Contents

LIST OF FIGURES

LIST OF TABLES

3 PROJECT DESCRIPTION

3.1 Introduction

This chapter provides a basic description of the nuclear technology and proposed project in terms of the salient activities comprising the four primary phases associated with the lifecycle of the proposed power station: preconstruction; construction; operation and decommissioning. It should be noted that this chapter provides a description of the proposed project in its entirety in order to portray a relatively complete conceptual understanding of the proposed development.

The environmental corridor area assessed in this EIA makes provision for the potential future expansion of the power station, to allow for a total capacity of approximately 10, 000 MW **.**The power station footprint includes the reactor and auxiliary buildings, laydown areas required during construction and topsoil storage areas (refer to **Table 3-1** below). The total area required for this nuclear power station is **250 – 283 ha** (area required for construction of the Nuclear infrastructures). This varies per site since topography and depth of soil to bedrock have an influence on the size of the footprint on a specific site. The footprint of the actual power station building (reactor units and turbines) will be approximately one third of this and the remainder of the disturbed area is affected by activities such as earthworks, topsoil stockpiles, contractors' yards and laydown areas. The areas of 250-283 ha also include potential future expansions areas for the proposed power station. Access roads connecting to existing public roads adjacent to the sites and their respective servitudes have also been assessed in this EIA.

Table 3-1: Sizes of the development footprints at the alternative sites[1]

Site	*Eskom owned Nuclear-1 property size*	*Total footprint of Nuclear-1*
Duynefontein	± 2 928.40 ha	±265 ha
Bantamsklip	± 1 708.84 ha	±283 ha
Thyspunt	± 3 828.51 ha	±250 ha

Text Box 2:
EIA and HV Yard corridors vs. *Footprints*

EIA and HV Yard Corridors

At the start of the EIA phase, areas of each of the three alternatives sites were defined as "EIA and HV yard corridors". These rectangular areas were defined as the most likely positions where the power station and HV yards would be placed on the sites (based on technical and environmental considerations) and were meant to focus the specialist studies.

The sizes of the EIA and HV Yard corridors vary from 321 to 454 ha for the EIA corridor and from 110 to 254 ha for the HV yard. It was understood that the power station would require an area of roughly 200-280 ha and would not occupy the entire EIA corridor, but would be placed somewhere within the EIA corridor.

Footprints

The effective disturbed area within the EIA and HV corridors is referred to as the footprint. This includes the area covered by the power station itself, as well as associated infrastructure and adjacent areas disturbed by earthworks, contractors' yards, laydown areas, etc.

[1] Correct at the time of writing. It must be noted that Eskom is in the process of buying more land at the Thyspunt site.

The proposed power station complex will include *inter alia* the nuclear reactors and their auxiliaries such as:

During construction:

- a temporary coffer dam in the ocean for construction;
- a temporary spoil pipeline into the ocean for construction; and
- laydown areas and other areas to be cleared during construction.

During operation:

- turbine halls;
- spent fuel and nuclear fuel storage facilities;
- 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;
- 132kV and 400kV transmission and distribution lines from the power station to the high voltage yard;
- roads;
- 400kV and 132kV 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.

Depending on the vendor that is chosen, a different number of units (nuclear island[2] with conventional island[3]) may be constructed up to the maximum of 4, 000 MWe[4] that has been applied for, as the capacity of the units of each of the vendors is different. The capacity of the largest unit under consideration is 1 650 MWe), in which case two units would be used to supply a total of 3, 300 MWe. In the case of other vendors who supply smaller units, a larger number of units could be constructed with a combined output of approximately 3 600 MWe.

The commencement of construction depends on various government and Eskom processes and is therefore uncertain.

3.2 Other projects related to Nuclear-1

There are a number of projects that are related and near the vicinity of the project areas. The projects are at various stages of the EIA process or construction. The projects are as follows:

- 3 X 400kV/ 765 kV Transmission lines: There are three separate EIA applications for the transmission lines that will convey power into the national grid from each of the three proposed power station sites (refer to www.eskom.co.za). The details of the routes for these lines are, therefore, not discussed in this report. It should be noted that the environmental impacts associated with new transmission power lines (400 kV and 765 kV) conveying power from the HV yard off the Eskom property are not assessed in this EIA and are therefore subject to separate applications for environmental authorisation.
- Various alternative off-site public roads are under consideration for upgrade as well as new roads to act as access routes at all the different sites. The environmental impacts associated with the proposed upgrades of roads off the sites do not form part of this EIA

[2] The "Nuclear Island" is that part of the power station that houses the reactor core, the balance of the nuclear steam supply system and all other systems which support the nuclear processes.
[3] The "Conventional Island" houses the turbines, generator, condenser and other operational equipment.
[4] MWe is the term used for the electrical output of the power station

and will therefore require separate applications for environmental authorisation. The off-site public roads under consideration are discussed in Section 3.14.

- An environmental authorisation has been granted for construction of an administrative complex and training centre campus at the Duynefontein (Koeberg) site.
- Development of off-site accommodation for construction and operational personnel (discussed in Section 3.8.8).
- Upgrades to harbours near the sites to handle abnormal loads for the power stations (if necessary) will not form part of this EIA and will therefore require separate applications for environmental authorisation.

The cumulative environmental impacts that could arise from the above-mentioned developments have been assessed at a strategic level in **Chapter 10** of this report**.**

3.3 Principles of producing nuclear heat for electricity generation

Nuclear power relies on low enriched uranium and/or mixed oxide, rather than fossil fuels, as a source of fuel to produce heat. The heat generated during nuclear reactions results from a process called "fission". Fission entails the splitting of nuclei of atoms by even 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 emitting 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 atoms and the subsequent release of energy is referred to as nuclear fission.

This process is controlled within the reactor and the energy released heats up water excessively in primary and secondary water coolant heat exchange circuits and co-produces steam, which drives a turbine. The turbine is connected to a generator, which produces electricity. Electrical transformers are used to step up the voltage of electricity generated and feed it into the national grid via transmission lines.

There are several by-products of the fission process, which are contained in the nuclear fuel elements (e.g. plutonium). The fission of uranium (and the plutonium generated in the process) is used as a source of heat in a nuclear power station in the same way that the burning of coal, gas or oil is used as a source of heat in a fossil fuel power plant. The nuclear fission process is, however, more efficient at producing energy than the use of fossil fuels. Typically, some 44 million kilowatt-hours of electricity are produced from one ton of natural uranium. The production of this amount of electrical power from fossil fuels would require the burning of over 20 000 tons of coal or 8.5 million m^3 of gas (www.world-nuclear.org/info/inf03.html - accessed on 22 October 2009). Nuclear power production is estimated by a variety of sources to emit between two and 20 tons of CO_2 per gigawatt-hour (t CO_2 / GWh) of electricity produced (approximately the same as wind power),

> ***Text Box 3:***
>
> *Explanation of nuclear terminology used in the Environmental Impact Report*
>
> - Reactor type: Refers to the main category of nuclear reactor selection. This category includes Light Water Reactor (LWR), Heavy Water Reactor (HWR), High Temperature Gas Cooled Reactor (HTGCR), Pebble Bed Modular Reactor (PBMR), etc.
> - Technology: Refers to the second level to describe a specific reactor. The LWR type can for instance be broken down into Pressurised Water Reactors (PWR) and Boiling Water Reactors (BWR);
> - Plant options: Refers to the final plant type that can be purchased from a vendor; and
> - Conventional Nuclear: A term used by Eskom only, to distinguish PWR nuclear technology options from new technology proposed for the Pebble Bed Modular Reactor (PBMR) or any other type of untested nuclear technology.

compared to coal-fired electricity production, which emits around 891 t CO_2/MWh.

3.4 History of Nuclear Power Plants

The nuclear power industry has been developing and improving reactor technology for almost five decades since the first nuclear power station came into operation in the 1950s. Since then the development of the nuclear power generation industry can be summarised as follows (http://www.world-nuclear.org/info/reactors.html: accessed on 07 July 2015):

- There are now some 437 commercial nuclear power reactors operating in 30 countries, with 380 GWe of total capacity;
- A total of 58 reactors has been shut down or are at different stages of decommissioning between 1996 and 2015;
- Nuclear power stations provide about 11.5 % of the world's electricity as continuous, base-load power, and their efficiency is increasing;
- Fifty six countries operate a total of about 240 research reactors and a further 180 reactors power 140 ships and submarines; and
- A total of 66 nuclear power reactors with a combined output of 68.997 GW were under construction on 01 June 2015. China is currently building 24 units and Russia is constructing 9 units.

There have been three major reactor accidents in the history of nuclear power – Three Mile Island, Chernobyl and Fukushima. These are the only major accidents to have occurred in over 14 500 cumulative reactor-years of commercial nuclear power operation in 32 countries.

Several generations of reactors are commonly distinguished in the following manner:

- Generation I reactors were developed in the 1950-60s. The only ones of this generation still in operation are found in the United Kingdom, Gas Cooled Reactors (AGRs). .
- Generation II reactors are typified by the present United States fleet of PWRs and are in operation in most countries. The two PWRs at the Koeberg Nuclear Power Station are classified as Generation II reactors.
- Generation III/III+ reactors are advancements of Generation II reactors largely due to safety enhancements to the Generation II reactors. Power stations using these reactors are currently being constructed in Japan, Finland, France and China. It is this generation of PWRs that is proposed to be installed for the Nuclear-1 project. Generation III / III+ PWR, Advanced Boiling Water Reactor (ABWR) and Vodo-Vodyani Energetichesky Reactor (VVER) 1,000s power plants are operational, but there are a number that are under construction. No Generation III/III+ Advanced Boiling Water (ABW) reactors are in operation in Japan since 1996 and two are under construction in Taiwan.
- Generation IV designs are still on the drawing board and will not be operational before approximately 2025 and will not be evaluated by Eskom at this stage. A South African company, namely Pebble Bed Modular Reactor (PBMR), was designing its Pebble Bed High Temperature Reactor (HTR) technology. A demonstration power plant of this technology was the subject of a separate EIA process, but this application has since been withdrawn and the project terminated. Other Generation IV reactors include Gas-cooled Fast Reactors (GFR), Lead-cooled Fast Reactors (LFR), Molten Salt Reactors (MSR), Sodium-cooled Fast Reactors (SFR), Supercritical Water Reactors (SCWR) and Very High Temperature Reactors (VHTR).

3.5 Nuclear technology for Nuclear-1

Pressurised Water Reactor (PWR) technology **(Figure 3-1)** was chosen by Eskom as the technology to be used for Nuclear-1. The PWR uses light water as a coolant and moderator. Details regarding the various types of reactors (light water and heavy water) and technologies (PWR and boiling water reactors) were described in the Final Scoping Report for Nuclear-1. Eskom has been using this technology for the past 29 years at Koeberg Nuclear Power Station and is therefore familiar with this technology. The PWR used at Koeberg was based on a design by Westinghouse of the USA and built by Framatome, a French company. It must be emphasized that Eskom has not decided on a preferred supplier for Nuclear-1 and that any suppliers and plant types named in this report are meant only for reference purposes to provide an indication of a typical power station conforming to Eskom's requirements. Thus, detailed descriptions of the proposed plant are not available. The approach in this EIA process has therefore been to assess a generic nuclear power station design in the EIA process and to specify enveloping environmental and other relevant requirements to which the power station design and placement on site must comply.

Salient features of the Generation III designs are (World Nuclear Association 2009):

- A standardised design for each type to expedite licensing, reduce capital cost and reduce construction time;
- A simple and rugged design, making them easier to operate and less vulnerable to operational upsets;
- High availability and longer operating life that Generation II reactors - typically 60 years;
- Reduced possibility of core melt accidents;
- Minimal effect on the environment;
- Higher burn-up to optimise fuel use and reduce the amount of waste; and
- Burnable absorbers to extend fuel life.

The most significant departure of Generation III designs from second-generation designs is that the former incorporates passive or inherent safety features[5] which require no active controls or operational intervention to avoid accidents in the event of malfunction, and may rely on gravity, natural convection or resistance to high temperatures (World Nuclear Association 2009).

[5] Traditional reactor safety systems are 'active' in the sense that they involve electrical or mechanical operation on command. Some engineered systems operate passively, e.g. pressure relief valves. They function without operator control and despite any loss of auxiliary power. Both require parallel redundant systems.

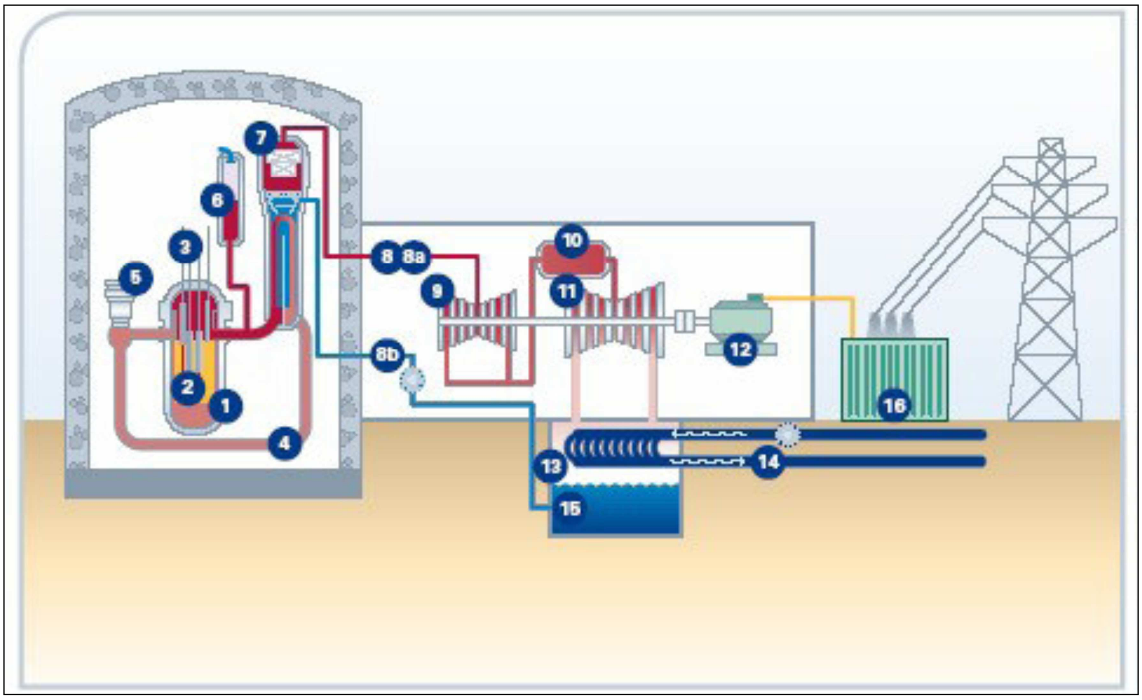

Figure 3-1: Key features of a Pressurised Water Reactor

(1) Reactor, (2) Core, (3) Control rods, (4) Primary circuit (water circuit), (5) Main reactor coolant pump, (6) Pressurizer, (7) Steam generator, (8) Secondary circuit (steam), (8a) Steam for the turbine, (8b) Water for the steam generators, (9) High pressure turbine, (10) Reheater, (11) Low pressure turbine, (12) Generator, (13) Condenser, (14) Cooling circuit, (15) Condensation water, (16) Transformer.

3.6 Operation of a typical nuclear power station

A nuclear power station has a central control room containing all plant operating and monitoring equipment required for plant operation. All major parameters are displayed on large wall mounted screens and there are a number of control desks at which all active components can be manually operated **Figure 3-1** and **Figure 3-2** provide simplified diagrammatic depictions of the nuclear energy process, brief details of which are explained in this section.

3.6.1 Cooling circuits

A PWR nuclear power station operates with three main cooling circuits. The water of these cooling circuits does not mix and transfer of heat takes place in heat exchangers. Heat exchangers have two flow paths of water in the device to facilitate heat exchanging between the two liquids.

The cooling circuits operate as follows:

- Primary circuit. The water in the primary circuit flows through the reactor, steam generators and back to the reactor via the reactor coolant pumps. Primary water never leaves the containment building. Water in the primary circuit removes heat from the reactor and disposes this heat in the steam generator. The pressure of this circuit is typically 15.5 MPa, thus preventing boiling at temperatures of up to 320 °C.
- Feed-water circuit. The flow path of this water is from the steam generators to the turbines, condenser, feed-water pumps and back to the steam generators. This water boils in the steam generators and is condensed to water in the condenser. The water accumulates energy from the steam generators and disposes of this energy in the turbines and condenser.

- Circulating water circuit. This water is pumped from the sea through the condenser in the conventional island and back to the sea. The nuclear power station uses the sea (or a large dam) as the ultimate heat sink.

3.6.2 Reactor pressure vessel

The following information was taken from Ragheb (2008). In a PWR unit **(Figure 3-2)** the coolant is pressurised but is not allowed to boil. The pressurised water is pumped to steam generators where steam is produced and subsequently fed to the turbine plant for the production of electricity. The reactor vessel and the associated steam generators, pressurisers and coolant pumps are enclosed in a containment structure.

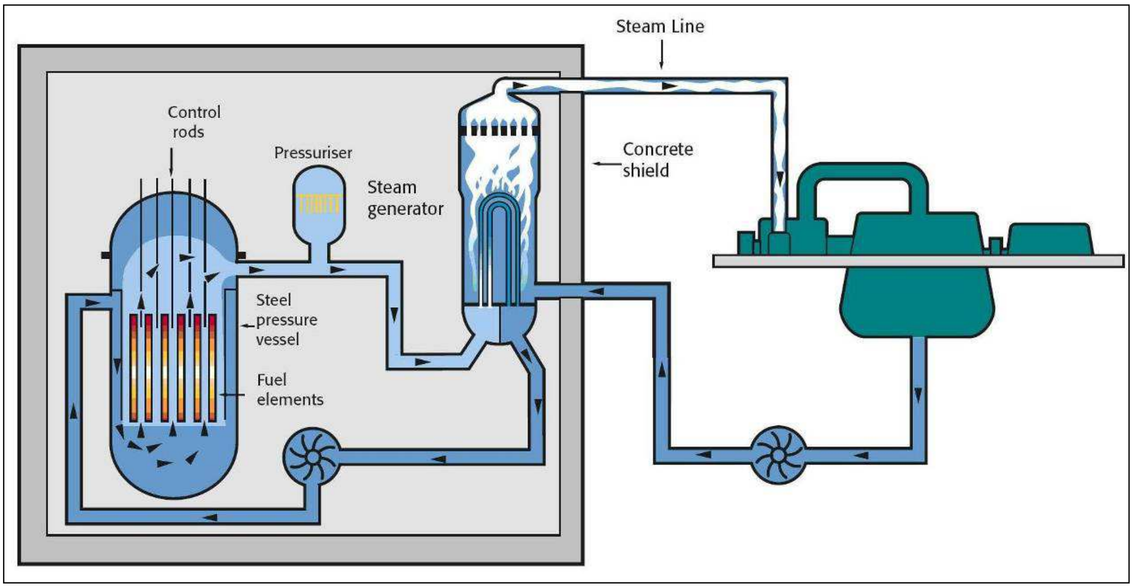

Figure 3-2: Simplified diagrammatic depiction of a Pressurised Water Reactor (PWR)[6] (Ragheb, 2008)

High pressure water is pumped into a pressure vessel containing the reactor core (**Figure 3-3)** The water flows through an annular region between the reactor vessel containing the reactor core and is subsequently distributed by a nozzle system to the core for cooling the fuel elements. The reactor coolant pumps move the coolant to the steam generators, where steam is produced and fed to the turbine plant. The coolant is condensed in a condenser then fed by the feed water pumps back to the steam generators. The water sourced from the ocean serves as a heat sink for the condenser.

The reactor pressure vessel is generally designed to withstand a pressure of 17, 1 MPa and a temperature of 351 °C. The flow rate of the coolant is generally between 18 and 33 m^3 per second depending on the thermal power of the reactor. The normal working pressure of the coolant is generally 15.5 MPa. The hot and cold leg temperatures are generally in the order of 330 °C and 295 °C, respectively.

[6] Although the nuclear power station in this figure does not obtain its cooling water from the sea, the principle of its operation remains the same.

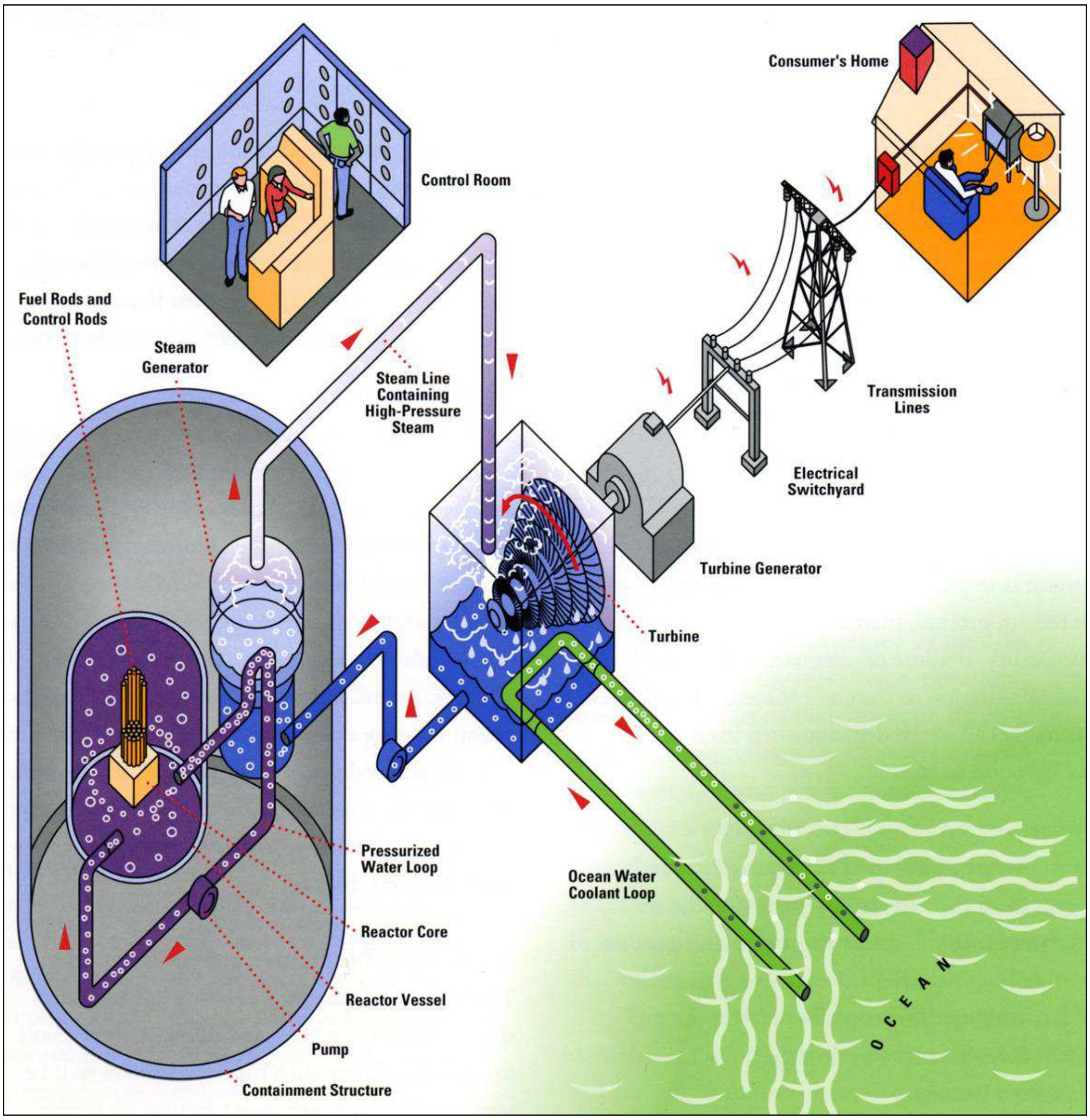

Figure 3-3: Simplified diagrammatic depiction of a nuclear power station

3.6.3 Reactor core and fuel

The reactor core contains fuel material where the fission reaction, which produces energy, occurs. The equipment within the core is used to physically support the fissile material, to control the fission reaction or to channel the coolant. The reactor core consists of a specified number of fuel rods, which are held in bundles by spacer grids and top and bottom fittings. A typical fuel assembly consists of fuel rods arranged in a 17 x 17 or 16 x 16 square or hexagonal array. The fuel rods consist of uranium or MOX (uranium plus plutonium) pellets stacked in a cladding tube plugged and seal-welded to encapsulate the fuel. The pellets are approximately 8.13 mm in diameter and 15.2 mm in length and are enclosed in Zircalloy-4 cladding tube with a wall thickness of approximately 0.635 mm. Zircalloy is used as a result of its low neutron absorption, which assists the neutron economy of the PWR (Ragheb 2008).

Figure 3-4: A display of nuclear fuel pellets in a cladding tube at Koeberg Nuclear Power Station

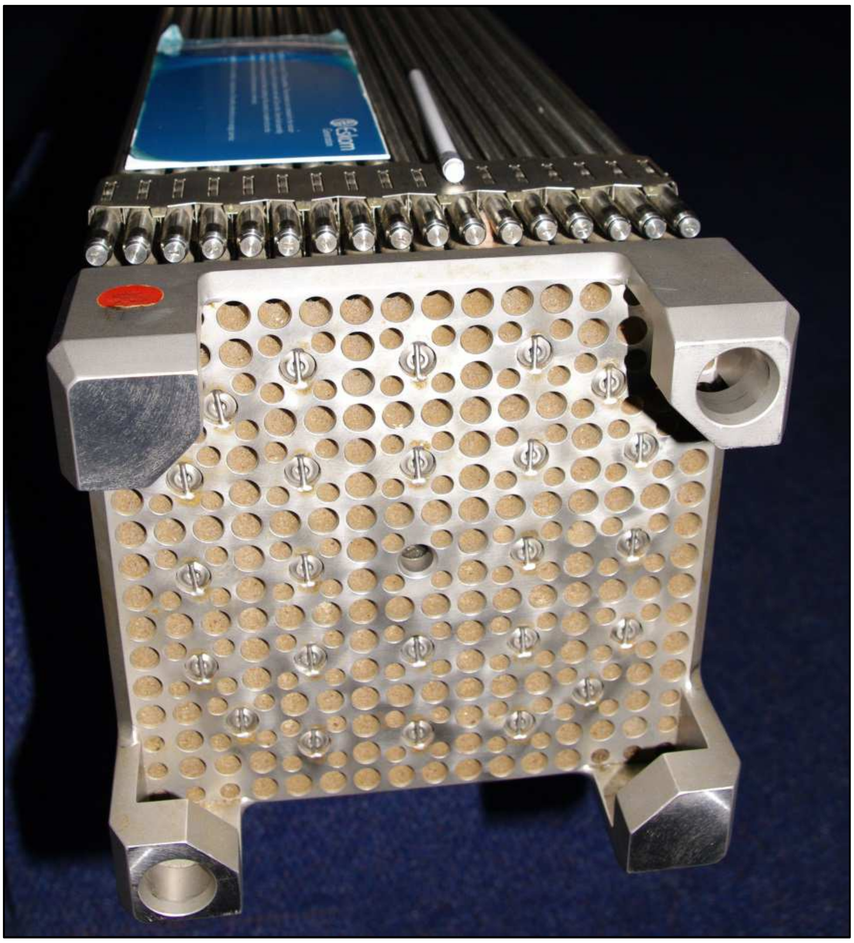

Figure 3-5: A display of a nuclear fuel assembly of 17 x 17 fuel rods at Koeberg Nuclear Power Station

The nuclear fuel consists of uranium that is enriched to 4.95 %. Over time, the fuel becomes less effective as it loses its uranium-235 content and fission product (waste) begins to form. The concentration of fission fragments and heavy elements will increase to the point where it is no longer practical to continue to use the fuel. Thus after 12 - 24 months the 'spent fuel' is removed from the reactor. When removed from a reactor, the fuel will continue to emit both radiation and heat. Used fuel is unloaded into a storage pond immediately adjacent to the reactor to allow the radiation levels to decrease. In the ponds the water shields the radiation and absorbs the heat. Used fuel is held in such pools for several months to several years. The spent fuel is then either kept on site or permanently disposed at an off-site nuclear waste repository facility. In South Africa, the spent fuel has been kept on site at Koeberg and the government strategy on used fuel is still under development. The National Radioactive Waste Disposal Institute Act (“NRWDIA”) came into operation on 1 December 2009 and provides for the establishment of the National Radioactive Waste Disposal Institute in order to manage radioactive waste disposal on a national basis. As this Institute is not yet operational, the NECSA currently performs nuclear waste management activities in South Africa.

3.6.4 Pressuriser

The function of the pressuriser is to establish and maintain the reactor’s coolant system pressure during steady state operation and transients. It also acts as a surge container and water reserve to accommodate the primary coolant volume changes during operation. The pressuriser contains electric heaters in its bottom section, which are normally immersed in water. The operator can activate the electric heaters until the required system pressure is attained. When the system pressure increases, some steam can be condensed by the activation of the water spray from the reactor coolant line, thereby reducing the pressure to normal operating levels.

3.6.5 Steam generator

The function of the steam generator is to transfer the heat from the primary coolant to the secondary feed water to generate steam for the turbine generator set. Steam turns the bladed wheels of a turbine. The turbine is coupled to a generator, which produces electricity and together are referred to as the turbine generator set. Steam generators for the PWR design are shell and tube heat exchangers with high pressure primary water passing through the tube side and lower pressure secondary feed water and steam passing through the shell side. In addition to generating steam, steam generators double as a barrier between the primary and secondary coolants. The main steam produced by the steam generators, exits the reactor building via the steam lines, which subsequently enter the turbine building.

3.6.6 Turbine

The high pressure, high temperature steam expands and the energy that is released causes the turbine shaft to rotate. All energy from steam is used to drive the turbine. Due to mechanical and ambient losses, approximately one third of the heat generated in the reactor core is ultimately converted into electrical energy.

3.6.7 Condensers

The condensers are heat exchangers in which circulating water, obtained from the ocean, flows through numerous titanium tubes. When the steam contacts the cold condenser tubes, the steam is converted into water droplets. The condensers thus convert the steam exiting the turbine back into water and this water is referred to as condensate. The condensate is pumped back to the steam generator where it is heated, evaporated and re-circulated through the system.

3.6.8 Electricity generation

The steam turbine drives a generator, which converts the rotational energy of the turbine shaft into electrical energy. The principle underlying this process is electromagnetic induction. When a magnetic field moves past a conducting coil, an electrical voltage is produced in the coil, causing a current to flow in a connected conductor circuit. The electricity generated by the turbine generator set is stepped up via transformers and fed into the off-site grid via high voltage switch gear, housed in the high voltage yard.

3.7 Timeframes for construction and power station life cycle

The commencement of all construction and operational activities will be initiated if and when Eskom obtains all the relevant authorisations from the DEA and The NNR. The timeframe for the decommissioning phase remains undetermined at this stage. It would take approximately 9 years to complete the construction of Nuclear-1.

Table 3-2: Main construction activities per year (Eskom Truck Load Table, 17/05/2010)

Activity	Year 1		Year 2		Year 3		Year 4		Year 5		Year 6		Year 7		Year 8		Year 9	
Preparation																		
Roads	■																	
Excavations	■	■	■															
Site offices and Visitor centre		■	■	■	■													
Construction																		
Construction (all units)				■	■	■	■	■	■	■	■	■	■	■				
Commissioning													■	■	■	■	■	
Close-out of construction																		■

3.8 Major associated infrastructure and other activities required during construction

3.8.1 Access roads

Existing off-site access routes will be used and upgraded for the Duynefontein and Bantamsklip sites, but the Thyspunt site will require the upgrade of existing public roads. As indicated in Section 3.14, the environmental impacts of off-site access roads are not assessed in this EIA.

Two on-site roads from public roads will be required for access to all sites for emergency purposes. Three alternative routes are under consideration at Thyspunt: an eastern, western and northern access route, although the northern access road was rejected for environmental reasons. The environmental impacts associated with the route identification for Thyspunt's new access route formed part of this EIA process. The relevant specialists assessed the affected areas and provided input into the route determination process. This is explained in Chapter 5 and maps indicating the proposed alternative access routes are provided in the same Chapter.

Generally all temporary and permanent services will be routed parallel to on-site access roads. This potential services infrastructure will include inter alia:

- Pipes for sand pumping;

- Conveyors to transport aggregate and spoil;
- Potable water pipes;
- Distribution power lines;
- Communication and data cables;
- Sewer lines; and
- Stormwater channels, pipes and culverts.

3.8.2 Security fencing around the property

The fencing around Eskom property will be of appropriate quality, having taken into account all inputs regarding its fitness for purpose. Based on the faunal specialist recommendations, it is important that the fencing allows for the mobility of faunal species.

The terrace[7] on which the power station is situated will be secured with a high security electrified fence referred to as the inner security fence. The off-terrace facilities are also likely to be surrounded by a low security fence referred to as the outer security fence.

3.8.3 Delineation of the Owner Controlled Boundary

The Owner Controlled Boundary is a fence around the entire Eskom owned land (See **Figure 3-6 to Figure 3-8**). Amongst others, it requires a minimum distance of 100 m between the nuclear buildings and the coastline in order to ensure the maintenance of coastal corridors along the coastline and reduce the corrosive effects of the marine environment on the power plant. However, Eskom has accepted a recommendation by the specialists in this EIA that a distance of at least 200 m must be maintained between the high water mark and the power station. The potential impact of sea level rise has also been taken into account to determine the distance between the current high water mark and the power station.

Access control points will be established at the Owner Controlled Boundary and/or property boundary and the inner and outer security fences. The level of security checks performed at the various access control points will depend on the level of the security risk prescribed for the respective area being entered or exited.

[7] Excavated / levelled area on which the power station and ancillary buildings/ facilities required for the construction and operation of the power station are constructed.

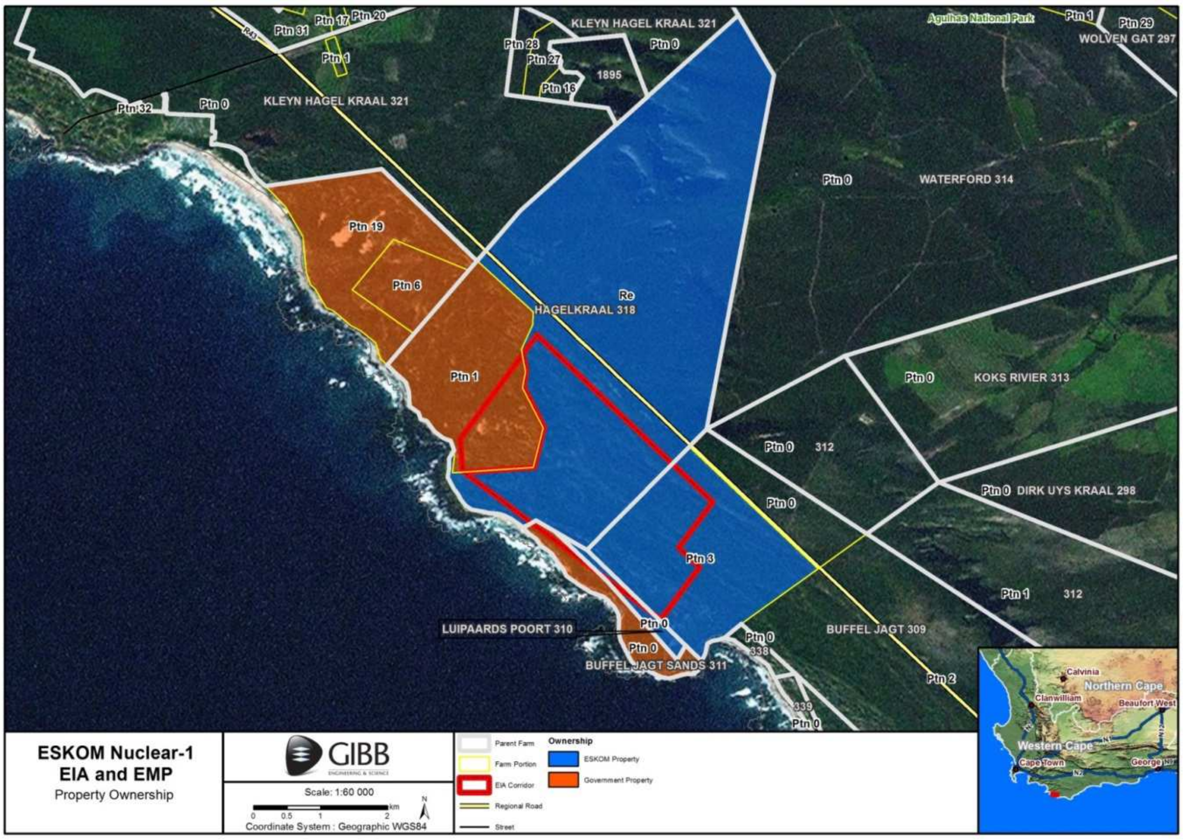

Figure 3-6: Landowners Boundaries for Bantamsklip

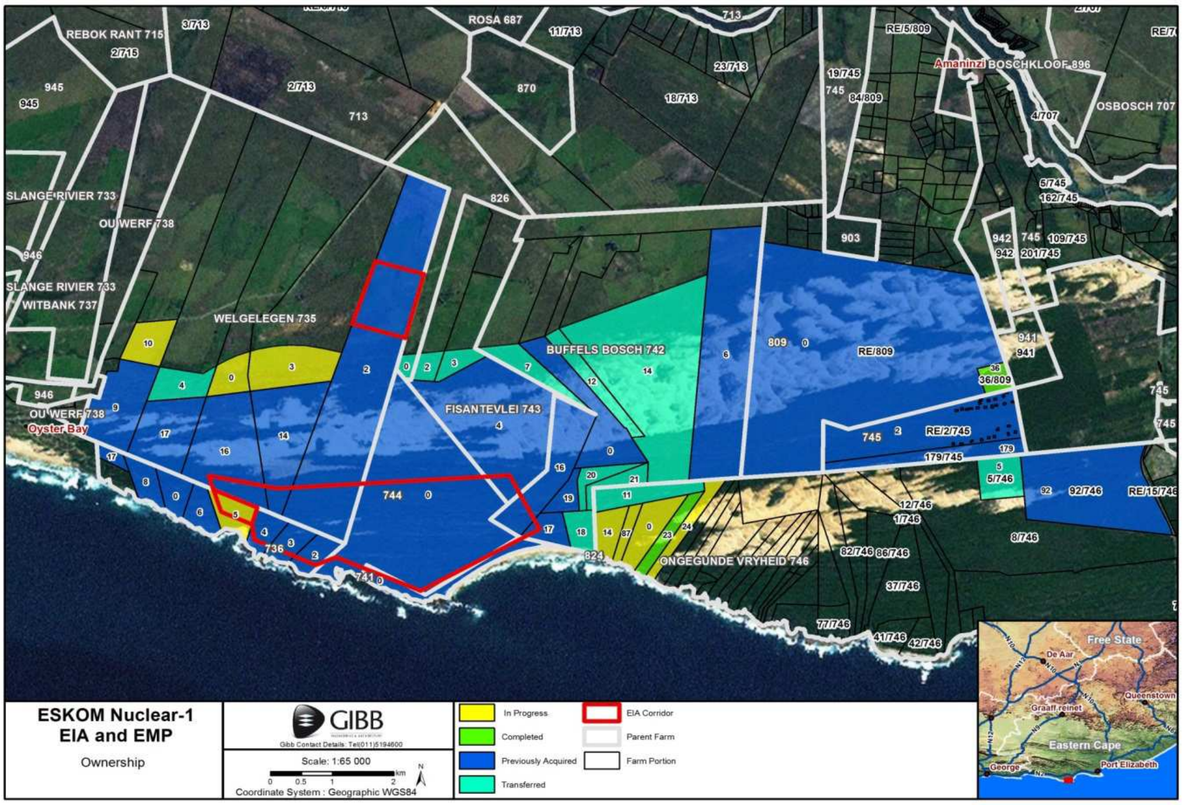

Figure 3-7: Landowners Boundaries for Thyspunt

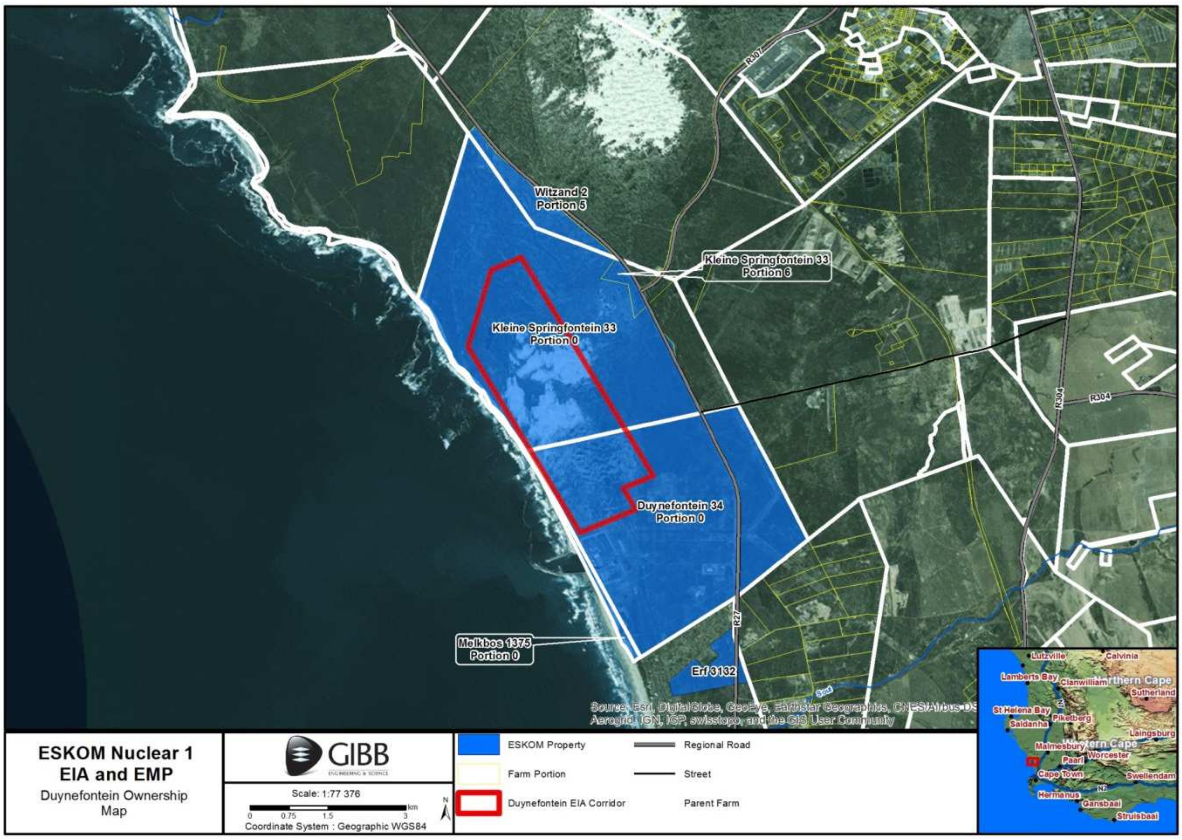

Figure 3-8: Landowners Boundaries for Duynefontein

3.8.4 Power supply to the site

A nuclear power station requires a number of power connections during construction and operation. The following power supplies will be constructed for the Nuclear-1 project:

- **Construction Power.** Power will be required during the construction and commissioning phases. The initial power will be supplied by means of distribution power lines up to a maximum of 132 kV. It is estimated that the initial power requirement will be approximately 5 MVA when vendors access the sites to commence construction, and power demand will peak at about 200 MVA during commissioning. As the power requirements on site increases beyond the capability of the distribution power network capability, completed transmission lines for the evacuation of the nuclear power station energy will be used to supplement the distribution network from the national transmission grid.
- **Evacuation of power.** Transmission lines with minimum voltage of 400 kV will be used to evacuate the power from the nuclear power station. These lines will connect to the nuclear power station's HV Yard.
- **Grid Reliability.** A nuclear power station must have a reliable off-site power supply to ensure that safety systems can operate for extended periods in case of an incident at the plant. The 132 kV lines and gas turbines will be used at all sites to supplement the national transmission grid reliability. Normally the transmission lines fulfil this requirement but as an additional safety precaution, it was decided to install these gas turbines to supplement the grid (e.g. in case large sections of power lines are destroyed through external natural events).It is anticipated to install a combination of gas turbines with a maximum combined capacity of 60 MW. The total capacity of the gas turbine installation is dependent on the plant type chosen through a commercial process, thus this figure is indicative and may change upon vendor selection. In the vicinity of the gas turbines will be the diesel storage tanks, synchronising equipment and switchgear.

- **Emergency Power.** Each nuclear power station has emergency diesel generators on site to supply all essential services with power in the event that all external and internal power is lost. These diesel generators are supplied with diesel storage tanks with a minimum capacity of 240 hours.

3.8.5 Water supply to the site

Water will be required on-site throughout the project life cycle with a markedly increased demand during construction. It is estimated that water demand will be 9.0 Ml/day during construction and 6.0 Ml/day during operation.

The following options were considered with regard to water supply:

- Boreholes;
- Municipal water; and
- Desalination of sea water.

The water requirements for the station are significant and the use of municipal and borehole water in the long term will not be feasible. This, coupled with the fact that sea-water intake systems will be developed for component cooling creates an ideal condition for the incorporation of a desalination plant. The existence of desalination and power generation plants in unison is a well-documented occurrence globally.

Prior to the desalination plant becoming operational, Eskom intends to use groundwater resources for a period of approximately one year prior to commissioning of a permanent desalination plant at the Thyspunt and Duynefontein sites. The amount required is 17 to 23 L/s. This may be obtained from existing boreholes or from a combination of existing boreholes and additional production and monitoring boreholes under supervision of a geo-hydrologist. Planning for the use of boreholes will be done to ensure that it has no impact on existing boreholes used for domestic purposes adjacent to the site.

3.8.6 Site offices

Temporary site offices will be established either in a developed area, close to the site, or in one of the buildings on the Eskom property. These offices will be used to coordinate the ongoing investigations and construction of services, which will provide access to the site for the contractors. Once the contractors are given access to the site, offices for Eskom and the various contractors will be established within the Owner Controlled Boundary for the duration of the construction and commissioning period.

It is Eskom's intention to develop a fitness for duty centre in a suitable town close to the construction site. This office complex will cater for the following services and will be removed after completion of construction:

- Employment office (ten staff members);
- Medical examination office (six staff members);
- Security screening and permit office (four staff members);and
- Facility available for induction training (two staff members).

Additional to the services mentioned above, the facility will have a kitchen, ablution facilities, a reception area as well as a parking area.

The building will either be hired as an existing building or a new building will be constructed specifically for this requirement. A separate EIA and local authorisations may be required for this facility. It is expected that there will be approximately twenty-two staff members in this office as well as another six contract service providers.

Eskom also plans to develop a temporary information centre in a suitable town close to the construction site. This office will be in operation until the visitor centre on site is completed.

This office in town is required to keep the public informed of the project and will be established as soon as a site is approved by the DEA. The building will either be hired as an existing building or a new building will be constructed specifically for this requirement. A separate EIA and local authorisations may be required for this facility. The information centre is planned to have a reception area, a display area, a lecture area, two offices, a kitchen, ablution facilities and a parking area. It is expected that two permanent staff members and two contract service employees will work at this facility.

3.8.7 Groundwater monitoring

There is already a network of boreholes that have been created for groundwater monitoring at all three sites. If necessary, additional boreholes will be sunk around the power plant once the final layout has been identified. Groundwater sampling for groundwater levels, changes in groundwater chemistry and radio-isotope detection has been in operation since 2010 and will continue throughout the operational and decommissioning phases. The frequency of the ground water sampling will be determined by the recommendations of appropriate specialists and prescribed in the Environmental Management Plan (EMP).

3.8.8 Development of construction and operational accommodation

Details of the proposed accommodation provided by Eskom (2008) required for the Nuclear-1 power station are summarised in **Table 3-3.**

Table 3-3: Accommodation requirements per nuclear power station site

Description	Units
Vendors Construction Village for Migrant Workers	3 750 Beds
Vendor Staff Village	2 172 Units
Eskom Nuclear-1 Project Team	220 Units
Eskom Power Station Operational Team	1 000 Units

The accommodation requirements do not form part of this EIA and may therefore require separate applications for environmental authorisation. The accommodation will be integrated as far as possible with areas dedicated for housing in the existing planning processes of the local authorities within which the power station is proposed to be located. Where possible, employees (especially operational employees) will obtain accommodation in existing settlements. The approximately 1, 400 operational staff will either buy existing properties, build new accommodation or rent in the adjacent towns. If new urban developments have already been approved in or near the nearest towns, it would be Eskom's preference to make use of the opportunities provided by these developments rather than create new residential developments that would require separate EIAs.

Eskom has completed initial investigations into housing around all three alternative sites. Apart from Bantamsklip, the current development around Humansdorp, Jeffrey's Bay and in the greater Cape Town would accommodate housing needs and therefore would be highly unlikely to require a separate EIA.

The number of beds indicated above for the vendor's construction village was reduced by 25 % to allow for labour sourced out of the local community. The proposed project thus aims to provide accommodation for 1, 400 staff members, to prevent over-supply as some of the staff may be married couples, workers from the local community and workers that may prefer private accommodation. The minimum land requirements for the accommodation are estimated in **Table 3-4.**

Table 3-4: Minimum land requirements (hectares) required for accommodation

Description	Area (hectares)
Vendor’s Construction Village for Migrant Workers	50.9
Vendor Staff Village	89.5
Eskom Nuclear-1 Project Team	12.0
Eskom Power Station Operational Team	65.7
Sport and Recreation Facilities	18.0
Schools with sport facilities (3)	55.0
Total area of land required	**291.1**

The construction village for migrant workers will typically have the following facilities:

Housing
- 6 bed units (73 %); and
- 3 bed units (27 %).

Support facilities
- Bus Terminus and parking laundry;
- Canteen;
- Lapa with TV;
- Liquor outlet;
- Administration office;
- Clinic; and
- Sewage treatment.

Typical recreation
- Tennis (x4);
- Basketball (x4);
- Soccer (x2);
- Rugby (x1);
- Swimming pool (x1); and
- Cloak rooms and ablutions.

The areas of the land will be finalised in terms of the residential densities prescribed by the Spatial Development Plan for the properties that are available. Eskom must provide rezoned land for the vendor to build a construction village for migrant workers. It will be Eskom’s responsibility is to facilitate the EIA processes for these facilities.

In addition, Eskom may provide serviced residential stands for the vendor to build staff accommodation. The accommodation will be finalised once the vendor is appointed. The land development will be included in the overall community integration strategy for the Eskom residential developments. It is also possible that Eskom will rent accommodation for the vendor staff from the community / developers.

The possible construction of further phases of power plants could result in the use of the Vendor’s accommodation for a period of 10 to 15 years to accommodate contractors and may even be expanded during this period. The accommodation facilities will be upgraded and handed over to Eskom in good condition at the end of each contract.

3.9 Construction of the terrace and power station

3.9.1 Site layout and position of plant

All major plant and support buildings will be constructed within the demarcated EIA corridor. This consists of the Nuclear Island, Conventional Island and associated administration, storage and training facilities etc.

There are limitations to where the plant can be built within the EIA corridor. It is ideal that the plant be kept as close to the coastline as possible. Moving the plant inland means a significant increase in pumping costs associated with the intake of cooling water resulting in an increase in the operating costs of the plant as a result of larger pumps being required. In addition from an environmental perspective, moving the plant further inland would result in a larger amount of spoiled material since a deeper excavation is required to reach bedrock. This is as a result of an increase in elevation and depth to bedrock with increasing distance from the coastline and applies to all three sites.

3.9.2 Excavation and disposal of spoil

As part of the site preparations for the establishment of the Nuclear Island and the turbine hall, significant quantities of soil and rock will be excavated from the terrace area. Earthworks will involve the removal of the overburden sands down to bedrock level, which may differ from site to site.The same process will be applied to other terraces, which support ancillary buildings and facilities used in the construction and operation of the power station although, where possible, terraces will be constructed at elevations above the Nuclear island and Turbine Hall terrace*.* Further excavation of the overburden will be required around the major power plant buildings down to the surface of the bedrock.

Rock spoil material may be used to provide protection and barriers, the construction of rock retaining walls required to stabilise landforms and as a wearing course on the contractors' yards. However, the quantity of spoil required for this purpose is negligible in comparison to the quantity that will be excavated and large quantities of the spoil would therefore need to be disposed. Possible options that have been considered for disposal of spoil include:

- Creation of the HV yard terrace; and
- Disposal and dispersion in the sea as per the recommendations of relevant EIA team specialists.

Chapter 5 provides a discussion regarding the alternative options for utilising / discarding the spoil material.

Undetermined volumes of suitable backfill material may need to be conveyed to the site. This material can be obtained from an appropriate source that can provide suitable material, which can either be commercial off site or material sourced from elsewhere on the site. A suitable study will have to be conducted to establish available sources. Power plant buildings will be founded on either bedrock or engineered fill, neither of which should be susceptible to large deformations during and following strong motion earthquakes.

3.9.3 Dewatering

The excavation for the Nuclear Island and Turbine Hall will need to be dewatered prior to removal of sand to ensure that working conditions are safe during the construction of the power station foundations i.e. groundwater will need to be pumped out. The extent of dewatering will be confirmed once the detailed layout for the nuclear power station is known. Requirements to which the dewatering process needs to comply are specified in the EMP, based on recommendations from the relevant specialists. As recommended by the wetland specialist, a groundwater monitoring programme has been ongoing at all three sites since

2010 and will continue until the end of construction. One of the functions of this monitoring programme was to confirm whether assumptions made in the Wetland Assessment (**Appendix E12**) regarding the potential impact of dewatering on wetlands at the Thyspunt site are valid. The results of the monitoring programme have confirmed that large wetlands such as the Langefonteinvlei Wetland at the Thyspunt site can be protected against groundwater drawdown caused by dewatering.

3.9.4 Buildings

After the foundations for the nuclear island and turbine hall buildings are established, the excavations will be backfilled and the buildings will be constructed to their full height.

3.9.5 Permanent terrace road and lay down storage area

The permanent terrace road will be constructed to allow for the transportation during construction and operation. Lay down and storage areas will be demarcated to allow for the safe storage and manufacturing of the plant equipment.

3.9.6 Installation of plant/equipment

Upon the delivery of the plant/equipment to the site, the selected vendor will commence with the installation thereof. Transportation of heavy loads required for the construction phase is discussed in **Section 3.13**.

3.10 Additional associated infrastructure

Table 3-5 provides a summary of the typical infrastructure that will be associated with the nuclear power illustrate where each of these elements of infrastructure will be located on each of the alternative sites.

Table 3-5: Nuclear Power Station and associated infrastructure requirements

Item	Infrastructure	Brief Description
1.	Access control points	Offices and security check points
2.	Access Roads and parking	Vehicle access paths to and on site
3.	Administration building for technical staff	Complex 4 which Serves the power station
4.	Administration building (General)	Offices
5.	Auxiliary cooling towers	Emergency cooling to safety systems
6.	Boiler building	External diesel boiler
7.	Camera masts	Approximately 40 m high masts to monitor the site
8.	Canteen	Cooking and Eating facility
9.	Central receiving building	Warehouse and stores
10.	Chlorination facility	Chemical process plant for production of chlorine
11.	Coffer dam	Temporary structure in the surf zone during construction only
12.	Containment/Reactor building	A containment building is a steel and/or reinforced concrete structure enclosing a Nuclear Steam Supply System. In an

Item	Infrastructure	Brief Description
		emergency it is the final barrier to a radioactive release.
13.	Contractor and construction staff facility complex	Offices, stores and workshops
14.	Construction substation	Substation
15.	Cooling water Intake basin	Area storing cooling water prior to distribution by the pump houses.
16.	Cooling water Intake tunnels	Intake tunnels for delivery of cooling water to the intake canal
17.	Cooling water Outlet tunnel	Cooling water pumped through the condensers and other plant via these tunnels into the sea
18.	Cooling water pump house	Infrastructure required to deliver cooling water from the intake canal to the condensers and other plant requiring cooling
19.	Decontamination Workshops	Workshops which Decontamination of equipment
20.	Demineralisation plant and chemical laboratory	Demineralised water production and chemistry laboratory
21.	Desalination plant	Desalinisation of sea water and storage thereof to create potable water
22.	Diesel building	Houses the emergency diesel generators
23.	Diesel storage tanks	Diesel storage
24.	Dog kennels	Security
25.	Emergency control and support centre	External Control centre for emergencies
26.	Eskom buildings	Offices
27.	Estate and horticulture complex	Offices and workshops
28.	Fire and Rescue centre Fire training area	Fire fighting facility and coordination centre for emergency action on the site.
29.	Fitness for Duty centre	Administration area
30.	Floodlight masts	Approximately 30 m high masts to illuminate the site
31.	Fuel building	Storage of new and spent fuel
32.	Gas storage area	Gas storage
33.	Helipad	Designated area for helicopter landing and take-off
34.	High level mast lighting	Lighting
35.	High voltage yard	High voltage switchgear and associated systems
36.	Hydrochloric plant	acid regeneration plant
37.	Laydown areas	Temporary storage areas on site
38.	Low and Intermediate Level Waste Storage	Storage are for contaminated waste
39.	Meteorological mast[8] and microwave communication towers	120 m and 60 m high steel structure

[8] The Draft EIR has recommended that an alternative weather monitoring technology, which does not require a mast, be used instead.

Item	Infrastructure	Brief Description
40.	Nuclear auxiliary building	Contains nuclear process equipment associated with the Nuclear Steam Supply System
41.	Outfall structure	Discharge point
42.	Other security fences	Perimeter fence, security fence around all buildings outside power station security fence and temporary construction fences
43.	Parking / Lay down area during construction	Temporary storage of heavy plant during construction and parking during operation
44.	Power station security fence	Security fence complying with National Key Point regulations including lighting and cameras
45.	Reactor buildings	Houses reactors
46.	Safeguard building	A building that contains safety equipment
47.	Sewage sump and pump station	Underground sumps with pumps to evacuate sewage
48.	Sewage treatment plant	Process plant to treat sewage
49.	Skills assessment building	Offices
50.	Stack[9]	Approximately 96 m tall
51.	Technical buildings and workshops	Stores and workshops for the repairs of equipment
52.	Training centres	Offices
53.	Transformer Area	Contains transformers
54.	Turbine hall	Contains the turbines, generator and associated plant
55.	Visitor's centre	Information centre
56.	Waste building (low & medium)	Temporary storage for low and intermediate level radioactive waste
57.	Waste collection areas	Collection area for construction and domestic/hazardous waste
58.	Waste water retention basin	Storage and cleaning of storm water runoff drains
59.	Water tank	Water storage container
60.	Weather station	Offices
61.	Workshop and stores	Complex 4 which Serves the power station

The key elements of the associated infrastructure are discussed below.

3.10.1 Helipad

A helipad will be constructed in a suitable area and will be used as and when required. It may also be used when the helicopter is required to assist with the lifting of heavy equipment. The helipad will require aviation fuel storage of 5 m^3.

3.10.2 Meteorological station

A meteorological mast will be constructed to a height of approximately 120 m. The tower is likely to be of a lattice design supported by guy ropes. Typically, the meteorological station will undertake measurements of wind, temperature, precipitation and relative humidity, but the

[9] The nature of emissions from the stack is discussed in Section 3.15

exact requirements for the meteorological station will be determined by legal requirements and new technology development.

3.10.3 Backup power supply

A number of diesel generators will be available in the event of a station black out. The backup power supply provides a safety function, as it enables the cooling of the reactors in the event that the main power supply is interrupted. Diesel storage tanks with sufficient bunding (in the event of a leak) with a capacity of 1, 000 m^3 will be required for this purpose. The backup generators will be located at a height above sea level to provide sufficient safety of supply in the event of a tsunami or extreme weather event and will be tested periodically to ensure they are in good working order.

3.10.4 Visitors' centre

Areas will be demarcated for the following facilities covering a total floor area of approximately 1, 764 m^2:

- Exhibition area;
- Lobby;
- Cafeteria;
- Information centre;
- Administration offices;
- Meeting room;
- Ablution facilities;
- Storage facilities;
- Auditorium;
- Kitchen facilities; and
- Supporting facilities.

3.10.5 Water requirements

During the construction phase, water will be primarily used for the manufacture of concrete in batching plants; earthworks, including the construction of roads; wetting of soil stockpile, roads and terraces to control the generation of dust; and potable water. **Table 3-6** indicates the estimated water consumption during the site establishment, earthworks and construction phases.

Table 3-6: Estimated water consumption during construction and operation phases

Project Stage	Activity	Unit	Consumption
Stage 1	Site establishment	m^3/day	300
		m^3/s	0.003
Stage 2	Earthworks	m^3/day	9 000
		m^3/s	0.104
	Construction	m^3/day	1 300
		m^3/s	0.015
	Commissioning	m^3/day	2 100
		m^3/s	0.024
Stage 3	Operation	m^3/day	6 000
		m^3/s	0.069

To ensure a constant supply of water to the power station the following storage reservoirs, which are closed and protected from the environment will be required on site.

Table 3-7: Reservoirs required on site

Description	Capacity
Demineralised Water Storage Tanks	4 x 2,200 m³ + 2 x 800 m³
Potable Water Storage Tanks	2 x 9,000 m³
Fire Water Storage Tanks	2 x 1,800 m³

The required capacity of the reservoirs is approximately 32 million litres. The creation of reservoirs of this magnitude will require separate authorisation from the DWA.

Current planning is for all water for the construction and operational phases to be obtained from desalinisation. However, additional fresh water may need to be obtained from other sources for short periods of time during construction (especially during site establishment).

3.10.6 Sewage treatment plant

A sewer network will be established and will comprise, as far as possible, gravity flow lines leading to a central sump. The location of the main sewer pump will be chosen based on its appropriateness to the final plant and administrative buildings layout, and will be based on the recommendations of the specialist studies.

Sewage will be pumped from the main sump to the sewage treatment plant. During construction, based on a maximum of 8, 000 people on site during construction, it is estimated that the water consumption will be in the order of 120 litres per person per day, of which approximately 70 % will be destined for the sewer treatment works. To ensure spare capacity, the sewage treatment plant will be designed to treat approximately 1, 000 m^3 of water per day. The effluent will be treated in accordance with statutory standards in the sewage treatment plant, prior to its discharge into the ocean via outfall tunnels. The layout and elevation of the infrastructure will be established once the terrace layout has been finalised.

3.10.7 Desalination plant

A temporary modular desalinisation plant will be installed during construction. This relatively small plant in container units will use beach wells for the intake of seawater. Beach wells are wells sunk into the beach and the water which fills these wells will serve as intake seawater for the temporary desalination plan as well as to initially supply the permanent desalination plant. The sea water intake area will be lined with waterproof material. Assuming a maximum intake of 22, 500 m^3/day, the required capacity of the beach well will be approximately 45, 000 m^3/day.

The permanent desalination plant will be constructed and commissioned during the construction phase and will continue to operate during the operation of the power station. It will consist of three units, each capable of producing 3, 000 m^3 of desalinated water per day (see **Figure 3-9**). The intake water for the construction phase will be drawn from beach wells and for the operational phase it will be drawn from the intake tunnels from the sea (or from the condenser, to improve the efficiency). The intake of sea water for the desalinisation process will be at maximum rate of 22, 500 m^3/day, which amounts to 0.34 % of the total volume of water derived from the ocean via the cooling water intake tunnels. The desalinated water will be stored either in a storage reservoir or a lined pond.

Assuming a 40 % recovery of freshwater, 260 ℓ/s of sea water will be required as input to the desalination plant, while 156 ℓ/s of brine will be generated. During construction the brine (hypersaline effluent) will be disposed into ocean at an appropriate depth and distance from shore (beyond the breaker zone) to aid quick mixing and dissipation. During operation, brine will be disposed into the sea via the cooling water discharge system, to ensure instant dilution. The salt concentration of the seawater is 35, 000 parts per million (ppm) while the brine that is produced is expected to have a salt concentration of 59,000 ppm. The brine and the effluents of reverse washings in the water will be directed to a collection sump. The mixture of water and chemicals will be pumped to a neutralisation pit, which will dilute the salt and chemicals. The diluted mixture will be discharged into the sea, along with the water that was used for cooling in the plant.

During the operational lifetime of the nuclear power station, water will be used for input into the demineralised water treatment plant. The demineralisation plant, which is used to produce filtered water, is required because water in its pure chemical state avoids corrosion and the formation of mineral deposits within the system. It is proposed that the demineralisation plant will comprise of two units, each with a capacity to demineralise 2,000 m^3 per day.

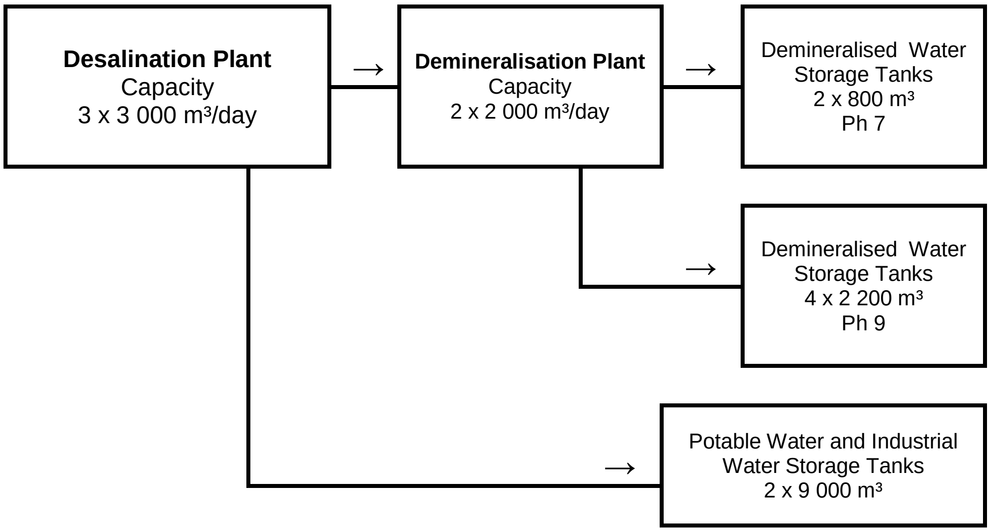

Figure 3-9: Schematic depiction of the desalinisation and demineralisation plants

3.10.8 Chlorination Plant

The chlorination plant will serve to protect the seawater cooling systems against the growth of biofilm and biological fouling (seaweed; marine organisms and debris) through the injection of sodium hypochlorite into the systems. Ordinarily, the sodium hypochlorite is produced *in situ* from the electrolysis of seawater, which occurs in the chlorination plant. At Koeberg for example, chlorination is carried out once the temperature of the seawater reaches 12°C. The process involves discharging both residual oxidants into the sea (both in the Free State and as chlorine compounds) and trihalomethanes (as bromoform).

During normal operation, the cooling systems will receive a continuous injection of sodium hypochlorite at a concentration of two parts per million. In addition, the cooling systems will receive a shock treatment of sodium hypochlorite, at a concentration of four parts per million, three times daily for 15 minutes each.

The effluent emanating from the chlorination plant will be discharged into the ocean via the outfall tunnels along with cooling water.

3.11 Marine works

During operation the power station will require significant volumes of water to cool the condensers of the turbines and to extract heat from heat exchangers on the nuclear island.

The following options exist for intake and outfall water into the power station:

- Open water intakes/outfalls (e.g. open channels, breakwater systems etc);
- Beach Wells (intake); and
- Intake/outfall tunnels.

Beach wells will be used for the construction phase but were excluded from consideration for the operational phase of the power station as they would not be able to supply the large quantities of water required. An open water system would jeopardise the accessibility and visual integrity of the coastline and would therefore not be preferable.

Water for the operational phase will be obtained from the ocean by means of the intake tunnels and expelled from the power plant via outfall pipelines/ tunnels. In the event that a tunnel boring machine is used, this machine will need to be assembled prior to the commencement of the tunnel boring activities. The conceptual method of construction is discussed below.

3.11.1 Intake tunnels

An undersea intake tunnel will draw cooling water from the sea into the cooling water intake basin adjacent to the cooling water pump houses. No detailed design for the intake tunnel(s) has been done, but the design will comply with the requirements of the relevant specialist recommendations, so as to minimise the impact on marine ecosystems and sediment movement. The following basic principles will, however, apply. The construction of the intake tunnel(s) will involve sinking of a shaft on land to a depth of approximately 65 m below mean sea level. At this point the tunnel will be driven seawards underneath the seabed. The tunnels will be lined with precast or in-situ poured concrete. At the other end of the tunnel, a tower extending approximately 5 m to 10 m above the sea bed floor will be constructed to connect the intake structure and the tunnel. Fixed dredging may need to be installed at the base of this tower. The length of the tunnel from the onshore access shaft will be approximately 1 km to 2 km and the depth of water in which the intake structure will be constructed is limited to 30 m.

3.11.2 Outfall tunnels/channels

The outfall pipelines/tunnels dispose the seawater used to cool the turbo-generators and other smaller heat exchangers as well as diluted chemical effluent into the ocean. It is estimated that six pipelines of approximately 3 m diameter will be required for the outfall works. The marine biologist recommends the use of multiple discharge points in order to facilitate dispersion of the warmed water and mixing with the relatively cooler sea water. The objective of the outfall works will be to transfer the heated water at least beyond the surf zone (estimated to be in the order of 500 m to a depth of 5 m below mean sea level). The final depth and distance of release of the heated water will be determined by the results of the marine specialist study. The water released into the ocean will be 12 °C warmer than the seawater, as a result of the heat absorbed from the power generation process. The primary objective is to ensure that the heated water has minimal impact on sea life. The velocity of the water in the pipes will be fast enough to ensure adequate dispersion into the sea. A high velocity of the expelled water ensures an adequate rate of mixing with the sea water, which reduces thermal pollution of the benthic environment.

3.12 High voltage yard

A high voltage yard (HV yard) will be constructed within the site boundary. When the foundations for the nuclear power station are completed, the high voltage yard will be installed. The high voltage yards form part of the scope of the current EIA process for the nuclear power station.

3.13 Materials required for construction

Table 3-8 provides an indication of the quantities of some of the materials that will be used during the construction of the key elements of the nuclear power station. <u>It should be noted that these quantities are vendor dependent and hence, are indications only of the possible material usage.</u>

Table 3-8: Material required for the construction of key elements of the nuclear power station

Activity**	Material	Approximate Quantities	Comment
CONSTRUCTION			
On main terrace***; Off main terrace; Marine works; HV yard and transmission lines	Concrete	289,000 m³	Estimated quantities per unit
	Concrete pouring per day	1,000 m³	
	Concrete reinforcing	39,500 t	
	Structural steel	15,213 t	
	Large bore pipe	70 219 m	
	Cable	1,111 km	
	Terminations	158,252 each	
	Sand removal (spoil to be discharged at Thyspunt)	6,372,044 m³	
	Bedrock to stockpile at Thyspunt	708,356 m³	
On main terrace; Off main terrace; Marine works; HV yard and transmission lines	Concrete	108,660 m³	Balance of plant estimates
	Concrete reinforcing	6,766 t	
	Structural steel	1,299 t	
	Small bore pipe	12,836 m	
	Large bore pipe	163,914 m	
	Conduit	381,256 m	
	Cable	906,884 m	
	Terminations	22,025 each	

*Values are subject to change dependent of the nuclear power station vendor
** Materials and quantities are applicable to each component
***The terrace refers to that section of the site that has been levelled and compacted to support the Nuclear Island, Turbine Hall and Auxiliary Buildings inside the high security fence.

Abnormal loads will be transported to and from the closest suitable harbour to the selected Nuclear-1 site. This section discusses the existing road infrastructure as well as the upgrades and / or requirements associated with the transport infrastructure. The management of the transportation of abnormal loads should be detailed in a heavy load traffic management plan. All aspects of transport of abnormal equipment have been investigated in a detailed traffic impact assessment by GIBB (2009). This study indicates upgrades that will have to be undertaken on roads to the sites.

3.14 Roads

Abnormal loads will be transported to and from the most suitable harbour to the authorised Nuclear-1 site. This section discusses the existing road infrastructure as well as the upgrades and / or requirements associated with off-site transport infrastructure. The management of the transportation of abnormal loads should be detailed in a heavy load traffic management plan. All aspects of transport of abnormal equipment have been investigated in a detailed traffic impact assessment by GIBB in Appendix E25. This study indicates new/upgrades that will have to be undertaken on off-site roads to the Nuclear-1 sites.

It should be noted that the environmental impacts associated with the upgrade of off-site roads do not form part of this EIA and will therefore require separate applications for environmental authorisation.

Depending on the authorised site, Eskom will have to reach an agreement with the owners of the different sections of road for any upgrades and studies to be done on the infrastructure.

The proposed access roads that were considered as alternatives in this EIA are discussed in Chapter 5.

3.14.1 Duynefontein

An investigation "Transport Study from Saldanha Harbour to Koeberg Power Station for the Exceptionally Heavy SSC" was undertaken in June 2005. The results of the above-mentioned study indicated that the route from the Port of Saldanha to the Nuclear-1 site is a viable option, provided that the route from Saldanha Bay Harbour to the R27 is subjected to several minor road upgrades coupled with an upgrade of the Modder River Bridge. The Traffic Impact Assessment conducted by GIBB indicated that the **Duynefontein** site requires no significant upgrades during the construction and operational phases of Nuclear-1 with regard to intersection, heavy load transport road upgrades and emergency evacuation upgrades. Duynefontein, however, requires a significant number of stand-by evacuation vehicles to ensure safe evacuation of construction workers if an accident does occur at the adjacent Koeberg Nuclear Power Station during the construction period. These vehicles can also be used to shuttle the construction workers to and from the site during the AM and PM peak periods.

3.14.2 Bantamsklip

Transport of the abnormal loads will have to be undertaken from Cape Town Harbour to the N2 and finally the R43 that bisects the site. The distance from the Cape Town Harbour to Bantamsklip is approximately 150 km. Due to the difficulty of road transport across mountain passes, an option to use a barge from Table Bay to the site was investigated. A suitable site on the beach close to Bantamsklip would have to be identified and a landing site with loading / off-loading facilities would have had to be constructed. However, the surf at the site is too high and the potential environmental impacts associated with construction of barging facilities has not been assessed. Several upgrades to roads and bridges will have to be undertaken along the road route if this site is used. The Traffic Impact Assessment conducted by GIBB indicated that the **Bantamsklip** site will have a significant impact on the transport network, with upgrades required to the public transport system, heavy load routes and road upgrades required for emergency evacuation purposes and for bypassing Gansbaai.

3.14.3 Thyspunt

The Traffic Impact Assessment conducted by GIBB indicated that the **Thyspunt** site requires significant transport upgrades with regard to public transport, access and emergency evacuation during construction. The recommended routes in Version 12 of this Report were revised as a result of public input and recommendations received in 2011. Based on the feedback received, the R330 is now proposed to be used only for passenger vehicle traffic and abnormal load transport, and sections will require upgrading for this purpose. The existing dirt road between Humansdorp and Oyster Bay Road is proposed to be upgraded to a surfaced road and used during the construction and operational phases for staff access, light vehicle traffic, heavy vehicle traffic and as an emergency evacuation route for areas such as Oyster Bay. The DR1762, which links the R330 and Oyster Bay Road, is proposed to be surfaced to provide improved east-west connectivity.

Industrial Bypass C, and Southern Bypass is being proposed so that heavy vehicle traffic from the N2 bypasses Humansdorp. The Voortrekker Road / Main Street intersection can be bypassed with an alignment bypassing the industrial area on the western side to avoid the major Humansdorp intersection. While there are gradient design challenges, the re-alignment can be achieved (**Figure 3-10**).The bypass will be constructed as a new road, which intersects at Hankey Road (R330) to the north of the Bosbok Street intersection and reconnects with Old Cape Road, bypassing the entire Kruisfontein area. The proposed bypass will cross the railway line before it reaches Old Cape Road. The rail traffic experienced at the railway line is light and therefore considered insignificant. A crossing with traffic signals or booms will be sufficient to ensure safety between vehicle and railway traffic.

It is proposed that Searle Street be realigned to join Voortrekker Road and become the new entrance to the Kruisfontein area. The proposed industrial bypass will join the new Searle Street / Voortrekker Road intersection as a northern approach to connect with Old Cape Road (southern approach). The major advantage of this alignment is the bypass of the entrance to Humansdorp for construction traffic. The disadvantage is the substantial upgrading of the Searle Street / Voortrekker / Industrial Bypass / Old Cape Road intersection.

Figure 3-10: Industrial Bypass C and Southern Bypass around Humansdorp

3.15 Operational inputs and outputs

The information provided in **Table 3-9** indicates the anticipated inputs and outputs related to operational phase of the nuclear power station. The amounts are based on a standard reactor, given that the preferred site will play a role in terms of the number of units that the site can accommodate. According to Eskom, the specifications are in line with the European Utility Requirements (EUR) standards for Light Water Reactors (LWR) plants, and the PWR falls within this category.

Table 3-9: Inputs and outputs related to the operational phase under normal operating conditions

Activity	Input / Output	Approximate Quantities	Comment
Cooling water	Total cooling water flow (Reactor Coolant Flow Rate) Fresh water	2 396 736 000 m³/year 196 992 000 m³/month 6 566 400 m³/day 76.0 m³/s 2 190 000 m³/year 180 000 m³/month 6 000 m³/day 0.069 m³/s	
Fuel	Enrichment of fuel (by weight) Rods / Assembly Assemblies / load Fuel active height Fuel assembly pitch Mass of fuel rod Mass of assembly Total assembly mass in reactor Duration of fuel in reactor Spent fuel over lifecycle (Approx)	4.95 % 265 each 241 each 4.20 m 0.215 m 2.80 kg 780 kg 187.98 ton 18 months 468 m³	
Water	Demineralised (filtered) water Demineralised water: Spray Packing Glands Turbine Hall Total Average drinking water	25 000 m³/year 2 083 m³/month 68.49 m³/day 40 000 m³/year 75 000 m³/year 115 000 m³/year 9 583 m³/month 315.07 m³/day 30 600 m³/year 2 550 m³/month 83.84 m³/day	
Demineralisation Plant	Units Capacity per unit Conductivity of water	2 each 2 000 m³/day 0.2×10^{-6} S/cm	

Activity	Input / Output	Approximate Quantities	Comment
	Silica SiO_2 Sodium Suspended solids	20×10^{-6} g/l 1×10^{-5} g/l 50×10^{-6} g/l	
Waste	Waste produced (wet solidified, dry compacted or non-compactable)	Detailed information required	< 50 m^3 per 1000 MW plant / year of normal operation (In accordance with the European Utility Requirements for LWR nuclear power station)
Fire water	Storage Tanks	2 x1 800m³	
Chlorination *(Koeberg values)*	CRF (Main cooling water): Normal Operation-Continuous Shock (3x/day for 30 min) Continuous consumption rate Shock consumption rate Total consumption rate SEN (Auxiliary cooling water): Normal Operation-Continuous Shock (3x/day for 30 min) Continuous consumption rate Shock consumption rate Total consumption rate	 2.00 mg/kg 4.00 mg/kg 13 565 kg 848 kg 14 413 kg 2.00 mg/kg 4.00 mg/kg 656 kg 41 kg 697 kg	
Hydrogen Plant (H_2)	H_2 Plant / Unit (Nm^3/h @ 25Bar) 4 x Storage Tanks (Nm^3)	15 30	
Auxiliary Steam Boiler	Auxiliary Steam Boiler (x3) (t/h) Diesel Storage Tanks (x2) (m³)	32 230	
Radiation effluent	Discharge	*Limit to be set by the NNR*	Will be established by the NNR
Non-radioactive releases	Stack: Gas Location of release point Height of release above ground Vent tip diameter Exit gas velocity (normal) Exit gas velocity (outage) Exit gas temperature (winter) Exit gas temperature (summer) Gas Turbine Exhaust Gas: Exhaust gas mass flow Exhaust gas temperature Gas Composition - N_2 O_2 CO_2 H_2O Ar SO_2	 Ventilation Next to reactor 96.00 m 3.00 m 5.80 m/s 6.35 m/s Ambient °C Ambient °C 85 kg/s 538 °C 74.80 % Vol 13.90 % Vol 4.20 % Vol 6.20 % Vol 0.90 % Vol 0.00 % Vol	

3.16 Construction waste

Waste generation in this phase will be of temporary nature, until the completion of the construction activities. Waste generated during this phase will be non-radioactive. Two main types will be created during this phase i.e. General and Hazardous. The latter category includes low-hazard waste (**h**) and high hazard waste (**H**). The waste typically produced during the construction phase is that resulting from the actual construction activities as well as from numerous construction workers, support functions and support activities.

3.16.1 General construction waste

Research indicates that the types of waste that will be commonly encountered together with an estimation of the total amounts are as indicated in **Table 3-10** These quantities are indicative for a typical nuclear power station.

Table 3-10: Typical waste types during construction of nuclear power station for a similar plant (Pöyry Energy Oy and Lithuanian Energy Institute 2008)

Type of waste	1 × 1,600 / 1,700 MW reactor	2 × 1,600 / 1,700 MW reactors
Paper Glass Packaging waste Metal scraps Tyre scraps End-of-life vehicles Sewage sludge Concrete sludge Lead batteries Contaminated soils Used oils Residual paints, solvents	Total amount: 14,500 t 1,000 – 2 000 t not suitable for further utilization (lower limit) 385 t/month as peak quantity	Total amount: 27,000 t 2,000 – 4,000 t not suitable for further utilization (lower limit) 740 t/month as peak quantity
Drinking and raw water – waste water treatment	730,000 m^3 20,000 m^3/month as peak quantity	1,400,000 m^3 40,000 m^3/month as peak quantity

General wastes that will be generated by these activities include packaging material, paper, food waste, vehicle tyres, construction debris, wood, scrap metal, cement bags etc. and will primarily be solid waste. An exception is likely to be wash water from construction and maintenance activities. An additional general waste that requires attention is that of natural materials from excavation and blasting.

Solid waste, excluding radioactive waste, will be transported to and disposed of at permitted off-site solid waste disposal sites. A number of disposal sites may need to be identified depending on the type of materials being disposed of. This waste relates to construction debris generated during building of the power plant and which comprises concrete and steel, as well as domestic waste generated from the canteens on site.

Solid waste production is likely to peak around the end of the first year and during the second year of construction, slowly and steady decreasing thereafter. The total amount of general waste generated every year is expected to be around 450 – 500 tons for one operational reactor unit and 850 – 900 tons if two units will be operational. The exact amounts of these different materials, as well as the portions that may be recycled and placed in landfill will depend on the operational structure of the licensed waste disposal facility, as well as that of the site-specific operations.

3.16.2 Non-radioactive hazardous construction waste

Non-radioactive hazardous waste generated during the construction phase of the power station will include, amongst other materials, used lamps/bulbs, batteries, used oil/grease, construction chemicals and contaminated wash water. A significant contributor will be hazardous wastes from concreting activities. Typically this includes wash water, dust and unused concrete from the batching plant – from the actual mixing process, as well as from the cleaning of equipment and transport trucks.

The hazardous waste will be sorted, packaged and confined by the contracting company and then transported by a licensed contractor to an appropriately permitted hazardous disposal site outside the construction site.

3.17 Operational waste

3.17.1 General operational waste

Operational wastes will arise from the support activities (offices, ablutions, canteens, etc.) and is likely to cover the conventional spectrum of packaging material, paper, food waste, plastics, glass, etc. Waste from maintenance activities is likely to also include scrap metal, non-hazardous chemicals and garden waste. General waste will represent more than 80% of the total waste volume produced during operations.

3.17.2 Non-radioactive, hazardous operational waste

This stream is likely to contain used lamps/bulbs, batteries, used oil/grease and chemicals and reflects the specialised nature of the non-radioactive operations.

3.17.3 Radioactive, hazardous operational waste

Solid radioactive waste may be categorised into categories as indicated in
Table 3-11**:**

Table 3-11: Categories of Radioactive Waste (NNR 2001)

Waste Classes	Typical Characteristics
Exempt Waste	Activity levels at or below levels found in natural materials (natural background radiation levels).
Low Level Waste (LLW) and Intermediate Level Waste (ILW) or a combination thereof	Activity levels above background levels but below those of High Level Waste. These may be long-lived waste (LILW-LL) or short lived waste (LILW-SL).
High Level Waste (HLW)	Spent (used) nuclear fuel if designated to be disposed of as spent fuel, or the residues resulting from the reprocessing of spent fuel.

The quantity of waste will depend on the operating procedures in force at the power plant. The proposed power station, similar to the Koeberg Nuclear Power Station, will produce levels of LLW, ILW, and HLW. LLW and ILW contain radioisotopes, which decay relatively quickly in nuclear terms (30 to 300 years, respectively). Spent fuel produced at both Koeberg Nuclear Power Station and the Safari Reactor at Pelindaba decays to very small fractions of its original radioactivity after approximately 1,000 years, whilst long-lived waste produced by mining and mineral processing takes longer to decay.

(a) Low Level Radioactive Waste (LLW)

Generally, Low-level Radioactive Waste (LLW) may be generated by hospitals, laboratories and industry. It comprises paper, rags, tools, clothing, masks, gloves, plastics, insulation material, soil and other protective clothing (e.g. disposable overalls) and contains small amounts of mostly short-lived radioactivity. LLW is not dangerous to handle, but must be disposed of more sensitively than normal waste. In most instances around the world such waste is placed in sealed containers (steel drums) and is normally buried in shallow landfill sites, such as Vaalputs in South Africa (**6** and **7**). Based on the extrapolated quantities of LLW generated at Koeberg, Nuclear-1 is expected to produce approximately 470 steel drums of LLW per annum.

(b) Intermediate Level Radioactive Waste

Intermediate-level Radioactive Waste (ILW) contains higher amounts of radioactivity than LLW and requires special containment. It typically comprises sludge, spent ion exchange resins, chemical sludge, filter cartridges and reactor components, evaporator concentrates as well as contaminated materials (e.g. irradiated scrap metal) from reactor decommissioning. Worldwide this level of waste contributes approximately seven percent of the volume and four percent of the radioactivity of all radioactive waste. This type of waste is typically combined with concrete or bitumen to solidify it prior to disposal. Based on the extrapolated quantities of Intermediate Level Radioactive Waste generated at Koeberg, the Nuclear-1 power station will produce approximately 60, 480 ton metal-lined concrete containers of ILW on an annual basis.

The Nuclear-1 plant will implement a Solid Waste System as part of the Waste Handling System to segregate, handle, analyse, process, store, and transport radioactive LLW and ILW generated during normal operation, maintenance activities, and upset conditions. These functions are performed in order to maintain releases of radioactive materials within regulatory limits and As Low As Reasonably Achievable (ALARA). The basic activities involved in managing this waste are indicated in **Figure 3-11**.

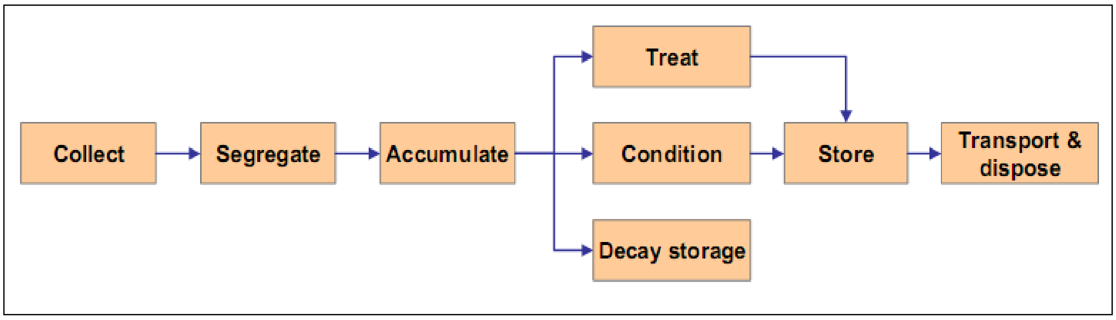

Figure 3-11: General waste management activities for ILW and LLW

Compactable waste is compacted in drums to reduce its volume and stored on site until it can be transferred for disposal. Non-compactable waste is immobilised in concrete, in order to prevent the spreading of contamination if the container is damaged. The radiological properties of the waste determined whether it is metal or concrete containers are used for conditioning the waste. See **Figure 3-12** for an example of compacted LLW in a steel drum, as well as non-compactable ILW, set in a concrete matrix, in a steel drum prior to casting in a concrete mould. Standard steel and concrete drums that are currently used for LLW and ILW waste disposal at Vaalputs are shown in **Figure 3-13.**

Provision will be made to store ILW and LLW on site to optimise the efficiency of waste transport by transporting it in bulk to Vaalputs. An example of a facility of this nature at Koeberg Nuclear Power Station is provided in **Figure 3-14**. A similar facility will be provided at Nuclear-1.

Figure 3-12: Compactable (LLW) and non-compactable (ILW) radioactive waste storage containers

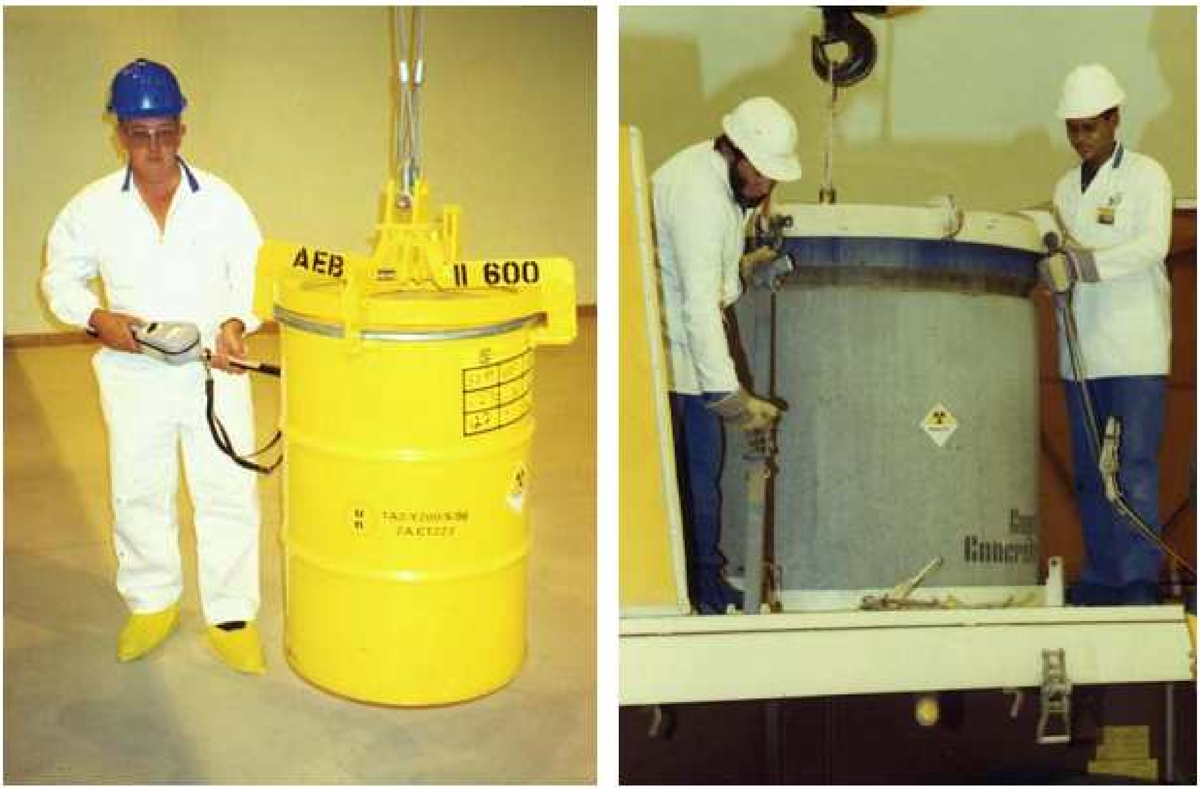

Figure 3-13: Standard steel and concrete containers used for radioactive waste disposal at Vaalputs

Figure 3-14: Storage facility for ILW and LLW showing concrete drums in the background and steel drums in the foreground

(c) Vaalputs radioactive waste disposal site

The South African Nuclear Energy Corporation (NECSA) owns and operates the Vaalputs radioactive waste disposal facility. Vaalputs has been designed and permitted with sufficient capacity for handling the Koeberg's L&ILW, plus three additional conventional nuclear power stations. In terms of the National Radioactive Waste Management Policy and Strategy, this is the designated facility for the disposal of L&ILW in South Africa. 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).

The currently active area used for waste disposal at Vaalputs is 1 km^2, of which approximately 5 % has been used after the more than 20 years of Koeberg's operation. The total area of the property is 10 000 ha (Beyleveldt, pers. comm. 2010).

The bulk of the L&ILW stored at Vaalputs at present and for which authorisation was granted, is generated by Koeberg. Standardised containers (in terms of dimensions and mass) are being used as far as practicable to ensure uniformity, compatibility, and safe handling during all waste management processes. A 210 litre metal container and the KNPS types C1, C2, C3, and C4 concrete containers are currently being regarded as standard containers (Aquisim Consulting 2008).

Near surface trenches are currently being used as disposal concept at Vaalputs. As shown in **Figure 3-15** two sets of trenches are presently being used for the disposal of LLW and ILW. The area set aside for L&ILW disposal is 500 m by 700 m. **Figure 3-15** presents the provisional trench layout until the assumed closure date of 2036, which takes into account a ratio between LLW to ILW of 3:1. The provisional trench layout may be changed in future in accordance with disposal needs.

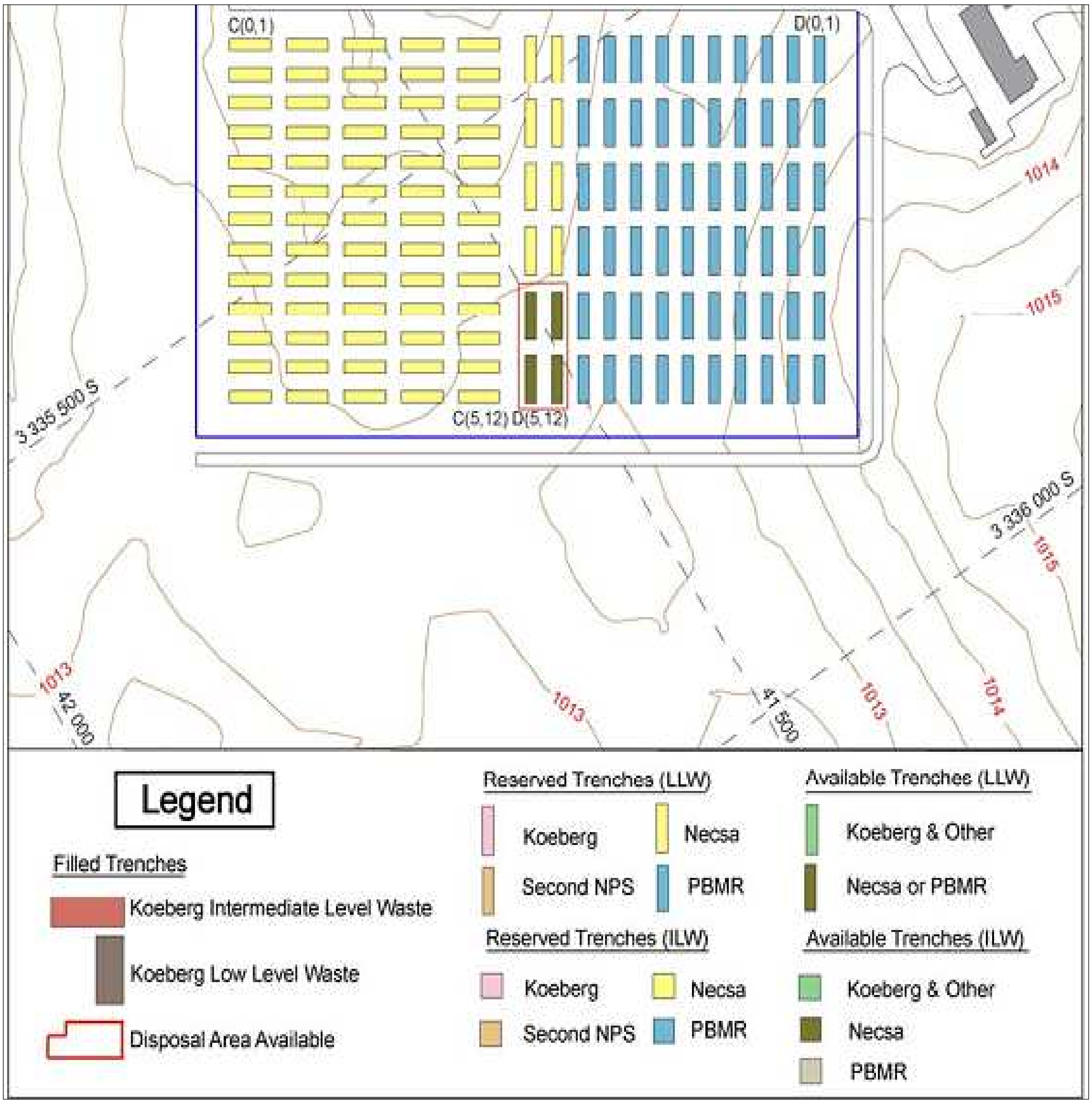

Figure 3-15: Trench layout for low and intermediate level waste at Vaalputs (Aquisim 2008)

(d) High Level Radioactive Waste

In general, High-Level Waste (HLW) can either be the spent fuel itself, or the principal waste from reprocessing (which will only be relevant if a decision is made in the future to reprocess nuclear fuel). While it represents three to four percent of the volume of all radioactive waste, it holds 95 % of the total radioactivity. It contains highly radioactive fission products and some heavy elements with long-lived radioactivity. HLW generates a considerable amount of heat and requires cooling, as well as special containment during handling and transport. HLW is highly radioactive and thus people handling it must be shielded from radiation. Such materials are transported in special containers, which block the radiation and which are designed not to rupture in the event of an accident.

The radioactivity of some of the materials in high-level radioactive waste reverts to natural levels within relatively short periods of time but other materials, however, remain radioactive for several thousands to some hundreds of thousands of years. Responsible storage and disposal of HLW is therefore imperative.

Two options for the long-term management of spent fuel are pursued internationally:

(a) direct final storage of the spent fuel in a deep underground geological storage facility (referred to as Geological Disposal[10]);

(b) reprocessing of the spent fuel to extract unused uranium and plutonium for re-use and concentration and storage of the residual (about 3 – 4 % of the spent fuel) high level waste in a deep underground geological storage facility.

In South Africa, where there are currently no facilities for the reprocessing of fuel or for geological storage, all the HLW will remain in the fuel facility inside the plant (as is the case at Koeberg). As a result, the entire fuel facility is treated as HLW. Storage of HLW in this manner occurs under the regulatory control of the NNR and is subject to the requirements of the National Radioactive Waste Management Policy and Strategy and associated legislation or regulations. The producers of spent fuel are required to store the HLW at the plant until a national policy surrounding the disposal of nuclear waste is finalised.

To ensure that the performance of a reactor is optimised, approximately one-third of the spent fuel is removed every 12 to 18 months and replaced with new fuel. When the spent fuel is removed from the reactor, it is highly radioactive, which causes a great deal of heat to be produced, and they must, therefore, undergo cooling and be shielded from people. It is therefore placed in water-filled storage ponds in the nuclear island **(Figure 3-18)** or in dry storage. The storage ponds are steel-lined concrete tanks, approximately eight metres deep. The heat and radioactivity decrease over time, and after about 40 years the radioactivity is reduced to about 1/1000th of what it was when the spent fuel was initially removed from the reactor.

The amount of spent nuclear fuel estimated from Nuclear-1 (4, 000 MWe) over its life cycle per generating unit is estimated at 1, 880 tons.

[10] The term geological disposal refers to the disposal of solid radioactive waste in a facility located underground in a stable geological formation (usually several hundreds of meters or more below the surface) so as to provide long term isolation of the radionuclides in the waste from the biosphere (IAEA 2006).

Figure 3-16: Low Level (steel) and Intermediate Level (concrete) radioactive waste drums (respectively above and below) at Vaalputs. The drums are covered with layers of clay.

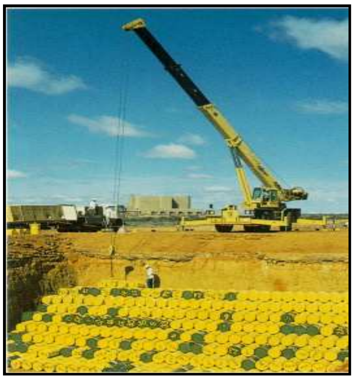

Figure 3-17: Placement of Low Level Waste steel drums at Vaalputs

.

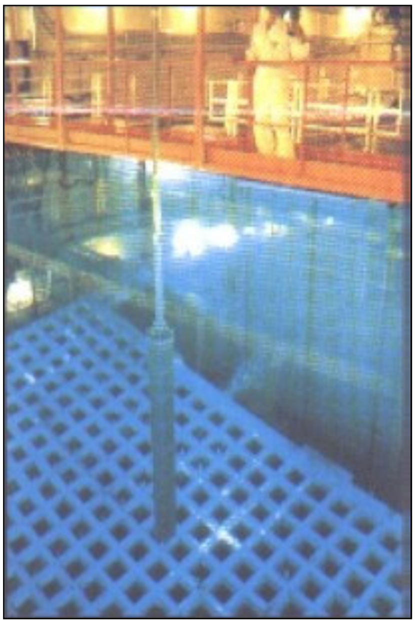

Figure 3-18: Storage pond for HLW at Koeberg Nuclear Power Station

3.18 Transportation of solid radioactive waste

South Africa is a member of state of the International Atomic Energy Agency (IAEA) and therefore subscribes to the Transport Regulations set out by the IAEA for the safe transport of radioactive materials. Transportation of radioactive materials is controlled in South Africa by the NNR and this section is merely included in as information to the general public. The IAEA published a series of documents defining the safe conditions for transport for all types of radioactive material and includes a detailed description on packaging, labelling and safe transportation requirements. The objective of the IAEA Transport Regulations is to “protect persons, property and the environment from the effects of radiation during the transportation of radioactive material” (NNR 2005). This is achieved by making recommendations with regards to the methods of containment, shielding and prevention.

Explanations thereof are presented below (NNR 2005):

- Containment refers to the correct packaging of the different categories of radioactive material to prevent loss of material;
- Shielding refers to the manner in which one controls the external radiation dose at the package surface to acceptable levels; and
- Prevention refers to limiting the chances of exposing the material to criticality and exposure to heat related damage.

The existing truck and trailer at Koeberg Nuclear Power Station can accommodate 80 steel drums and three concrete drums. The mass of a steel drum can range between 50 and 100 kg while the mass of a concrete drum is 6.3 tons.

3.19 Transportation of nuclear fuel

[11]The holder of a nuclear authorization is responsible for the safe transport of any radioactive material fuel within the authorization. The National Nuclear Regulator is responsible for regulating the safe transport of radioactive materials that fall within the ambit of the National Nuclear Regulator Act, 1999 (Act 47 of 1999) (NNRA). These materials include nuclear fuel, low level radioactive waste and minerals concentrates. The responsibilities and activities of the NNR fall within the portfolio of the Department of Mineral and Energy.

Nuclear fuel delivery to Nuclear-1 will occur during the operational stage approximately 2 to 3 times a year as for the Koeberg Nuclear Power Station. The fuel will be manufactured internationally and will enter South Africa via a major port and transported by road to the proposed Nuclear-1 site.

Uranium fuel assemblies are manufactured at fuel fabrication plants from Nuclear vendors. The fuel assemblies are made up of ceramic pellets formed from pressed uranium oxide that has been sintered at a high temperature (over 1400°C). The pellets are aligned within long, hollow, metal rods, which in turn are arranged in the fuel assemblies, ready for introduction into the reactor. Intercontinental transports are mostly by sea, though occasionally transport is by air.

The precision-made fuel assemblies are transported in packages specially constructed to protect them from damage during transport. Uranium fuel assemblies have a low radioactivity level and radiation shielding is not necessary. Fuel assemblies contain fissile material and criticality is prevented by the design of the package, (including the arrangement of the fuel assemblies within it, and limitations on the amount of material contained within the package), and on the number of packages carried in one shipment.

The fuel is transported in specially designed robust steel packages and transported by road or by sea (shipment). The International Atomic Energy Agency (IAEA) Regulations for the Safe Transport of Radioactive Material set the basis for nuclear fuel cycle material transport. The NNR oversee that these regulations are complied with by conducting regular inspections and audits to ensure compliance.

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.

[11] Information booklet: Transportation of Radioactive Materials, Department of Minerals and Energy and the National Nuclear Regulator

3.20 Gaseous emissions

The description of gaseous emissions below is based on Airshed (2010).

Construction phase emissions will be in the form of fugitive dust emissions from general construction activities (clearance, excavation, scraping, road surfaces, etc.) and emissions emanating from vehicles and equipment. Operational phase emissions, on the other hand, will include non-radioactive and radiological materials.

Potential sources of non-radioactive air emissions during the operational phase include:

- Carbon, sulphur and nitrogen oxides in the exhaust gases from engines of the backup electricity generators – these will be switched on only when the main power supply is interrupted and for periodic testing;
- Formaldehyde and carbon monoxide emitted by the insulation when installations go back into operation after servicing; and
- Ammonia discharged as the temperature rises in the steam generators during start-up.

Trace quantities of radiological materials will be released to the environment during the operational phase. The main source these emissions is the gaseous component arising within the coolant circuit. These gases are collected by the gaseous radioactive waste system and held for decay storage in an activated carbon bed delay system. The effluent passes through a radiation monitor and discharges to the ventilation exhaust duct. The gaseous radioactive waste system is used intermittently and it is inactive most of the time during operation.

The predicted maximum effective doses for all three sites are indicated in **Table 3-12** below.

Table 3-12: Maximum inhalation and external effective dose predicted in the 40 km by 40 km study area for all three nuclear power station sites

Site	Effective Dose (µSv / annum)
Duynefontein	4.07
Bantamsklip	4.60
Thyspunt	11.31

Government Notice No. R 388 of 2009 under the NNR Act specifies that the annual effective dose limit for members of the public from all authorised actions is 1 000 µSv, with an additional provision of an annual dose constraint of 250 µSv. The highest predicted inhalation and external effective dose of 11.3 µSv is therefore about 4.5 % of the dose constraint and about 1 % of the annual effective dose limit.

3.21 Liquid effluent

The operation of the power station will result in the creation of chemical effluent. The main sources of effluent and the management thereof are discussed further in this section. The distinction is made between radioactive and non-radioactive chemical effluent produced during the operational phase of the proposed development.

3.21.1 Non-radioactive effluent

Typical chemical substances not associated with liquid radioactive waste are present in the following discharges:

- Discharge produced by the desalinisation and demineralisation plants;

- Sewer discharge, including rainwater, wastewater, oily water; and
- Discharges associated with seawater chlorination treatment.

a) Desalinisation and demineralisation plants

The demineralisation and desalination units will discharge iron, total suspended solids, chlorides, sodium, sulphates, detergents and brine. The maximum expected annual amounts of discharged chemicals are shown in **Table 3-13**. The values are calculated assuming that the desalinisation unit runs continuously, that pre-processing in the current demineralisation unit runs for several hours per day and that the regeneration cycles operate for 40 days per year.

Table 3-13: Maximum quantities of chemical effluent discharged from demineralisation and desalinisation plants

Substance	Maximum Annual Additional Discharge (kg)
Chlorides	3 616
Sulphates	11 725
Sodium	13 523

It is assumed that the effluent will be treated in the waste water treatment works, prior to its discharge into the ocean, along with the cooling water via the outfall tunnels.

b) Sewer

The chemical substances discharged into the sea via the sewers are specified below:

- Chemical discharge from the treatment plants and individual drainage installations;
- Discharged hydrocarbons; and
- Phosphate and amines.

Chemical discharge from the treatment station is characterised by a Biological Oxidation Demand that will comply with statutory limits. Wastewater from plant could contain hydrocarbons derived from the treatment of on-site scrubbers and oil filters. The hydrocarbon concentration in the discharge will comply with statutory limits. Phosphate and amine discharge is generally not continuous, and will also comply with statutory limits.

c) Seawater chlorination

The cooling systems are protected against the development of biofilm and biological fouling by seawater chlorination. This process involves discharging both residual oxidants (both in a free state and as chlorine compounds) and trihalomethanes (in the form of bromoform) into the sea. The effluent will be diluted with the water used for cooling.

3.21.2 Radioactive effluent

According to Pöyry Energy Oy and Lithuanian Energy Institute (2008), the estimated annual liquid waste is approximately 8, 000 m^3/year per unit.

The main chemical substances associated with radioactive waste discharged by the plant originate from the addition of the following substances in the process:

- *Boric acid*: Boron 10 is a neutron absorber mainly used in the primary coolant systems in the form of boric acid to compensate for slow changes in reactivity such as those associated with fuel burn up between the start and end of the cycle;

- *Lithium hydroxide*: this is a base that is used in the primary system to maintain a constant, slightly alkaline pH to minimize materials corrosion of the system. Its concentration is adjusted during the cycle in conjunction with that of the boric acid;
- *Hydrazine*: this is mainly used for its reducing properties;
- *Ammonia*(*): this is a weak, volatile base, used to obtain a slightly alkaline pH in the systems. In normal operation, it is used in the secondary system as an anti-corrosion treatment. During unit shutdown, it is used for wet lay up of the steam generators and mainly in combined treatment – "hydrazine / ammonia";
- *Morpholine*[12]: like ammonia, morpholine is a weak, volatile base used for anti-corrosion treatment in the secondary system. It is used to maintain an alkaline pH in the whole steam-water system;
- *Ethanolamine*(*): like ammonia and morpholine, ethanolamine is a weak, volatile base used for anti-corrosion treatment in the secondary system. It is used to maintain an alkaline pH in the whole steam-water system;
- *Trisodium phosphate*: this acts as a corrosion inhibitor. It is used in alkaline environments, in particular to treat systems in contact with air where volatile treatment cannot be used. The main systems using trisodium phosphate are the component cooling systems and the auxiliary boiler systems;
- *Detergents*: the site uses detergent products in the laundry to wash and decontaminate work clothing used in restricted areas, and also for cleaning the premises; and
- *Metals and suspended solids*: these originate from component wear.

Liquid radioactive will be treated prior to it entering the environment through dedicated clean up systems. These clean up systems reduce the amount of radioactivity in such substances to well within the specified limits. The risk of public exposure from that portion of radiation released to the environment is controlled through the implementation of a radiological effluent management programme. This ensures that the risk that such effluent poses to the public is not significant. Public Doses are limited to 1mSv/a and constrained to 0.25 mSv/a . The limit for occupational exposure is 50 millisievert (mSv) for workers, which is the same for the USA DoE workers, compared to a multiple scan average dose 50m Sv for medical purposes.

The derivation of Authorised Discharged Quantities (ADQs) is site-specific and operation-specific and takes into consideration all the potential exposure pathways from the point of release to set limits that if the authorized quantities are released. Members of the public will still be protected at levels less than the dose constraint (0.25 mSv per annum). The NNR will approve these quantities for both gaseous and liquid waste, which means that the operation will be allowed to release these quantities on an annual basis without the risk of compromising human health. While the quantities are for annual releases, it is managed on a monthly (or even weekly or daily) basis. Compliance will be monitored at source and at the point of release into the environment. Releases will be managed and controlled through continuous monitoring at source, so the operator will know what has been released to date and what capacity remains available for the year to remain compliant. If higher quantities are released an alarm goes off to stop releases. If the annual quantities are exceeded, then no more releases will be allowed. If these quantities are exceeded it will be a non-compliance, but since it is limited to values less than the dose constraint, it does not mean that members of the public will be exposed to values above the dose limit (1 mSv per annum). In reality the ADQ is much lower than the dose constraint.

3.22 Safety

Since the commercial use of nuclear energy to generate electricity began, it has arguably proved to be one of the world's safest energy generation technologies, with the exception of accidents such as Chemobyl, Three Mile Island and Fukushima. Due to the concerns around nuclear safety, safety forms a major component of the design, construction, operation and

[12] Ammonia, or morpholine (with added ammonia), or ethanolamine (with added ammonia) are used.

decommissioning of nuclear power stations. There are a number of systems that monitor, control, and support the safe operation of the reactor at each power plant. These systems provide maximum safety and reliability and reduce the chance of an accidental release of radioactivity into the environment. This section provides a brief description of general safety considerations, nuclear emergency planning zones, occupational and public exposure as determined by the NNR.

3.22.1 General safety considerations

The design of a nuclear power station incorporates many physical barriers that protect against the accidental release of the nuclear fission products, which become both hot and radioactive during its use. These barriers include the ceramic form of the fuel pellets; the metal encasing of the fuel pins, the reactor vessel with some 25 cm thick walls of steel and a containment building with a lining of steel and walls of reinforced concrete (www.uic.com.au/nip14.htm).

The decade-long tests and analysis programmes show that less radioactivity escapes from molten fuel than initially assumed, and that this radioactive material is not readily mobilized beyond the immediate internal structure. Thus, even if the containment structure that surrounds all modern nuclear plants ruptured, it would still be highly effective in preventing the escape of radioactivity (www.uic.com.au/nip14.htm).

There are numerous safety systems that have been engineered to assist in preventing an accident with the reactor or to reduce the effects in the event that an accident should occur. All critical safety systems have backup systems that duplicate the jobs that the system is supposed to perform. An example of such a backup system would be the large stainless steel pipes of approximately 600 mm in diameter, which carry water to the reactor core, where it cools the fuel. Should these fail for some reason there are a number of other independent emergency cooling systems, included in the design of the plant, which can provide the necessary cooling.

Another key aspect to consider when looking into the safety of a nuclear power station is the training and preparedness to which the people who operate these stations are exposed. For example, reactor operators are trained and tested on the procedures and administrative processes of power plant operation, and in order to train such staff, utilities around the world use sophisticated power plant simulators, which are replicas of the control room of the real power plant in which they will be working. The simulators are computer controlled, allowing the operators to gain practical experience in managing all types of normal and unusual occurrences without posing any danger to the public or the environment.

The nuclear industry throughout the world has rigid safety standards. In South Africa these standards are set and regulated by the NNR, and Eskom has to prove to the NNR that the proposed plant can and will meet these stringent safety standards. Periodic inspections also ensure that each facility operates safely.

It is a misconception amongst the general public that a nuclear reactor can explode like an atomic bomb. This cannot happen, as a nuclear explosion requires a very high enrichment of fissile uranium, which is not the level of enrichment that is found in nuclear power station fuel. The uranium used is generally enriched below 5 %, whereas an atomic bomb contains uranium enriched above 90 %.

3.22.2 Nuclear emergency planning zones

All nuclear power stations are required to have emergency plans in the event of a disaster. At this stage, the exact delineation of the Emergency Planning Zones (EPZs) is unknown and the sizes of the EPZ have been assumed, based on current international practice for Generation III reactors. The extent of the emergency planning zones will be set by the NNR licensing process.

EPZs assist in accomplishing the emergency response goals by careful controlling the activities in the region closest to a nuclear power station. In order to provide some clarity on the purpose of such zones, the existing Koeberg power station emergency zones are briefly discussed below as an example. Given that the technology of nuclear reactors has changed significantly since the commissioning of Koeberg, it is likely that the EPZ will be reduced in comparison to Koeberg Nuclear Power Station's EPZs. The emergency planning zones for Koeberg are characterised by 5 km and 16 km radii around the power station. The 5 km radius around Koeberg is referred to as the Protective Action Zone (PAZ) and the zone between 5 - 16 km radius is referred to as the Urgent Protective Zone (UPZ).

It is likely that the corresponding EPZs for the new nuclear power station will be reduced to 800 m and 3 km respectively. The EPZs for the Koeberg Nuclear Power Station should, therefore, be regarded as worst case scenarios, which are unlikely to be applied to the new Generation III technology. The reduced EPZs are based on European Utility Requirements (EUR) standards, which prescribe that modern nuclear power plants should have no or only minimal need for emergency interventions (e.g. evacuation) beyond 800 m from the reactor. The EUR standards also provide a set of criteria that a reactor must meet in order to demonstrate that it can be built to comply with such emergency planning requirements.

In addition to the actual footprint of the power station, there will be two categories of exclusion zones around the power station complex for emergency planning purposes. The Emergency Planning Zone (EPZ) sizes of the European Utility Requirements (EUR) have been used as a basis for Nuclear-1.The proposed radii of the different EPZs sizes are indicated in **Table 3-14***.* **The basis for adopting the EUR by Eskom is that the EUR aims at ensuring that the design that is adopted has minimal impact on man and environment. Eskom has chosen the EUR as this specification is sound and robust, it also allows for alignment with the international nuclear community. The Emergency Plan boundary allows for minimal restrictions around the site, while also providing for safer designs.**

Table 3-14: Radii of proposed emergency planning zones and actions required within these zones

Size (km)	Action	Implementation Time	Justification
0 - 0.8	Evacuation (all sector)	4 hours	Reduces the deterministic effects of pre-emptive evacuation to a radius where deterministic mortality effects will not occur. A deterministic effects means a health effect of radiation for which generally a threshold level of dose exists above which the severity of the effect is greater for a higher dose. Such an effect is described as a severe deterministic effect if it is fatal or life threatening or results in a permanent injury that reduces quality of life. The level of the threshold dose is characteristic of the particular health effect but may also depend, to a limited extent, on the exposed individual. Examples of deterministic effects include erythema and acute radiation syndrome (radiation sickness).
	Shelter (all sectors) based on in-plant conditions		Reduces the risk of stochastic effects
	Thyroid blocking (all sectors) based on in–plant conditions		In line with international practice

Size (km)	Action	Implementation Time	Justification
0.8 - 3	Temporary relocation (based on environmental monitoring)	1 week	Reduces the risk of stochastic effects (means a radiation induced health effect, the probability of occurrence of which is greater for a higher radiation dose and the severity of which (if it occurs) is independent of dose. Generally occur without a threshold level of dose. Examples include solid cancers and leukaemia) from long-term exposure to deposition and ground shine(is a gamma radiation from radionuclides deposited on the ground).
0.8 – 40	Food ban (based on environmental monitoring)	1 week	
0 – 40	On-going monitoring and public communication	Long-term action	In line with international practice

These radii of the zones are measured from the extremities of the station footprint in which the nuclear installation is located. The station footprint is located within a preferred owner-controlled boundary that demarcates the property owned by Eskom. This owner-controlled boundary has a nominal radius of 2 km. The extremity of the footprint may not be closer than 0.8 km from the owner-controlled boundary. This means that no off-site evacuation will be necessary.

The EUR standards were initiated by a group of power utilities from six European countries in 1992. The initial intention of the EUR was to agree on a common set of safety requirements with regulators, but later included the development of standardised designs that would be accepted across Europe. Although the EUR standards cover high-level generic safety requirements, they also include some requirements applicable to specific designs. Further discussion on the EUR requirements is contained in the Emergency Response Report (**Appendix E26**).

The NNR has indicated to Eskom, as well as in presentations to Parliament (NNR 2010), that it is revisiting its current regulatory requirements, guidelines and processes and updating them accordingly taking cognisance of:

- Current international regulatory practices and safety objectives as related to these actions;
- Past experience with licensing of nuclear facilities; and
- Changes in the national and international environments linked to a potential expansion in nuclear activities.

The NNR (2010) states that one major outcome of these new designs is that the emergency planning zones, specifically the Urgent Planning Zone, would in all likelihood be reduced from 16 km in the case of the Koeberg Nuclear Power Station, to a much smaller radius that could fall within the property owned by the power station operator, thereby minimising the issue of the control on urban developments that could potentially threaten the viability of nuclear sites.

3.22.3 Security zones

The National Intelligence Agency (NIA) will undertake a security assessment to recommend a security exclusion zone around the power station. This zone is specified to protect the power station from unauthorised access by the public. Currently, there is a security exclusion zone of 2 km offshore from the high water mark specified for Koeberg. Although the recommendations of the NIA are yet to be made, it is assumed that a 1 km security exclusion zone will be specified for Nuclear-1. Access to this area will be subject to a permit application. In addition the current NNR R.927 regulations on licensing of sites for new nuclear installations requires an assessment on the suitability of the site, from a nuclear security perspective as determined by the NNR.

3.22.4 Occupational exposure to radio nuclides

The NNR sets the limit of occupational and public exposure arising from operations at nuclear installations in South Africa. The exact radiation exposure, resulting from controlled radiological releases cannot be determined until the final plant is identified.

According to the NNR annual report (2005 and 2006), the regulatory limit for occupational exposure is 50 millisievert (mSv) per annum and an average effective dose of 20mSv per year averaged over five consecutive years. For the year 2005, the Koeberg site achieved an individual dose level of 0.9 mSv, which is substantially lower than the approved limits. The highest individual dose accrued at the Koeberg site was 17.2 mSv and the total annual collective effective dose for workers was 2, 260 person-mSv (NNR 2005 and 2006). The highest annual individual dose accrued during 2008 was 12.6 mSv, compared to 12.5 mSv in 2007 and 20 mSv averaged over five consecutive years up to 2009 (NNR 2009). These figures indicate that the levels at which Eskom currently operates its facilities are well within regulatory limits.

3.22.5 Public exposure to radio nuclides

According to the NNR (2005 and 2006), various gaseous and liquid effluents are produced during the routine operation of a nuclear power station. However, such substances are treated prior to it entering the environment through dedicated clean up systems. These clean up systems reduce the amount of radioactivity in such substances to well within the specified limits. The risk of public exposure from that portion of radiation released to the environment is controlled through the implementation of a radiological effluent management programme. This ensures that the risk that such effluent poses to the public is not significant.

One of the key features of this programme, as implemented at Koeberg power station, is the control of the level of radioactivity in effluent discharges to within the Annual Authorised Discharge Quantities (AADQ). Besides these tests and clean up systems, radiological surveillance of the environment surrounding the power station is conducted, which ensures that strict control is placed over potential public exposure to radioactive releases.

According to the NNR (2005 and 2006), the public exposure to radiation as a result of Koeberg's operations has been less than 0.02 mSv per annum in general and less 0.006 mSv per annum in 2005/6, which is far below the limit set by the NNR of 1 000µSv (www.nnr.co.za). The public radiation predicted for the proposed nuclear power station during normal operation is 0.1 mSv. In the event of an incident or accident, this increases to 10 mSv.

Radioactivity in liquid and gaseous discharges from the Koeberg power station during 2007 and 2008 contributed a projected total individual dose of 0.004 mSv to the hypothetically most exposed public group. The projected doses, as a result of gaseous and liquid discharges, were 0.00047 mSv and 0.0038 mSv respectively for 2008 (0.00094 mSv and 0.003 mSv respectively for 2007), which is well within the NNR dose constraint of 0.250 mSv per annum (NNR 2009).

3.23 Human resources

The personnel required during the various phases of the project differ. This section provides an indication of the labour and staff required during the construction and operational phases as well as the accommodation and transport requirements associated therewith. It is important to note that the number of vendor construction and Eskom operational staff will vary considerably depending on the plant type chosen for Nuclear-1. The figures below indicate maximum values.

3.23.1 Construction personnel

During the peak of construction, it is estimated that 5, 000 vendor construction workers will be on site. In addition, there will around 2, 200 vendor staff, 140 Eskom project staff and 40 Eskom consultants present on site.

3.23.2 Operational personnel

According to the Eskom (2008) the operation of a nuclear power station of approximately 4,000MW requires a staff complement of up to 1, 385 Eskom Operations personnel[13], who collectively have a variety of scientific, engineering and other technical backgrounds in fields required to effectively and safely operate and maintain the plant will be recruited from within Eskom, South Africa and as a last resort, globally. The required skills include *inter alia* the following: nuclear operators, maintenance, nuclear engineering, instrumentation and control, electrical engineering, mechanical engineering, radiation protection, chemistry, emergency preparedness, safety analysis and assessment.

There is also a requirement to have access to national or international expertise to support the power station's operating organisation and regulatory body in terms of specialised scientific areas such as neutronics, physics, thermo hydraulics and other technical areas such as radiation protection, radioactive waste management, quality management, maintenance and spare parts management (IAEA 2007).

3.23.3 Transport and traffic

Transport of people and materials to and from the construction sites will increase steadily to a peak during the 6th year of construction, and then fall off until the end of construction in year 9. Eskom and / or the vendor will provide public transportation for the construction workers, but a proportion of management level staff will use their own transport to and from the site. The numbers of vehicles and types of vehicles over the nine year construction period are summarised in **Table 3-15** below.

Table 3-15: Estimated traffic figures for the construction phase

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
Vendor staff vehicles per day (buses and sedans)	*13*	*30*	*34*	*63109*	*374*	*449*	*236*	*112*	*4*
Eskom staff vehicles per day (buses and sedans)	*28*	*33*	*98*	*209*	*355*	*528*	*628*	*643*	*608*
Heavy delivery vehicles per day	*190*	*216*	*338*	*208*	*204*	*201*	*109*	*45*	*45*
Total vehicles per day	*159*	*198*	*342*	*447*	*856*	*1 102*	*932*	*783*	*640*
Total vehicles per month	*4 835*	*6 005*	*10 409*	*13 599*	*26 024*	*33 513*	*28 337*	*23 810*	*19 461*
Total vehicles per annum	*58 025*	*72 061*	*124 905*	*163 190*	*312 286*	*402 159*	*340 049*	*285 725*	*233 530*

Trips of all vehicles that can carry loads of 10 - 100 ton, and ultra heavy vehicles (>100 ton) are included in the above figures. However, these vehicles will not travel on a daily basis and

[13] It is assumed that only 1000 will require accommodation.

their figures are therefore given monthly. Estimated numbers of trips for abnormal vehicles are provided in **Table 3-16** below*.*

Table 3-16: Estimated monthly trips of abnormal loads for the construction phase

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
Ultra-heavy vehicles (>100 ton)	0	6	13	13	13	13	6	0	0
Heavy vehicles (10-100 ton)	0	20	40	40	40	40	40	0	0

At Bantamsklip and Duynefontein, all vehicles will use a single access point, but at Thyspunt, the distribution of vehicles will be divided between an eastern and western access road. The eastern access road at Thyspunt is required for abnormal vehicles due to the road geometry that allows the turning of ultra-heavy vehicles, although other vehicles will also use this access road.

3.24 Environmental aspects related to the nuclear power station

Based on the above information, the environmental aspects[14] related to the Nuclear Power Station can be summarised into inputs and outputs as follows:

Inputs

- Sea water;
- Fuel (enriched Ur);
- Labour;
- Diesel;
- Land use;
- Electricity;

Outputs

- Hot water and brine;
- Radioactive discharges;
- Spent fuel;
- Radioactive emissions of spent fuel;
- General waste;
- Sewerage effluent;
- Fumes (SOx, NOx etc);
- Noise;
- Non – Radiological Hazardous Waste; and
- Non – Radioactive releases (H, NOx, SOx, Ar etc).

[14] *Environmental Aspects as defined in ISO 14001:2004 and the ISO DIS 14001:2015 Interim Working Draft, is an element or characteristic of an activity, product, or service that interacts or can interact with the environment. Environmental Aspects can cause Environmental Impacts. They can have beneficial impacts or adverse impacts which can have a direct / decisive impact on the environment or contribute partially or indirectly to an larger environmental change.*

3.25 Decommissioning of the proposed nuclear power station

Decommissioning of the facility will be controlled and monitored in South Africa by the NNR. It must be borne in mind that the operating life of Nuclear-1 will be 60 years, which is longer than the existence, in total, of the principle of nuclear power generation (the first four electric bulbs were illuminated by electricity produced by a nuclear reactor in December 1951). Just as operating regulations have changed significantly since 1951, it stands to reason that legislation and regulations for decommissioning of nuclear power plants will change as much from practices in place today. What is discussed under decommissioning below is based on current knowledge, legislation and guidelines and much of this may have changed significantly by 2078, the anticipated date of decommissioning. What is important however, is firstly to know that the NNR will monitor the process and secondly that the requirements will be more stringent and, thirdly, that the decommissioning processes and techniques will have developed profoundly over time.

When the nuclear power station has reached the end of its viable lifetime approximately 60 years after commissioning, it will be decommissioned. According to the United States Nuclear Regulatory Commission (2000) decommissioning means shutting down the plant and taking steps to reduce the level of radiation in order for the land to be used for other purposes. 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 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 that takes into account the importance of the health and safety of the operating staff, the general public and protection of the environment.

The International Atomic Energy Agency (IAEA) technical document series (Nuclear # 1394 2004) notes that careful planning and management is essential in ensuring that decommissioning is accomplished in a safe and cost-effective manner. The IAEA guidelines (2004) state that until the mid-1980s experience associated with decommissioning was scarce, but much has been learnt in the intervening period in all aspects of the discipline. Sometimes the magnitude of the projects was over-estimated and projected costs were believed to be very high. This often gave rise to a slowdown, or even failure to start the decommissioning process while on other projects the tasks were underestimated, resulting in errors. With experience, confidence has been gained and there has often been an incentive to publish and make much information available, particularly in the form of lessons learned. Numerous guidance documents have been published, particularly by the IAEA on subjects such as technologies, strategy, safety, waste management, regulation and by other organizations such as the US DOE[15], OECDNEA[16], and the European Commission. Such guidelines should form a useful basis for the decommissioning of the proposed nuclear power station.

IAEA technical document series (Number 1478 2005) provides a detailed understanding of the manner in which a nuclear power station can be decommissioned. The IAEA guidelines (2005) state that when selecting a proper decommissioning strategy in a specific facility, a range of general and site specific factors require consideration, typically, in a multi-attribute analysis. These factors include cost, health, safety issues and environmental impacts, availability of resources as well as stakeholder involvement.

The key considerations that form part of Eskom's decommissioning strategy are as discussed in **Section 3.25.1** to **Section 3.25.3** below.

[15] Department of Energy

[16] Organisation for Economic Co-operation and Development (OECD) Nuclear Energy Agency (NEA)

3.25.1 <u>Decommissioning strategies</u>

Three decommissioning strategies have been defined by the IAEA, namely immediate dismantling, deferred dismantling and entombment. ‘No action’ is currently not regarded as an acceptable decommissioning strategy and therefore it will not be further discussed.

Immediate dismantling commences shortly after shutdown following a short transition period to prepare for implementation of the decommissioning strategy. Decommissioning is expected to commence after the transition period and continues in phases or as a single project until an approved end state, including the release of the facility or the site from regulatory control, has been reached.

As an alternative strategy, dismantling may be deferred for a period of up to several decades. Deferred dismantling is a strategy in which a facility or site is placed in a safe condition for a period of time, followed by decontamination and dismantling. During the deferred dismantling period, a surveillance and maintenance programme is implemented to ensure that the required level of safety is maintained. During the shutdown and transition phases, facility-specific actions are necessary to reduce and isolate the source term (removal of spent fuel, conditioning of remaining operational or legacy waste) in order to prepare the facility/site for the deferred dismantling period.

Entombment is a strategy in which the remaining radioactive material is permanently encapsulated on site. A low- and intermediate-level radioactive waste repository is effectively established and the requirements and controls for the establishment, operation and closure of waste repositories are applicable.

Although evaluation of the prevailing factors could clearly indicate one of the above-mentioned strategies, constraints and overruling factors may occur in practice, and these necessitate a combination of strategies or exclude one or more strategies from consideration.

3.25.2 Factors influencing the choice of decommissioning strategy

The following are regarded as general factors that have an influence on the selection of decommissioning strategies (IAEA 2005):

a) National policies and regulatory frameworks

- Policy documents that address programmes and directions of the nuclear industry on a national level;
- Legal framework covering regulatory functions and infrastructure as well as requirements and standards pertaining to decommissioning; and
- Authorisation / licensing processes to ensure regulation of the full lifecycle of the facility, in particular regulations for the planning and execution of decommissioning.

b) Financial resources / Cost of implementing a strategy

- Availability of adequate financial resources and funding mechanisms;
- Direct cost of implementing the decommissioning strategy; and
- Indirect costs associated with the strategy (e.g. costs related to stakeholder involvement and social acceptance).

c) Spent fuel and waste management system

- National spent fuel and waste management policy and strategy;
- Availability of facility-specific spent fuel and waste management plans and facilities; and
- Amounts and types of decommissioning waste.

d) <u>Health, safety and environmental (HSE) impact</u>

- Safety / health risks;
- Environmental impacts including impacts associated with the transportation of material / waste;
- Physical status of the facility e.g. expected integrity of buildings over time;
- Radiological and hazardous material characteristics; and
- On-site industrial safety hazard impacts.

e) Knowledge management and human resources

- Availability of suitably qualified and experienced personnel;
- Lessons learned from previous decommissioning projects;
- Operational history and adequacy of decommissioning related information (records, drawings);
- Resources from other operating nuclear facilities either on site or in the country; and
- Reasons for permanent shutdown, if not consistent with the original planning basis (economic, political, accident).

f) Social impacts and stakeholder involvement

- Impacts on local communities from decommissioning processes;
- Public/stakeholders concerns and perceptions; and
- Reuse options for the site.

g) Suitable technologies and techniques

In terms of the existing South African legislation (the EIA Regulations under the National Environmental Management Act), a full EIA will not have to be undertaken prior to the closure and decommissioning of a nuclear power station if the power station was authorised in terms of the same legislation. However, a full EIA will have to be undertaken prior to the storage and/ or disposal of hazardous waste. In addition, under the NNR Act, decommissioning also requires authorisation by the NNR to ensure that it is performed safely and that radiological standards are adhered to.

The IAEA guidelines (2005) highlight important constraints and conditions that influence the strategy selection and therefore require full consideration within the South African context:

- Inadequate funds;
- Limited or inadequate legal and regulatory frameworks;
- Inadequate spent fuel and waste management systems;
- Lack of skills within the nuclear field;
- Demand for reuse of facility or site;
- Specific issues in case of small nuclear programmes and limited resources; and
- Influence of local economy and social issues.

According to the IAEA guidelines (2005), the process of selecting a decommissioning strategy typically starts by collecting and assessing available data, by considering all potentially influential factors such as applicable regulations, waste routes and associated good practice indicators. A set of possible decommissioning options is subsequently devised together with a preliminary decommissioning plan for implementing each option. These plans can be relatively brief at this stage, but sufficiently well-defined that the associated major hazards and risks can be visualised.

The next step is to perform strategy selection studies. During this process, formal decision aiding techniques and 'workshop' discussion sessions can be employed. It should be noted that strategy selection studies (even when using formal methods such as multi-criteria analysis) involve aspects that are judgmental and subjective, potentially leaving the conclusions open to challenge. This problem is increasingly being addressed by public involvement (stakeholder dialogue) in the strategy selection process.

The processes of selecting a preferred decommissioning strategy and the subsequent detailed planning are best approached by ensuring that the planning team clearly understands the underlying safety logic. This logic can be applied to each of the possible options (at an appropriate level of detail), as part of the process of selecting a preferred option. The key point is to ensure that there is a demonstrated connection between the facility condition at shut-down, the proposed decommissioning activities, the associated risks in performing these activities, the resultant safety management arrangements and associated costs. For example, analysis of the risks involved logically determines the requirements for such key aspects as additional or modified equipment, staff training, procedures, work instructions, maintenance and security arrangements.

3.25.3 Preparation of a decommissioning plan for Nuclear-1

The National Nuclear Regulator (NNR) legislated the need to establish a decommissioning plan for nuclear power stations. The decommissioning plan must be submitted before the nuclear authorisation is granted and at such other frequency thereafter as required by the NNR. The decommissioning plan must address all the activities necessary commencing from the cessation of the operation to the point where the nuclear authorisation may be surrendered and the period of responsibility terminated.

Decommissioning of Nuclear-1 does not require a separate EIA process. In terms of the EIA Regulations (Activity No. 23 of Government Notice No. R 386 of 2006), a Basic Assessment process must be undertaken for decommissioning of a number of activities, including a nuclear power station, only for activities that were not authorised in terms of the current EIA regulations. Should the competent authority grant authorisation for Nuclear-1 based on the current EIA process (which includes an assessment of potential impacts associated with decommissioning), then a Basic Assessment process would not be required for decommissioning as it would have been authorised in terms of the current EIA regulations.

The decommissioning plan for Nuclear-1 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 radio nuclides 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 spent fuel pool cooling separation plan*.*** Following the fuel transfer to the spent fuel pool, the spent fuel pool separation plan is implemented.
- **Phase 4: Decommissioning operations,** including the following tasks:
  - Demolition of conventional island and auxiliaries;
  - Safe enclosure preparation; and

- Electromechanical dismantling.

- **Phase 5: Spent fuel removal and electromechanical dismantling of the fuel building and auxiliaries.** After 10 years of decay in the spent fuel pool, the last full load of fuel would have sufficiently cooled down to be removed from the pools. The spent fuel is then relocated to dual-purpose casks (storage and transport) for transfer to a national repository[17]. Once the spent 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.**

  As stated before, the exact contents of the decommissioning plan are unknown at this stage and it would only be finalised if and when nuclear authorisation is granted by the NNR.

[17] South Africa currently does not have a national repository and high level nuclear waste at Koeberg is currently stored on site. Should no national repository be in place by the time that Nuclear-1 is decommissioned, Eskom may have to re-assess Phases 4 to 6 of Nuclear-1's decommissioning plan.

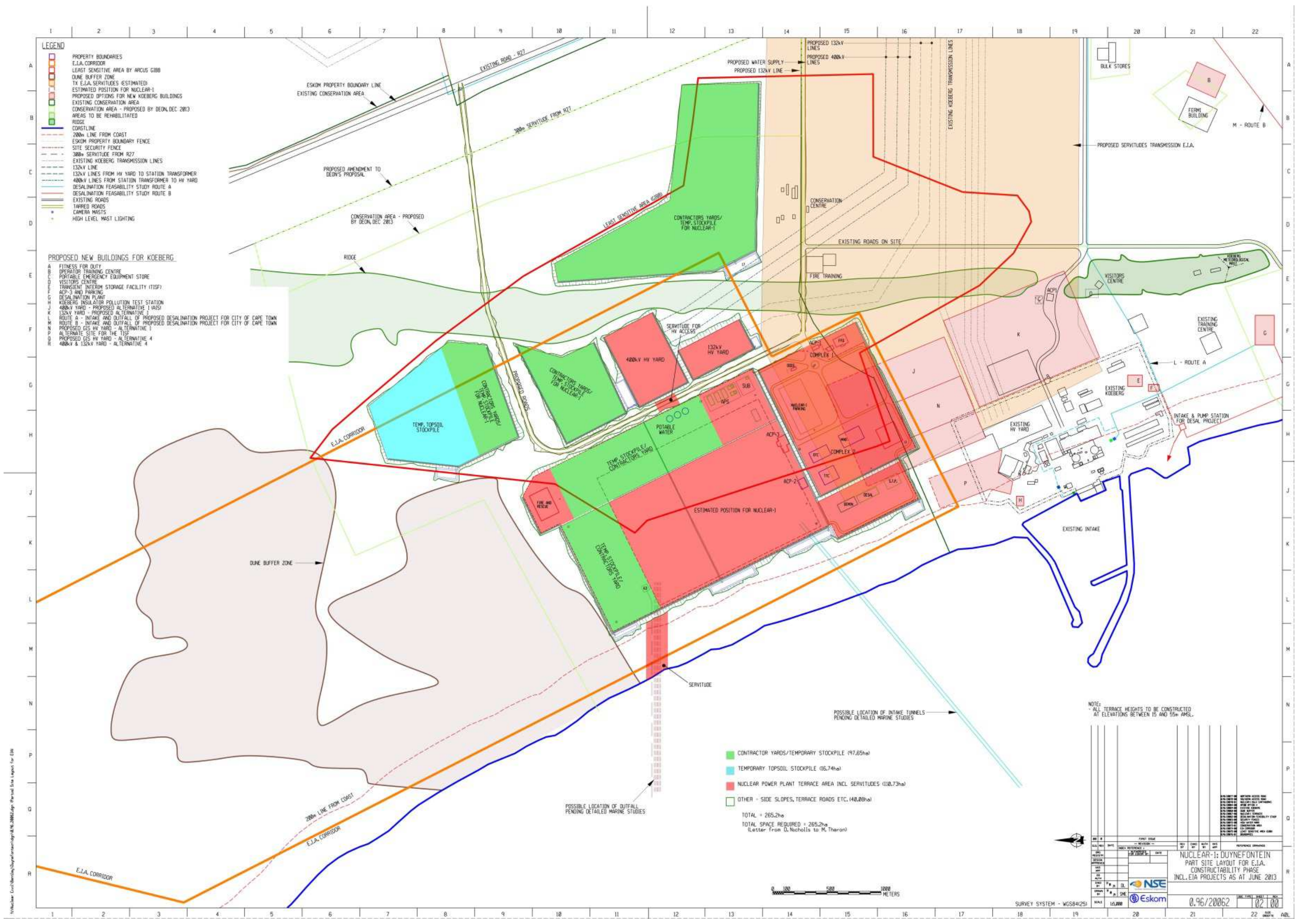

Figure 3-19: Duynefontein partial layout during construction

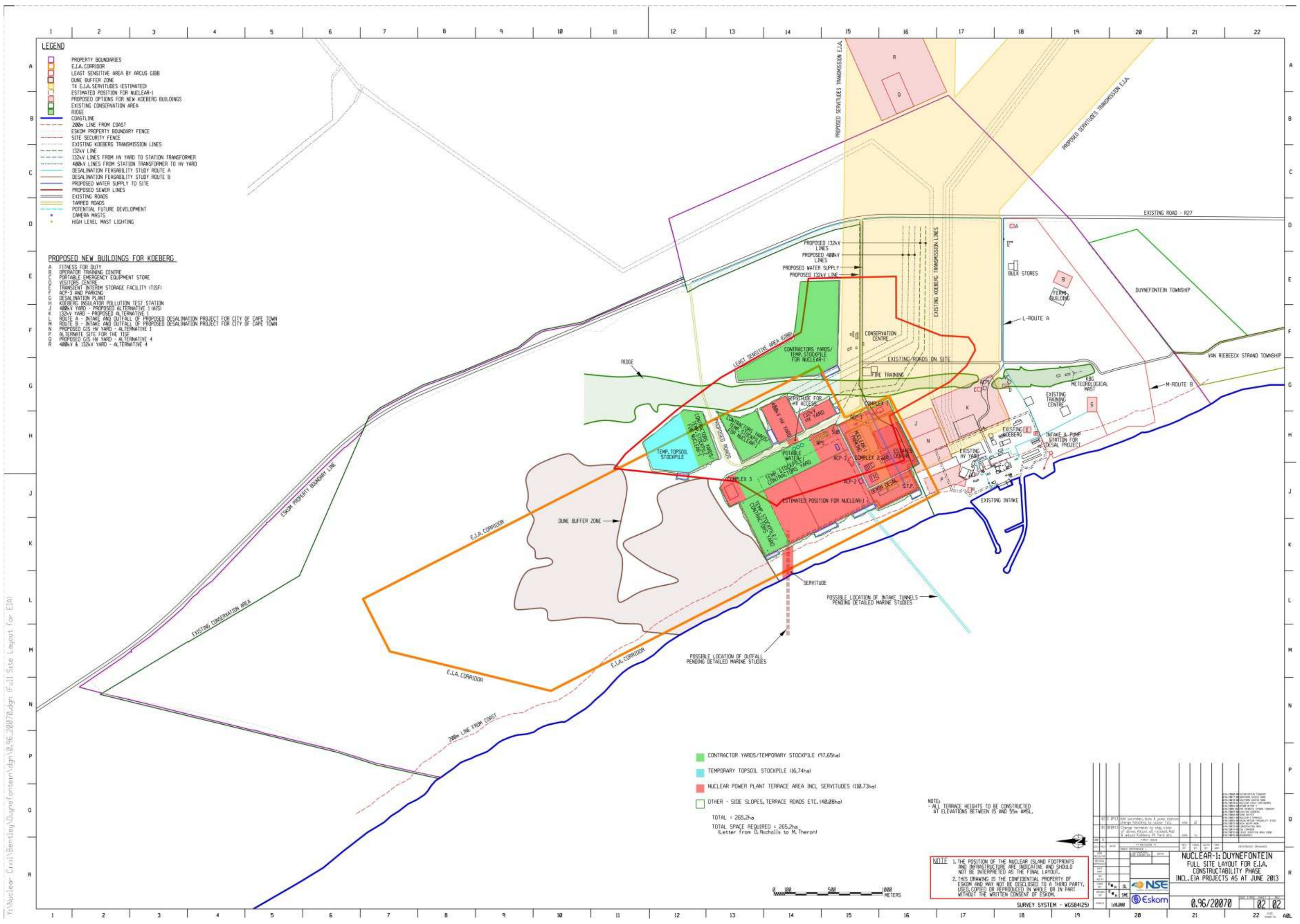

Figure 3-20: Duynefontein full layout during construction

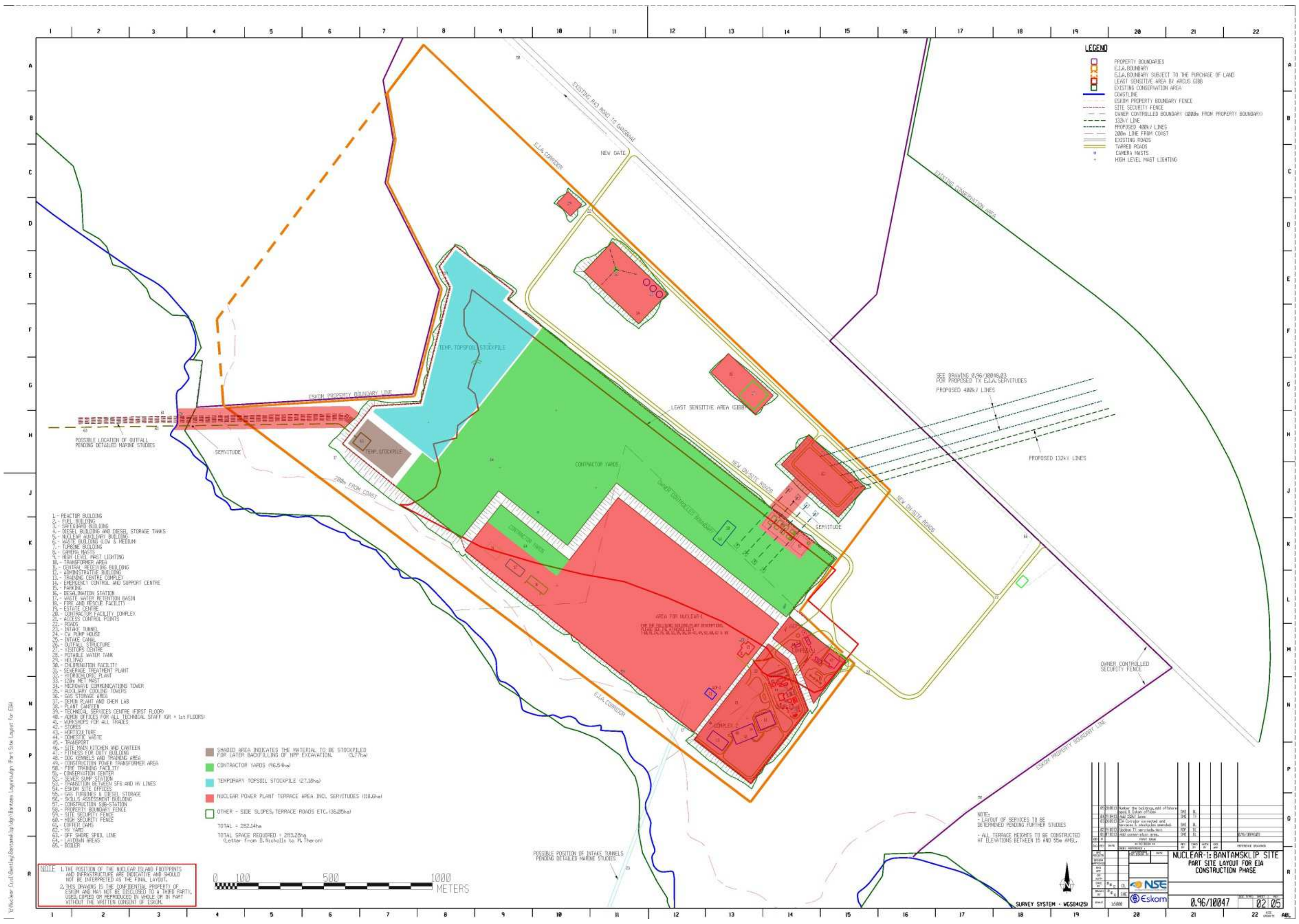

Figure 3-21: Bantamsklip partial layout during construction

Figure 3-22: Bantamsklip full layout during construction

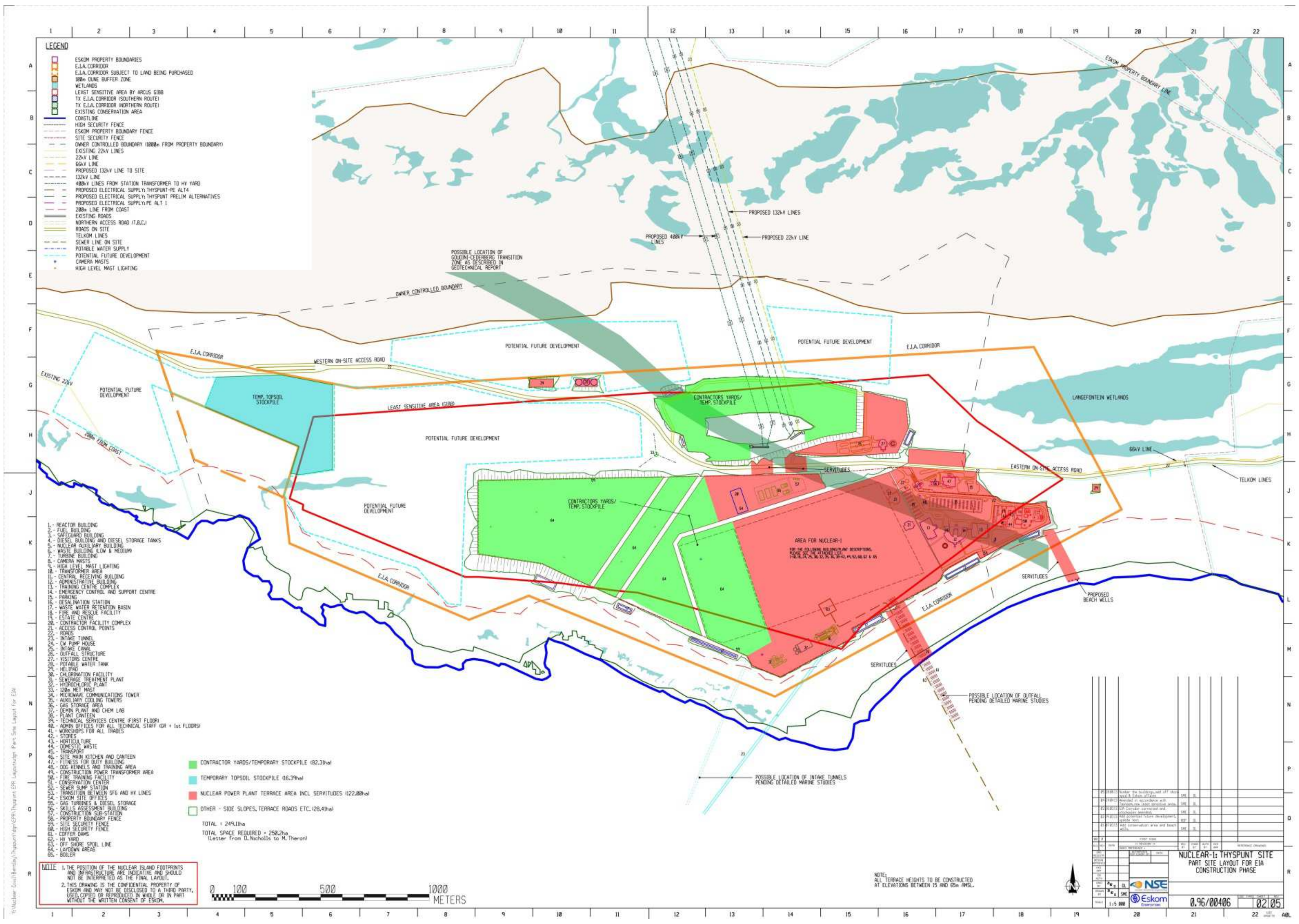

Figure 3-23: Thyspunt partial layout during construction

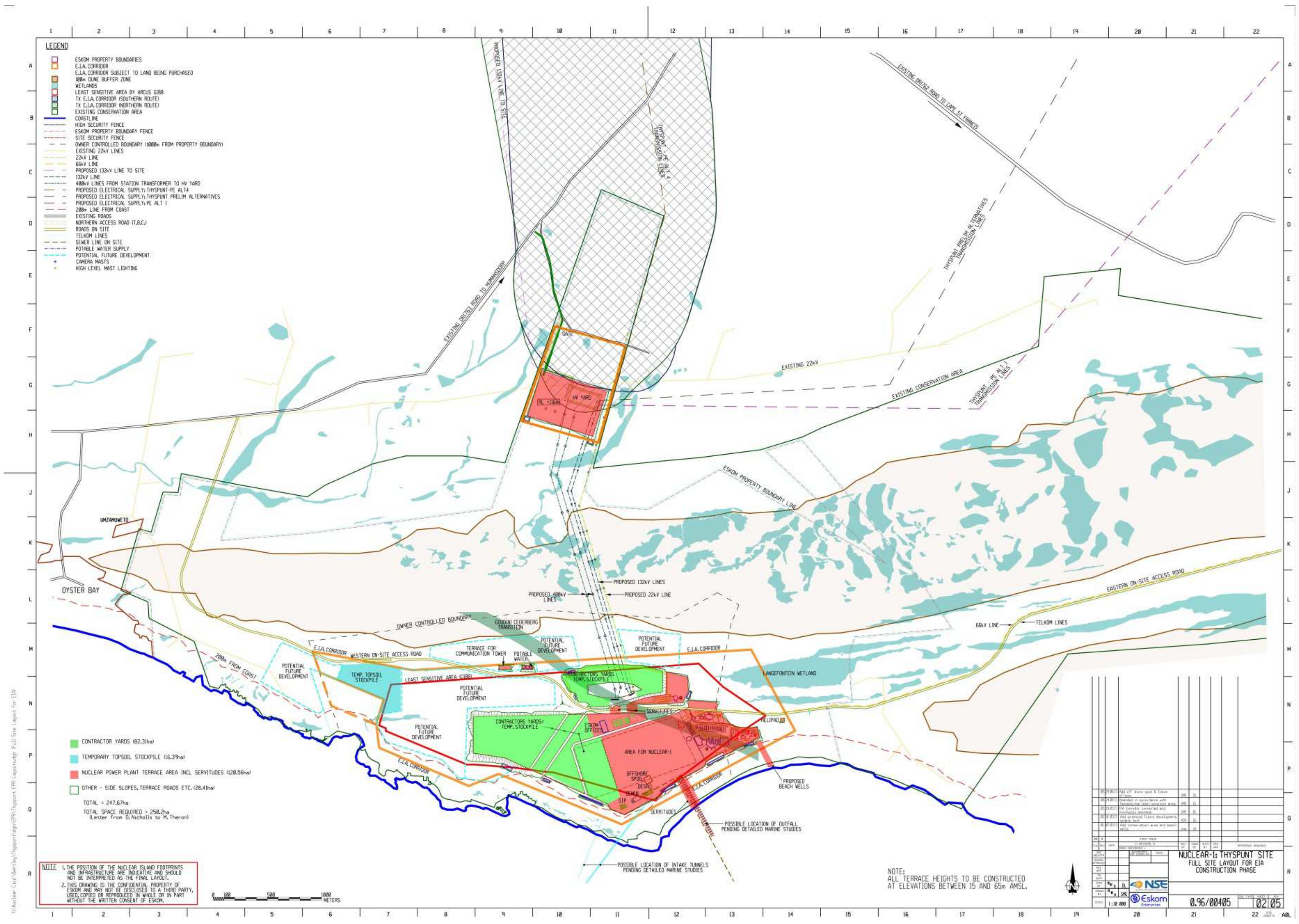

Figure 3-24: Thyspunt full layout during construction