030 persons by 2086. The small coastal settlement of Oyster Bay/Umzamawethu is the only settlement located within 6,5 km of the site. This settlement had approximately 340 residents in 2001. This settlement is projected to have a population of approximately 870 persons by 2086.

It is not likely that a population centre of 25 000 or more persons would develop within 6,5 km of the site over the life of the nuclear installation. In view of the possibility that a nuclear installation may be constructed at the site, further expansion of Oyster Bay/Umzamawethu should nevertheless be restricted. The projected total resident population within the 40 km zone is less than 140 500 for the year 2086.

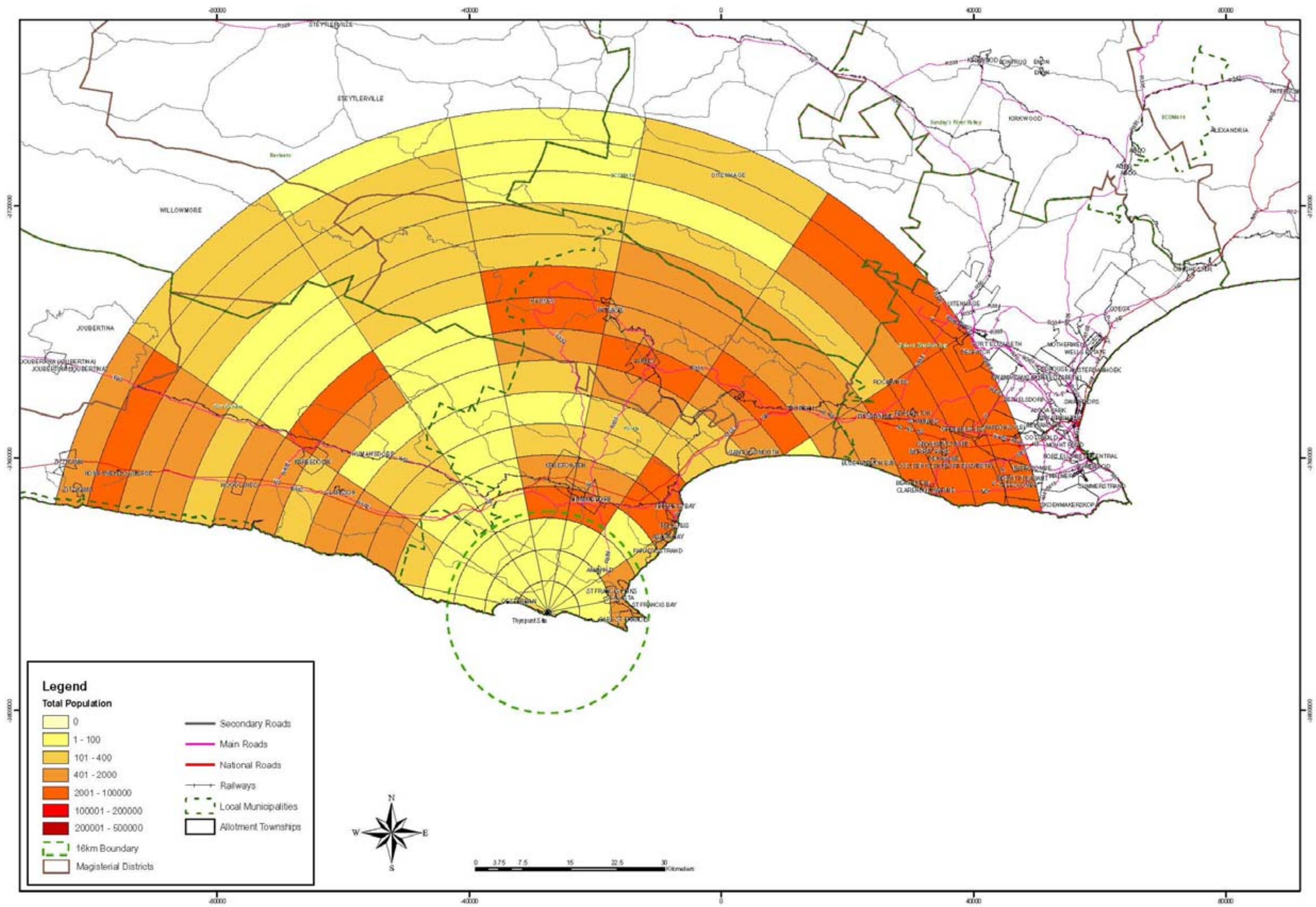

Figure 18: Population distribution within 5 km distance bands around the Thyspunt site (22,5° radial grid) up to 80 km (2001)

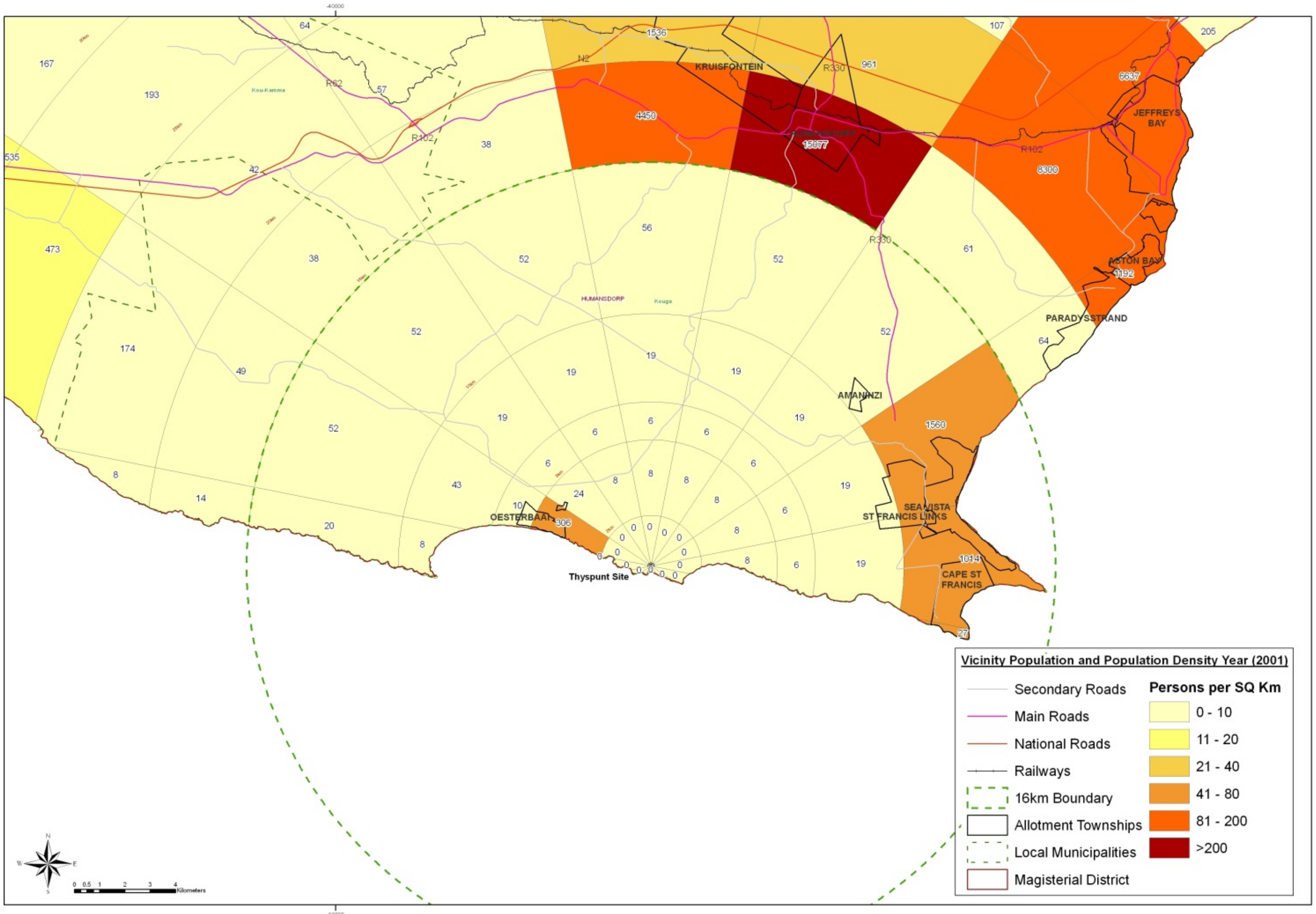

Figure 19: Vicinity population and population density (2001)

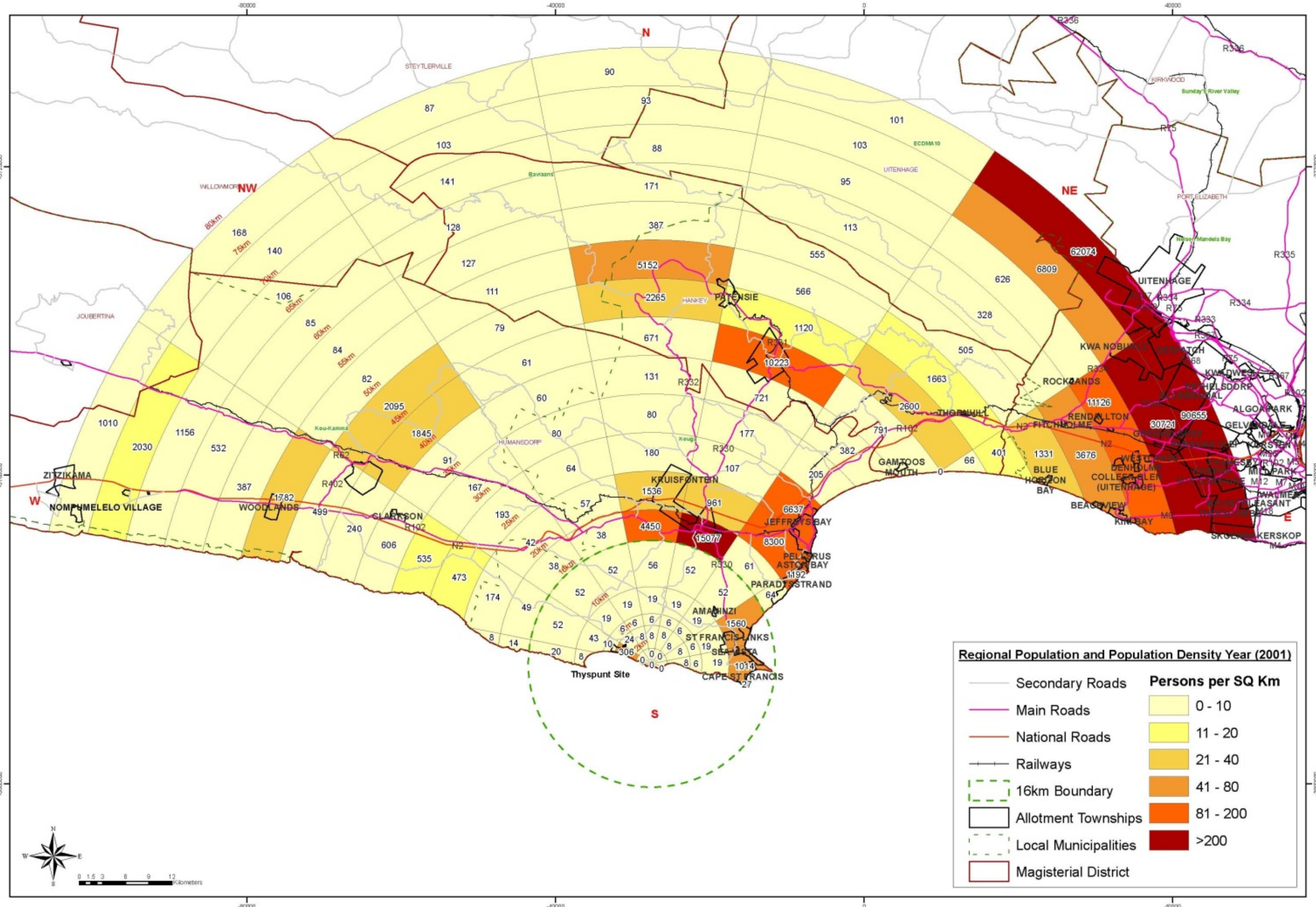

Figure 20: Regional population and population density (2001)

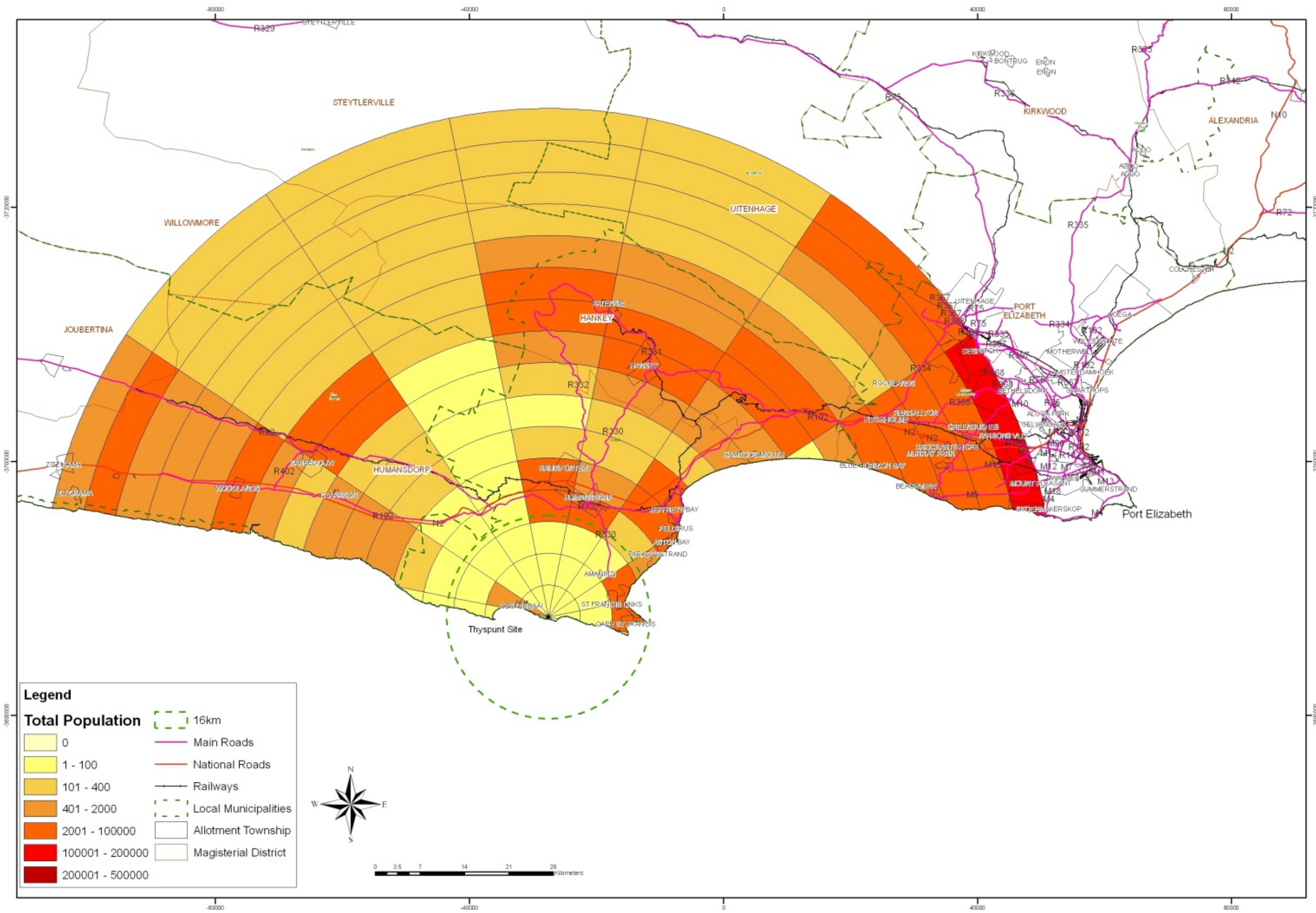

Figure 21: Total maximum cumulative population within 5 km distance bands around the Thyspunt site (22,5° radial grid) up to 80 km (2008)

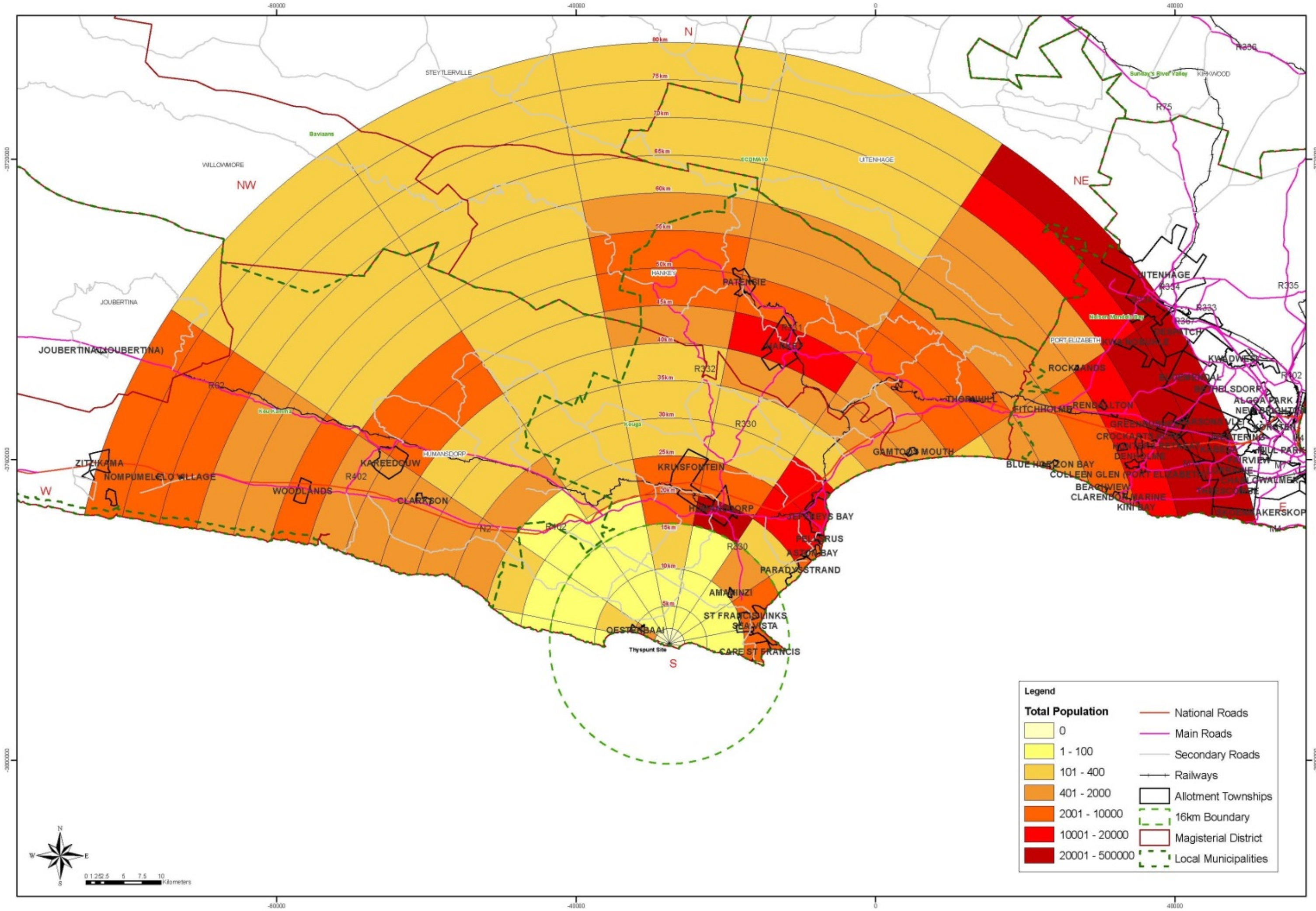

Figure 22: Projected population within 5 km distance bands around the Thyspunt site (22,5° radial grid) up to 80 km (2086)

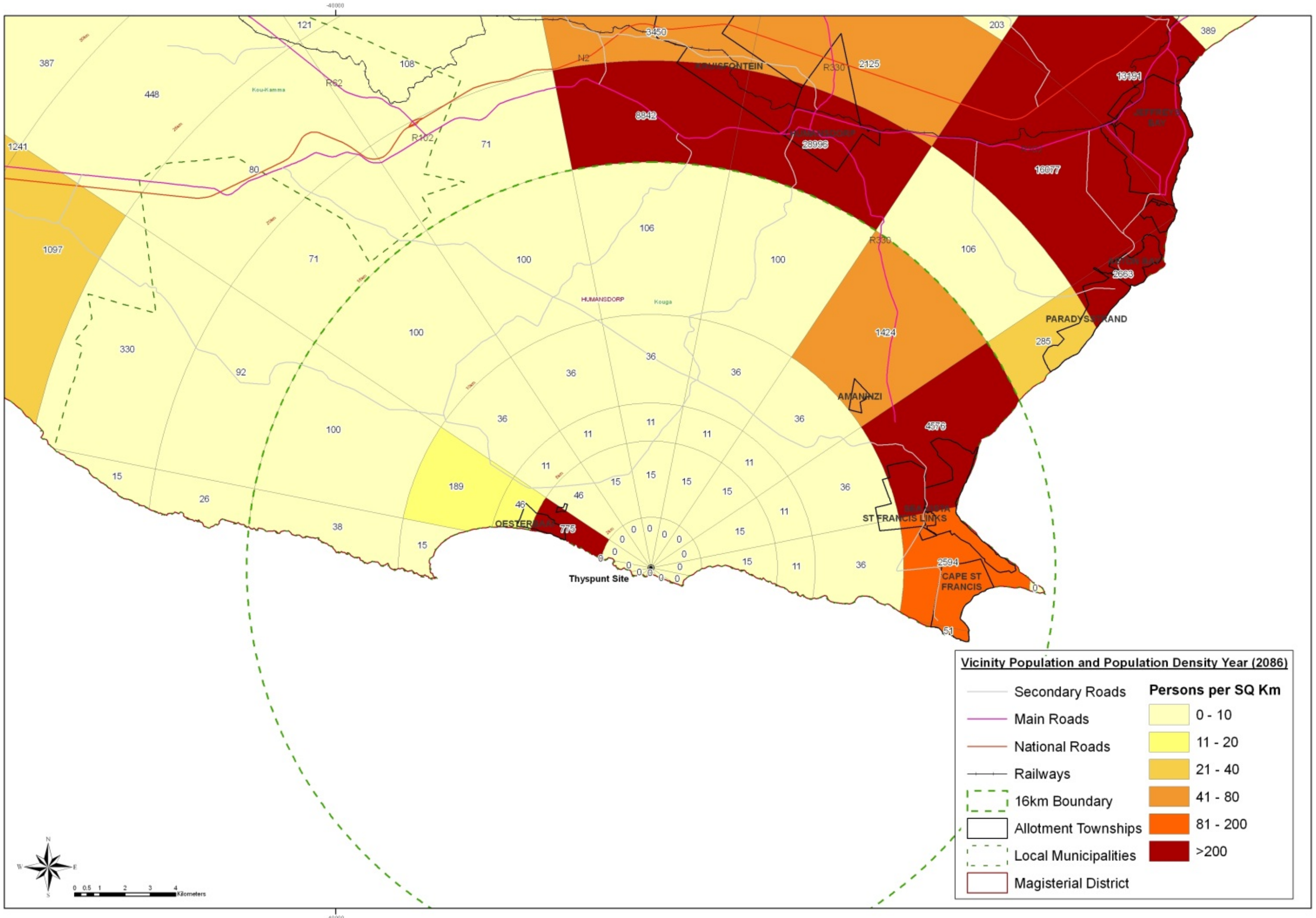

Figure 23: Cumulative vicinity population and population density (2086)

6.3.4.2 Land and Water Use

The use of land and water was characterised in order to assess the potential effects of the potential nuclear installation in the region and in particular for purposes of preparing emergency plans. The investigation covered land and water bodies used by the population or that could serve as a habitat for organisms in the food chain.

Land use within 16 km of the site is dominated by agricultural land, which is for the most part utilised for dairy farming and associated agricultural production such as beef and fodder crops. The Humansdorp district produces about 20% of the country's milk and about 40% of the milk produced in the Eastern Cape. A large number of dairies are present in the 16 km zone, in particular in the west-northwest, northwest, and northeast segments. Milk is delivered to large dairy producers in Humansdorp and Port Elizabeth.

Other agricultural products include sheep from 2,5 km in the northeast sector and game 10 km to the north-east.

Fruit and vegetable production is concentrated in the Gamtoos River Valley near Hankey and Patensie, between the 30 km and 55 km radii from the site.

There are several coastal resort towns in the site vicinity. Oyster Bay is located less than 5 km to the west of the site, and Cape St. Francis and St. Francis Bay are situated approximately 12,5 km to the east. These coastal towns are important and well-established tourist destinations. Other urban settlements within the 20 km radius of the site include Humansdorp and the southern portion of Jeffreys Bay (Paradise Beach). Limited expansion of towns within 16 km of the site is envisaged at local government level. The largest expected growth areas are planned at a strategic municipal level for Humansdorp and Jeffreys Bay urban settlements.

Future land use is not expected to be significantly different from the current use. Spatial development frameworks indicate that the coast in the area of the site is deemed important for nature conservation, tourism, and recreation. It also states that rural and agricultural land should be retained for agricultural purposes as far as possible.

About 1,2% of the region accommodates surface water resources. This water is used for irrigation and potable water supply within the site region. A large part thereof is transferred to the Nelson Mandela Bay metropole via the Algoa water supply system. Groundwater is an important water resource for the coastal towns and in the southern part of the region. Towns that rely on groundwater resources for potable water include Humansdorp, St. Francis Bay, Cape St. Francis, Oyster Bay, and Jeffreys Bay. The main aquifer tapped comprises fractured sandstone of the Table Mountain Group Aquifer.

Water used for irrigation in agricultural land is obtained from rivers in the region and three large dams, namely the Kouga, Churchill, and Impofu dams. Several smaller dams and groundwater extraction facilities are also used for irrigation.

6.3.4.3 Adjacent sea use

Marine species such as squid, south coast rock lobster, and fish are commercially harvested in the area. Recreational fishing is also popular and is practised from the accessible coastal sites and ski boats. The beach areas at Oyster Bay, St. Francis Bay, and Cape St. Francis are popular tourist destinations. The area stretching from Jeffreys Bay to Cape St. Francis represents one of the prime surfing destinations in the world.

6.3.4.4 Potential radiological impact on the public and the environment

An assessment of operational radioactive discharges from the nuclear installations envisaged for the site and the resulting potential radiological impact on the public and the environment was conducted.

The purpose was to demonstrate that the constraint on annual effective dose defined for the public by the national safety standards can be met. Apart from the safety assessment for humans, a screening assessment of the potential radiological impact on non-human species was also conducted.

A range of potential annual dose values for members of the public was determined. The doses to subcritical groups at ten different localities close to the site were investigated. All age groups were considered in respect of exposure pathways resulting from the following exposure types:

- Normal and routine airborne and liquid discharges;
- Short-term contingency discharges; and
- Direct external gamma radiation.

6.4 LESSONS LEARNED FROM THE FUKUSHIMA ACCIDENT

Lessons learned from the Fukushima accident and other related accidents were taken into consideration during siting investigations. The following are of particular relevance:

- Loss of off-site power (LOOP) together with the failure of on-site backup systems can have severe consequences.
- Flooding from the sea was found to be a significant hazard that has to be taken into account in the design of the nuclear installation(s), i.e. the terrace will need to be positioned above the design-basis flood level, or a protective revetment will need to be designed in front of the terrace.
- Loss of ultimate heat sink (i.e. loss of sea water cooling) can lead to loss of the decay heat removal system.
- Inoperable communication and transport networks around the nuclear installation site may jeopardise the implementation of safety related measures by operators and the emergency planning organisation by making escape routes impassable and isolating

the plant site in a possible emergency, with consequent difficulties in communication and supply.

Most of the lessons learned will be assessed for the specific design that will be chosen for the site. This will be done in later licensing stages.

6.5 CONCLUSION ON ADEQUACY OF SITE INVESTIGATIONS

The Thyspunt nuclear site has been extensively investigated with regard to all the site characteristics that could be significant to safety of the proposed nuclear installation. Characteristics of the natural environment in the site region that might be affected by potential radiological events in normal operational states and in accident conditions were also investigated.

Possible natural phenomena and human-induced situations and activities in the region of the site have been identified and evaluated according to their significance for the safe operation of the nuclear installation.

Pre-historical, historical, and instrumentally recorded information and records, as applicable, of the occurrences and severity of important natural phenomena or human-induced situations and activities have been collected for the region and have been carefully analysed for reliability, accuracy, and completeness.

Appropriate methods following international codes and standards and safety were adopted for establishing the hazards that are associated with major external phenomena, for example, a state-of-the-art methodology, the senior seismic hazard analysis committee (SSHAC) Level 3 process was followed to determine the seismic hazard for the site.

The size of the region to which a method for establishing the hazards associated with major external phenomena was applied, was large enough to include all the features and areas that could be of significance in the determination of the natural and human-induced phenomena under consideration and for the characteristics of the event.

In the evaluation of the site to determine its potential radiological impact on the region for normal operational states and accident conditions that could warrant emergency response actions, appropriate estimates of expected or potential releases of radioactive material were derived, with account taken of the enveloping characteristics of proposed facilities to be constructed on the site and its safety features.

The direct and indirect pathways by which radioactive material could potentially reach and affect people and the environment were investigated and evaluated, taking into account specific regional and site characteristics.

7 SAFETY CASE ELEMENTS

The Thyspunt site investigations have been conducted with Nuclear Professional diligence within a structured management environment, collected comprehensive information about the characteristics of the site, defined site specific design parameters and demonstrated site suitability in accordance with Eskom's requirements whilst also fulfilling the relevant national nuclear regulators safety requirements, i.e. National Nuclear Regulator (NNR) Act and the Regulations on Licensing of Sites for New Nuclear Installations.

7.1 SAFETY ANALYSIS

Evaluation and screening of external events at the Thyspunt site do not preclude the site from the establishment of a nuclear installation. External events evaluated were either:

- screened out from being considered further as a design basis;
- screened out conditional on the basis that the status be confirmed when the specific design is selected; or
- will be compensated for by means of:
    - design features of the envisaged nuclear installation(s); or
    - site protection measures.

The radiological dose assessment performed has shown that the annual dose for any age group lies between an upper value representing adult dose and a lower value representing the 1-year-old age group dose. The estimated annual dose to the critical group is less than 72 µSv/a. Hence, the annual dose to the public is well below the regulatory dose constraint requirement of 250 µSv/a.

The results of the radio-ecological screening assessment indicate a small radiological impact on non-human species. None of the organisms included as representative species in the ERICA code has a total dose that exceeds the screening value of 10 µGy/h.

7.2 MANAGEMENT SYSTEM

A comprehensive and integrated system for managing safety and quality was established to control the effectiveness of the execution of the site investigations and assessments and engineering activities performed in the different stages of the site evaluation.

The management system covers the organisation, planning, work control, personnel qualification and training, verification, and documentation, therefore ensuring that the required quality of work was achieved. Records are kept of the work carried out in the activities for site evaluation for the full life cycle of the nuclear installation(s).

A quality assurance programme was implemented for all activities that could influence safety or the derivation of parameters for the design basis for the site. The quality assurance programme was graded in accordance with the importance to safety of the individual siting activities under consideration.

The Eskom siting team had the overall responsibility for implementing siting activities. The siting team consist of a number of scientists/experts who were suitably qualified and experienced in the relevant disciplines required for siting. This team specified the work to be done and has overseen the investigations and acceptance reviews of the siting reports that document the siting investigation results.

Due to the wide range of subject areas and to provide the range of technical expertise required for the characterisation of the site and development of the safety case (SC), the siting team was augmented by procuring the services of specialist consultants. Contracts were entered into with a number of established South African consultants. All contracted resources were approved nuclear service providers and were appointed for specific work on the basis of their respective qualifications and experience. Consultants were qualified in accordance with Eskom quality and safety management requirements as well as that of the NNR's RD-0034 (*Quality and Safety Management Requirements for Nuclear Installations*), pertaining to the nuclear safety level of the service/product they provided. Consultants implemented RD-0034 and ISO 9001:2008 compliant management systems. The management systems provide the framework for the promotion, monitoring, maintenance, and enhancement of a strong safety culture, ensuring a common understanding of the key aspects of the safety culture. Adherence to local statutory requirements and compliance to specific national regulations and regulatory requirements from the NNR were verified. In particular, implementation of the RD-0034 requirements and the requirements of RG-0016 (*Requirements for Authorisation Submissions involving Computer Software and Evaluation Models for Safety Calculations*) by the performers of the relevant tasks were recorded and acceptance reviews were performed by Eskom.

7.3 OPERATIONAL SUPPORT PROGRAMMES

For the purpose of the NISL application, the operational support programme to be implemented is only briefly described. The operational support programme will be explained in much more detail in the PID to be developed as part of the NIL application.

The operational support programme (OSP) is a suite of safety programmes, plans, and procedures that are used to control the operation of the plant so that the plant safety parameters are respected, and assumptions made in the safety analyses remain valid. The OSP documents and programmes shall be developed in accordance with the safety case requirements for each licensing stage of the NISL application and shall take into account the selected vendor and the nuclear power plant type, once established. The OSP shall address the following areas:

- OSP requirements description document;
- OSP development programme;
- The operating technical specifications (OTS);

- Maintenance programme;
- In-service testing (IST);
- In-service inspection (ISI) programme;
- Configuration management programme;
- Emergency planning development programme;
- Environmental surveillance programme;
- Meteorology monitoring programme;
- Maintenance and update of the site safety report;
- Radiation protection programme;
- Spent nuclear fuel and radiological waste disposal programme;
- Plant operating experience and corrective action programme;
- Physical security plan;
- Operating procedures (normal, incidents, accidents);
- Severe accident mitigation design alternatives.

Some of the documents related to the disciplines listed above may only be completed once the technology or vendor has been selected as this may affect the systems, structures, and components of the plant and their functionality. The personnel required to compile and review these documents shall be adequately trained and authorised for their area of expertise in accordance with the relevant Eskom training procedures.

7.4 COMPLIANCE WITH SAFETY STANDARDS

7.4.1 Regulatory Framework

The legal basis for obtaining an NISL is given in the NNR Act (Act No. 47 of 1999), specifically sections:

- 5(b) of the Act that grants the NNR the power to, amongst others, exercise regulatory control related to safety over the siting, design, construction, operation, manufacture of component parts, decontamination, decommissioning, and closure of nuclear installations through the issuing of nuclear authorisations.
- 20(1) of the Act that states that: "*No person may site, construct, operate, decontaminate, or decommission a nuclear installation, except under the authority of a nuclear installation licence".* In terms of the provisions of this section, the siting, construction, operation, decontamination, or decommissioning of any nuclear installation must be authorised by way of a nuclear licence granted by the NNR.

- 21(1) of the Act which requires that any person wishing to site, construct, operate, decontaminate, or decommission a nuclear installation may apply in the prescribed format to the chief executive officer of the NNR for a nuclear installation licence and must furnish such information as required by the NNR board of directors.
- 23 of the Act which states that the chief executive officer may impose (and amend) conditions of authorisation which are necessary to ensure the protection of persons, property, and the environment against nuclear damage, or to provide for rehabilitation of the site.

Other regulatory requirements applicable to siting of nuclear facilities are:

- R.388 (*Regulation on Safety Standards and Regulatory Practices*)
- R.927 (*Regulation on Licensing of Sites for New Nuclear Installations*)
- RD-014 (*Emergency Preparedness and Response Requirements for Nuclear Installations*)
- RD-0024 (*Requirements on Risk Assessment and Compliance with Principal Safety Criteria for Nuclear Installations*)
- RD-0034 (*Quality and Safety Management Requirements for Nuclear Installations*)
- RG-0011 (*Interim Guidance for the Siting of Nuclear Facilities*)
- RG-0016 (*Guidance on the Verification and Validation of Evaluation and Calculation Models Used in Safety and Design Analyses*)
- RG-0020 (*Interim Guidance on Emergency Preparedness and Response for Nuclear and Radiological Emergencies*)
- PP-0014 (*Consideration of External Events or Nuclear Installations*)
- PP-0015 (*Emergency Plan Technical Basis for New Nuclear Installations*)

Other regulations taken into consideration include:

- Occupational Health and Safety Act (OHSA), 1993 (Act No. 85 of 1993)
- Environmental requirements in terms of the National Environmental Management Act (NEMA), 1980 (Act No. 47 of 1980)

7.4.2 International Standards, Experience, and Best Practice

The Thyspunt site investigation studies took into account relevant international safety standards and recommendations, as well as lessons learned and best practice from countries with experience in the field of site evaluation and development of new nuclear installations. The main sources considered are listed below.

7.4.2.1 International Atomic Energy Agency (IAEA) guides, codes, and standards

- Fundamental Safety Principles, Safety Fundamentals No. SF-1
- Site Evaluation for Nuclear Installations, Specific Safety Requirements No. SSR-1
- Dispersion of Radioactive Material in Air and Water and Consideration of Population Distribution in Site Evaluation for Nuclear Power Plants, Safety Guide No. NS-G-3.2
- External Event Excluding Earthquakes in the Design of the Nuclear Power Plants. Safety Standard Series, Safety Guide No. NS-G-1.5
- Meteorological and Hydrological Hazards in Evaluation for Nuclear Power Installations. Safety Standard Series No. SSG-18
- External Human Induced Events in Site Evaluation for Nuclear Power Plants. Safety Guide No. NS-G-3.1
- Seismic Hazards in Site Evaluation for Nuclear Installations. Safety Standard Series No. SSG-9
- Geotechnical Aspects of Site Evaluation and Foundations for Nuclear Power Plants. Safety Guide No. NS-G-3.6
- Managing Siting Activities for Nuclear Power Plants. Technical Report No. NG-T-3.7
- Site Survey and Site Selection for Nuclear Installations. Safety Guide No. SSG-35

7.4.2.2 United States Nuclear Regulatory Commission (USNRC)

- USNRC 10 Code of Federal Regulations Chapter 1, Part 100, Reactor Site Criteria
- USNRC 10 Code of Federal Regulations Part 52 (10CFR52) Process for Early Site Permits, Standard Design Certification and Combined Construction and Operating Licence
- USNRC Regulatory Guide 4.7 on General Site Suitability Criteria for Nuclear Power Stations
- USNRC Regulatory Guide 1.208 Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion
- USNRC Regulatory Guide 1.132. Site Investigations for Foundations of Nuclear Power Plants
- USNRC NUREG-0800 Standard Review Plan for the Review of Safety Analysis Report (SAR) for Nuclear Power Plants
- USNRC NUREG/CR-6966 Tsunami Hazard Assessment at Nuclear Power Plant Sites in the United States of America
- USNRC Regulatory Guide 1.27 Ultimate Heat Sink for Nuclear Power Plants

- USNRC Regulatory Guide 1.59 Design Basis Floods for Nuclear Power Plants
- USNRC Regulatory Guide 1.70 Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants
- USNRC Regulatory Guide 1.206 Combined Licence Applications for Nuclear Power Plants
- USNRC Regulatory Guide 1.102 Flood Protection for Nuclear Power Plants

7.4.2.3 Electric Power Research Institute (EPRI)

- Siting Guide on Site Selection and Evaluation Criteria for an Early Site Permit Application

7.4.2.4 International Organisation for Standardisation (ISO)

- ISO 9001-2008, Quality Management Systems – Requirements
- ISO 14001: 2005, Environmental Management Systems – Requirements
- ISO 9225:1992 Corrosion of Metals and Alloys – Corrosivity of Atmospheres – Measurement of Pollution
- ISO 9224:1992 Corrosion of Metals and Alloys – Corrosivity of Atmospheres – Guiding Values for the Corrosivity Categories
- ISO 17025:2005. General Requirements for Competence of Testing and Calibration Laboratories

7.4.2.5 International Commission on Radiological Protection (ICRP)

- The 2007 Recommendations of the International Commission on Radiological Protection. Annals of the ICRP, Publication 103
- Assessing the Dose of the Representative Person for the Purpose of Radiation Protection of the Public and the Optimisation of Radiological Protection: Broadening the Process. Annals of the ICRP, Publication 101
- Age Dependent Doses to Members of the Public from Intake of Radionuclides: Part 5 Compilation of Ingestion and Inhalation Dose Coefficients. Publication 72 Volume 26
- General Principles for the Radiation Protection. Annals of the ICRP, Publication 75

7.4.2.6 American Nuclear Standards Institute (ANSI)

- Criteria for Investigations of Nuclear Facility Sites for Seismic Hazard Assessments. Standard ANSI/ANS-2.27-2008

7.4.2.7 American Society of Civil Engineers (ASCE)

- Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities. ASCE/SEI 43-05

7.4.2.8 South African National Standards (SANS)

- SANS 241:2006. South African Standard Code of Practice for the General Procedures and Loadings to be adopted in the Design of Buildings

7.4.2.9 European Utility Requirements (EUR) Organisation

- European Utility Requirements for Light Water Reactor (LWR) Nuclear Power Plants

7.4.2.10 Compliance with regulatory requirements

Results from the siting investigations were assessed against compliance with the national nuclear regulatory requirements, in particular:

- R.388, that requires:
    - The dose constraints applicable to the average member of the critical group within the exposed population will be well below the regulatory dose constraint requirement of 250 μSv/a and that the annual effective dose limit for members of the public from all authorised actions will not exceed the 1 mSv limit.
    - A safety culture was fostered and maintained to encourage a questioning and learning attitude to nuclear safety.
    - Management systems (quality management programmes) were established.
- R.927, that requires:
    - New nuclear installation(s), reflects through their design, construction and operation, an acceptably low probability of postulated events that could result in the release of quantities of radiological material.
    - The site location and the engineered safety features of all nuclear installations, included as safety measures against the hazardous consequences of postulated events, ensure an acceptably low risk of public exposure.
    - The site is such that radiological dose and risk from normal operation and postulated events associated with all nuclear installations in the vicinity will be acceptably low.
    - Natural phenomena and potential man-made hazards are appropriately accounted for.
    - Adequate emergency plans and nuclear security measures can be developed.

  - The cumulative radiological impact all nuclear installations and actions, in the vicinity, is quantified.

- RG-0011, that requires:
  - Assurance is provided that the nuclear safety criteria (pertaining to dose and risk), relating to the safety of the public, can be complied with given the characteristics of the site and its environs, and preliminary information on the design and operation of the facilities.
  - The site characteristics do not preclude the designs of the technologies proposed for construction on the site.
  - It is feasible to develop and implement emergency and security plans, given the characteristics of the site and its environs.
  - It will be feasible to make arrangements for controlling developments in the vicinity.
- RD-0024, that requires:
  - Risk to the public due to accident conditions be identified.
  - Dose to the public due to normal operations be identified.
- RD-0034 requires that Eskom and its consultants implement integrated management systems for the management of siting investigations and the resultant reporting of the results thereby ensuring a defensible product is delivered.
- RG-0016 requires that all calculation models and/or evaluation models used in the site safety analyses are verified and validated, thereby ensuring robustness of all models and accuracy of the results.

8 NUCLEAR AND RADIOLOGICAL EMERGENCY PREPAREDNESS AND RESPONSE PLAN

8.1 PROPOSED EMERGENCY PLANNING

It is a licensing requirement that the licensee of an operational nuclear facility or an applicant to construct a new nuclear facility demonstrates that emergency preparedness and response plan is feasible. The primary objectives of a nuclear and radiological emergency plan are to:

1) Prevent deterministic health effects (death and injury) by:
    a. taking action before or shortly after a major (core damage) release or exposure from a reactor accident;
    b. keeping the public and emergency worker doses below the threshold for deterministic health effects.
2) Reduce the risk of stochastic effects on health (primarily cancer and severe hereditary effects) by:
    a. implementing protective action in accordance to the IAEA guidance;
    b. keeping emergency worker dose below the regulatory worker dose limit.

Prevention of deterministic health effects can be achieved by taking protective actions shortly after or before the release. These actions must be based on plant condition and revised based on the environmental measurements. Similarly, prevention of risk of stochastic health effects is reduced by taking actions based on ambient dose rates and analysis of environmental samples.

For construction of a new nuclear power station (NPS), assessment of the feasibility of the emergency planning (EP) was done as part of the environmental impact assessment (EIA) of the project and also as part of the site safety analysis which culminated in the environmental impact report (EIR) and site safety report (SSR) respectively. The feasibility assessment of the EP is a component of a comprehensive safety assessment that grows in detail during multiple nuclear licensing stages. It culminates in the final emergency plan which is based on the detailed design and completed construction of the NPS prior to initial operation which will be submitted to NNR for acceptance.

The EP includes arrangements based on criteria set in advance to determine when to take different protective actions and what capability is required to protect and inform personnel at the scene and the public. The arrangements are based on emergency planning zones (EPZs) which represent the areas in which planning for specific protective actions are based on projected health risks posed by those accidents that could, under severe conditions, release radioactivity to the environment. Protective actions include measures to limit the exposure of the public to radioactive contamination through external radiation exposure, inhalation of airborne radioactivity, and ingestion of contaminated foodstuff. For nuclear emergencies, two sets of requirements have to be fulfilled;

- Functional (response) requirements; and
- Infrastructure (preparedness) requirements.

Functional response requirements refer to the “capability” to perform an activity. The “capability” includes having in place the necessary authority and responsibility, organisation, personnel, procedures, facilities, equipment, and training to effectively perform the task or function when needed during an emergency. It also includes having in place the necessary infrastructure needed during an emergency response. Infrastructure in this context means transport and communications networks, industrial activities and in general all resources that one may need for a rapid and free movement of members of the public out of the affected area in the shortest period possible. The specific requirements that the applicant must comply with to demonstrate the feasibility EP programme are summarised in the NNR siting regulations R.927 and PP-0015.

As stated in the siting regulations, the identification and determination of EPZs consider the characteristics of the site, reactor design information, estimation of source terms (the quantity, composition, time, and duration of the radioactivity release) for each of the accidents considered. Calculation of the projected off-site doses arising from the release is based on site-specific or generic information and the latest meteorological and population data of that region. Radiological health impact analysis will take into consideration the age of the exposed group.

8.2 THE BASIS OF FEASIBILITY OF AN EMERGENCY PREPAREDNESS AND RESPONSE PLAN

The basis/measure of feasibility of an emergency plan is the capability of the emergency response organisation such as provincial and national disaster management’s ability to respond within the prescribed period to prevent undue health effects as a result of exposure to radiation. This means that there should be no adverse site conditions which could hinder the sheltering or evacuation of the population in the region or the ingress or egress of external services needed to deal with an emergency. The size of the population in the EPZ should not exceed the threshold level which impedes viability of emergency planning and response plan. Other important factors that are taken into consideration in determining the feasibility of emergency planning are:

- Distance of the site from population centres;
- Special groups of the population who are difficult to evacuate or shelter, such as people in hospitals, old age homes, schools, or prisons;
- Particular geographical features such as islands, mountains, and rivers which may have an effect on the migration of the plume and evacuation efforts and subsequently on the consequence of a radiological accident;
- Characteristics of local public transport and communications networks;
- Industrial facilities which may entail potentially hazardous activities;

- Agricultural activities that are sensitive to possible discharges of radionuclides;
- Possible concurrent external events; and
- Weather conditions at the time of an emergency.

Various layers of defence are included in the design of an NPS to prevent accidents. Such a design concept which features a number of layers of safety is referred to as defence in depth. Only when the most extreme accident conditions occur resulting in failure of multiple layers of defence, could there be a release of radioactivity to the outside environment. The last layer of defence to protect people is the emergency plan.

The input data into the design of the emergency preparedness and response plan are the postulated severe accidents of that particular reactor design combined with lessons learnt from real-life accidents that have occurred in the world such as the Three Mile Island (TMI), Chernobyl, and Fukushima nuclear accidents, as well as nuclear accidents originating from non-nuclear power plants.

8.3 EMERGENCY PLANNING ZONES

It is an international norm that three EPZs made up of three circles of different radii centred from the reactor, are established. In determining the EPZ, the following criteria should be used in the definition of the required zones (refer to Figure 24):

- EZ: Effective dose (projected) of 100 mSv over in the first 7 days;
- LPZ: Effective dose (projected) of 100 mSv per annum; and
- Overall EPZ: Effective dose (projected) of 1 mSv per annum

The radii of different EPZs are calculated by using the radioactive source term from a postulated severe accident, referred to as the reference accident case to avert radiological health risk. The reference accident is determined by evaluating all accidents that scoped the highest percentage of severe accidents and the corresponding highest percentage of risk. Therefore, since accidents with the highest probability do not necessarily translate into accidents with the highest risk, an extensive study is conducted to find the point where severity of an accident balances with the risk. In most Generation II PWRs, the reference accident has been found to scope 98% of severe accidents with frequency of one in a million years (10^{-6} per annum) and scoped 72% of the risk.

To evaluate and select the acceptability of the technology, a similar criterion will be used in conjunction with the plant parameter envelope (PPE). The assessment will not only be based on price/affordability and design criteria, but will also ensure that the magnitude of EPZs is adequate so that the operation of the reactor does not pose undue risk to members of the public. The intention for the parameters is to achieve the following objectives:

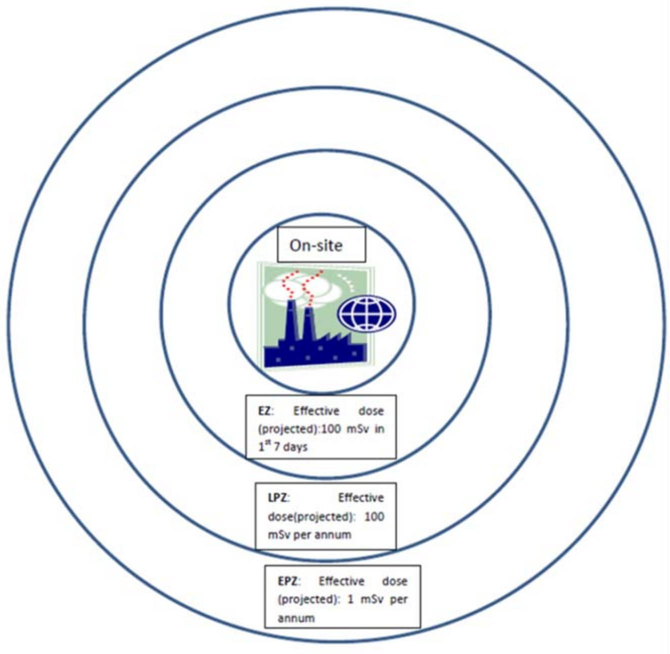

Figure 24: Relationship among various zones around the nuclear power plant (in accordance with PP-0015)

- Minimal emergency protection action beyond 800 m from the reactor should the accident result in early releases of radioactivity to the atmosphere from the reactor containment building;
- No delayed action such as temporary transfer of people at any time beyond approximately 3 km from the reactor;
- No long-term action involving permanent (longer than 1 year) resettlement of the public at any distance beyond 800 m from the reactor;
- Restriction on the consumption of foodstuff and crops should be limited in terms of timescales and ground area in order to limit the economic impact.

8.4 URGENT PROTECTIVE COUNTERMEASURES

The implementation of the urgent protective measures is based on the generic intervention levels (GILs), which are levels for the implementation of that countermeasure. These are summarised in Table 10: Protective actions and their corresponding generic intervention levels alongside their respective protective action. It is important to mention that the GILs values tabulated below are not unique to South Africa's nuclear regulatory requirements; they were derived by the International Atomic Energy Agency (IAEA) and are used worldwide.

Table 10: Protective actions and their corresponding generic intervention levels

Protective Action	Generic Intervention Level	Exposure Duration	Objective for EPZ Distance, km
Sheltering	10 mSv	2 days	0,8
Evacuation	50 mSv	7 days	0,8
Iodine prophylaxis	100 mGy	—	0,8
Temporary relocation	30 mSv during initial 30 days and 10 mSv in subsequent 30 days		3
Permanent resettlement	1 000 mSv	Lifetime	0,8
Food banning/replacement			40

8.5 TAKING CREDIT FOR THE EFFECTIVENESS OF PROTECTIVE COUNTERMEASURES

It has been proven that when protective countermeasures are implemented in time, there is a reduction in the dose to which members of the public are exposed to. Dose reduction depends on the intervention adopted and the time it was implemented after notification of an emergency.

8.5.1 Sheltering

The effectiveness of sheltering in addition to the time of implementation of countermeasures also depends on the type of building, e.g. type of building material used, as well as their shielding factors. The shielding factor as used in this context refers to an indication or a measure of how effective the building material is in reducing the dose to the public, which translates to how well the public is protected from nuclear or radiological accident.

8.5.2 Evacuation

The effectiveness of evacuation in addition to the time of its implementation also depends primarily on how far the public is evacuated from the source. Other factors such as the background radiation of the location where the public has been evacuated to and type of vegetation will only contribute a small fraction to the reduction of the dose compared to if they are evacuated by a large distance. The projected distance for evacuation is based on the weather conditions (whether it is raining or not), distance from the reactor where dose rate measurements are taken and the ambient dose from deposition taken 1 m above the ground.

The evacuation distance will be shorter if it is raining because of washout, however there will be high activity on the ground because of high rate of deposition in that distance than would have been if it was not raining. Therefore evacuation will reduce the exposure to the public quite significantly, implying that taking credit for evacuation to the projected distance from the reactor will significantly reduce the risk of many radiation-induced sicknesses.

8.5.3 Iodine Prophylaxis

8.5.3.1 Protection mechanism

In 1989, the World Health Organisation (WHO) launched a study to investigate how the effects of radioiodine after nuclear/radiological accident involving nuclear reactors could be minimised. In 2010, the European Union instituted a similar study with a much wider scope with the purpose of protecting members of the public in case such an accident occurred. Both studies discovered that the protective mechanisms of action of iodine prophylaxis is due to isotopic dilution and saturation, which are the principal mechanisms of the protective action of potassium iodide (KI): the two mechanisms compete with radioactive iodine via an active iodine transport system in the thyroid. Thus, under normal circumstances, excess iodine decreases sodium iodide symporter (NIS) on the thyroid-cell surface, thereby inhibiting the further entrance of iodine into the thyroid. Excess iodide administration at the appropriate time decreases the thyroid radioactive iodine uptake by decreasing NIS and by increasing the amount of non-radioactive iodine available for binding to thyroid cells. However, while the active transport mechanism of iodine is being saturated, penetration of radioiodine is still possible due to its passive diffusion.

Whatever the chemical form used KI or KIO_3, the active chemical entity is the ionic iodide (I-). The iodide ion acts on the thyroid and prevents binding of radioiodine by five mechanisms:

- As substrate, it will dilute the radioactive iodine circulating inside the body available for thyroid uptake;
- By saturating the active transport mechanism of iodine mediated by the sodium iodide symporter (NIS) located on the thyroid-cell surface;
- By inhibiting the organification of iodide, also called the Wolff-Chaikoff (W-C) phenomenon, a mechanism of action of stable iodine by means of which the stable iodine saturates the iodine transport mechanism, thereby reducing transport of radioactive iodine (^{131}I) to the thyroid as a result reducing the uptake of radioactive iodine. Studies show that this could lead to a decrease of synthesis of thyroid hormones and a possible hypothyroidism. The W-C effect is usually of short duration, but the foetus and the newborn can be affected;
- By generating an organic iodine compound that inhibits the binding of ^{131}I;
- By inhibiting the secretion of iodine organification by the thyroid.

It is therefore important to note that KI or KIO_3 pills cannot prevent radioactive iodine from entering the body; it only protects the thyroid from radioactive iodine, not other parts of the body. As a result, stable iodine cannot reverse the health effects caused by radioactive iodine once damage to the thyroid has occurred. Also, stable iodine cannot protect the body from radioactive elements other than radioactive iodine.

8.6 CONTROL OF FOODSTUFF: GENERIC ACTION LEVELS

Control of food and water may have to be instituted to prevent members of the public from consuming contaminated foodstuff. The circumstances that influence the decision whether to institute such countermeasures, may be divided into three categories: availability of alternative supplies; where alternative supplies are scarce; and for distribution in international trade. Control or withdrawal of foodstuff from consumption is implemented when the radioactivity of a certain group of isotopes in a certain category of food stuff has reached a pre-determined level of radioactivity; and this radioactivity level is known as the generic action level (GAL). The generic action levels that have been established for use by national authorities when alternative supplies of food are available are listed in Table 11. As stated, the GAL values depend upon the type of foodstuff and the type of contaminating radionuclide. The radionuclides in question are those most likely to be of concern in foods following an accident. In situations where extensive restrictions on food supplies could result in nutritional deficiencies or, in the extreme, starvation, case-by-case evaluations will be required. In most such situations, relocation will be indicated and alternative food made available. However, when this is not possible, the radiation hazard must be considered realistically in comparison to competing health hazards, and higher action levels should invariably be adopted. Following any event that may contaminate foodstuffs, a variety of countermeasures may be instituted at various stages in production and marketing. These should be implemented to ensure that, to the maximum extent practicable, foodstuffs are maintained below the action levels. The generic action levels for foodstuffs will also satisfy the requirements for distribution of foodstuffs in international trade for consumption in countries unaffected by an accident.

The results show that emergency actions for the two reference reactor technologies would be limited. No off-site short-term emergency interventions would be required beyond the owner controlled boundary of the NPS. However, the final emergency plan will be based on EPZs agreed to by the NNR.

The feasibility of an emergency plan that can be extended even beyond the calculated EPZs, depends on acceptable site aspects such as the absence of adverse conditions which could hinder the ingress or egress of external services that may be needed to deal with an emergency. These aspects are discussed in the next section.

Table 11: Generic action levels for foodstuff

Foodstuff destined for general consumption		
Isotope Group	**Radionuclide**	**Generic Action Level (GAL) [kBq/kg]**
1	^{134}Cs, ^{137}Cs, ^{103}Ru, ^{106}Ru, ^{89}Sr, ^{131}I	1
2	^{90}Sr	0,1
3	^{241}Am, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{242}Pu	0,01
Milk, Infant food, and water		
4	^{134}Cs, ^{137C}s, ^{103}Ru, ^{106}Ru, ^{89}Sr	1
5	^{90}Sr, ^{131}I	0,1
6	^{241}Am, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{242}Pu	0,001

8.7 CLASSIFICATION OF NUCLEAR EMERGENCIES

There are progressive stages of response to a nuclear emergency plan, depending on the seriousness of the potential consequences of an accident. These are;

- **Unusual Event**: An abnormal occurrence that indicates an unplanned deviation from normal operations, the actual or potential consequences of which require notification of the emergency controller and activation of the appropriate components of the nuclear emergency plan.
- **Alert**: A situation exists that could develop into a site or general emergency and therefore requires notification of all emergency personnel in order to obtain a state of readiness to respond.
- **Site Emergency**: An emergency condition exists that poses a serious radiological hazard on site but poses no serious radiological hazard beyond the public exclusion boundary.
- **General Emergency**: An emergency condition exists that poses, or potentially poses, a serious radiological hazard beyond the public exclusion boundary.

An analysis to demonstrate the viability of an emergency plan should take into account the characteristics of the site relevant to the design assessment, risk and dose calculation, external events, meteorological data, land-use, population demographics, regional development, and projection of the above data commensurate with the design life of the nuclear installation.

9 RADIOACTIVE WASTE MANAGEMENT AND DECOMMISSIONING STRATEGY

9.1 PROVISIONS FOR THE MANAGEMENT AND DISPOSAL OF RADIOACTIVE WASTE

Radioactive waste will be managed in accordance with the Radioactive Waste Management Policy and Strategy for the Republic of South Africa of 2005.

The NNR regulates all nuclear activities and the management of radioactive waste in terms of its mandate set forth in the National Nuclear Regulator Act (1999). In terms of the Nuclear Energy Act (1999) the authority over radioactive waste and irradiated fuel waste is the Minister of Energy.

The quantity of waste will depend on the operating procedures in force at the power station. The proposed power station, similar to the KNPS, will produce levels of low-level waste (LLW), intermediate-level waste (ILW), and high-level waste (HLW). LLW and ILW contain radioisotopes that decay relatively quickly in nuclear terms (30 to 300 years, respectively).

9.2 VAALPUTS RADIOACTIVE WASTE DISPOSAL SITE

In accordance with the National Radioactive Waste Management Policy and Strategy, Vaalputs Radioactive Waste Disposal Site, located in the Northern Cape, is the designated facility for the disposal of L&ILW in South Africa. Vaalputs has been designed and permitted with sufficient capacity for handling the L&ILW from KNPS and any new nuclear power station(s). Disposal at the site is carried out in terms of a nuclear authorisation granted by the NNR under the National Nuclear Regulator Act, 1999 (Act No. 47 of 1999).

Historically, the South African Nuclear Energy Corporation (NECSA) was charged with and operating the Vaalputs radioactive waste disposal facility.

The role of NECSA will be transferred to the National Radioactive Waste Disposal Institute established as an independent entity by statute under the provision of section 55(2) of the Nuclear Energy Act (No. 46 of 1999) and the National Radioactive Waste Disposal Institute Act, (No. 53 2008) to provide professional Nuclear Waste Management and Disposal Services in South Africa on behalf of the state.

9.3 DECOMMISSIONING STRATEGY

When the nuclear power station has reached the end of its viable lifetime approximately 60 years after commissioning, it will be decommissioned. According to RD-0026, decommissioning is defined as an administrative and technical action taken to allow the removal of all the regulatory controls from a facility (except for a repository which is not closed and not decommissioned). For nuclear facilities, decommissioning is the final phase in its lifecycle after siting, design, construction, commissioning, and operation. It is a complex process involving operations such as detailed radiation surveys, decontamination, and dismantling of plant, equipment and facilities, demolition of buildings and structures, site remediation, as well as the management of resulting waste and other materials. All activities take place under a regulatory framework prescribed and authorised by NNR (refer to RD-0026) that takes into account the importance of the health and safety of the operating staff, the general public and protection of the environment.

A decommissioning strategy developed in accordance with Regulation R.388 and RD-0026 will be submitted to the NNR as part of the conceptual decommissioning plan at the design phase and will be updated throughout the operation of the authorised action of the plant as a basis of a detailed decommissioning plan.

The decommissioning plan for the proposed nuclear installation(s) is likely to be similar to the plan for Koeberg Nuclear Power Station. This plan provides for the following key phases of decommissioning.

Phase 1: Preparations

This phase will be initiated seven years prior to shutdown of the nuclear power station. It includes a detailed list of preparatory functions (e.g. development of a decommissioning project team organisation), investigations and studies (e.g. environmental impact assessment, cost effective feasibility study, compilation of quantities of radioactive material to be secured, control mechanisms, and waste characterisation, including a quantitative estimate of the type, amount, and location of important radionuclides at the end of operating life, etc.), procedures and technical specifications (e.g. final shutdown and defueling sequencing, procedures for occupational exposure control, control and release of liquid and gaseous effluent, processing of radioactive waste, site security, emergency programmes, and industrial safety), and temporary construction facilities to support dismantling activities (e.g. centralised processing areas to facilitate equipment removal and component preparation for off-site disposal, upgrading of roads to facilitate hauling and transportation, fabricate shielding in support of removal and transportation activities, construction of contamination control envelopes, and the procurement of specialised tooling.)

Phase 2: Plant shutdown and defueling

Decisions are made about the final shutdown dates of the units (namely after the winter peaks or at the optimum fuel utilisation stage) and the detailed final plant shutdown and defueling plan is implemented.

Phase 3: Implement the used fuel pool cooling separation plan

Once the fuel has been transferred to the spent fuel pool, the spent fuel pool separation plan is implemented to establish an independent spent fuel pool cooling system.

Phase 4: Decommissioning operations

This phase includes the following tasks:

- Demolition of conventional island and auxiliaries;

- Safe enclosure preparation; and
- Electromechanical dismantling.

Phase 5: Used fuel removal and electromechanical dismantling of the fuel building and auxiliaries

After 10 years of decay in the used fuel pool, the last full load of fuel would have sufficiently cooled down to be removed from the pools. The used fuel is then relocated to dual-purpose casks (storage and transport) for transfer to the national repository. Once the used fuel pools have been emptied, the plant can be decontaminated and decommissioned in accordance with the plan.

Phase 6: Demolition of remaining structures and site rehabilitation

The dismantling of the non-essential structures at the site will commence once fuel transfer operations are complete. Site areas affected by the dismantling activities are cleaned and the plant area graded as required to prevent pounding and inhibit the floating of sub-surface materials.

The exact contents of the decommissioning plan are unknown at this stage and it would only be finalised once an application is made for the decommissioning of the nuclear installation.

10 TRANSPORTATION OF RADIOACTIVE WASTE AND RADIOACTIVE MATERIAL

South Africa is a member state of the International Atomic Energy Agency (IAEA) and therefore subscribes to the transport regulations set out by the IAEA (refer to IAEA Safety Requirements No. TS-R-1 and Specific Safety Requirements No SSR-6) for the safe transport of radioactive materials such as nuclear fuel, low and intermediate level radioactive waste, and mineral concentrates. These requirements have been incorporated into South African regulations (refer to RG-0007: Regulatory Guide on Management of Safety, RG-0008: Regulatory Guide on General Transport, and the General Nuclear Safety Regulations (DRAFT)). Authorisation from the NNR must therefore be obtained before any radioactive material is transported. These include the application for a nuclear vessel licence to transport nuclear fuel from the manufacturer to a harbour near the nuclear power station.

The purpose of adopting the IAEA transport regulations and incorporating them into South Africa's regulations is to "…*protect persons, property, and the environment from the effects of radiation during the transportation of radioactive material*…". This is achieved by making recommendations with regards to the methods of containment, shielding, and prevention.

The nuclear fuel will be transported by sea (shipment) in specially designed robust steel containers to the nearest harbour like in the case of abnormal and heavy haul loads in accordance with the IAEA regulations and NNR regulatory requirements which set the basis for nuclear fuel cycle material transport. The NNR oversees that these regulations are complied with by conducting regular inspections and audits. Internationally, there have been no serious incidents in the history of nuclear material transport, mainly due to the effort and expense which goes into ensuring safety.

Radioactive waste (low and intermediate level) that will be generated by the nuclear power station will be transported to Vaalputs Radioactive Waste Disposal Site. It is proposed to be transported via the N2 to Cape Town and onto the N7 to Vaalputs.

11 CONCLUSION

This document provides members of the public with a broad overview of the project; the regulations that Eskom has to comply with before an authorisation for nuclear site licence (NISL) and NIL can be obtained (given that these are two separate processes). As alluded to earlier, the NIL represents the primary authorisation for the construction, operation, maintenance, decontamination, and decommissioning of the nuclear installation based on a specific technology design. The associated PID for this NIL application will be developed once an application for an NIL is made.

Every effort has been made to provide the public with all pertinent information on the nature of the NISL authorisation applied for and the associated hazards. In particular, clear evidence has been provided that all hazards that could result in ionising radiation have been identified and that these can be kept ALARA. It can therefore be concluded that the Thyspunt site has been adequately characterised as a suitable site to locate a new nuclear installation(s).