CHAPTER 5.10: HYDROLOGY AND HYDRAULICS		
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Authors' declaration:	**I declare that appropriate diligence and quality assurance was applied in the compilation of this report. As such I am confident in the results here described and the conclusions drawn.**	
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EXECUTIVE SUMMARY

Duynefontyn is a brown field site with two existing reactors of the Koeberg Nuclear Power Station (KNPS) for which limited surface water investigations have previously been carried out. This pre-existing information has been supplemented with further detailed site-specific investigations, input from the Meteorology, Oceanography and Geohydrology sections, data analysis and modelling to produce this section of the Site Safety Report.

Based on the results and knowledge gained to date, the following key conclusions are drawn:

- A conservative approach has been adopted by applying the probable maximum values and if these were not available the 1:10 000 return period was considered. This relates to a 90% probability of non-occurrence in 1 000 years design life for the 1:10 000 year return period event. A range of extreme storm events were also determined (up to a 10^{-8} annual probability of exceedance for the 95th percentile) which included predicted increases in rainfall intensities due to climate change. In addition, the probability of occurrence from a site safety perspective further decreases when making the assumption that the extreme still high water sea levels occur simultaneously with the extreme storm event.

- The Duynefontyn site is dominated by two main vegetation types, namely Dune Thicket on sand and limestone and Sand Plain Fynbos on marine-derived, leached acid sand, with a transitional vegetation type between the two also being present. The catchments have a low run-off coefficient due to high infiltration as a result of the sandy soils and moderate vegetation. Due to the topography and locality of the proposed nuclear installation(s), the runoff from external catchments potentially impacting the Duynefontyn site are relatively small (size of catchments less than 4.0 km^2) and the flood water levels are controlled by the backup from the extreme sea water levels. There are no perennial watercourses close to the Duynefontyn site and the closest major watercourse is the Diep Rivier approximately 15 - 20 km located in a different quaternary catchment. The majority of run-off occurs along drainage lines and temporarily ponds within the low-lying areas between the dunes during a storm event.

- There are no significant dams upstream of the Duynefontyn site (nor associated watercourses traversing through or near the site) which may impact on the safety of the nuclear installation(s) and no further investigation on possible dam failure is required.

- Due to the extensive inter-dune temporary ponding areas, low flows and flow velocities, there is minimal erosion potential which may impact on the safety of the nuclear installation(s). Any potential flooding due to sedimentation within watercourses is negligible (as is the presence of well-defined watercourses) and will not impact on the safety of the nuclear installation(s).

- Surface water quality from the virgin Duynefontyn site is currently not a concern since monitoring has indicated that all constituents comply with the Water Quality Guidelines: Coastal Marine Waters (Department of Water Affairs and Foresty, 1996) and poor water quality does not impact on the safety of the nuclear installation(s).

- The 10^{-4}, 10^{-6} and 10^{-8} annual probability of exceedance for the 95th percentile flood depths and flow velocities have been mapped along the drainage lines and ponding areas on the site, based on the extreme rainfall conditions and extreme downstream still sea water levels. Any nuclear installation(s) constructed within these areas would require 1.5 m high berm constructed around the proposed 12 m amsl platform or alternatively raise the platform by 1.5 m and construct a 1.5 m deep channel around to cut-off external run-off, ensuring safety of the nuclear installation(s). This would be subject to the final platform elevation requirements from ***Section 5.9*** (Oceanography and Coastal Engineering). During the detailed design the localised surface water run-off would need to be collected and diverted around any of the platforms.

- During the proposed construction stage, a large increase in local runoff peaks and volumes is expected in excavations due to the high run-off potential of the rock floor of the nuclear installation foundation excavations. This could be compounded by the side slopes possibly being covered by erosion control measures such as cement stabilised liners, which would cause a higher runoff due to being less permeable than the surrounding soil. This higher run-off setting will result in localised flooding of any deep excavations to bedrock but considered temporary as the wells and pumps will extract the water from the open excavation. This potential impact would need to be addressed during the detailed design.

- There is an insignificant difference in run-off peaks and volumes between the operation and the construction stage as it is assumed that most of the nuclear installation sites would be paved once the excavations have been backfilled and hence the percentage hard surface would be similar for both stages (operation and construction excavations). These run-off characteristics will need to be catered for in the detailed design.

From a site safety perspective, the nuclear installation(s) is not located along any major watercourses which could potentially impact the site during an extreme external flood event. A conservative approach was adopted throughout the study which considered a combination of extreme events occurring simultaneously resulting in a low probability of occurrence. Due to the small contributing catchments, extreme flood levels are impacted primarily by extreme downstream still sea water levels rather than water levels generated by surface water run-off from the minor catchments. Similarly, from a site safety perspective, the KNPS site is not located along any major watercourses which could potentially impact the site during extreme external flood events. A conservative approach was also adopted throughout the study and considered a combination of extreme events occurring simultaneously resulting in a low probability of occurrence.

With the appropriate remedial measures in place, the safety consequence (Hazard x Vulnerability) is low and does not adversely impact the development of a nuclear installation(s) from a site safety perspective (surface water hydrology and hydraulics). Similarly, the existing KNPS site has a low safety consequence (Hazard x Vulnerability) for the current 8 m amsl platform.

Due to uncertainty of the impact of climate change, locality of the final nuclear island footprint and platform elevation, the surface water model will need to be updated for the 10^{-4}, 10^{-6} and 10^{-8} annual probability of exceedance (95th percentile) flood event for the nuclear installation(s) during the detailed design, prior to construction.

AMENDMENT RECORD			
Rev	**Draft**	**Date**	**Amendments**
0		6/09/13	Revised to comply with Eskom Nuclear Engineering comments and Technical Writer comments.
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5.10 HYDROLOGY AND HYDRAULICS

5.10.1 Introduction

This section of this Site Safety Report (SSR) presents the overall site characterisation and results of the evaluation of the hydrological and hydraulic aspects of the site. These aspects include existing watercourses, ponding areas and flow paths which could have a negative impact on the planned nuclear installation(s) under flood conditions. The site is shown in ***Drawing 5.10.1*** and includes the existing Koeberg Nuclear Power Station (KNPS) units 1 and 2, the enveloping footprint for the new nuclear installation(s), and the illustrative nuclear installation footprint in the context of the local and regional physiographic setting. The illustrative nuclear island footprint represents a possible site for the nuclear terrace where the new nuclear reactors and main auxiliary buildings would be situated.

5.10.2 Purpose and Scope

The purpose of this section is to document how the results of the hydrological characteristics demonstrate the suitability of the site for the establishment of a nuclear installation(s) from a safety perspective. This is achieved through surface water modelling of the regional drainage area as well as the site, incorporating outputs published in ***Sections 5.8*** (Meteorology), ***5.9*** (Oceanography and Coastal Engineering), ***5.11*** (Geohydrology) and ***5.12*** (Water Supply).

More specifically, this section covers interpretation of the following:

- surface water and potential contaminant flow paths (watercourses and sheet flow areas);
- groundwater quality and levels and their influence on surface water features;
- wetlands and their hydraulic properties;
- surface water quality;
- existing surface water use;
- impacts of surface water control measures on the local hydrology;
- current and future monitoring results and requirements;
- management of uncertainties;
- consequences that the surface water overland flow paths and defined watercourses may have on the nuclear installation(s).

Hydrological and hydraulics modelling and evaluation are performed on the site as well as the regional drainage area consisting of quaternary catchments, namely: G21A, G21B and G21F (see ***Drawing 5.10.1***).

5.10.3 Regulatory Framework

Chapter 2 of the Duynefontyn Site Safety Report presents the legal and regulatory basis for the evaluation of the site in support of Koeberg Nuclear Power Stations' continued operation and licensability and the development of a new nuclear installation(s) on the Duynefontyn site.

The characterisation of hydrology and hydraulics of the site, and the potential impacts on the safety of the operation of a nuclear installation(s), need to comply with both national acts as well as international standards and guidelines. The following regulations are also considered:

- National Water Act No. 36 of 26 August 1998, (Republic of South Africa, 1998);
- The national regulations relevant to a surface water investigation for an SSR - The Regulations on Licensing of Sites for New Nuclear Installations (Department of Energy, 2011);
- RD-0034, Quality and Safety Management Requirements for Nuclear Installations (National Nuclear Regulator, 2008).

5.10.4 Requirements Documents and Guidelines

The following position papers, requirements documents and guides (that are considered more directly applicable to development of an SSR considering hydrology and hydraulics) are also considered:

- Eskom's Technical Specification for Site Safety Reports, NSIP01388 (Rev 1). Section 5.10: Hydrology and Hydraulics (Eskom, 2010);
- RG-0016: Requirements for Authorisation Submissions Involving Computer Software and Evaluation Models for Safety Calculations (National Nuclear Regulator, 2016);
- RG-0011: Interim Guidance on the Siting of Nuclear Facilities, Rev 0 (National Nuclear Regulator, 2016);
- South African Water Quality Guidelines Coastal Marine Waters Volume 1 for the Natural Environment (Department of Water Affairs and Forestry, 1996);
- International Atomic Energy Agency (IAEA) Safety Requirements No. SSR-1, Site Evaluation for Nuclear Installations (International Atomic Energy Agency, 2019);
- International Atomic Energy Agency (IAEA) Specific Safety Guide SSG-18, Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations (International Atomic Energy Agency, 2011);

- United States Nuclear Regulatory Commission (NRC) Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: NUREG-0800, Chapter 2 (United States Nuclear Regulatory Commission, 2011);
- United States Nuclear Regulatory Commission (NRC) Design-Basis Flood Estimation for Site Characterization at Nuclear Power Plants in the United States of America: NUREG/CR-7046 (United States Nuclear Regulatory Commission, 2007).

5.10.5 Approach to Evaluation

The approach adopted for the hydrological evaluation was as follows:

- defining the regional drainage area of the site that could have an impact on the nuclear installation(s) - The area of investigation covers drainage region G21A and G21B as shown in ***Drawing 5.10.1***.
- obtaining the baseline information on hydrological aspects of the site such as rainfall patterns and run-off coefficients;
- obtaining existing historical information on all flood-related events within drainage regions G21A and G21B, as shown in ***Drawing 5.10.1***;
- quantification of possible safety risks to the nuclear installation(s) by flooding using both hydrological and hydraulic modelling techniques;
- identification of the various possible impacts rating the frequency and consequences thereof, and identifying mitigation measures to ensure the safety of the nuclear installation(s) and vice versa;
- employing the Best Management Practice (BMP) approach in identifying storm water control mitigation measures to further enhance safety of the nuclear installation(s).

A conservative approach has been adopted throughout the assessment. The conservative approach comprises applying the probable maximum values where applicable and where these were not available, the 1:10 000 return period was considered. This relates to a 90% probability of non-occurrence in 1 000 years design life for the 1:10 000 year return period event.

Extreme storm events were also determined (up to a 10^{-8} annual probability of exceedance for the 95^{th} percentile) which included predicted increases in rainfall intensities due to climate change.

Based on the above, data required to define and quantify the safety risks are described in ***Subsection 5.10.6***.

5.10.6 Data Collection

An important component of this study was the collection of data for the site and the surrounding quaternary catchments. A significant challenge generally encountered in South Africa, also applicable to the preparation of this SSR, is the lack of long-term meteorological and surface run-off data. Taking this into account, all available short and long-term data appropriate for the site have been collected and analysed by the relevant sections.

A summary of the main data collected for the site is given in ***Table 5.10.1*** which includes the data already available when compiling this section of this SSR.

Table 5.10.1
Summary of Main Sources of Data

Item	Data Received	Data Source
1	Aerial photography	Flown site survey for the Nuclear-1 Environmental Impact Assessment (EIA) Study and updated Topographical (LiDAR) survey (Southern Mapping Geospatial, 2021)
2	Detailed site contours	Flown site survey for the Nuclear-1 Environmental Impact Assessment (EIA) Study and updated Topographical (LiDAR) survey (Southern Mapping Geospatial, 2021)
3	Site 'illustrative footprints' and locality	Eskom[1]
4	Rainfall data	SA Weather Services and Daily Rainfall Data Extraction Utility, Institute for Commercial Forestry Research and University of KwaZulu-Natal (Pietermaritzburg campus), (ICFR) (Institute for Commercial Forestry Research, 2003) and adopted rainfall values sourced from ***Section 5.8*** (Meteorology)
5	Surface water infiltration and geological information	***Section 5.11*** (Geohydrology) and infiltration test results (***Appendix 5.10.B***)
6	Tidal and tsunami information	***Section 5.9*** (Oceanographic & Coastal Engineering)

5.10.7 Hydrology

5.10.7.1 Regional Hydrological Evaluation

Evaluation of the hydrological aspects of the site for the purposes of this SSR covered the investigation of areas draining into and through the site and the adjacent catchments which could have an impact on the nuclear

[1] Eskom Holdings, further referred to as Eskom

installation(s) (see ***Drawing 5.10.1***).

5.10.7.2 Description of the Site and Surrounding Major Catchments

Quaternary and Major Catchments

The Duynefontyn site currently hosts the KNPS, which is situated on Cape Farm Duynefontyn No. 1552 (previously consisting of Farm Duynefontyn No. 34 and Farm No. 1375 which were consolidated by the City of Cape Town in 2015).

The site centroid is defined by the coordinates X: -52727.4000 and Y: -3727966.6500.

The site is located on the coast 30 km north of the Cape Town city bowl. The quaternary catchments in the area are as follows:

- Catchment G21A drained by the Modder River located 15-20 km north of the site;
- Catchment G21B within which the site is situated, drained by the Salt River located 5-6 km southeast of the KNPS.

The regional surface water features and the major catchments are presented in ***Drawing 5.10.1*** and ***Drawing 5.10.2***.

Other (local) Sub-Catchments

Run-off along natural drainage paths may occur during high rainfall events passing through the illustrative nuclear island footprint in a southwesterly direction. Run-off from the existing KNPS catchment is not expected to drain towards the illustrative nuclear island footprint as existing drainage lines flow in a southwesterly direction towards the Salt River.

5.10.7.3 Surface Water Resources

A brief description of the main surface water resources is given in this section.

Surrounding Area Outside Duynefontyn Site

The Duynefontyn site is located within the Berg River Water Management Area (Department of Water Affairs and Forestry, 2002) and within the West Coast Rivers sub-area. This catchment has negligible yield from surface water and is entirely reliant on groundwater and water transfers.

There are no dams and associated well-defined watercourses that may cause a safety threat to the site within the G21A and G21B quaternary catchments (***Drawing 5.10.1*** and ***Drawing 5.10.2***).

The Duynefontyn Site

Wetlands are prominent and are situated mainly in the slacks of the vegetated dunes, in a linear arrangement. Although the wetlands are seasonal, they are important ecological features and contribute to the overall diversity of the local ecosystem. These are discussed in more detail in ***Section 5.11*** (Geohydrology).

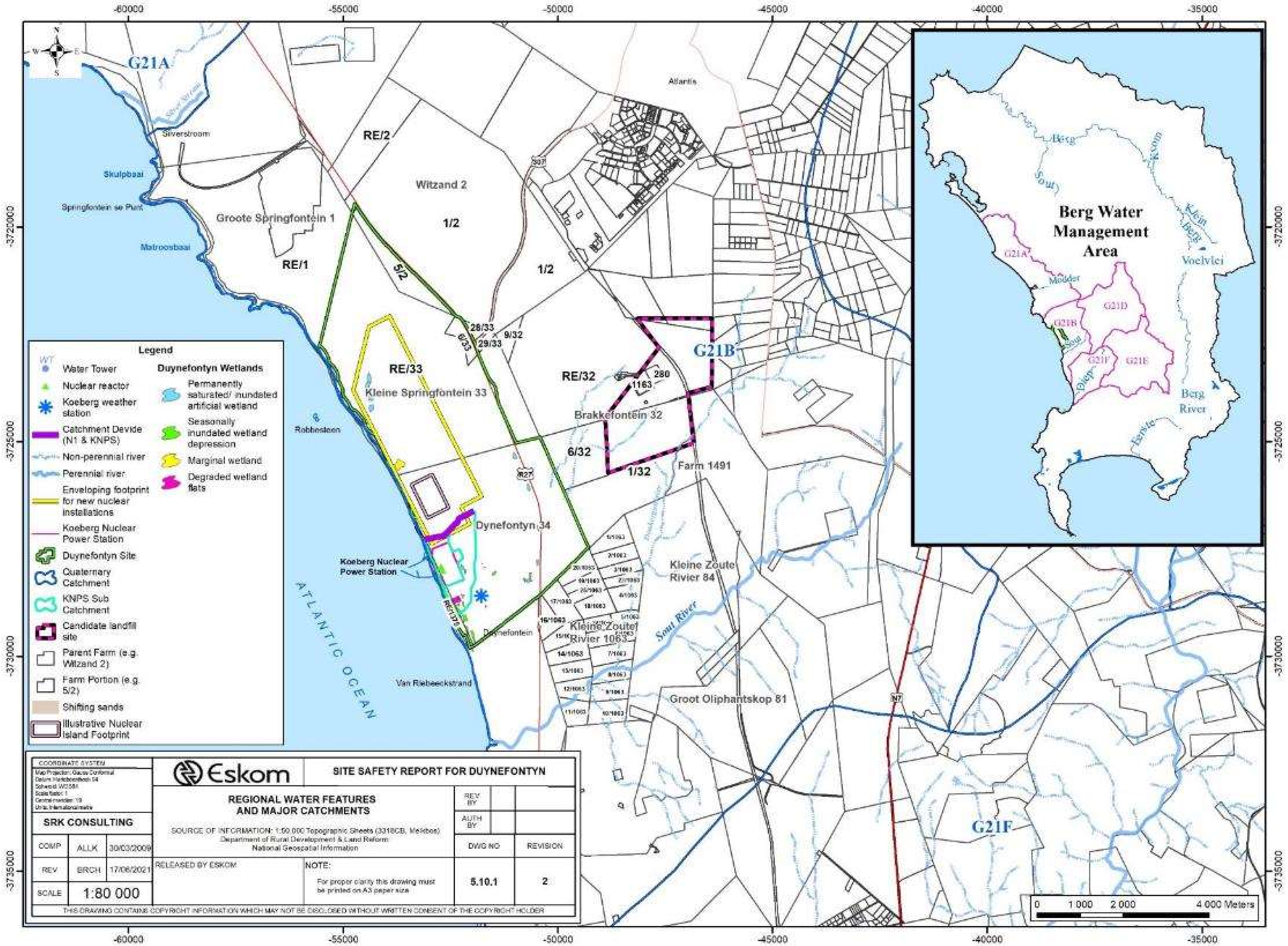
5.10.7.4 Terrain and Site Proximity to Major Watercourses

The Duynefontyn site is located along the coastline and falls within the G21B quaternary catchment (Water Research Commission, 2012). There are a few drainage lines within the area which are addressed in the subsequent sections.

The closest minor watercourse within catchment G21B is the Sout Rivier (includes the Donkergatrivier tributary), located approximately 5 to 6 km southeast of the site flowing in a southwesterly direction. The other minor watercourse is Modder River (includes Louws Kloof tributary), located approximately 15 to 25 km north of the site and on a different quaternary catchment.

The closest major watercourse is Diep Rivier, approximately 15 to 20 km east of the site but on a different quaternary catchment, flowing in a southwesterly direction.

The terrain and proximity of the site to major watercourses is presented in ***Drawing 5.10.2***.



G21A
G21B
G21F
Atlantis
Silverstroom
Skulpbaai
Springfontein se Punt
Matroosbaai
Groote Springfontein 1
RE/1
RE/2
Witzand 2
1/2
5/2
RE/33
Kleine Springfontein 33
RE/32
280
1163
Brakkefontein 32
6/32
1/32
Farm 1491
Robbesteen
Dynefontyn 34
Koeberg Nuclear Power Station
Kleine Zoute Rivier 84
Kleine Zoute Rivier 1063
Sout River
Groot Oliphantskop 81
Van Riebeeckstrand
ATLANTIC OCEAN
Berg Water Management Area
Berg
Sout
Klein Berg
Voelvlei
Berg River
Diep
Eerste
Legend
Water Tower
Nuclear reactor
Koeberg weather station
Catchment Devide (N1 & KNPS)
Non-perennial river
Perennial river
Enveloping footprint for new nuclear installations
Koeberg Nuclear Power Station
Duynefontyn Site
Quaternary Catchment
KNPS Sub Catchment
Candidate landfill site
Parent Farm (e.g. Witzand 2)
Farm Portion (e.g. 5/2)
Shifting sands
Illustrative Nuclear Island Footprint
Duynefontyn Wetlands
Permanently saturated/ inundated artificial wetland
Seasonally inundated wetland depression
Marginal wetland
Degraded wetland flats
SRK CONSULTING
COMP ALLK 30/03/2009
REV BRCH 17/06/2021
SCALE 1:80 000
SITE SAFETY REPORT FOR DUYNEFONTYN
REGIONAL WATER FEATURES AND MAJOR CATCHMENTS
SOURCE OF INFORMATION: 1:50 000 Topographic Sheets (3318CB, Melkbos) Department of Rural Development & Land Reform National Geospatial Information
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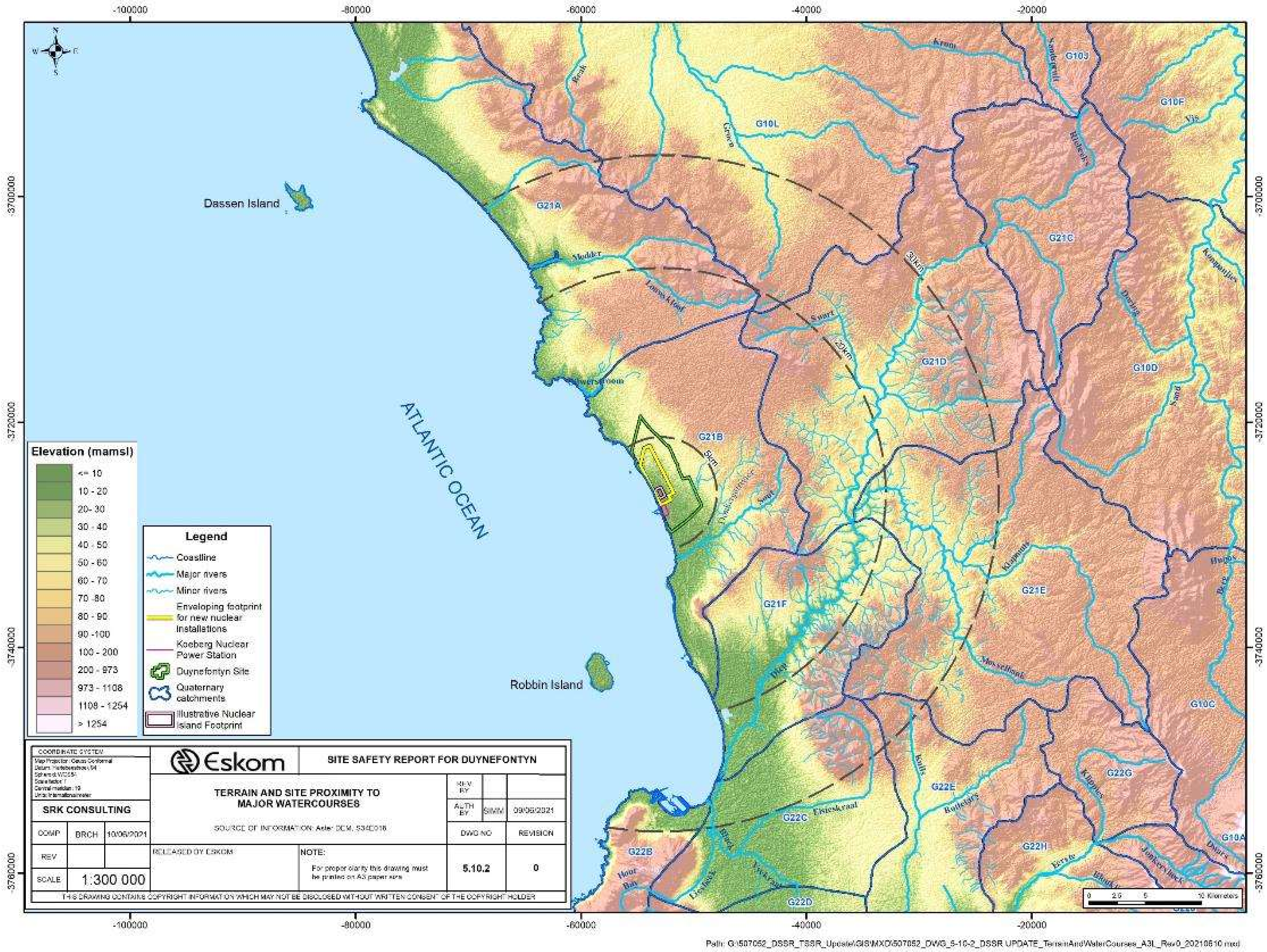

Dassen Island
ATLANTIC OCEAN
Robbin Island
Elevation (mamsl)
<= 10
10 - 20
20 - 30
30 - 40
40 - 50
50 - 60
60 - 70
70 - 80
80 - 90
90 - 100
100 - 200
200 - 973
973 - 1108
1108 - 1254
> 1254
Legend
Coastline
Major rivers
Minor rivers
Enveloping footprint for new nuclear installations
Koeberg Nuclear Power Station
Duynefontyn Site
Quaternary catchments
Illustrative Nuclear Island Footprint
G21A
G21B
G21C
G21D
G21E
G21F
G10L
G10J
G10F
G10D
G10C
G22B
G22C
G22D
G22E
G22G
G22H
G10A
SRK CONSULTING
Eskom
SITE SAFETY REPORT FOR DUYNEFONTYN
TERRAIN AND SITE PROXIMITY TO MAJOR WATERCOURSES
SOURCE OF INFORMATION: Aster DEM, S34E018
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-3760000

5.10.7.5 Catchment Characteristics

The existing catchment characteristics covering the site are uniform in terms of soils (permeability) and vegetation cover (***Section 5.11***) and therefore no further extrapolation of these input parameters regarding model run-off coefficients was required. The catchments are expected to have a low run-off coefficient due to sandy soils, moderate vegetation and undulating topography creating temporary storage areas. This also correlates to the infiltration rates determined of approximately 5 m per day (208 mm/h) (***Section 5.11***). Conservative values have been considered and more details on infiltration rates are given in ***Appendix 5.10. B***.

The Duynefontyn site is dominated by two main vegetation types, namely Cape Flats Dune Strandveld and Cape Flats Sand Fynbos or Atlantis Sand Fynbos, both previously known as Sand Plain Fynbos (***Section 5.3***). The Cape Flats Dune on sand and limestone, and Sand Plain Fynbos on marine-derived, leached acid sand. There is also a transitional vegetation type between the two.

5.10.7.6 Precipitation

There is approximately 32 years of usable rainfall data at the KNPS site, but this data is too short to carry out any longer-term rainfall predictions except by including additional stations and applying statistical analysis.

Existing rainfall data with the required reliability and length of record were therefore extracted from the Daily Rainfall Data Extraction Utility (Institute for Commercial Forestry Research, 2003) using surrounding South African Weather Services stations, as summarised in ***Table 5.10.2***.

Meteorology data has since been updated for longer-term rainfall and further details on current and extreme rainfall are discussed in ***Section 5.8***.

Table 5.10.2
Summary of Rainfall Stations Considered

Station No.	Years of Record	Distance from Site (km)	Elevation (m amsl)[2]	Mean Annual Precipitation (mm)
21130 (Vanschoorsdrift)	148 (* 31.9% reliability)	16.2	42	347
41060 (Burgherspost) – daily records	150 (* 32% reliability)	21.0	180	584
20649 (Robben Island) – daily records	148 (* 69.1% reliability)	17.7	18	584
KNPS Site	32 (100% reliability)	-	24	375

* *The daily rainfall utility program gives the reliability percentage of the rainfall records by weighting the patched/missing data*

Station 20649 (Robben Island) has a long reliable rainfall record (69.1 per cent) and is located only 18 km from the site and has therefore been selected to be representative of the rainfall in the area. The selected station has 148 years of patched rainfall records (Institute for Commercial Forestry Research, 2003) which is significantly less than the record required for estimating the PMP or 10^{-8} annual probability of exceedance design rainfall depth, required for determining the estimated run-off flows and volumes. The recorded data from this station requires statistical extrapolation to predict higher recurrence interval storm events. This station has been selected particularly for its long record and highest reliability in addition to proximity to the Duynefontyn site. The above data has since been updated using additional stations and more recent data and documented in in ***Section 5.8***.

The extreme runoff flows and volumes for the higher recurrence interval events for the site are estimated using the 24-hour rainfall depths supplied in ***Section 5.8***.

The 24-hour rainfall duration was considered appropriate as shorter duration rainfall records (e.g. 5 minute interval) are not readily available which is a common challenge in South Africa and many hydrological models in South Africa are based on the 24-hour precipitation and rainfall distribution curves.

The 24-hour extreme rainfall depths (defined as the total expected precipitation in a 24-hour period) were calculated using a statistical approach. A statistical analysis using the Annual Maximum Series (AMS) was undertaken using various probability distributions from Flood Risk

[2] Metres above mean sea level

Reduction Measures (Alexander, 2001) and determined in ***Section 5.8***. These adopted extreme value predictions for the 24-hour rainfall depths are presented in ***Table 5.10.3***.

Table 5.10.3
Extreme Value Predictions for 24-Hour Rainfall Depth

Probability of Occurrence (yrs)	Base Case (mm)		Including Climate Change (mm)	
	Mean	95th Percentile	Mean	95th Percentile
10^{-1}	48.9	56.7	56.2	65.2
10^{-2}	69.0	82.7	79.4	95.1
10^{-3}	88.8	108.3	102.1	124.5
10^{-4}	108.5	133.9	124.8	154.0
10^{-5}	128.1	159.3	147.3	183.2
10^{-6}	147.8	184.9	170.0	212.6
10^{-8}	187.2	236.0	215.3	271.4

According to the 5th Assessment Report (AR5) on climate change (Intergovernmental Panel on Climate (IPCC), 2014) the IPCC projects annual rainfall to decrease by about 30 mm (75th percentile) at the site by 2100. However, this does not necessarily apply to the changes in rainfall intensities, which may increase.

Unfortunately, the AR5 report on climate change (Intergovernmental Panel on Climate (IPCC), 2014) does not predict intensity changes. ***Section 5.8*** includes the adopted methodology on climate change for forecasting extreme events which proposes an estimated increase in 24-hour precipitation of between 0 and 15 percent from 2044 and 2130 respectively.

As described in ***Section 5.8,*** to accommodate the uncertainties in future emission scenarios, a standard set of scenarios were used to ensure that the starting conditions, historical data, and projections employed by the different groups are complementary, comparable, and consistent across the various branches of climate science. These scenarios are called Representative Concentration Pathways (RCPs), and describe alternative assumptions about selected approximate total radiative forcing values[3] for the year 2100 relative to 1750 (IPCC 2013). RCPs are scenarios depicting the evolution of emissions and concentrations of the most important

[3] Radiative forcing is the change in energy flux caused by natural and anthropogenic substances and processes that alter the Earth's energy budget. It is quantified in watts per square metre (W/m²), and it is calculated at the tropopause.

greenhouse gases (GHGs - carbon dioxide (CO_2) methane (CH_4) and nitrous oxide (N_2O)), aerosols, chemically active gases and those related to changes in land use and land cover resulting in specified levels of radiative forcing. For each category of emissions, an RCP contains a set of starting values and the estimated emissions up to 2100, based on assumptions about economic activity, energy sources, population growth and other socio-economic factors. There are four pathways, namely RCP8.5, RCP6, RCP4.5 and RCP2.6, with each numerical referring to the radiative forcing in W/m^2. Therefore RCP8.5 implies radiative forcing higher than 8.5 W/m^2 by 2100, whereas radiative forcing stabilizes at approximately 6 W/m^2, 4.5 W/m^3 and 2.6 W/m^3 after 2100 in the RCP6, RCP4.5 and RCP2.6 pathways, respectively. Further description of these pathways is as follows:

- RCP8.5 is characterised by increasing greenhouse gas emissions over time, representative of scenarios in the literature that lead to high GHG levels.
- RCP6 is a stabilization scenario in which total radiative forcing is stabilized shortly after 2100, without overshoot, by the application of a range of technologies and strategies for reducing GHG emissions.
- RCP4.5 is a stabilization scenario in which total radiative forcing is stabilized shortly after 2100, without overshooting the long-run radiative forcing target level.
- The pathway in RCP2.6 is representative of scenarios in literature that lead to very low GHG concentration levels. It is a "peak-and-decline" scenario; its radiative forcing level first reaches a value of around 3.1W/m^2 by mid-century and returns to 2.6 W/m^2 by 2100. To reach such radiative forcing levels, GHG emissions (and indirectly emissions of air pollutants) are reduced substantially, over time.

For the hydrology modelling the PCP8.5 was used, and a 15 percent increase was applied to the 24-hour rainfall intensities to account for climate change over an approximate 100-year lifetime of the nuclear installation (s).

The monthly rainfall data for Station 20649 can be seen in ***Appendix 5.10.A***. and the highest recorded 24-hour rainfall depth for Station 20649 (148 years) was 72 mm (7 June 1968) and 70 mm for the site data (32 years) from ***Section 5.8***.

The actual 148 years' of data are reliable, but the probability distribution for the > 1:100-year recurrence intervals is less reliable. The associated management of uncertainties for the rainfall has been addressed in ***Section 5.8***.

The adopted values were based on the 24-hour rainfall depth for the 95th percentile and the values were obtained from and are explained in more detail in ***Section 5.8***.

The adopted 24-hour design rainfall depth[4] is presented in ***Table 5.10.4***.

Table 5.10.4
Adopted 24-Hour Design Rainfall Depths

Probability of Occurrence (yrs)	24-Hour Storm rainfall (mm)
10^{-1}	65.2
10^{-2}	95.1
10^{-3}	124.5
10^{-4}	154.0
10^{-5}	183.2
10^{-6}	212.6
10^{-8}	271.4

5.10.7.7 Tidal Data

The impacts of tidal effects and sea level rise have been considered in ***Section 5.9***. The most up to date and relevant information at the time of modelling and writing this report has been obtained from ***Section 5.9*** for use in the hydraulic model which calculates the relevant flood water level for a 10^{-1} year to 10^{-8} year probability of occurrence storm event based on the sea level rise (RCP8.5) due to climate change over an approximate 100-year lifetime of the nuclear installation(s). The information that was used is summarised in ***Table 5.10.5***.

[4] Design Rainfall Depth is an estimation of the total storm rainfall depth that should be used in terms of the U S Nuclear Regulatory Commission guidelines for the assessment and design of storm water control measures (United States Nuclear Regulatory Commission, 2011).

Table 5.10.5
Still High Water level including Climate Change

Annual Probability of Exceedance (yrs)	Water Level Component	Unit	Mean	95th Percentile
10^{-4}	90th Percentile of high tides	(m amsl)	1.00	1.00
	Sea level rise	(m)	1.80	1.80
	Storm surge	(m)	1.31	1.69
	Still high water level	**(m amsl)**	**4.11**	**4.49**
10^{-6}	90th Percentile of high tides	(m amsl)	1.00	1.00
	Sea level rise	(m)	1.80	1.80
	Storm surge	(m)	1.80	2.50
	Still high water level	**(m amsl)**	**4.60**	**5.30**
10^{-8}	90th Percentile of high tides	(m amsl)	1.00	1.00
	Sea level rise	(m)	1.80	1.80
	Storm surge	(m)	2.31	3.39
	Still high water level	**(m amsl)**	**5.11**	**6.19**

The above data were obtained from ***Section 5.9*** and list still high water levels due to storm events and used in the hydraulic model to determine the flood hazard at the nuclear installation(s). The adopted values were based on the still water levels with a 10^{-4}, 10^{-6} and 10^{-8} annual probability of exceedance for the 95th percentile (upper values of the 90 per cent confident intervals) and considered a low probability. The values used for downstream boundary conditions (high water level) in the hydraulic model excludes wave set-up and run-up as these represent an instantaneous boundary condition rather than a steady downstream boundary condition.

The following downstream boundary conditions (still high water level) were therefore adopted in the hydraulic modelling:

- 10^{-4} year event is 4.49 m amsl;
- 10^{-6} year event is 5.30 m amsl;
- 10^{-8} year event is 6.19 m amsl.

5.10.7.8 Long-Term Hydrology Details

A factor to also consider in this study is the potential long-term base flow at the nuclear installation(s). This is relevant both during construction and operational phases of the nuclear installation(s) and gives an indication of how much sub-surface flow can be expected at the nuclear installation(s) from a regional perspective. The detailed modelling and impacts of sub-surface flow have been considered in ***Section 5.11***. In the absence of long-term site-specific data, use has been made of the extensive research carried out in the development of the water resources series of reports commissioned by the Water Research Commission (WR2012) (Water Research Commission, 2012). The key long-term hydrology characteristics adopted from these reports which are considered relevant for the site are summarised in ***Table 5.10.6***.

Table 5.10.6
Summary of Quaternary Catchment Information

Catchment ID	Gross Area (km^2)	Alien Vegetation Area (km^2)	Irrigation Area (km^2)	Evaporation Zone	MAE (mm)	Rain Zone	MAP (mm)	MAR (mm)	Net MAR ($x10^6m^3$)
G21B	304	67.6	1.28	23C	1445	G2A	332	25.1	7.63

Note: *MAE = Mean Annual Evaporation*
MAP = Mean Annual Precipitation
MAR[5] = Mean Annual Run-off

The location of catchment G21B in which the site is situated is shown in ***Drawing 5.10.1***. The values given in the above table consider both the summer and winter average rainfall. The MAP of 332 mm in ***Table 5.10.6*** is lower than the MAP derived from the Robben Island station of 584 mm, and the 372 mm at the Koeberg weather station (from 1980 to 2019). WR2012 MAP represents weather stations in the entire regional catchment G21B whereas the Robben Island and Koeberg values are specific to that weather stations.

When considering storm run-off peaks for the nuclear installation(s) it is more accurate to use the site-specific data rather than the regional G21B data bearing in mind that the nuclear installation (s) are situated along the

[5] Mean Annual Run-off (MAR) - is the expected average run-off from a catchment on a yearly basis due to an average rainfall over the catchment

coastline. Based on ***Table 5.10.6*** and the data for catchment G21B, an MAR of approximately 25.1 mm is expected. Due to the high infiltration rate of the sandy soils (approximately 208 mm/h) a low MAR is expected on the site and from the KNPS catchment prior to the development of the nuclear installation(s).

The detailed modelling and impacts of sub-surface flow have been considered in ***Section 5.11*** for the nuclear installation(s) and KNPS site.

5.10.7.9 Regional Hydrological Modelling

The regional hydrology includes all catchments that naturally drain towards and/or through the site/site vicinity and which may therefore have an impact on the site. To quantify the volume and peak flows resulting from the regional catchments at the site during the life cycle of the nuclear installation(s), either a deterministic and/or an empirical method can be used.

The site layout, location of low-lying ponding areas and surface water sampling points are presented in ***Drawing 5.10.3*** and the sub-catchments for the region in ***Drawings 5.10.4*** to ***5.10.6***.

Considering the location of the site, it is difficult to utilise empirical methods as these methods are based on statistical correlation of observed peaks and regional catchment properties rather than local catchments in the vicinity of the site. For this reason, a deterministic modelling approach has been adopted for this SSR. The Soil Conservation Services (SCS-SA) (University of KwaZulu-Natal, 2004) deterministic model was selected as this model is particularly suited to small to medium-sized catchments of about 0.5 km^2 to 10 km^2 in area. For model validation and verification reports, which include a description of the model setup, parameterisation, calibration, sensitivity testing, assumptions and limitations see ***Appendix 5.10.F***.

The model predicts runoff peaks based on a 24-hour rainfall distribution using the storm type for the catchment area. The Curve Number (CN) represents the run-off potential considering the soil type and infiltration potential (University of KwaZulu-Natal, 2004). As seen in ***Table 5.10.8*** below, the catchment areas modelled are all <10 km^2 in extent and hence the SCS-SA model is suitable to estimate the run-off peaks and volumes. The SCS-SA computer software for the run-off calculations has been verified and validated over many years by the software vendor, as required by the NNR RG-0016: Requirements for Authorisation Submissions Involving Computer Software and Evaluation Models for Safety Calculations (National Nuclear Regulator, 2016) on computer software.

The determination of the run-off flows and volumes are based on NRC NUREG/CR-7046 (United States Nuclear Regulatory Commission, 2011) recommendations and the NNR RG-0011 (National Nuclear Regulator, 2016), which makes use of statistically-derived floods and the Probable Maximum Flood (PMF) which is based on the Probable Maximum Precipitation (PMP)[6]. It is reasonable to use the PMF or the 1:10 000 return period as this provides reasonable assurance of non-exceedance for a 1 000 year period. For a 1 000 year design period, there will be a 90 per cent probability of non-occurrence for a 1:10 000 year return period event.

External Events for New Nuclear Installations (National Nuclear Regulator, 2012) position paper was also considered throughout the modelling. Extreme storm events were also determined (up to a 10^{-8} annual probability of exceedance for the 95th percentile) which included any increases in rainfall intensities due to climate change. The frequency ranges for the annual probability of exceedance are based on ***Chapter 6*** (Evaluation of external events) from Technical Specification NSIP01388 (Rev 1) (Eskom, 2010).

5.10.7.10 Input Data

The main input data for the catchments draining into and through the site as well as water courses within the site are presented in ***Table 5.10.7***. Model Input and output data are in ***Appendix 5.10.C***.

[6] Probable Maximum Precipitation is the predicted maximum rainfall depth for a given duration that is physically possible over a given storm area as recommended by the NRC.

Table 5.10.7
SCS-SA Model Input Parameters

Parameter	Value	Reason
Soil Conservation Services (SCS–SA Model)		
Probability of Occurrence (yrs) 10^{-1} 10^{-2} 10^{-3} 10^{-4} 10^{-5} 10^{-6} 10^{-8}	24-hour Rainfall depth (mm) 65.2 95.1 124.5 154.0 183.2 212.6 271.4	Only long-term daily rainfall data available for the area which is one of the SCS-SA models input parameters. The intensities are distributed over 24-hours using a storm type for the area. As detailed in ***Subsection 5.10.7.5*** Upper limit was the PMP or 10^{-4} return period as recommended by the NRC NUREG/CR-7046 (United States Nuclear Regulatory Commission, 2011) and NNR RG-0011 (National Nuclear Regulator, 2016). Extreme storm events were also determined based on ***Chapter 6*** (up to a 10^{-8} annual probability of exceedance frequency for the 95th percentile) which included any increase in rainfall intensities due to climate change.
Rainfall distribution	SCS type II	Storm type distribution as detailed in SCS manual.
Catchment curve number (CN) prior to nuclear installation development	27 81 (KNPS B)	Sandy soil, SCS Type 'A' with high infiltration rate (208 mm/h) ***Section 5.11*** (Geohydrology) and Triaxial permeability test results (***Appendix 5.10.B***) High run-off potential at KNPS B due to a combination of hard surface area and a portion of undeveloped land.
AMC (Antecedent moisture condition)	0.1	The AMC has been chosen to be 0.1 which is best suited for South African conditions. This gives a realistic starting point for the model infiltration

5.10.7.11 Peak Flow Estimation

The SCS-SA (University of KwaZulu-Natal, 2004) method is based on the United States Soil Conservation Service hydrograph generating technique. It is particularly suited to small catchments and takes into account the key factors that affect run-off, such as quantity, time distribution of rainfall, time of concentration, land use, soil type and size of the generating catchment. It is based on the principle that run-off is caused by the rainfall that exceeds the cumulative infiltration of the soil. Soil types are divided into four hydrological groups ranging from soils with low run-off potential (well-drained with high infiltration ability and permeability such as sand and gravel) to soils with high run-off potential (very low infiltration rates and permeability such as shallow soils with clay, peat or rock). The SCS-SA (University of KwaZulu-Natal, 2004) method is restricted by the software to catchments of <30 km² and hence is suited for this assessment.

Based on the above approach and model input parameters, the estimated peak flow rates for all catchments covering the site as shown in ***Drawing 5.10.4*** to ***Drawing 5.10.6*** are summarised in ***Table 5.10.8*** below.

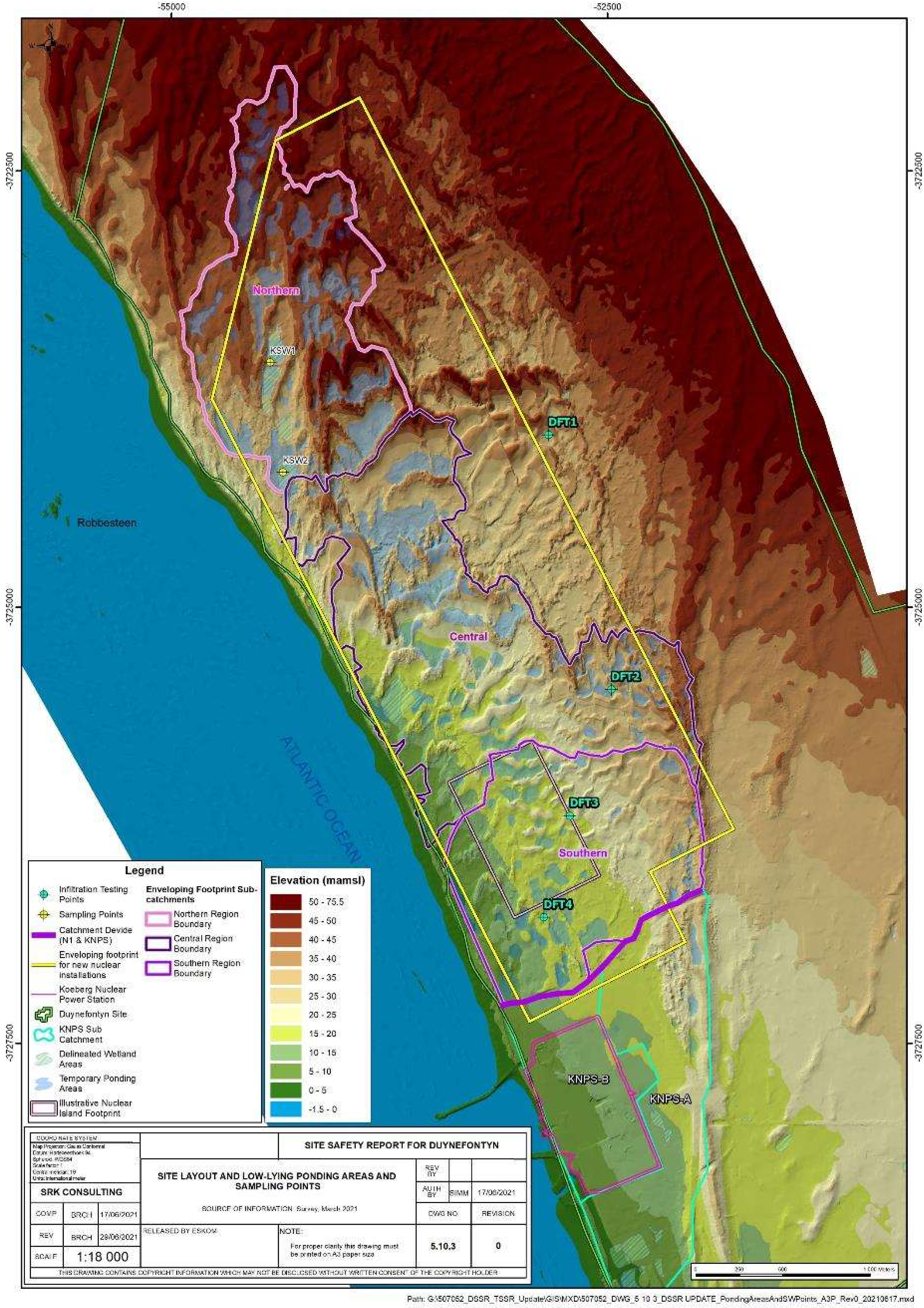
Table 5.10.8
Result of Regional Hydrological Modelling

Catchment Name	Area (km^2)	* Peak Flow (m^3/s) for Various Probability of Occurrence (yrs)						
		10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-8}
KNPS Area								
KNPS-A	1.04348	0	0.03	0.20	0.58	1.17	1.97	4.02
KNPS-B	0.65021	3.56	6.52	9.69	12.88	16.12	19.50	26.03
Central Area								
G21B_E1	0.0443	0.00	0.00	0.01	0.04	0.10	0.17	0.35
G21B_F1	0.0481	0.00	0.00	0.02	0.05	0.12	0.21	0.44
G21B_H1	0.0359	0.00	0.00	0.01	0.05	0.12	0.21	0.44
G21B_H2	0.2406	0.00	0.01	0.06	0.21	0.45	0.79	1.64
G21B_H3	0.0585	0.00	0.00	0.02	0.07	0.15	0.26	0.55
G21B_H4	0.1237	0.00	0.00	0.04	0.12	0.27	0.47	0.98
G21B_I1	0.0654	0.00	0.00	0.02	0.08	0.17	0.29	0.61
G21B_I2	0.0334	0.00	0.00	0.01	0.04	0.08	0.15	0.31
G21B_J1	0.0251	0.00	0.00	0.01	0.04	0.08	0.14	0.30
G21B_K1	0.0947	0.00	0.00	0.03	0.08	0.18	0.32	0.66
G21B_K1_C	0.1971	0.00	0.01	0.05	0.17	0.35	0.61	1.26
G21B_K2	0.1024	0.00	0.00	0.03	0.09	0.20	0.36	0.74

Catchment Name	Area (km^2)	* Peak Flow (m^3/s) for Various Probability of Occurrence (yrs)						
		10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-8}
G21B_K3	0.0506	0.00	0.00	0.02	0.07	0.17	0.29	0.61
G21B_K4	0.0719	0.00	0.00	0.02	0.08	0.19	0.33	0.69
G21B_K5	0.0376	0.00	0.00	0.01	0.05	0.11	0.20	0.42
G21B_K6	0.1331	0.00	0.00	0.04	0.12	0.26	0.46	0.95
G21B_K7	0.0585	0.00	0.00	0.02	0.06	0.14	0.25	0.51
G21B_M1	0.0314	0.00	0.00	0.01	0.04	0.08	0.15	0.31
G21B_N1	0.0795	0.00	0.00	0.02	0.08	0.17	0.30	0.62
G21B_N1_C	0.1672	0.00	0.00	0.04	0.13	0.27	0.47	0.97
G21B_N2	0.1677	0.00	0.00	0.04	0.13	0.28	0.49	1.01
G21B_N3	0.0877	0.00	0.00	0.02	0.08	0.16	0.29	0.59
G21B_N4	0.1664	0.00	0.00	0.04	0.14	0.29	0.51	1.06
G21B_N5	0.5075	0.00	0.01	0.12	0.38	0.79	1.36	2.82
G21B_O1	0.0673	0.00	0.00	0.02	0.08	0.17	0.29	0.61
G21B_P1	0.0816	0.00	0.00	0.02	0.07	0.16	0.28	0.57
Northern Area								
G21B_A1	0.3063	0.00	0.01	0.07	0.22	0.45	0.77	1.60
G21B_B1	0.0941	0.00	0.00	0.02	0.07	0.15	0.26	0.54
G21B_B2	0.0976	0.00	0.00	0.03	0.09	0.20	0.35	0.73
G21B_B3	0.1015	0.00	0.00	0.03	0.12	0.27	0.48	0.99
G21B_B4	0.1425	0.00	0.00	0.04	0.13	0.29	0.51	1.06
G21B_C1	0.2421	0.00	0.01	0.06	0.20	0.42	0.73	1.52
G21B_C2	0.1054	0.00	0.00	0.03	0.09	0.19	0.32	0.67
G21B_C3	0.0167	0.00	0.00	0.01	0.02	0.06	0.10	0.20
G21B_C4	0.0732	0.00	0.00	0.02	0.09	0.20	0.35	0.73
G21B_C5	0.1580	0.00	0.00	0.05	0.17	0.38	0.67	1.40
G21B_D1	0.1401	0.00	0.00	0.04	0.16	0.36	0.63	1.31
G21B_G1	0.0451	0.00	0.00	0.02	0.06	0.13	0.24	0.49
G21B_G2	0.1169	0.00	0.00	0.04	0.15	0.34	0.60	1.25
G21B_G3	0.1001	0.00	0.00	0.03	0.13	0.30	0.53	1.11
Southern Area								
G21B_DF1	0.1780	0.00	0.01	0.05	0.17	0.37	0.64	1.34
G21B_DF2	0.1767	0.00	0.01	0.05	0.17	0.36	0.63	1.31
G21B_DF2_C	0.7937	0.00	0.02	0.18	0.55	1.13	1.94	4.00
G21B_DF3	0.3693	0.00	0.01	0.09	0.28	0.59	1.01	2.09
G21B_DF4	0.2477	0.00	0.01	0.06	0.19	0.39	0.67	1.38
G21B_DF5	0.0788	0.00	0.00	0.02	0.08	0.18	0.31	0.64

Catchment Name	Area (km^2)	* Peak Flow (m^3/s) for Various Probability of Occurrence (yrs)						
		10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-8}
G21B_DF5_C	0.3303	0.00	0.01	0.07	0.22	0.46	0.79	1.63
G21B_DF6	0.2515	0.00	0.01	0.06	0.18	0.37	0.63	1.30
G21B_DF7	0.0611	0.00	0.00	0.02	0.06	0.12	0.21	0.45
G21B_DF7_C	0.2571	0.00	0.01	0.06	0.18	0.38	0.65	1.34
G21B_DF8	0.1960	0.00	0.01	0.05	0.16	0.33	0.58	1.19

**Due to the small catchment areas, low rainfall depth and high infiltration rates the lower storm events generated very low to zero run-off peaks.*



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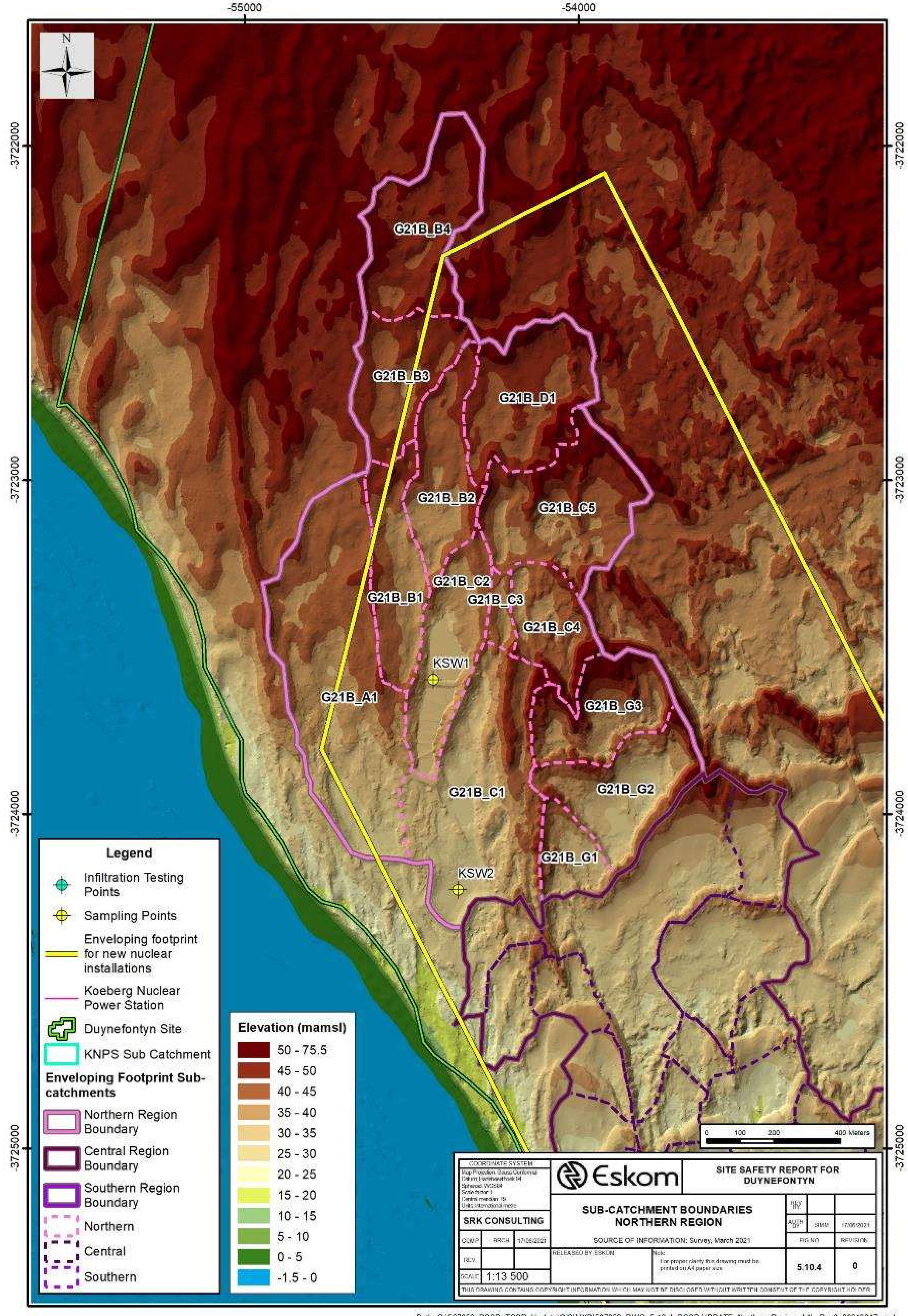

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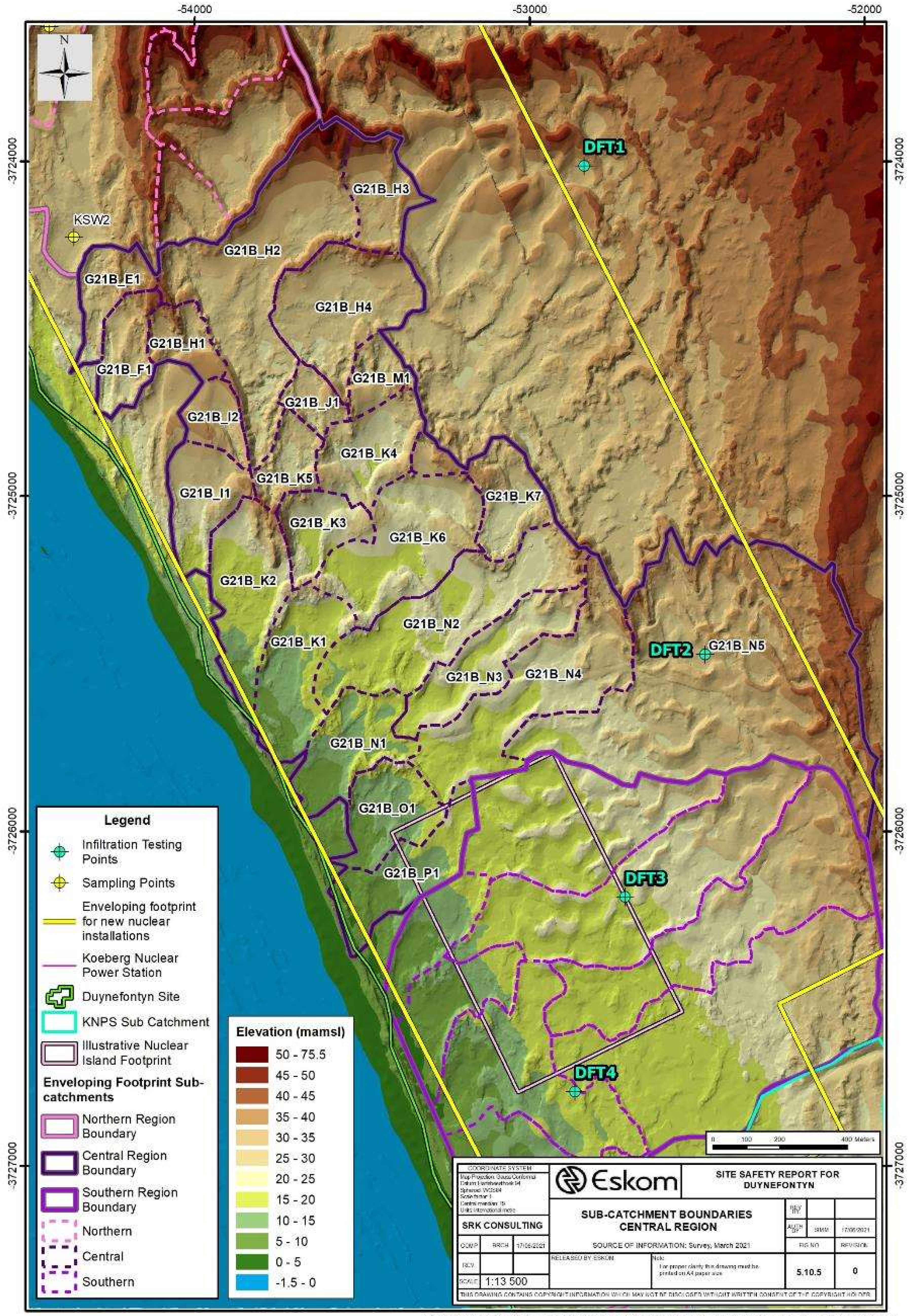

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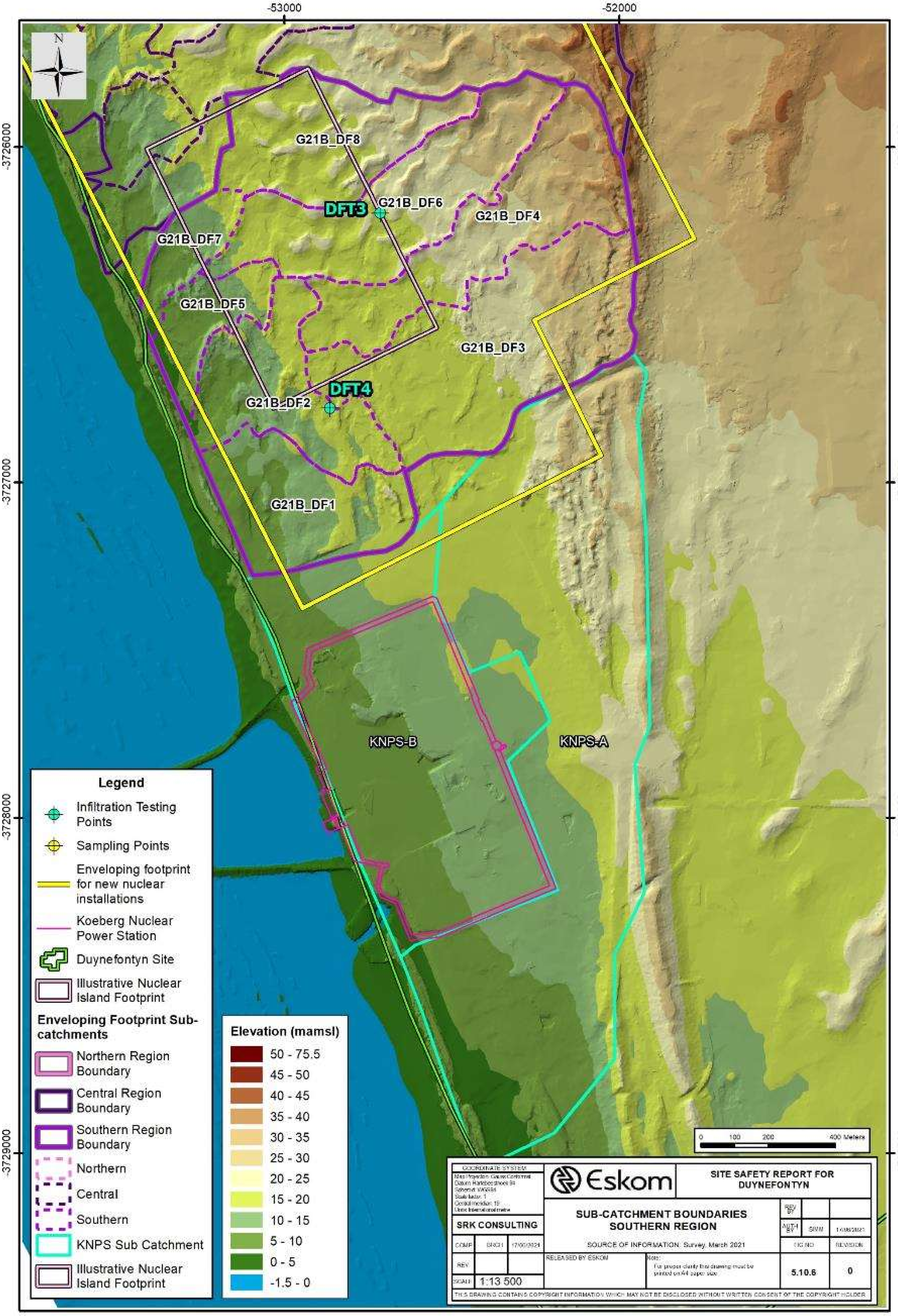

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The following conclusions for the regional peak flows can be made based on the results presented above:

- Extreme storm events were determined (10^{-1} to a 10^{-8} annual probability of exceedance for the 95th percentile) which included increases in rainfall intensities due to climate change.
- The Duynefontyn site is dominated by two main vegetation types, namely Dune Thicket on sand and limestone and Sand Plain Fynbos on marine-derived, leached acid sand, with a transitional vegetation type between the two also being present.
- The majority of the catchments have a low run-off potential due to high infiltration as a result of the sandy soils and moderate vegetation resulting in low peak flows for most of the catchments.
- The existing KNPS-B catchment indicated higher runoff peaks due to the hard surface areas within the catchment.
- Due to the small catchment areas, low rainfall depth and high infiltration rates, the lower storm events generated very low to zero run-off peaks.

5.10.8 Watercourse Sedimentation Dynamics

The Duynefontyn site falls within small, localised catchments (low lying areas) with the cumulative catchments having an area of < 1.0 km^2 and therefore the runoff volumes and peak flows are low. Negligible amounts of sediment are expected within the enveloping footprint due to the small catchments and high infiltration rate and are therefore not regarded as concern related to primary impacts. In addition, the potential for significant erosion is limited due to the relatively low flow rates, gentle slopes, permeable soils and site geometry. The final location (localised) of the illustrative nuclear island footprint is not yet known. Once this and the on-site terracing layout is known, and if this footprint falls within 100 m of any drainage path(s) through the planned nuclear installation(s) footprint or within the 1:100 year flood line[7], a sedimentation study may be required.

5.10.9 Dam Break Modelling

It is observed from ***Drawing 5.10.1*** and ***Drawing 5.10.2*** that no significant dams or associated defined watercourses are situated within the quaternary catchment G21B which drains towards the Duynefontyn site. The existing water bodies create natural storage areas which would not result in

[7] Flood line – A line drawn in plan indicating that area which is inundated with flood waters during a flood. As required in terms of the National Water Act, 1998 (Republic of South Africa, 1998)

significant backup of headwater. There are no man-made embankments crossing the watercourse which could increase the head of water and potentially breach during a storm event causing surges and damage to downstream infrastructure. According to the National Water Act No. 36 of 26 August 1998, (Republic of South Africa, 1998) a dam is classified as a safety risk when the dam has a storage capacity > 50 000 m^3 and with a maximum wall height > 5 m. There are no existing dams within the catchment draining towards the nuclear installation(s) and no major dams are planned in the foreseeable future in the lower Berg River. This is due to the high infiltration within the quaternary catchments yielding low runoff and hence not being viable for storage dams. There are two dams in the Lower Berg River Catchment, Misverstand Dam in quaternary catchment G10J, and Voëlvlei Dam in quaternary catchment G10F. Both these dams would have no impact on the site as they are in a different catchment and > 50 km away from the site.

In view of the above, there are no dams that pose a safety hazard for the site and no dam break analysis is required.

5.10.10 Regional Hydraulic Evaluation

5.10.10.1 Site Description

The expected high water levels in surrounding watercourses have been determined based on rainfall and subsequent runoff as specified in the safety standards (International Atomic Energy Agency, 2019) and ***Subsection 5.10.8***). A watercourse close to the site is defined as a potential drainage path and/or ponding area that could have a safety impact on the site due to flooding.

Within the site boundaries of the proposed nuclear installation(s) there are several small watercourses and potential ponding areas which can be seen in ***Drawings 5.10.3*** to ***5.10.6*** and are described as follows:

KNPS Area

This catchment drains the KNPS and a small area surrounding the KNPS site and is located within the Quaternary catchment G21B. The KNPS catchment is divided in two sub-catchments:

- KNPS-A catchment is the area to the east and south of KNPS that drains in a southwesterly direction towards the ocean.
- KNPS-B catchment is the built-up area of the KNPS site.

There is a main catchment division between the KNPS site and the enveloping footprint which prevents run-off from the KNPS site draining towards the enveloping footprint.

Southern Sub-Catchments

The sub-catchments G21B_DF1 to G21B_DF8 situated within the Southern Area of the enveloping footprint drain the local run-off via flow paths and ponding areas rather than defined watercourses. There are no natural watercourses within this area.

Central Sub-Catchments

The smaller sub-catchments G21B-N1 to G21B-N 5, G21B-01, B21B-P1, G21B-K1 to G21B-K7and G21B-H1 to G21-H4 situated within the central area of the enveloping footprint are also drained by flow paths rather than natural water courses. There are no defined watercourses within the above sub-catchments.

Northern Sub-Catchments

The smaller sub-catchments G21B-G1 to G21B-G3, G21B-C1 to G21B-C5, G21B-B1 to G2B1-B4, G21B-A1 and G21B-D1 situated within the northern area of the enveloping footprint are drained predominately by flow paths and low-lying potential ponding areas. No natural watercourses are situated within this area.

5.10.10.2 Description of Hydraulic Model

Several hydraulic models are available on the market internationally. The most well-known and widely used model is the Hydraulic Engineering Centre’s River Analysis System (*HEC-RAS*) Model, (Hydrologic Engineering Centre, 2010). However, due to low-lying areas experiencing sheet flow with limited defined outlets and the potential to partially retain runoff, the hydraulic modelling using the dynamic wave analysis of 2D-PCSWMM (Computational Hydraulics International, 2020) was used.

2D-PCSWMM software uses the US Environmental Protection Agency (EPA) Storm Water Management Model (SWMM) (US Environmental Protection Agency, 2015) which computes runoff based on the topography and land use; analysing the hydraulics of stormwater controls as well as simulating the overflow from controls once their capacity is reached.

SWMM is a dynamic rainfall runoff simulation model that computes runoff quantity. The runoff component of SWMM operates on a collection of sub-catchment areas that receive precipitation and generate runoff. The routing portion of SWMM transports this runoff through a system of channels. SWMM tracks the quantity of runoff generated within each sub-catchment including the flow rate and flow depth in each pipe and channel during a simulation period comprising of multiple time steps. SWMM was first developed in 1971, and since then has undergone several major upgrades. It continues to be widely used throughout the world for planning, analysis, and design related to stormwater runoff.

The 2D-PCSWMM computer software for the hydraulic calculations has been verified and validated over many years by the software vendor, as required by the NNR guidelines RG-0016: Requirements for Authorisation Submissions Involving Computer Software and Evaluation Models for Safety Calculations (National Nuclear Regulator, 2016). The expected peak flow hydrographs as determined by the SCS-SA model have been used in the 2D-PCSWMM model which calculates the expected high water level (depths) and velocities based on the peak flow rates.

For model validation and verification reports, which include a description of the model setup, parameterisation, calibration, sensitivity testing, assumptions and limitations see ***Appendix 5.10.F***.

5.10.10.3 Approach and Boundary Conditions

The approach adopted was to utilise the existing topographic and contour information to define the existing watercourse/flow path profile and to then estimate expected high water levels due to the peak flow rates derived by the SCS-SA hydrological model described above.

The governing equations for the conservation of mass and momentum for unsteady free surface flow conditions or conduits are known as the St. Venant equations sourced from SWMM manual (US Environmental Protection Agency, 2017).

The model makes use of open sheet flow using a 2D grid mesh for a given flow rate. It uses a mixed flow regime as the drainage lines vary in gradient or have temporary ponding areas in the low-lying topography. This causes the flow of water to be both super-critical in steeper gradient areas and sub-critical in flat areas. The Manning's roughness coefficient has been determined from site conditions and the SWMM manual (US Environmental Protection Agency, 2017) providing typical roughness coefficients for various types of vegetation.

The downstream boundary condition has been based on the still high water levels with a 10^{-4}, 10^{-6} and 10^{-8} annual probability of exceedance for the 95th percentile (upper values of the 90 per cent confident intervals) and considered a low probability. The values used for downstream boundary conditions (still sea water level) in the hydraulic model excludes wave set-up and run-up which present instantaneous rather than steady downstream boundary conditions.

The still water elevations were obtained from the oceanographic study (***Section 5.9***) and incorporated into the 2D-PCSWMM model as the downstream control. The probability of occurrence becomes even lower if the storm event occurs simultaneously as the highest still water level. This conservative approach (i.e. assuming still sea high water occurring at the same time as peak terrestrial runoff) was used to model the watercourse for the current natural conditions and boundary conditions as shown in ***Table 5.10.9***.

A typical section has been provided for the existing KNPS area and the future illustrative nuclear island footprint which indicates the downstream boundary condition elevations based on the extreme water levels, with 10^{-4}, 10^{-6} and 10^{-8} annual probabilities of exceedance for the 95th percentile (upper values of the 90 per cent confident intervals).

The section through existing KNPS and future illustrative nuclear island footprint is given in ***Figure 5.10.1*** and ***5.10.2*** below.

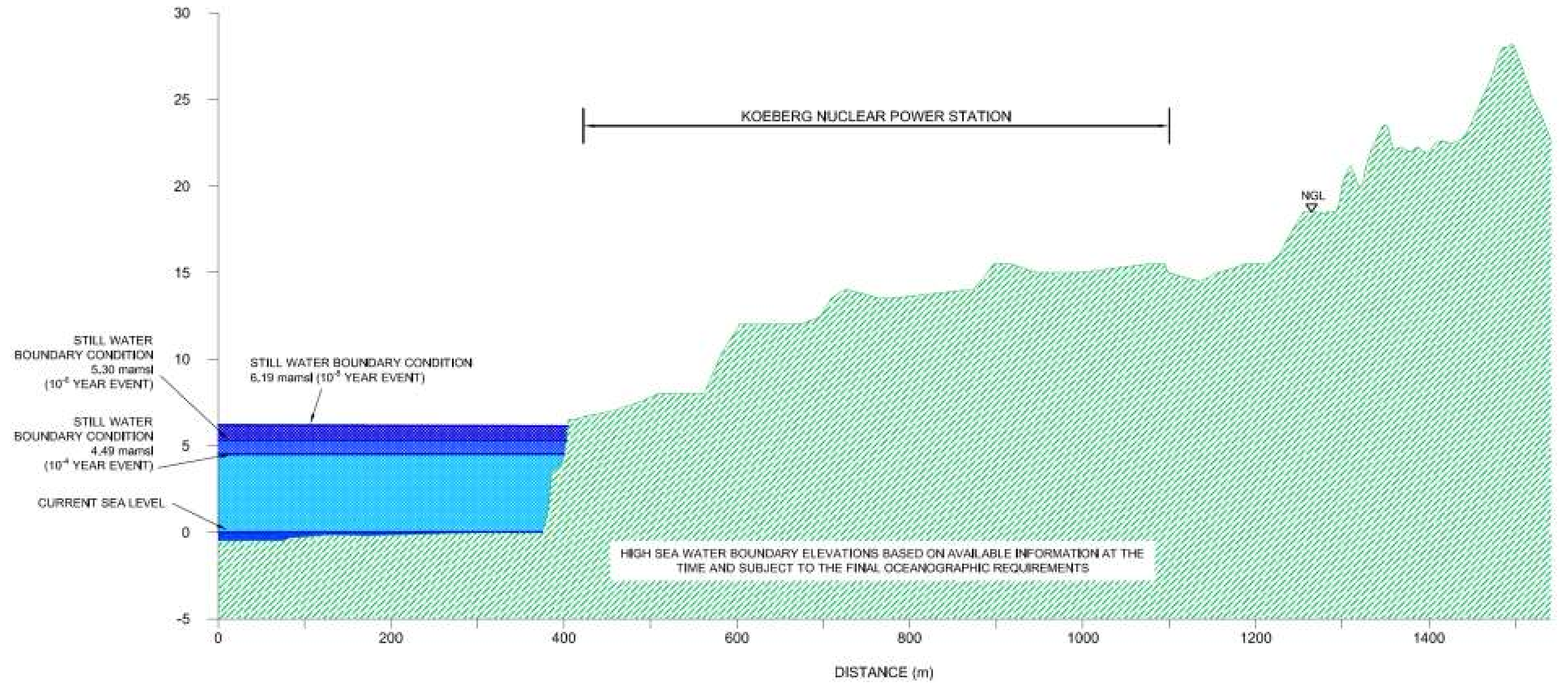


Figure 5.10.1: Typical Geographical Cross Section - Existing Duynefontyn Site

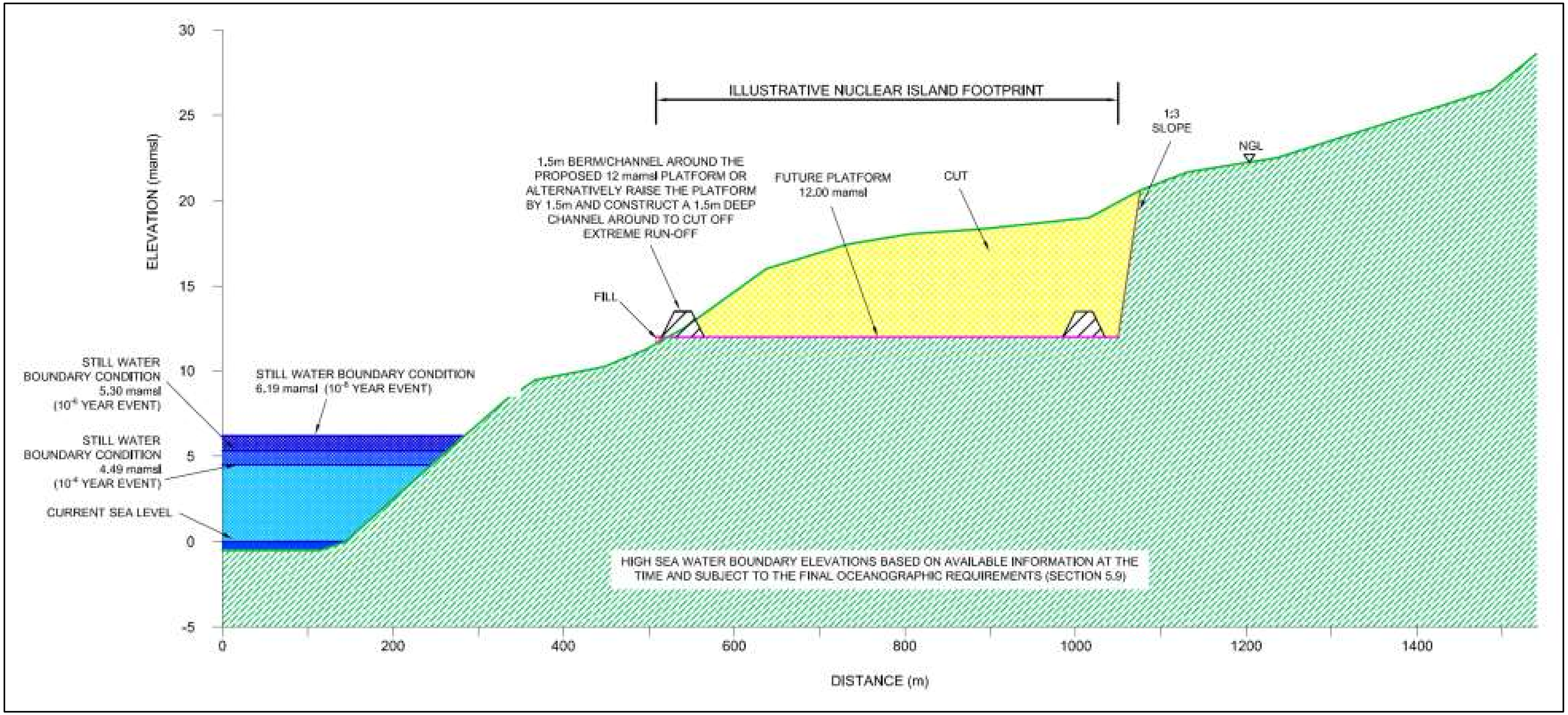


Figure 5.10.2: Typical Geographical Cross Section - Illustrative Nuclear Island

Table 5.10.9
Hydraulic Model Input Parameters

Parameter	Value	Reason
Manning's 'n'(roughness coefficient)	0.045 – 0.060	Well vegetated drainage line and floodplains SWMM Manual (US Environmental Protection Agency, 2017)
Boundary conditions (still high water level) 95th percentile' for 10^{-4}, 10^{-6} and 10^{-8} year annual probability of exceedance flood event. This excludes wave set-up and run-up for instantaneous conditions	4.49 m amsl (10^{-4}) 5.30 m amsl (10^{-6}) 6.19 m amsl (10^{-8})	Abstracted from oceanographic study ***Section 5.9***
Topography (DEM shape file from latest Lidar survey (Southern Mapping Geospatial, 2021)	2D geo-referenced grid mesh created from Lidar survey	Sheet flow modelling required
Peak Flows	Peak flow for each sub-catchment from Visual SCS-SA	Hydrographs generated at each sub-catchment

5.10.10.4 Flow Depth and Velocity Outputs

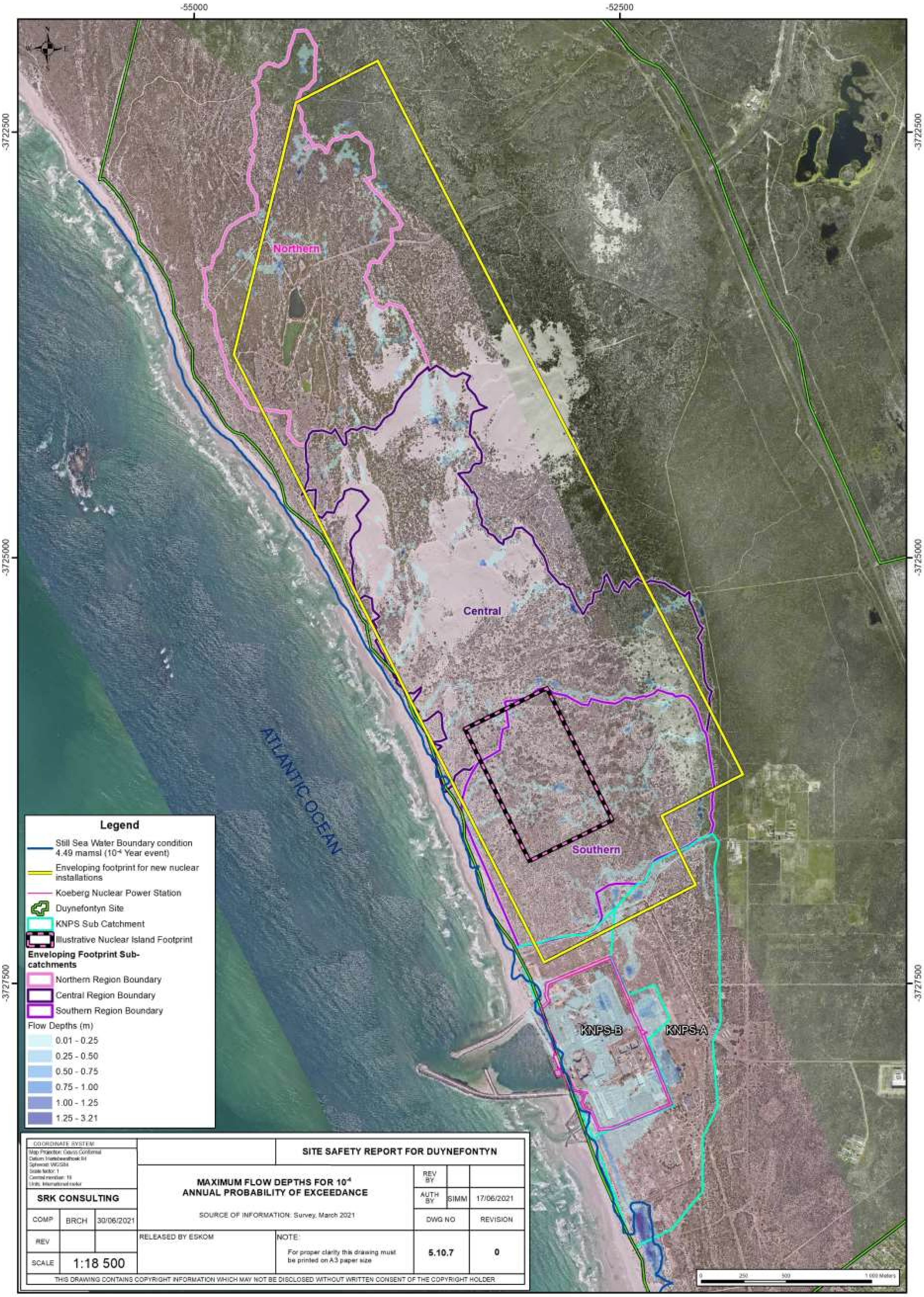
It is observed from the hydraulic model results that due to the low flood peaks for the lower return periods, insufficient run-off is generated to determine a flood line. No flood lines were therefore determined for the lower return periods. The locality of the expected maximum flooding depths and velocities are shown in ***Drawing 5.10.7*** to ***5.10.12*** for the 10^{-4}, 10^{-6} and 10^{-8} annual probabilities of exceedance respectively.

A summary of the average and maximum flow depths and velocities along the drainage lines for all defined sub-catchments within the site is given in ***Table 5.10.10*** below.

Table 5.10.10
Summary of Average and Maximum Flow Depths and Velocities

Catchment	Average and Maximum Flow Depth (m)						Average and Maximum Velocity (m/s)					
	10^{-4} (yrs)		10^{-6} (yrs)		10^{-8} (yrs)		10^{-4} (yrs)		10^{-6} (yrs)		10^{-8} (yrs)	
	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max
KNPS												
KNPS-A	0.04	1.35	0.06	1.62	0.07	1.81	0.03	1.2	0.05	1.94	0.06	2.48
KNPS-B	0.05	1.81	0.07	1.85	0.08	1.89	0.12	1.5	0.16	1.77	0.19	2.03
Central Region												
G21B_E1	0.01	0.65	0.03	0.98	0.05	1.31	0.01	0.26	0.02	0.34	0.02	0.45
G21B_F1	0.01	1	0.03	1.16	0.03	1.18	0.02	0.29	0.05	0.5	0.08	0.67
G21B_H1	0.02	0.36	0.05	0.67	0.08	1.02	0.02	0.22	0.05	0.33	0.06	0.44
G21B_H2	0.01	1.25	0.03	1.96	0.06	2.29	0.03	0.4	0.05	0.68	0.06	0.91
G21B_H3	0.03	0.69	0.07	1.07	0.12	1.42	0.05	0.33	0.09	0.56	0.13	0.75
G21B_H4	0.01	0.46	0.02	1.58	0.04	2.27	0.02	0.32	0.04	0.55	0.06	0.74
G21B_I1	<0.01	0.02	<0.01	0.06	0.01	0.09	0.02	0.12	0.06	0.29	0.09	0.38
G21B_I2	0.01	0.16	0.02	0.38	0.03	0.6	0.01	0.14	0.04	0.34	0.06	0.45
G21B_J1	0.01	0.17	0.03	0.35	0.06	0.51	0.02	0.27	0.05	0.34	0.07	0.45
G21B_K1	<0.01	0.23	0.01	0.53	0.03	0.87	0.02	0.31	0.03	0.53	0.04	0.71
G21B_K2	0.01	0.46	0.03	0.78	0.05	0.85	0.03	0.3	0.08	0.51	0.12	0.69
G21B_K3	0.02	0.19	0.05	0.45	0.09	0.7	0.03	0.24	0.07	0.49	0.09	0.65
G21B_K4	0.01	0.34	0.02	0.74	0.03	1.01	0.01	0.23	0.04	0.4	0.07	0.54
G21B_K5	0.04	2.33	0.11	2.74	0.2	2.8	0.02	0.23	0.04	0.42	0.06	0.63
G21B_K6	0.01	1.07	0.03	1.33	0.06	1.91	0.01	0.37	0.03	0.62	0.04	0.84
G21B_K7	<0.01	0.23	0.01	0.65	0.01	1.07	<0.01	0.1	0.01	0.23	0.01	0.31
G21B_M1	0.01	0.18	0.01	0.46	0.03	0.74	0.01	0.15	0.02	0.27	0.03	0.37
G21B_N1	0.01	0.11	0.01	0.18	0.03	0.65	0.02	0.43	0.04	0.72	0.07	0.96
G21B_N2	0.01	0.4	0.02	0.79	0.04	0.92	0.02	0.4	0.04	0.67	0.05	0.9
G21B_N3	<0.01	0.27	0.01	0.56	0.08	2.04	0.01	0.32	0.01	0.56	0.03	0.75
G21B_N4	0.02	2.29	0.06	3.1	0.09	3.21	0.01	0.54	0.02	0.9	0.04	1.21
G21B_N5	0.01	1.11	0.03	2.11	0.05	2.57	0.01	0.66	0.02	1.11	0.04	1.48
G21B_O1	0.01	0.34	0.02	0.64	0.04	0.89	0.02	0.38	0.05	0.65	0.08	0.86
G21B_P1	<0.01	0.05	0.02	1.04	0.03	1.07	<0.01	0.25	0.01	0.43	0.02	0.57
Northern Region												
G21B_A1	0.01	0.82	0.02	1.39	0.03	1.87	0.01	0.3	0.01	0.49	0.02	0.65
G21B_B1	0.03	0.94	0.08	1.53	0.15	1.99	0.04	0.34	0.08	0.57	0.11	0.75

Catchment	Average and Maximum Flow Depth (m)						Average and Maximum Velocity (m/s)					
	10^{-4} (yrs)		10^{-6} (yrs)		10^{-8} (yrs)		10^{-4} (yrs)		10^{-6} (yrs)		10^{-8} (yrs)	
	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max
G21B_B2	0.02	1.36	0.06	1.82	0.13	1.87	0.01	0.24	0.03	0.41	0.05	0.55
G21B_B3	0.01	0.54	0.01	0.62	0.02	0.96	0.01	0.37	0.02	0.64	0.03	0.85
G21B_B4	0.01	0.66	0.03	1.02	0.05	1.43	0.01	0.41	0.02	0.7	0.02	0.93
G21B_C1	0.01	0.99	0.02	1.87	0.04	2.44	<0.01	0.25	0.01	0.42	0.01	0.56
G21B_C2	<0.01	0.41	0.01	0.71	0.01	0.72	<0.01	0.09	<0.01	0.15	0.01	0.2
G21B_C3	<0.01	0.12	0.01	0.31	0.03	0.57	0.01	0.08	0.01	0.16	0.02	0.21
G21B_C4	0.01	0.62	0.02	1.19	0.03	1.84	0.01	0.37	0.02	0.58	0.03	0.78
G21B_C5	0.01	0.58	0.03	1.29	0.05	1.91	0.01	0.26	0.03	0.45	0.04	0.6
G21B_D1	0.01	0.86	0.02	1.23	0.04	1.5	0.02	0.32	0.03	0.55	0.04	0.74
G21B_G1	0.01	0.19	0.02	0.44	0.03	0.68	0.01	0.18	0.03	0.32	0.05	0.43
G21B_G2	0.01	0.38	0.02	0.72	0.03	1.01	0.02	0.37	0.03	0.65	0.05	0.88
G21B_G3	0.03	1.4	0.09	2.17	0.16	2.73	0.06	0.33	0.12	0.58	0.16	0.76
Southern Region												
G21B_DF1	0.01	1.02	0.03	1.5	0.08	2.06	<0.01	0.49	0.01	0.83	0.03	1.12
G21B_DF2	<0.01	0.29	0.01	0.5	0.01	0.51	<0.01	0.27	0.01	0.51	0.02	0.73
G21B_DF3	0.02	2.04	0.05	2.16	0.07	2.32	0.01	0.7	0.02	1.17	0.04	1.47
G21B_DF4	0.01	0.69	0.03	1.03	0.05	1.36	0.02	0.49	0.05	0.81	0.07	1.08
G21B_DF5	0.01	0.28	0.03	0.54	0.05	0.7	0.03	0.23	0.06	0.43	0.09	0.58
G21B_DF6	0.01	1.04	0.04	1.33	0.06	1.69	0.01	0.56	0.03	0.93	0.05	1.23
G21B_DF7	0.01	0.28	0.02	0.54	0.03	0.7	0.03	0.34	0.05	0.57	0.08	0.75
G21B_DF8	<0.01	0.52	0.02	0.89	0.05	1.2	<0.01	0.31	0.01	0.52	0.01	0.7



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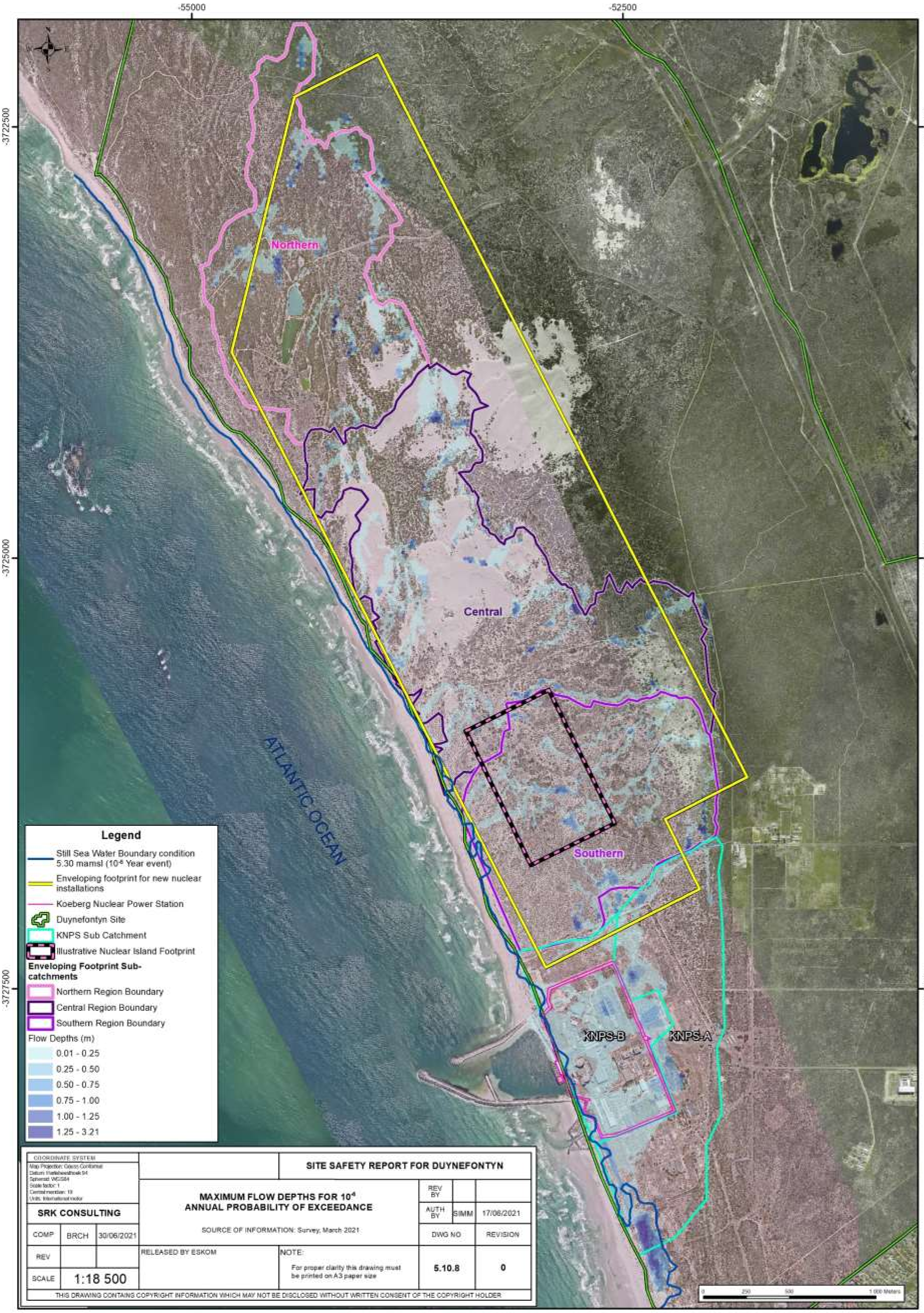

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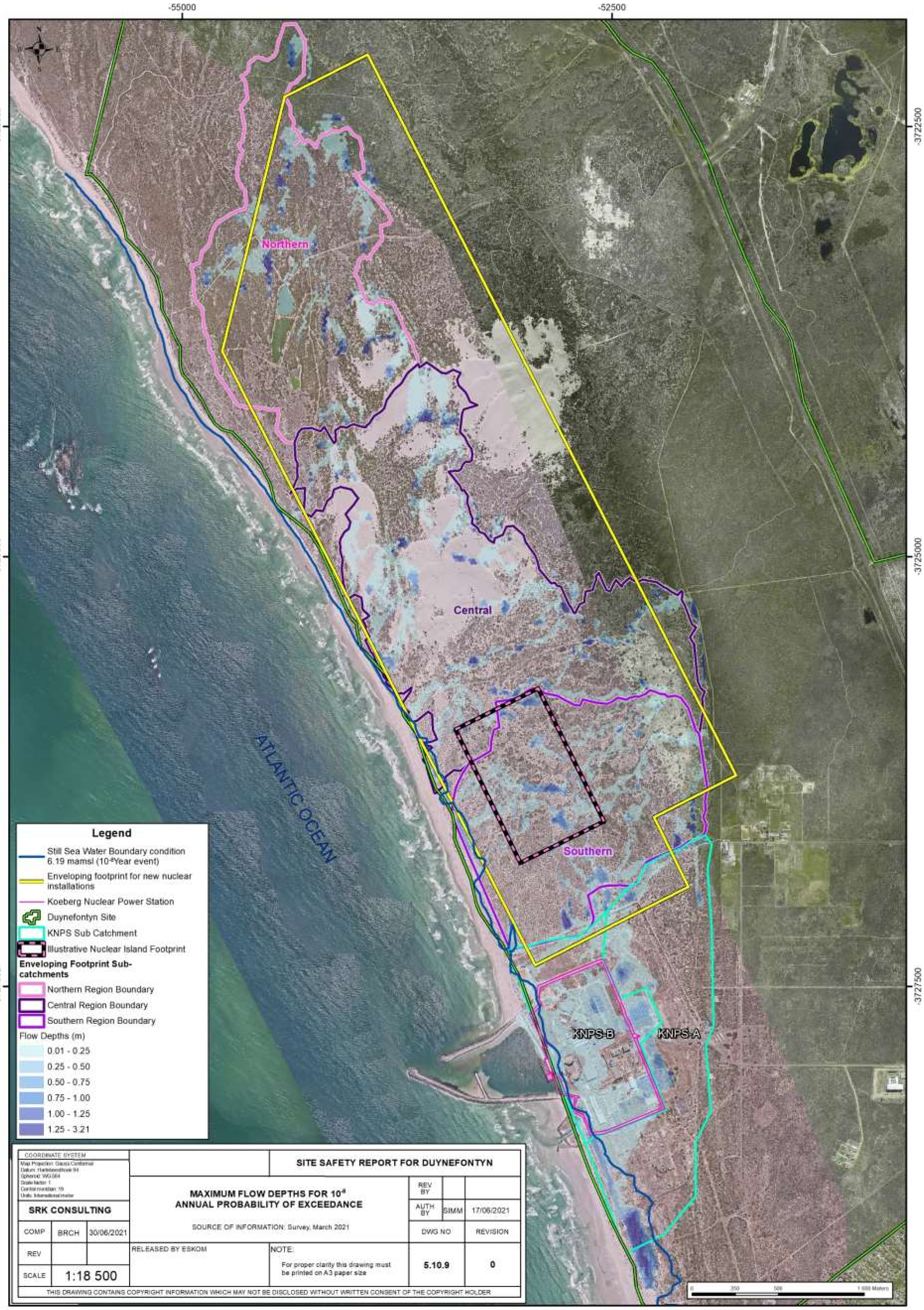

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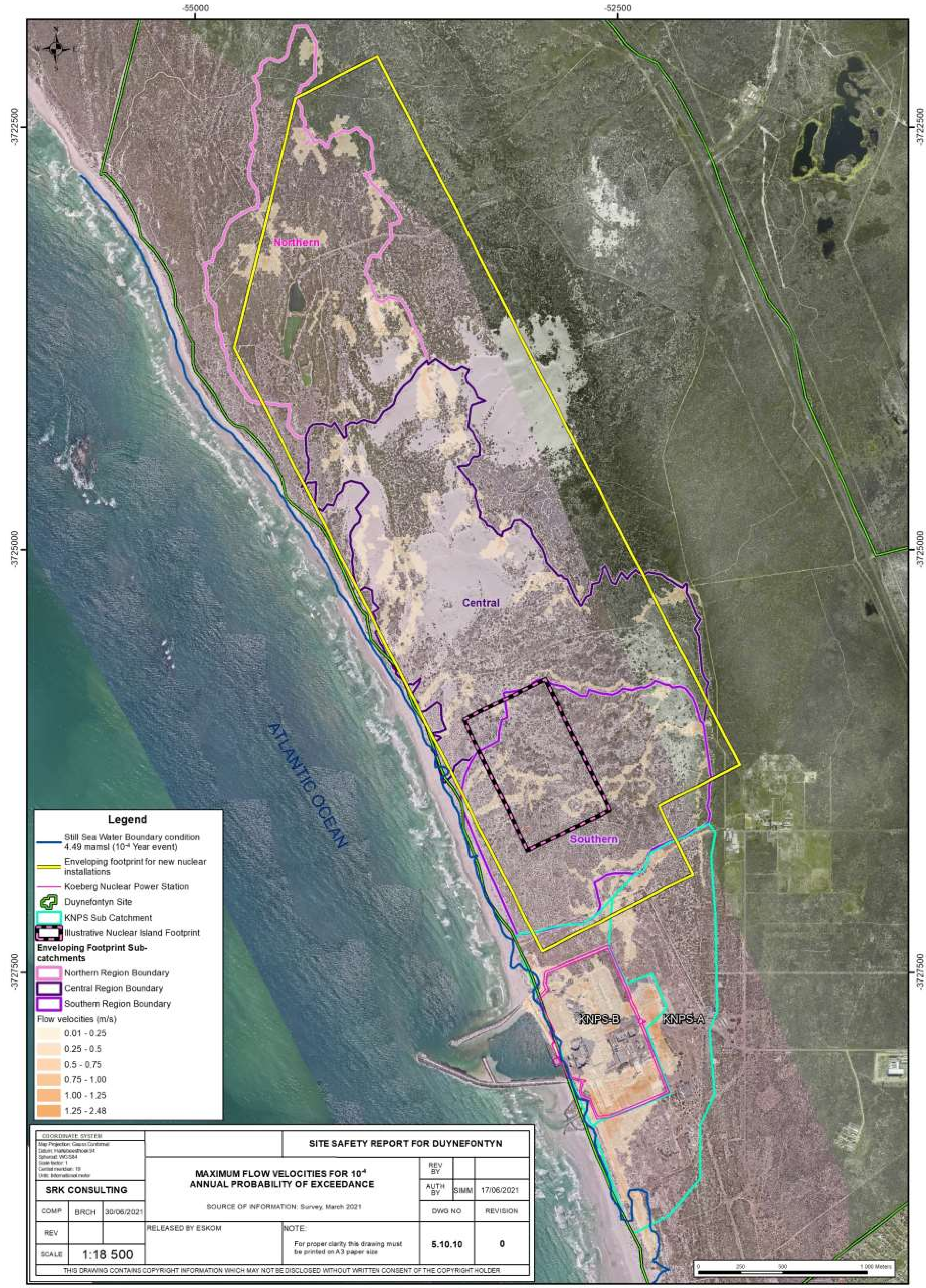

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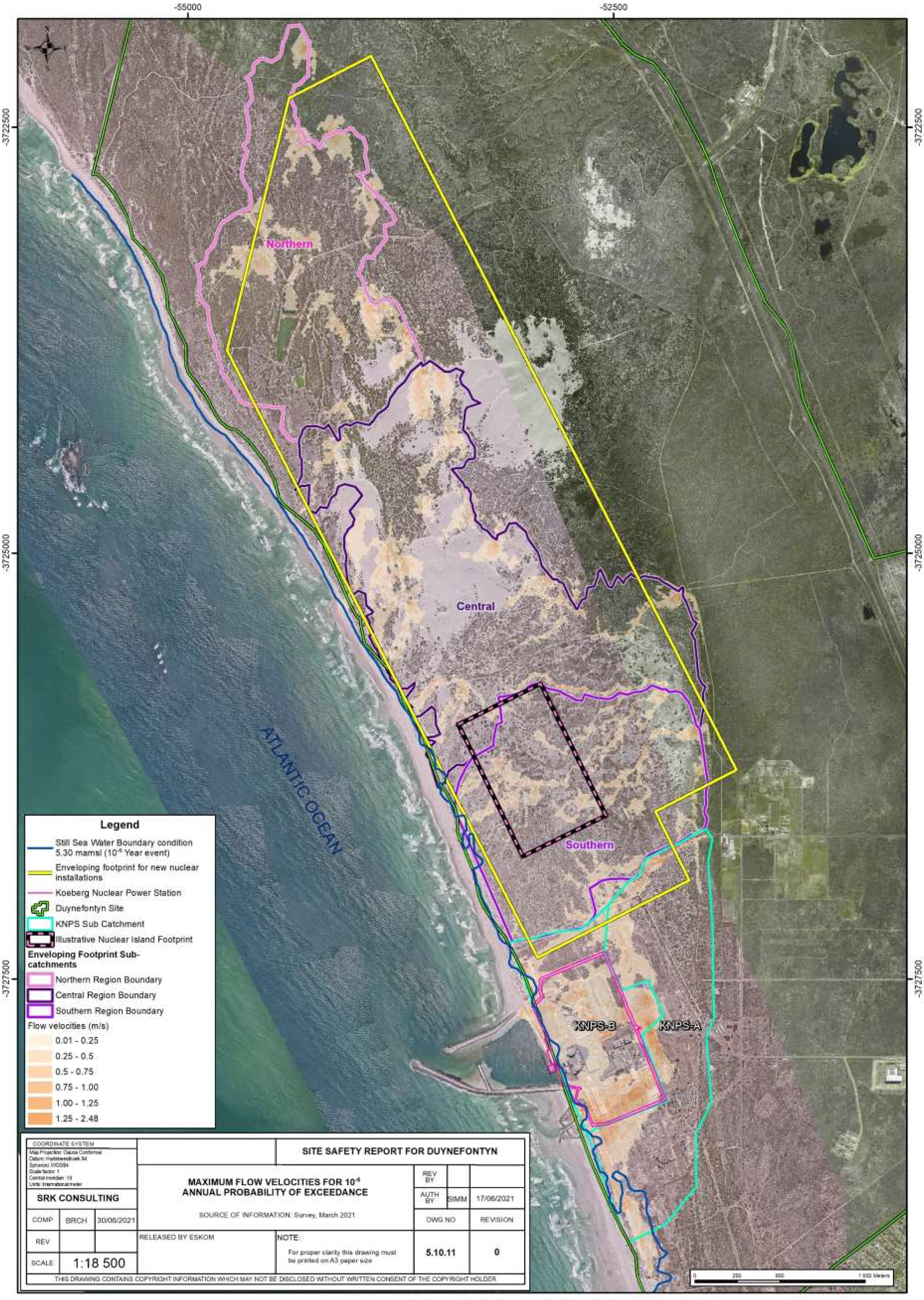

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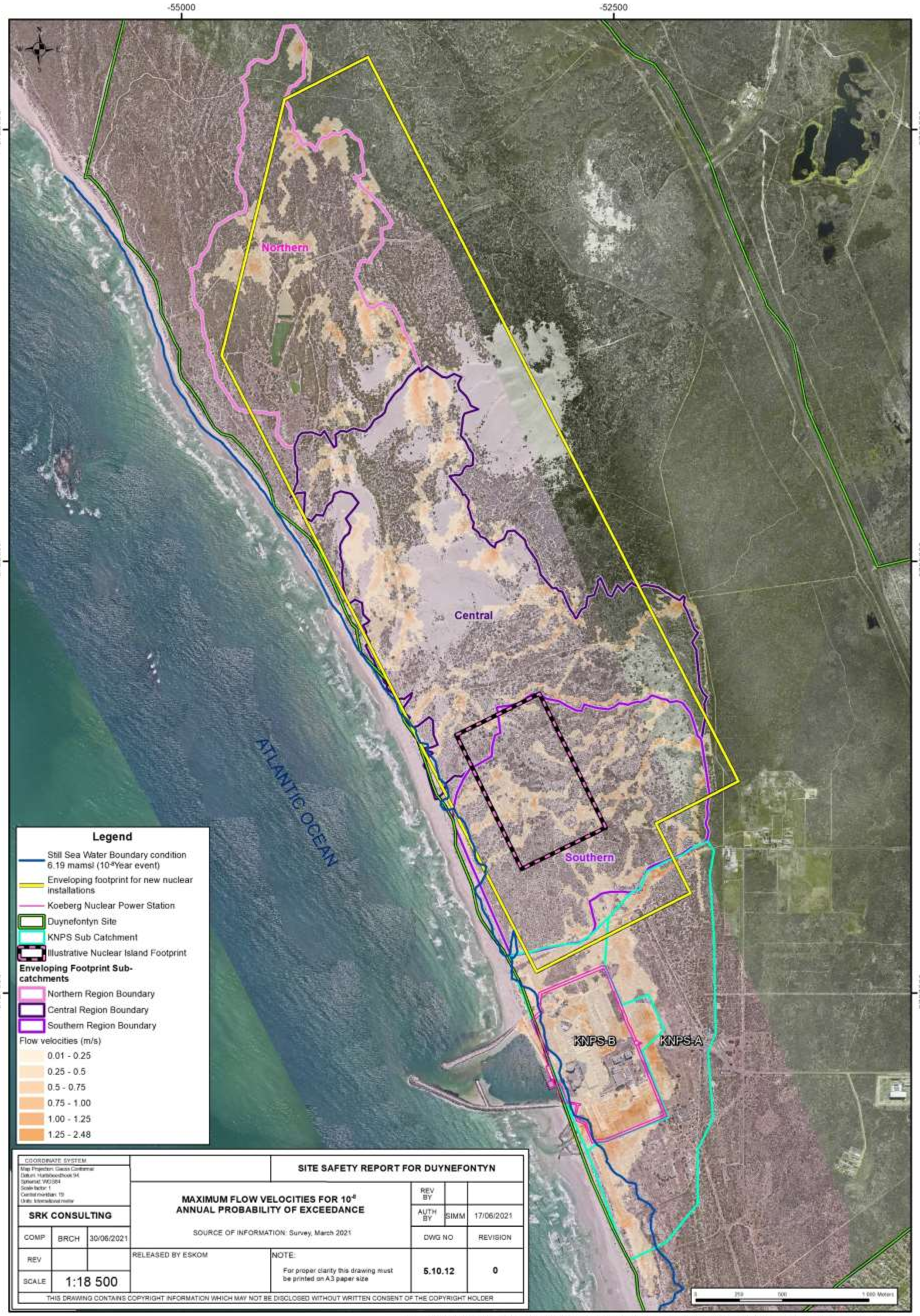

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The following is observed assuming current conditions and excluding the still high water boundary conditions:

KNPS Area

A few local ponding areas are evident in this area. None of the ponding areas are, however, expected to impact on the existing nuclear installation(s) as the KNPS site is built on a platform and surface water is engineered to drain in a southwesterly direction away from the site. The existing formalised storm water management system collects and drains the local runoff from the site. The average flow depths across the site vary from 0.05 m, 0.07 m and 0.08 m for the 10^{-4}, 10^{-6} and 10^{-8} annual probability of exceedance respectively. The maximum flow depths in the low-lying areas vary from 1.81 m, 1.85 m and 1.89 m for the 10^{-4}, 10^{-6} and 10^{-8} annual probability of exceedance respectively.

The average velocities across the site vary from 0.12 m/s, 0.16 m/s and 0.19 m/s for the 10^{-4}, 10^{-6} and 10^{-8} annual probability of exceedance respectively. The maximum velocities along the steeper slopes vary from 1.50 m/s, 1.77 m/s and 2.03 m/s for the 10^{-4}, 10^{-6} and 10^{-8} annual probability of exceedance respectively. Localised erosion or scour may occur during the higher probability of exceedance storm events but not expected to cause any major damage.

Southern Sub-Catchments

In these sub-catchments some potential ponding is evident and hence could have an impact on the illustrative nuclear island footprint. The average flow depths across the catchments vary from 0.02 m, 0.05 m and 0.08 m for the 10^{-4}, 10^{-6} and 10^{-8} annual probability of exceedance respectively. The maximum flow depths in the low-lying areas vary from 2.04 m, 2.16 m and 2.32 m for the 10^{-4}, 10^{-6} and 10^{-8} annual probability of exceedance respectively.

The average velocities across the site vary from 0.03 m/s, 0.06 m/s and 0.09 m/s for the 10^{-4}, 10^{-6} and 10^{-8} annual probability of exceedance respectively. The maximum velocities along the steeper slopes vary from 0.56 m/s, 0.93 m/s and 1.23 m/s for the 10^{-4}, 10^{-6} and 10^{-8} annual probability of exceedance respectively.

Central Sub-Catchments

In these sub-catchments limited ponding is evident, and hence could have a minor impact on the illustrative nuclear island footprint. The average flow depths across the catchments vary from 0.04 m, 0.11 m and 0.20 m for the 10^{-4}, 10^{-6} and 10^{-8} annual probability of exceedance respectively. The maximum flow depths in the low-lying areas vary from 2.33 m, 3.10 m and 3.21 m for the 10^{-4}, 10^{-6} and 10^{-8} annual probability of exceedance respectively.

The average velocities across the site vary from 0.05 m/s, 0.09 m/s and 0.13 m/s for the 10^{-4}, 10^{-6} and 10^{-8} annual probability of exceedance respectively. The maximum velocities along the steeper slopes vary from 0.66 m/s, 1.11 m/s and 1.48 m/s for the 10^{-4}, 10^{-6} and 10^{-8} annual probability of exceedance respectively.

Northern Sub-Catchments

In these sub-catchments some potential ponding is evident and hence could have an impact on the illustrative nuclear island footprint. The average flow depths across the catchments vary from 0.03 m, 0.09 m and 0.16 m for the 10^{-4}, 10^{-6} and 10^{-8} annual probability of exceedance respectively. The maximum flow depths in the low-lying areas vary from 1.40 m, 2.17 m and 2.73 m for the 10^{-4}, 10^{-6} and 10^{-8} annual probability of exceedance respectively.

The average flow velocities across the site vary from 0.06 m/s, 0.12 m/s and 0.16 m/s for the 10^{-4}, 10^{-6} and 10^{-8} annual probability of exceedance respectively. The maximum velocities along the steeper slopes vary from 0.41 m/s, 0.70 m/s and 0.93 m/s for the 10^{-4}, 10^{-6} and 10^{-8} annual probability of exceedance respectively.

In addition to the above assessment, the impact of the still sea water levels as per ***Section 5.9*** has been considered as a boundary condition. The boundary conditions for still high water level 95th percentile' for 10^{-4}, 10^{-6} and 10^{-8} annual probability of exceedance flood event excludes wave set-up and run-up that represent instantaneous boundary conditions. The expected flooding boundary condition along the coastline at the illustrative nuclear island footprint and the KNPS is shown in ***Drawing 5.10.7*** and ***5.10.9***. The downstream boundary condition is the still high sea water level and the following is noted:

- The expected still high water level (boundary condition) for a 10^{-4} year event is 4.49 m amsl.
- The expected still high water level (boundary condition) for a 10^{-6} year event is 5.30 m amsl.
- The expected still high water level (boundary conditions) for a 10^{-8} year event is 6.19 m amsl.

The above are the latest available values at the time of modelling and writing this report.

5.10.11 Evaluation of Flood Hazards and Safety Consequence

The expected storm water run-off peaks and volumes have been quantified for various development stages for both external regional major catchments draining towards the KNPS site and the illustrative nuclear island footprint as well as for sub-catchments within the enveloping footprint. Considering that there are flow paths and ponding areas within the enveloping footprint, a high-level flood hazard assessment has been performed as per the IAEA Specific Safety Guide SSG-18 (International Atomic Energy Agency, 2011). This conservative assessment allows the determination of the possible consequences flooding might have on the safety of the KNPS site and the illustrative nuclear island footprint including the surrounding area.

The flood hazard and safety consequence assessment is carried out for the following development conditions:

- prior to development (current topography);
- during construction (15 m deep open excavation for a portion of the illustrative nuclear island footprint) - This includes the 1.5 m high berm constructed around the proposed 12 m amsl platform or alternatively raise the platform by 1.5 m and construct a 1.5 m deep channel around to cut-off off external run-off;
- during operation (12 m amsl platform with 1.5 m high berm wall around platform or alternatively raise the platform by 1.5 m and construct a 1.5 m deep cut off channel around the platform). – A formalised storm water system would accommodate local rainfall falling on the illustrative nuclear island footprint.
- decommissioning (12 m amsl platform with 1.5 m high berm wall around platform or alternatively raise the platform by 1.5 m and construct a 1.5 m deep cut off channel around the platform). – A formalised storm water system would accommodate local run-off draining from the illustrative nuclear island footprint).

Further details of the models and findings are discussed below.

5.10.11.1 Historical Floods

There are no major watercourses in the vicinity of the site and historical flood records are not available for any of the minor watercourses within the enveloping footprint. In terms of the IAEA Specific Safety Guide SSG-18 (International Atomic Energy Agency, 2011), any development of a strategic nature must not be within a high or medium hazard area as defined in ***Subsection 5.10.11.2***

5.10.11.2 Hazard Assessment Approach

The consequence refers to the effect the hazard will have on the site safety and infrastructure depending on how vulnerable the site is to damage. The product of the safety hazard and safety vulnerability gives the safety consequence, sometimes referred to as the risk. The flood hazard is based on expected flow depth and flow velocity values based on 10^{-8} annual probability of exceedance for the 95th percentile (upper values of the 90 per cent confident intervals) relationship as shown in ***Figure 5.10.3***.

The approach followed at this stage is a deterministic method to develop probabilistic outcomes using quantitative values based on 10^{-4}, 10^{-6} and 10^{-8} annual probability of exceedance for the flood hazard assessment. The platform level assumed for this analysis of a new nuclear installation(s) is at least 12.0 m amsl and the current KNPS platform level is estimated at 8.0 m amsl. If further details on the position and level of the nuclear installation(s) are become known, the risk assessment would be revised.

The site safety consequence is a product of the flood hazard and the vulnerability of the site to the flood hazard. The flood hazard is rated in terms of a high, medium and low category based on ***Figure 5.10.3***. This figure is used to define where, within the hazard rating, a particular site is situated. This information is abstracted from *2D-PCSWMM* model giving an indication of a flow velocity and flow depth at a point of interest, based on the existing topography. From this information, the expected hazard is categorised as given below. The three categories are classified as follows:

- Low hazard (LH): mainly inconvenience, no damage to infrastructure and property;
- Medium hazard (MH): possible damage to infrastructure and property due to high flow depth and velocity;
- High hazard (HH): significant damage to infrastructure and property due to excessive flow depth and velocity.

The site vulnerability is an indicator of how vulnerable the site is to the flood hazard. The relevant categories are described as follows:

- Vulnerability (N): no vulnerability of the site to the hazard;
- Low vulnerability (L): a low degree of vulnerability to the hazard;
- Medium vulnerability (M): a medium degree of vulnerability to the hazard;
- High vulnerability (H): a high degree of vulnerability to the hazard.

The hazard assessment methodology conforms well to defined watercourses, but in the low-lying areas it becomes difficult to model and a conservative approach was adopted. The expected hazard categories and locality thereof are shown in ***Drawing 5.10.13*** to ***Drawing 5.10.21.***

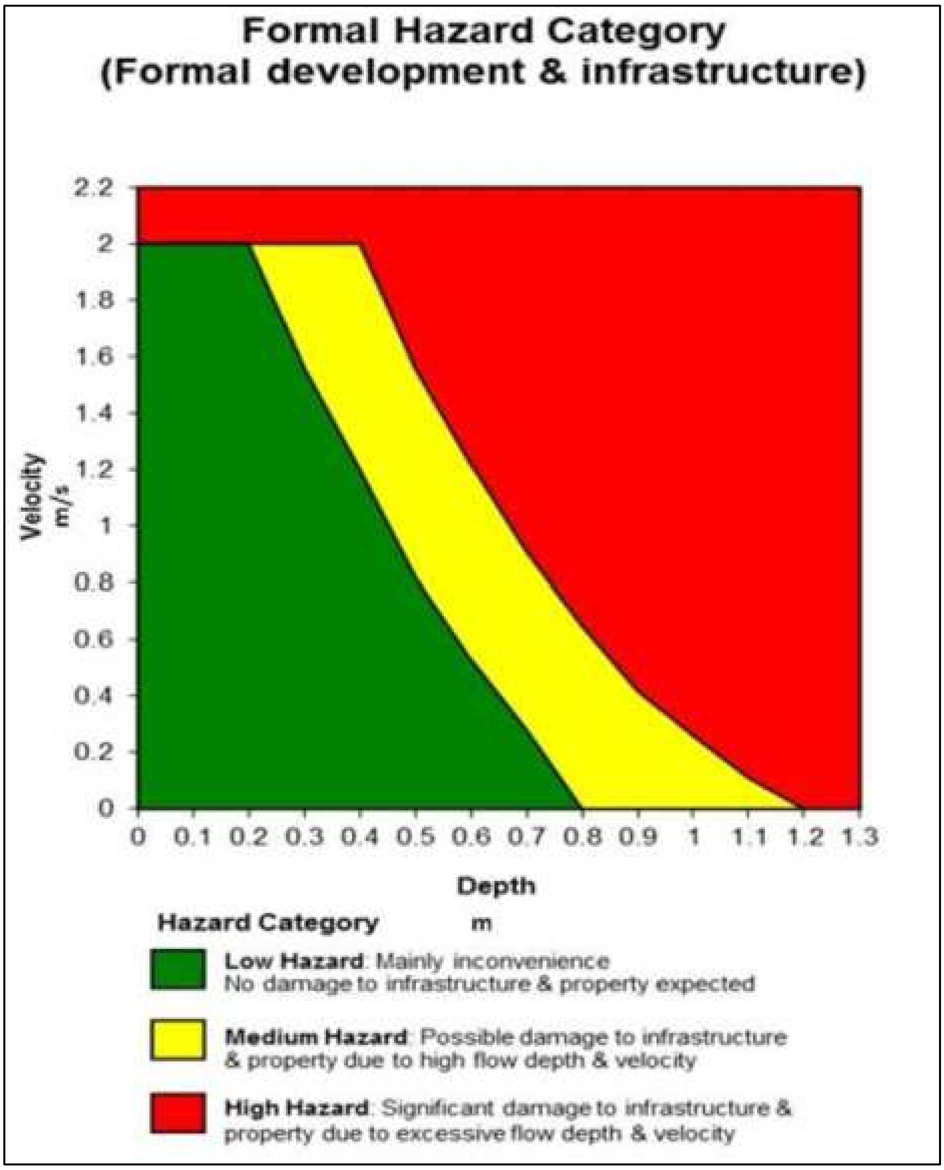


Figure 5.10.3: Flood Hazard Assessment

5.10.11.3 Regional Major Catchments and Sub-Catchments

In this section, both the regional catchments draining towards the KNPS site and the illustrative nuclear island footprint and the sub-catchments within the enveloping footprint and the KNPS catchment have been investigated. The expected hazard categories and locality thereof are shown in ***Drawing 5.10.13***. to ***5.10.21***. The hazard assessment has been based on the 1:10 000 year flood level (10^{-4} annual probability of exceedance) as recommended in the IAEA Specific Standard Guide SSG-18 (International Atomic Energy Agency, 2011) and up to 10^{-8} annual probability of exceedance (Eskom's Technical Specification for Site Safety Reports, NSIP01388 (Rev 1). Section 5.10: Hydrology and Hydraulics (Eskom, 2010).

The expected safety consequence is now quantified by considering the safety hazard values and vulnerability categories for each of the defined watercourses and ponding areas based on the Hazard x Vulnerability. A summary of the site safety consequences for all relevant sub-catchments (prior to construction, during construction and during operation) is given in ***Table 5.10.11*** to ***Table 5.10.13*** below.

Table 5.10.11
Expected Site Safety Consequences – Prior to Development

Catchment Name	Average Hazard Value Along Drainage Line (Velocity x Depth)			Maximum Isolated Hazard Value Along Drainage Line (Velocity x Depth)			[8]Vulnerability			Average Safety Consequence (Hazard x Vulnerability)		
	10^{-4}	10^{-6}	10^{-8}	10^{-4}	10^{-6}	10^{-8}	10^{-4}	10^{-6}	10^{-8}	10^{-4}	10^{-6}	10^{-8}
KNPS												
KNPS-A	<0.01	<0.01	<0.01	1.62	3.14	4.49	N	N	N	N	N	N
KNPS-B	0.01	0.01	0.02	2.62	3.28	3.84	L	L	L	L	L	L
Southern Region												
G21B_DF1	<0.01	<0.01	<0.01	0.5	1.25	2.31	N	N	N	N	N	N
G21B_DF2	<0.01	<0.01	<0.01	0.08	0.26	0.37	N	N	N	N	N	N
G21B_DF3	<0.01	<0.01	<0.01	1.43	2.53	3.41	N	N	N	N	N	N
G21B_DF4	<0.01	<0.01	<0.01	0.34	0.83	1.47	L	M	H	L	M	H
G21B_DF5	<0.01	<0.01	<0.01	0.06	0.23	0.41	L	L	L	L	L	L
G21B_DF6	<0.01	<0.01	<0.01	0.58	1.24	2.08	M	H	H	M	H	H
G21B_DF7	<0.01	<0.01	<0.01	0.1	0.31	0.53	L	L	L	L	L	L
G21B_DF8	<0.01	<0.01	<0.01	0.16	0.46	0.84	L	M	M	L	M	M
Central Region												
G21B_N1	<0.01	<0.01	<0.01	0.05	0.13	0.62	N	N	N	N	N	N
G21B_N3	<0.01	<0.01	<0.01	0.09	0.31	1.53	N	N	N	N	N	N
G21B_N4	<0.01	<0.01	<0.01	1.24	2.79	3.88	N	N	N	N	N	N
G21B_N5	<0.01	<0.01	<0.01	0.73	2.34	3.8	N	N	N	N	N	N

[8] Vulnerability – how vulnerable the site is to the flood hazard which includes the still high water boundary condition from the sea

Catchment Name	Average Hazard Value Along Drainage Line (Velocity x Depth)			Maximum Isolated Hazard Value Along Drainage Line (Velocity x Depth)			[8]Vulnerability			Average Safety Consequence (Hazard x Vulnerability)		
	10^{-4}	10^{-6}	10^{-8}	10^{-4}	10^{-6}	10^{-8}	10^{-4}	10^{-6}	10^{-8}	10^{-4}	10^{-6}	10^{-8}
G21B_O1	<0.01	<0.01	<0.01	0.13	0.42	0.77	L	L	L	L	L	L
G21B_P1	<0.01	<0.01	<0.01	0.01	0.45	0.61	L	L	L	L	L	L

Table 5.10.12
Expected Site Safety Consequences – During Construction

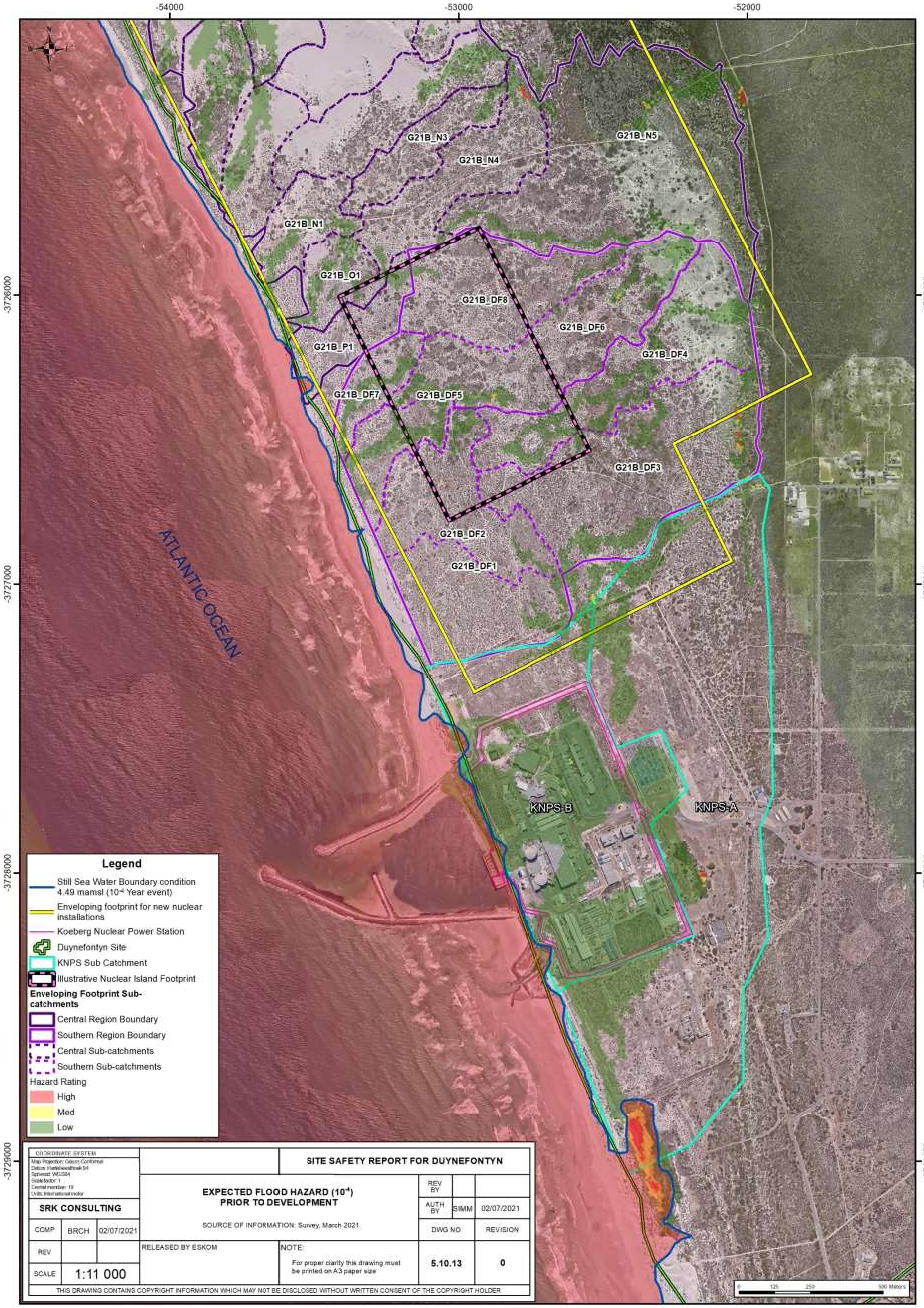
Catchment Name	Average Hazard Value Along Drainage Line (Velocity x Depth)			Maximum Isolated Hazard Value Along Drainage Line (Velocity x Depth)			[9]Vulnerability			Average Safety Consequence (Hazard x Vulnerability)		
	10^{-4}	10^{-6}	10^{-8}	10^{-4}	10^{-6}	10^{-8}	10^{-4}	10^{-6}	10^{-8}	10^{-4}	10^{-6}	10^{-8}
KNPS												
KNPS-A	<0.01	<0.01	<0.01	1.62	3.14	4.49	N	N	N	N	N	N
KNPS-B	0.01	0.01	0.02	2.62	3.28	3.84	L	L	L	L	L	L
Southern Region												
G21B_DF1	<0.01	<0.01	<0.01	0.5	1.25	2.31	N	N	N	N	N	N
G21B_DF2	0.01	0.01	0.02	0.08	0.26	0.37	H	H	H	H	H	H
G21B_DF3	<0.01	<0.01	0.01	1.43	2.53	3.41	H	H	H	H	H	H
G21B_DF4	0.01	0.02	0.03	0.34	0.83	1.47	H	H	H	H	H	H
G21B_DF5	0.02	0.03	0.04	0.06	0.23	0.41	H	H	H	H	H	H
G21B_DF6	0.03	0.04	0.05	0.58	1.24	2.08	H	H	H	H	H	H
G21B_DF7	0.04	0.05	0.06	0.1	0.31	0.53	H	H	H	H	H	H
G21B_DF8	0.05	0.05	0.06	0.16	0.46	0.84	H	H	H	H	H	H
Central Region												
G21B_N1	<0.01	<0.01	<0.01	0.05	0.13	0.62	N	N	N	N	N	N
G21B_N3	<0.01	<0.01	<0.01	0.09	0.31	1.53	N	N	N	N	N	N
G21B_N4	<0.01	<0.01	<0.01	1.24	2.79	3.88	N	N	N	N	N	N
G21B_N5	<0.01	<0.01	<0.01	0.73	2.34	3.8	N	N	N	N	N	N
G21B_O1	0.01	0.01	0.02	0.13	0.42	0.77	L	L	L	L	L	L
G21B_P1	0.02	0.03	0.03	0.01	0.45	0.61	L	L	L	L	L	L

[9] Vulnerability – how vulnerable the site is to the flood hazard which includes the still high water boundary condition from the sea and the open excavation during construction

Table 5.10.13
Expected Site Safety Consequences – During Operation

Catchment Name	Average Hazard Value Along Drainage Line (Velocity x Depth)			Maximum Isolated Hazard Value Along Drainage Line (Velocity x Depth)			Vulnerability[10]			Average Safety Consequence (Hazard x Vulnerability)		
	10^{-4}	10^{-6}	10^{-8}	10^{-4}	10^{-6}	10^{-8}	10^{-4}	10^{-6}	10^{-8}	10^{-4}	10^{-6}	10^{-8}
KNPS												
KNPS-A	<0.01	<0.01	<0.01	1.62	3.14	4.49	N	N	N	N	N	N
KNPS-B	0.01	0.01	0.02	2.63	3.28	3.84	L	L	L	L	L	L
Southern Region												
G21B_DF1	<0.01	<0.01	<0.01	0.5	1.25	2.31	N	N	N	N	N	N
G21B_DF2	<0.01	<0.01	<0.01	0.17	0.3	0.74	L	L	L	L	L	L
G21B_DF3	<0.01	<0.01	<0.01	1.43	2.53	3.41	L	L	L	L	L	L
G21B_DF4	<0.01	<0.01	<0.01	0.34	0.62	0.9	L	L	L	L	L	L
G21B_DF5	<0.01	<0.01	0.01	0.15	0.47	1.07	L	L	L	L	L	L
G21B_DF6	<0.01	<0.01	<0.01	0.45	0.8	1.1	L	L	L	L	L	L
G21B_DF7	<0.01	<0.01	<0.01	0.13	0.42	0.97	L	L	L	L	L	L
G21B_DF8	<0.01	<0.01	<0.01	0.02	0.09	0.22	L	L	L	L	L	L
Central Region												
G21B_N1	<0.01	<0.01	<0.01	0.05	0.13	0.62	N	N	N	N	N	N
G21B_N3	<0.01	<0.01	<0.01	0.09	0.31	1.53	N	N	N	N	N	N
G21B_N4	<0.01	<0.01	<0.01	1.24	2.79	3.88	N	N	N	N	N	N
G21B_N5	<0.01	<0.01	<0.01	0.72	2.34	3.8	N	N	N	N	N	N
G21B_O1	<0.01	<0.01	<0.01	0.23	0.67	0.91	L	L	L	L	L	L
G21B_P1	<0.01	<0.01	<0.01	0.18	0.76	1.37	L	L	L	L	L	L

[10] Vulnerability – how vulnerable the site is to the flood hazard which includes the still high water boundary condition from the sea and sufficient platform/berms and formalised system in place during operational conditions



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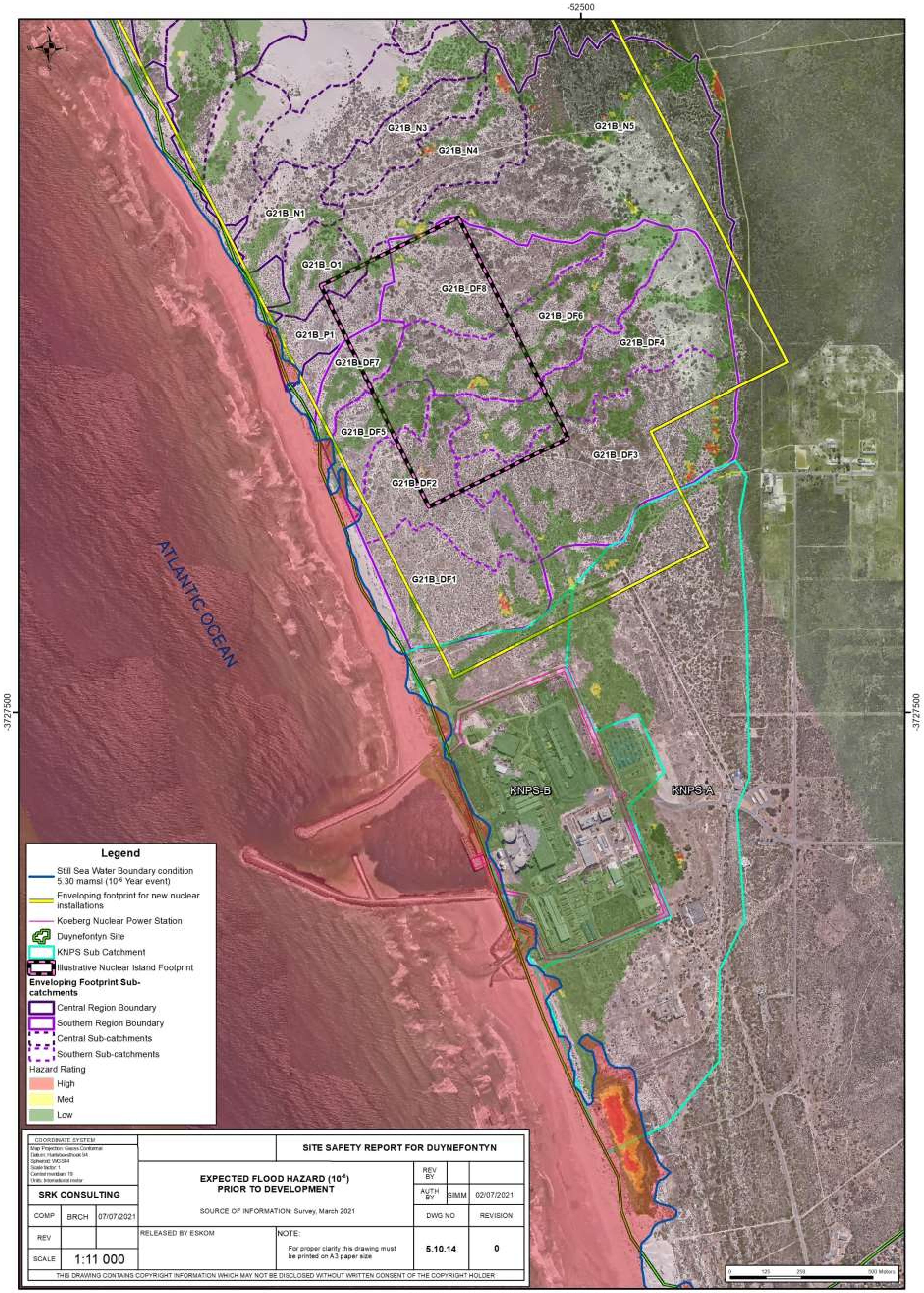

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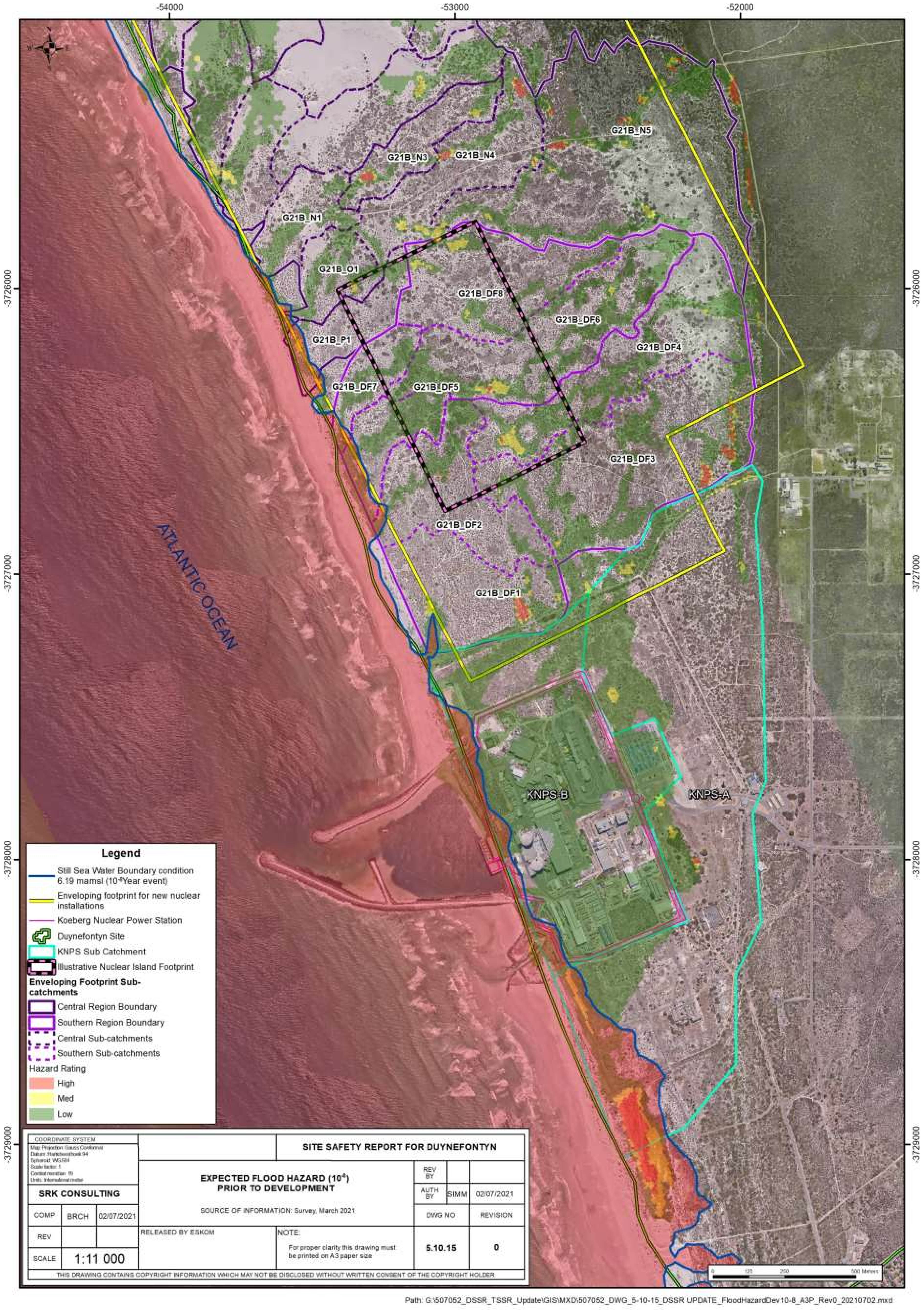

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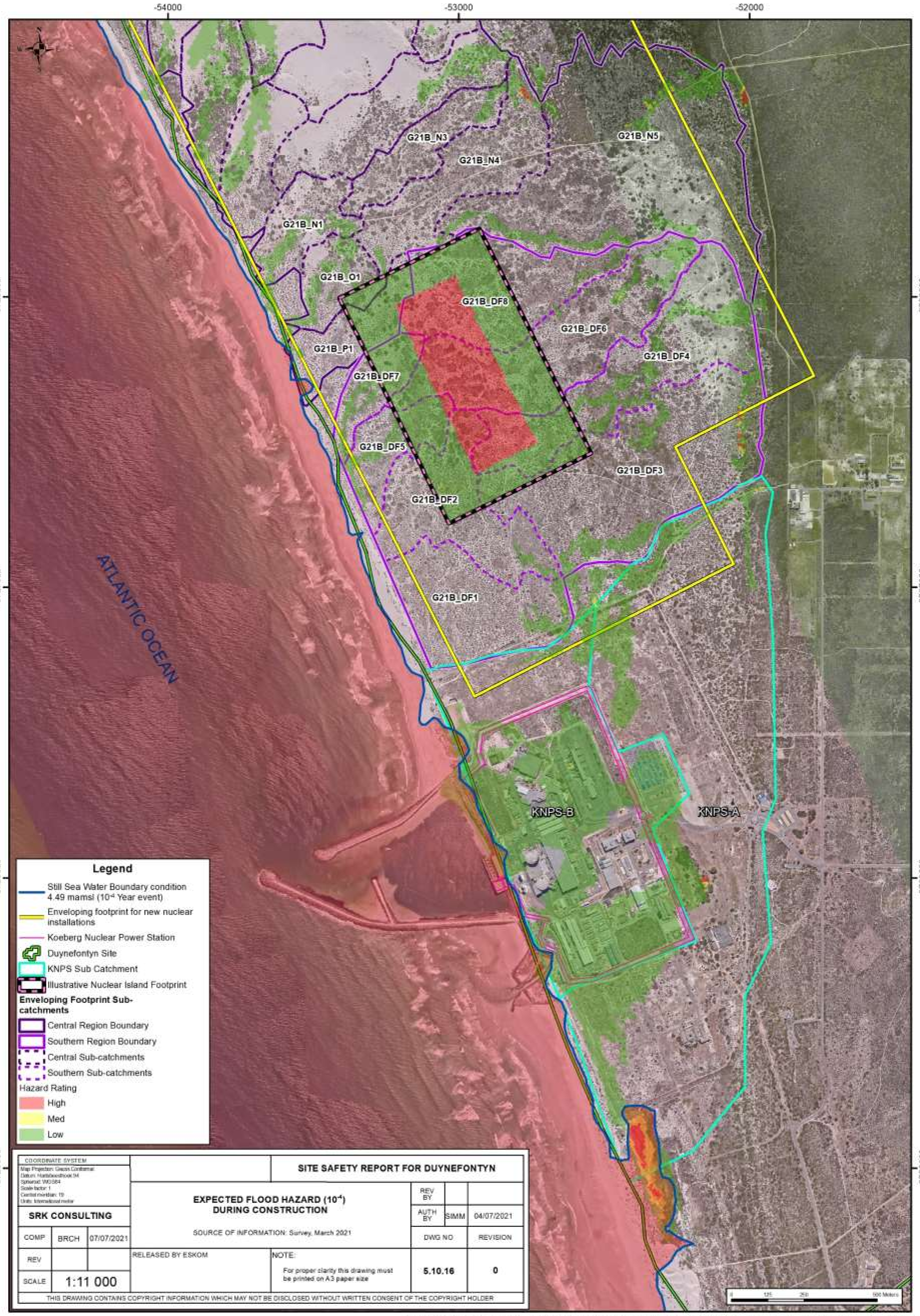

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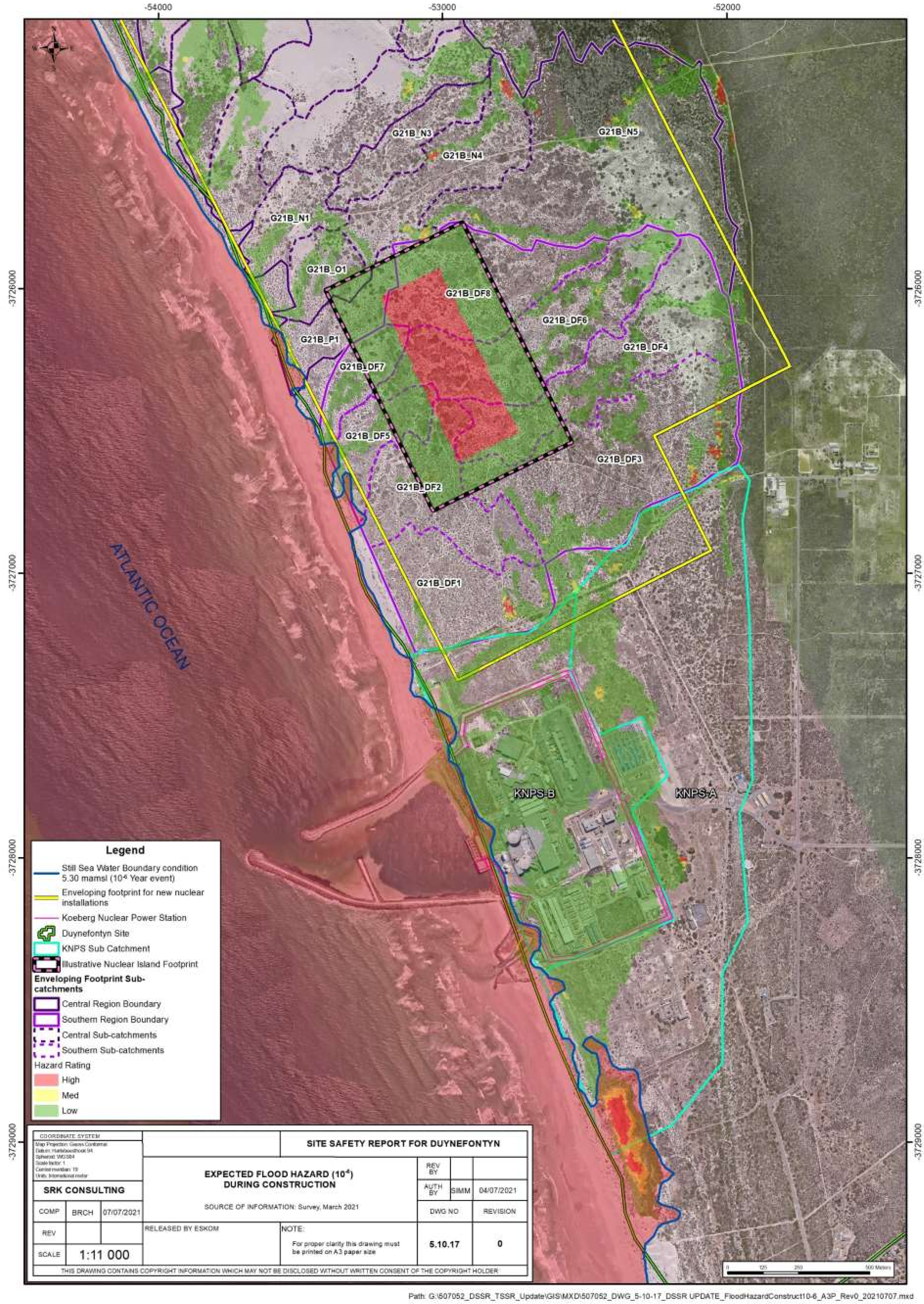

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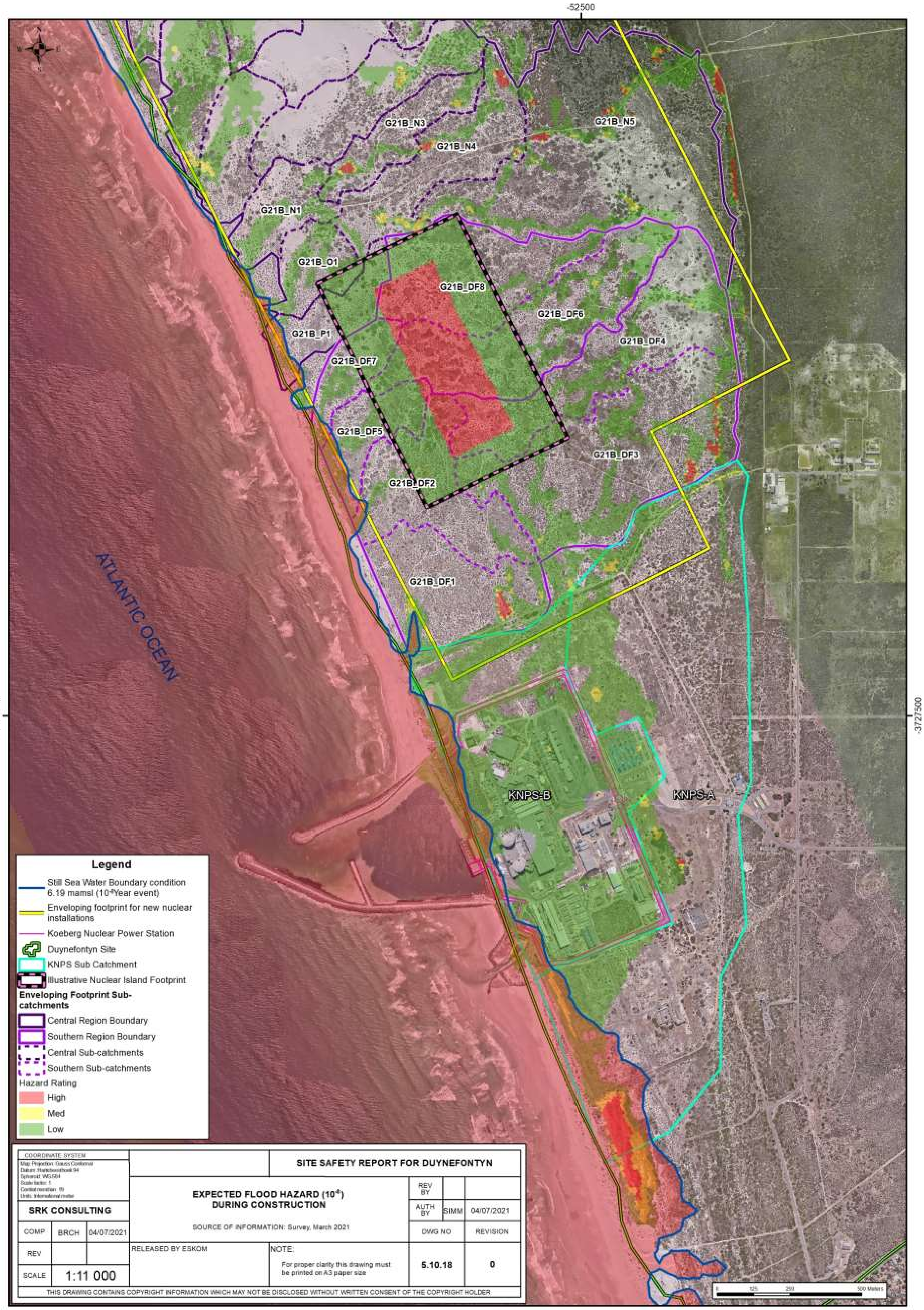

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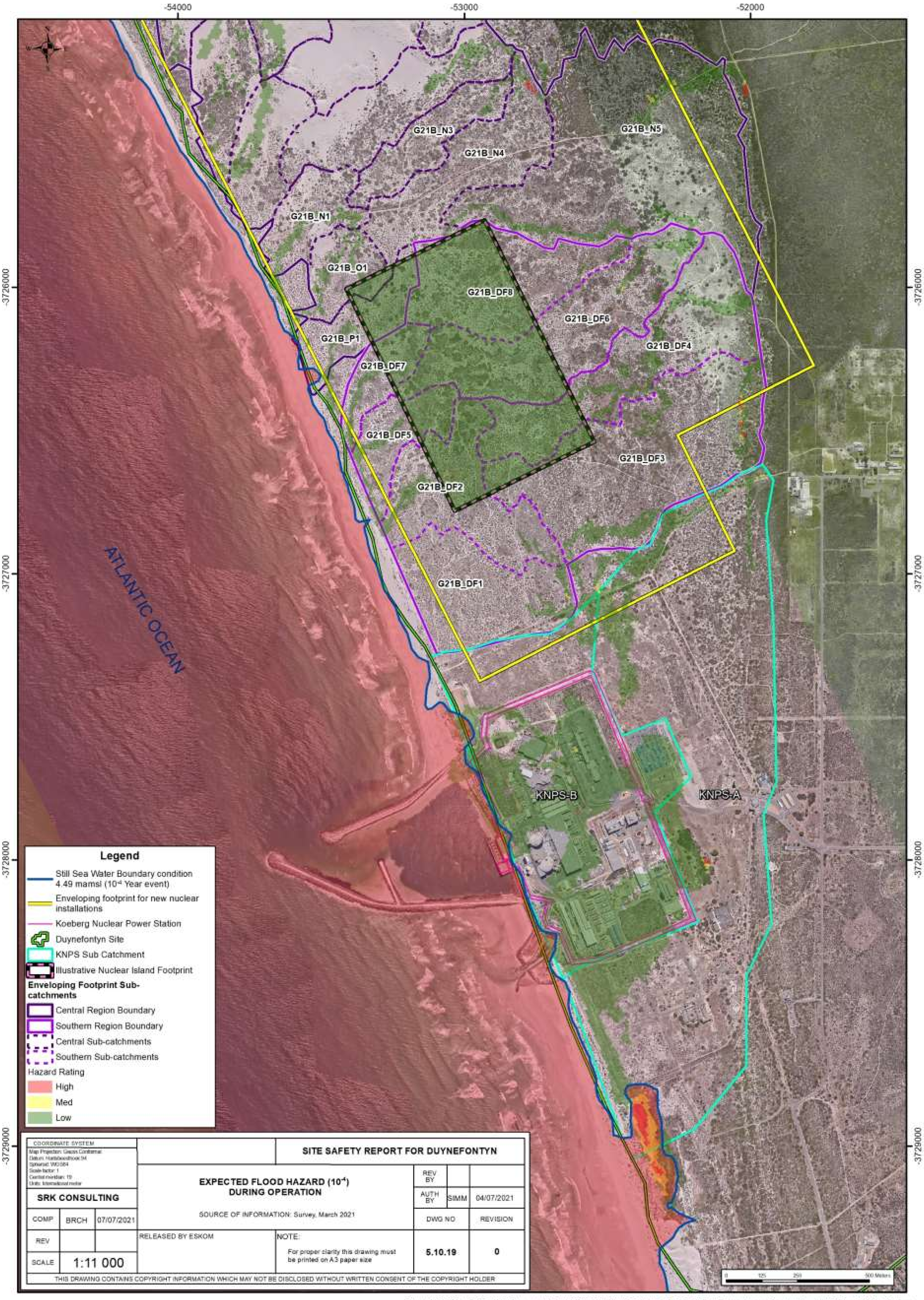

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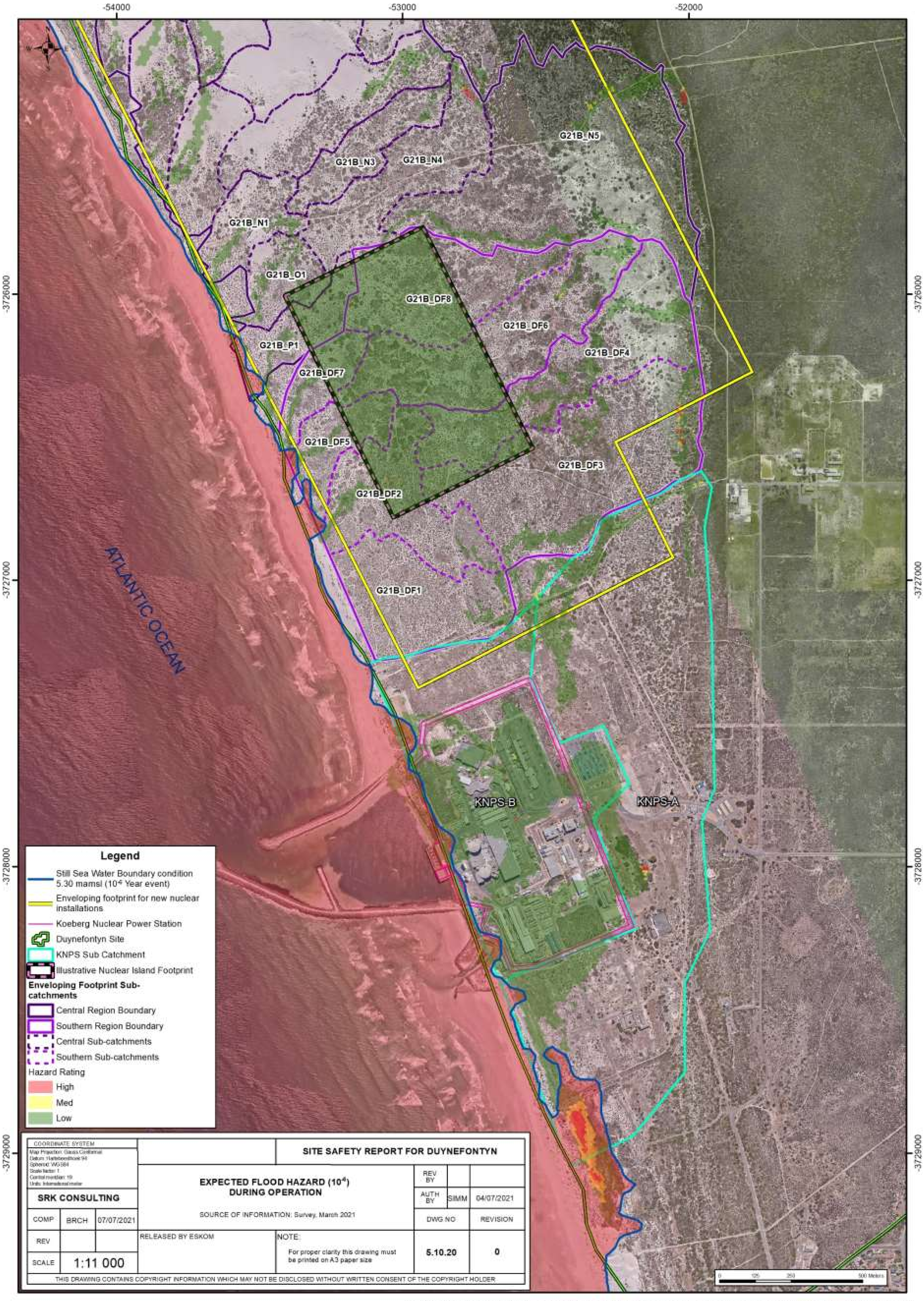

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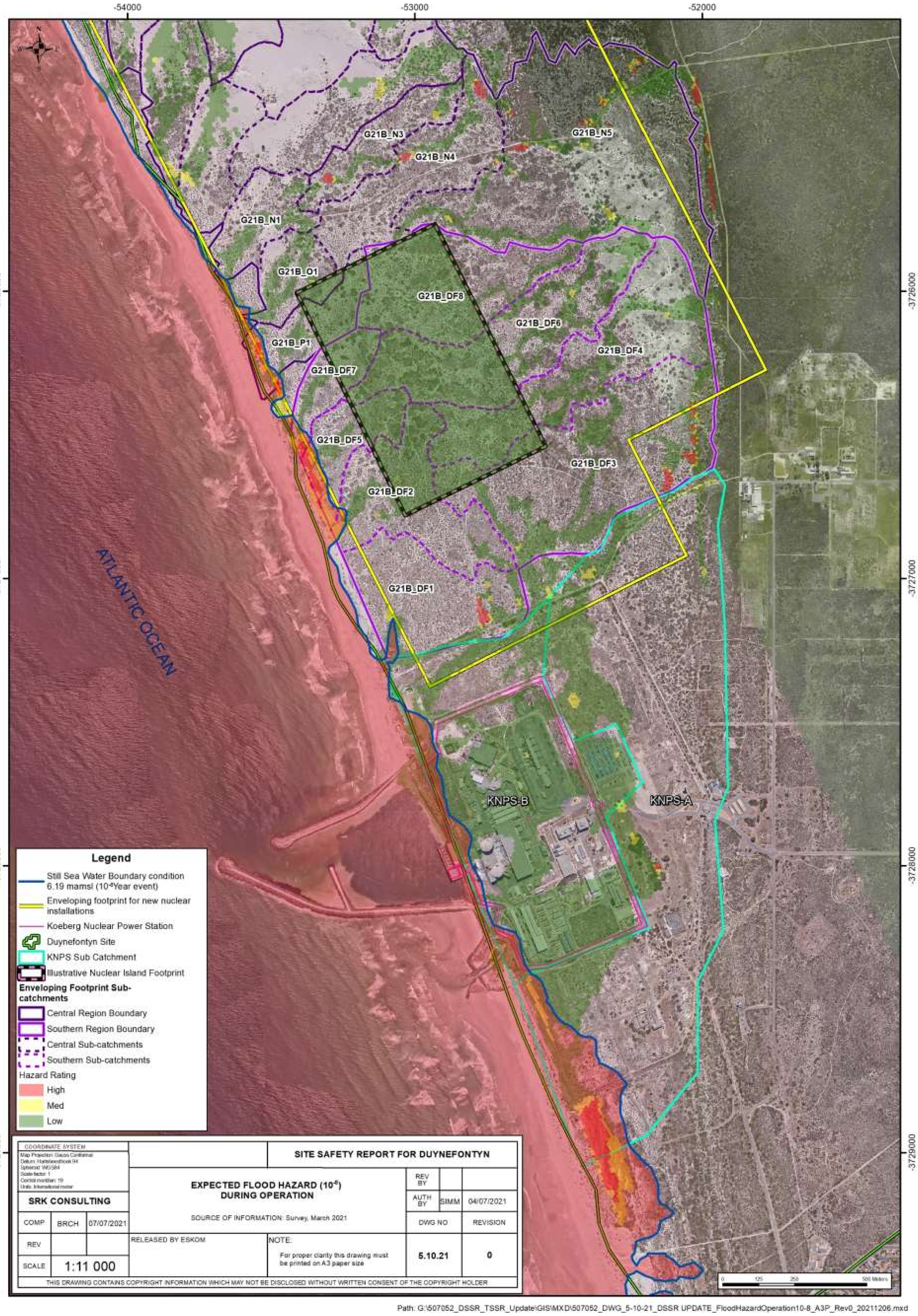
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G21B_O1
G21B_DF8
G21B_DF6
G21B_P1
G21B_DF4
G21B_DF7
G21B_DF5
G21B_DF3
G21B_DF2
G21B_DF1
KNPS-B
KNPS-A
Legend
Still Sea Water Boundary condition 6.19 mamsl (10-4Year event)
Enveloping footprint for new nuclear installations
Koeberg Nuclear Power Station
Duynefontyn Site
KNPS Sub Catchment
Illustrative Nuclear Island Footprint
Enveloping Footprint Sub-catchments
Central Region Boundary
Southern Region Boundary
Central Sub-catchments
Southern Sub-catchments
Hazard Rating
High
Med
Low
SITE SAFETY REPORT FOR DUYNEFONTYN
EXPECTED FLOOD HAZARD (10-6) DURING OPERATION
SRK CONSULTING
COMP
BRCH
07/07/2021
REV
SCALE
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SOURCE OF INFORMATION: Survey, March 2021
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The following conclusions for the expected flooding safety consequence can be made based on the results presented above:

KNPS Area

Prior to any development, the site has a low average hazard value and maximum high hazard value in isolated areas within the site. The average vulnerability and safety consequences (KNPS-B) are low which includes the still high water boundary condition from the sea. The still high water levels (4.49 m amsl, 5.30 m amsl and 6.19 m amsl for a 10^{-4}, 10^{-6} and 10^{-8} annual probability of exceedance respectively) are below the existing main terrace of approximately 8.0 m amsl (see ***Section 5.9***).

Southern Sub-Catchments

Prior to any development, the catchment has a low average hazard value and maximum low/medium/high hazard value in isolated areas within the sub-catchments (DF1-DF8). The average vulnerability and safety consequences (DF2, DF4-DF8) are low/medium/high across the catchment which includes the still high water boundary condition from the sea. The still high sea water levels (4.49 m amsl, 5.30 m amsl and 6.19 m amsl for a 10^{-4}, 10^{-6} and 10^{-8} annual probability of exceedance respectively) are above a portion of the catchment but below the illustrative nuclear island footprint of approximately 12.0 m amsl (see ***Section 5.9***).

During construction of a new nuclear installation(s), the catchment has a low average hazard value and maximum low/medium/high hazard value in isolated areas within the sub-catchments. The average vulnerability and safety consequences (DF2 - DF8) are high within the 15 m deep open excavation for the illustrative nuclear island footprint which includes the still high water boundary condition from the sea. The wells and pumps will extract water from the open excavation and high vulnerability and safety consequence can be considered temporary.

During operation, the catchment has a low average hazard value and maximum low/medium/high hazard value in isolated areas within the sub-catchments. The average vulnerability and safety consequences (DF2 - DF8) are low across the catchment which includes the still high water boundary condition from the sea and all sub-catchments within the illustrative nuclear island footprint. This assumes a 1.5 m high berm wall constructed around platform or alternatively raise the platform by 1.5 m and construct a 1.5 m deep cut-off channel around the platform. A formalised storm water system would accommodate local run-off from the illustrative footprint.

Central Sub-Catchments

Prior to any development, the catchment has a low average hazard value and maximum low/medium/high hazard value in isolated areas within the sub-catchments (E1 – P1). The average vulnerability and safety consequences (O1 and P1) are low/medium/high across the catchment which includes the still high water boundary condition from the sea. The still high water levels (4.49 m amsl, 5.30 m amsl and 6.19 m amsl for a 10^{-4}, 10^{-6} and 10^{-8} annual probability of exceedance respectively) are above a portion of the catchment but below the illustrative nuclear island footprint of approximately 12.0 m amsl (see ***Section 5.9***).

During construction of a new nuclear installation (s) the catchment has a low average hazard value and maximum high low/medium/hazard value in isolated areas within the sub-catchments. The average vulnerability and safety consequences (O1 and P1) are low for the illustrative nuclear island footprint which includes the still high water boundary condition from the sea.

During operation, the catchment has a low average hazard value and maximum low/medium/high hazard value in isolated areas within the sub-catchments. The average vulnerability and safety consequences (O1 and P1) are low across the catchment which includes the still high water boundary condition from the sea and all sub-catchments within the illustrative nuclear island footprint. This assumes 1.5 m high berm constructed around the proposed 12 m amsl platform or alternatively raise the platform by 1.5 m and construct a 1.5 m deep channel around to cut-off off external runoff. In addition, the formalised storm water draining the local runoff is in place.

Northern Sub-Catchments

In these catchments (A1 – G3) although some potential ponding is expected resulting in a low/medium/high flood hazard, the catchments fall outside the existing KNPS catchment and the illustrative nuclear island footprint. If the footprint is moved into these catchments, the safety consequence would need to be evaluated. The still high water levels (4.49 m amsl, 5.30 m amsl and 6.19 m amsl for a 10^{-4}, 10^{-6} and 10^{-8} annual probability of exceedance respectively) are below the catchment (see ***Section 5.9***).

In addition, the final extreme high water levels obtained from ***Section 5.9*** (will be used to determine the final height of the proposed plant terrace and the resultant impact on the site location once the final position and elevation of the terrace is known. The expected flooding safety consequence would need to be updated to incorporate the above changes.

5.10.12 Illustrative Nuclear Island Footprint Assessment

A safety hazard assessment for the nuclear installation nuclear installation(s) area has also been performed for the following four development conditions:

- prior to nuclear installation development, assuming current catchment conditions;
- during nuclear installation construction, assuming that a portion of the illustrative nuclear island footprint area is initially excavated to rock level at a depth of about 15 m - This includes the 1.5 m high berm constructed around the proposed 12 m amsl platform or alternatively raise the platform by 1.5 m and construct a 1.5 m deep channel around to cut-off off external run-off;
- nuclear installation operation, assuming that the nuclear installation illustrative nuclear island footprint area is fully developed with all storm water infrastructure completed and area fully paved. This includes the 1.5 m high berm constructed around the proposed 12 m amsl platform or alternatively raise the platform by 1.5 m and construct a 1.5 m deep channel around to cut-off off external run-off;
- during the decommissioning phase of the nuclear installation(s).

In addition to the above, an assessment has also been made for the existing KNPS catchment based on a current terrace level of approximately 8 m amsl. From the results given above it can be concluded that a small portion of KNPS site would be subjected to a high vulnerability and safety consequence due to the still high water boundary condition from the sea (see ***Section 5.9***) for low lying areas below the 8 m amsl existing terrace.

The expected hazard areas for the above development conditions (10^{-4}, 10^{-6} and 10^{-8} annual probability of exceedance respectively) for the 95th percentile (upper values of the 90 per cent confident intervals) are shown in ***Drawing 5.10.13*** to ***Drawing D-5.10.21***.

The illustrative nuclear island footprint terrace level is assumed to be approximately 12 m amsl. Final layout, elevations, and position of the planned nuclear installation(s) for the operation stage has not yet been concluded. This assessment would need to be updated once more details on the final position and elevation of the planned nuclear installation(s) are known.

5.10.12.1 Site-Specific Storm Water Management

Having quantified and assessed the regional hydrology and hydraulics of the site, local site storm water management is now considered for the nuclear installation(s). It is at this stage assumed that all the possible illustrative footprints of the nuclear installation(s) have the same area of approximately 47 ha.

5.10.12.2 Prior to Construction

The illustrative nuclear island footprint is covered mainly by fynbos and a few wetlands within the low-lying areas. The wetlands are primarily fed by groundwater as there are no noticeable local watercourses. In the event of significant rainfall, it is expected that some temporary ponding will occur in the low-lying areas between the sand dunes, parallel to the coastline. This is mainly based on the contour information which shows that there are several low-lying areas in which storm water will pond. The anticipated site conditions during various stages of the development are presented below.

5.10.12.3 During Construction

Based on previous experience gained from the KNPS catchment as well as other deep excavation sites, a large excavation will be required to get to bedrock for the foundations of the nuclear installation(s). It is expected that the site illustrative nuclear island footprint will have a surface area of approximately 47 ha and the depth would be about 15 m for the current site position.

5.10.12.4 During Operation

During operation, it is expected that the illustrative nuclear island footprint area would be covered mainly by paved areas and the elevation of the nuclear installation(s) would be at a safe level therefore not impacted by a still high water level. It is currently assumed that the platform for the illustrative nuclear island footprint will have an elevation of 12 m amsl. This includes the 1.5 m high berm constructed around the proposed 12 m amsl platform or alternatively raise the platform by 1.5 m and construct a 1.5 m deep channel around to cut-off external runoff.

5.10.12.5 During De-Commissioning

During this stage it is expected that run-off from the site could decrease due to demolition activities which would cause waste material to be stored and transported off the site, increasing the impervious area. The values will be like that of the operational stage. For the purpose of this study, the higher value of the two has been selected.

5.10.12.6 Description of Storm Water Model

The SCS-SA model (University of KwaZulu-Natal, 2004) has again been chosen as the most appropriate due to the size of the respective catchment for each of the above defined land use conditions.

5.10.12.7 Input Parameters

The abovementioned hydrological model has been used to determine the storm water peak flows and volumes and the potential impact on the nuclear installation(s).

The main input parameters and variations thereof for the storm water model are summarised in ***Table 5.10.14***.

Table 5.10.14
SCS-SA Input Parameters for Typical Nuclear Installation Site

Parameter	Value	Reason
Soil Conservation Services(SCS–SA Model)		
Probability of Occurrence (years) 10^{-1} 10^{-2} 10^{-3} 10^{-4} 10^{-5} 10^{-6} 10^{-8}	24-hour Rainfall depth (mm) 65.2 95.1 124.5 154.0 183.2 212.6 271.4	Only long-term daily rainfall data available for the area which is one of the SCS-SA models input parameters. The intensities are distributed over 24-hours using a storm type for the area. As detailed in ***Subsection 5.10.7.5*** Upper limit was the PMP or 10^{-4} return period as recommended by the NRC NUREG/CR-7046 (United States Nuclear Regulatory Commission, 2011) and NNR RG-0011 (National Nuclear Regulator, 2016). Extreme storm events were also determined based on ***Chapter 6*** (up to a 10^{-8} annual probability of exceedance frequency for the 95th percentile) which included any increase in rainfall intensities due to climate change.
Rainfall distribution	SCS Type II	Storm type distribution as detailed in SCS manual.
Catchment curve number (CN) - pre development - construction - operation	 27 81 85	Sandy soil, SCS Type 'A' with high infiltration rate (208 mm/h) ***Section 5.11*** (Geohydrology) *and* infiltration test results (***Appendix 5.10.B***) High run-off potential due to rock and paved areas for construction & operational stages.

5.10.12.8 Storm Water Modelling of the Illustrative Nuclear Island Footprint

As stated above, final details are not currently available on the layout and elevations of the plant area. At this stage one can only model a typical catchment and changes thereof for the illustrative footprint. This gives an indication of the expected changes in run-off peaks and volumes due to the different development stages. During the design phase, once more details on the plant layout are known, a detailed and refined risk assessment can be carried out. Based on the illustrative nuclear island footprint and above input parameters, total peak flows and volumes at the nuclear installation could be determined for the following stages:

- prior to development (current topography);
- during construction (15 m deep open excavation for a portion of the illustrative nuclear island footprint);
- during operation (12 m amsl platform for illustrative nuclear island footprint - This includes the 1.5 m high berm constructed around the proposed 12 m amsl platform or alternatively raise the platform by 1.5 m and construct a 1.5 m deep channel around to cut-off off external runoff);
- decommissioning (12 m amsl platform for illustrative nuclear island footprint - This includes the 1.5 m high berm constructed around the proposed 12 m amsl platform or alternatively raise the platform by 1.5 m and construct a 1.5 m deep channel around to cut-off off external runoff).

The results of the SCS-SA model for the nuclear installation(s) are summarised in ***Table T-5.10.15*** for the various development stages.

Table 5.10.15
Peak Flow Rates and Run-off Volumes

	Pre development		During Construction		Operation		De-commissioning	
*Probability of Occurrence (years)	Peak Flow (m^3/s)	Run-off Volume ($m^3 \times 10^3$)	Peak Flow (m^3/s)	Run-off Volume ($m^3 \times 10^3$)	Peak Flow (m^3/s)	Run-off Volume ($m^3 \times 10^3$)	Peak Flow (m^3/s)	Run-off Volume ($m^3 \times 10^3$)
10^{-1}	0.00	0.0	1.94	13.8	2.31	16.3	2.31	16.3
10^{-2}	0.01	0.5	3.55	25.1	4.05	28.5	4.05	28.5
10^{-3}	0.11	2.0	5.30	37.3	5.87	41.3	5.87	41.3
10^{-4}	0.35	4.4	7.06	49.6	7.65	54.1	7.65	54.1
10^{-5}	0.74	7.7	8.83	62.3	9.45	67.1	9.45	67.1
10^{-6}	1.27	11.8	10.69	75.6	11.31	80.7	11.31	80.7
10^{-8}	2.63	21.6	14.28	101.7	14.89	107.2	14.89	107.2

**Due to the small catchment areas, low rainfall depth and high infiltration rates the lower storm events generated very low to zero run-off peaks and volumes.*

Based on the above results, the following observations are made:

- During the stage prior to the nuclear installation(s) development, low run-off peaks and volumes are expected. This is due to the high infiltration rate as a result of the sandy soils.
- During the construction stage a large increase in runoff peaks and volumes is expected due to the high runoff potential of the rock floor of the foundation excavation, as well as mainly covered side slopes with an impervious layer for the stability of the excavation. The illustrative nuclear island footprint has a high average hazard value due to the flow depth with no direct outlet due to the deep foundation excavation but will have wells and pumps to extract the seepage and surface water during a storm event. This is considered a short term temporary scenario during the construction phase.
- For the operational stage there is little difference when compared with the run-off flows for the construction stage as it is assumed that once the deep excavations have been backfilled and closed most of the previously excavated area would now be paved and hence would still have a high run-off potential. With the 1.5 m high berm constructed around the proposed 12 m amsl platform or alternatively raise the platform by 1.5 m and construct a 1.5 m deep channel around to cut-off external run-off and the illustrative nuclear island footprint has a low average hazard value. This also assumes that local run-off due to the nuclear installation(s) will be accommodated in a formalised storm water management system draining towards the sea and not have any impact

on the existing KNPS.

- During the de-commissioning stage, it is expected that the majority of the illustrative nuclear island footprint would be disturbed by vehicular traffic as well as by waste materials from the nuclear installation(s). The run-off potential for this condition is expected to be like that of the construction stage.
- The peak flow is an indication of the total flow leaving the illustrative nuclear island footprint which would be accommodated in a formalised storm water system during the detailed design and subject to the final layout.

5.10.13 Mitigation Measures for Storm Water Control

Although this can be deemed detailed design, mitigating the impact around the plant area has been included as part of the site safety report. From the above assessment it is observed that the nuclear installation (s) would have a significant effect on the localised run-off peaks and volumes due to the increased impervious area. This impact needs to be mitigated to reduce the impact on the surrounding environment to an acceptable level. In terms of the National Water Act No. 36 of 26 August 1998, (Republic of South Africa, 1998) Government Notice 704 (GN704), water emanating from clean and dirty areas need to be separated and the dirty water contained on site. In terms of best practise, the increased peak flow from the catchment needs to be reduced to that of the virgin condition. One of the international best practice approaches is the application of BMPs when considering mitigation measures to prevent negative impacts on the environment. The BMPs approach is defined as a multi-disciplinary approach in applying appropriate technology to preserve the environment and comply with accepted safety standards. The BMPs approach is taken from the Best Management Practise Manual for New Jersey (New Jersey Department of Environmental Protection, 2004).

Best Management Practices can furthermore be divided into two main categories as follows:

- **structural BMPs** dealing with physical structural control measures;
- **non-structural BMPs** dealing with non-structural measures, such as policy documents, guidelines, contracts between various parties for the upkeep and maintenance of the structural BMPs.

BMPs are used internationally to minimise the impact from the site on the surrounding area due to a potential increase in run-off peaks and deterioration in water quality through non-structural practices and then providing treatment as necessary through a network of structural facilities distributed throughout the site.

BMPs place an emphasis on non-structural storm water management measures, seeking to maximise their use prior to utilising structural BMPs.

Non-structural BMPs used in low impact development seek to reduce storm water run-off impacts through sound site planning and design. Non-structural measures include such practices as:

- minimising site disturbance;
- preserving important site features;
- reducing and disconnecting impervious cover;
- flattening slopes;
- utilising native vegetation;
- minimising turf grass lawns;
- minimising erosion;
- maintaining natural drainage features and characteristics.

Structural BMPs used to control and treat run-off will be considered during the design phase of the nuclear installation(s). Structural BMPs include various types of basins, filters, surfaces, and devices located on site.

Storm water management on the site will require the maximum practical use of the following nine non-structural strategies at the site and will only be considered in detail during the design phase:

- protect areas that provide water quality benefits or areas particularly susceptible to erosion and sediment loss;
- minimise impervious surfaces and break up or disconnect the flow of run-off over impervious surfaces;
- maximise the protection of natural drainage features and vegetation;
- minimise the magnitude of decrease in the ‘time of concentration’ during construction and operation;
- minimise land disturbance including clearing and grading;
- minimise soil compaction;
- provide low maintenance landscaping that encourages retention and planting of native vegetation and minimises the use of lawns, fertilizers and pesticides;
- provide vegetated open-channel conveyance systems that discharge

into and through stable vegetated areas;

- provide preventative source controls.

5.10.14 Monitoring

Although not part of site safety, recording of daily rainfall events which will enhance future modelling of the site hydrology will continue as is presented in ***Table 5.10.13*** to both supply information for future decision-making and for monitoring the control measures implemented to mitigate any negative impacts.

Baseline monitoring of surface water quality is restricted to the site only, and surface water is only generated during a significant storm event. The resulting once-off baseline monitoring results are given in ***Appendix 5.10.E*** and the laboratory analytical certified results are included in ***Appendix 5.10.D***.

Three sampling points KSW 1, KSW 2 and KSW 3 were selected for baseline monitoring. Selection of sampling points was based on possible areas where ponding may occur within the enveloping footprint and flowing watercourses in the area. The selected sampling points are described as follows:

- KSW 1 and KSW 2 positioned at the far northern boundary of the enveloping footprint within the Koeberg Nature Reserve;
- KSW 3 positioned upstream and east of the existing KNPS.

Refer to ***Drawing 5.10.3*** showing the sampling point locations.

Analytical results were compared to the Water Quality Guidelines for the Natural Marine Environment (Department of Water Affairs and Forestry, 1996) since the receiving environment will be the marine environment. All constituents fall within the recommended specification for the natural marine environment.

Table 5.10.16
Summary of Proposed Measurements and Monitoring

Measurements	Specific Data	Frequency	Duration
Rainfall	Daily rainfall measured on a 15 min interval during rainfall events	Daily	Started in Jan 2008 and continuing in the future during life cycle of the nuclear installation(s) (***Appendix 5.10.A***).
Surface water quality (perennial rivers) and seasonal wetlands. Specific points KSW 1, KSW 2 and KSW 3 have been identified for the baseline monitoring. Additional monitoring points should be identified downstream of the planned nuclear installation(s) and be monitored on a continual basis. These points can only be confirmed once the final position and storm water outlet points of the nuclear installation(s) have been decided upon.	pH, EC, full spectrum chemical analysis including Inductively Coupled Plasma (ICP) for all metals Analysis done by an accredited laboratory. Certified results can be seen in ***Appendix 5.10.D***	Bi-annually. Once- off in December 2008 and May 2009	Once-off in both dry and wet season before construction to collect pre-development information. Monitoring should re-commence when construction starts and continue for full duration of the life of the nuclear installation(s) (Results evaluation are attached as (***Appendix 5.10.E***).
Infiltration and permeability	Permeability and infiltration testing ***Section 5.15***. (Geotechnical Characterisation).		Once-off measurement during field investigations prior to construction activities.

Once the final design on the selected footprint on site has been completed, the flood peaks and run-off volumes would need to be refined and updated. A refined water quality monitoring programme should be developed once the design of the nuclear installation(s) is complete.

The hydrology and hydraulics monitoring programme relates to design, construction, operational and/or related safety assessment stages. The monitoring under ***Sections 5.2*** (Monitoring), ***5.8*** and ***5.9*** covers the site safety compliance with the siting requirements.

5.10.15 Management of Uncertainties

The uncertainties associated with the hydrology and hydraulics for the site are carried through from ***Sections 5.8***, ***5.9*** and ***5.11.*** The relevant sections have been referenced accordingly.

Related uncertainties and management thereof in the current assessment are presented in ***Table 5.10.17*** below.

Table 5.10.17
Management of Uncertainties

Uncertainty	Description and Management
Rainfall data	The estimation of 24-hour design rainfall depths has been addressed and the uncertainty managed in ***Section 5.8*** (Meteorology).
Probability distributions	The limited available data to plot probability distribution has been addressed and the uncertainty managed in both ***Section 5.9*** (Oceanography & Coastal Engineering) and ***Section 5.8*** (Meteorology).
Infiltration and permeability data	Considered permeability and infiltration rates based on a ground water assessment and modelling at the site including once off infiltration rates measured on site. The infiltration and permeability has been addressed and the uncertainty managed in ***Section 5.11*** (Geohydrology).
Tidal and Wave Heights	The increase in water levels due to tides and wave heights has been addressed and the uncertainty managed in ***Section 5.9*** (Oceanography & Coastal Engineering).
Tsunami data	The increase in water levels during a Tsunami has been addressed and the uncertainty managed in ***Section 5.9*** (Oceanography & Coastal Engineering)
Climate change	The sea level rise has been addressed and the uncertainty managed in ***Section 5.9*** (Oceanography & Coastal Engineering) and the increase in rainfall intensities has been addressed and the uncertainty managed in ***Section 5.8*** (Meteorology).

5.10.16 Management System

A quality assurance programme was established to control the effectiveness of the execution of these investigations, the data analysis, and the formulation of conclusions on the site acceptability. This conforms to the overall management system for this SSR, which is described in detail in ***Chapter 10*** (Management System). The hydrology and hydraulics evaluation of the site has been determined as Safety Class B in terms of Eskom's Safety Classification Procedure (Eskom, 2010), and, in terms of the quality and safety procedure, the minimum RD-0034 (National Nuclear Regulator, 2008) requirements for Level 2 processes must be complied with.

The activities carried out as part of the evaluation of the site and the results achieved are presented in detail in appendices to this section. These appendices provide the quality assurance records for key decisions and methodologies used and provide the back-up for the data presented in this section. They present a clear and auditable trail showing how key decisions were made and conclusions reached. The information presented in the appendices includes:

- ***Appendix 5.10.A*** - Meteorological Data;
- ***Appendix 5.10.B*** - Infiltration Data and Calculations;
- ***Appendix 5.10.C*** - Hydrological and Hydraulic Model Parameters;
- ***Appendix 5.10.D*** - Chemical Laboratory Certified Results;
- ***Appendix 5.10.E*** - Chemical Results Evaluation;
- ***Appendix 5.10.F*** - Quality control data pack including a detailed process map containing references to the various data files.

The above-listed documents and quality data pack contained in ***Appendix 5.10.F*** include:

- List of approved suppliers used;
- Rationale for testing methods used and risk assessment;
- Certified results of accreditation for laboratories used;
- Modelling rationale, benchmarking, validation and verification;
- Peer review reports;
- SRK's Integrated Quality Management System and associated Work Instructions;
- The project-specific Project Quality Plan;
- Method Statement;
- Quality Control Plan;
- Project Process Chart;
- V&V Plan and V&V Report.

Electronic records have been stored in a secure central repository with regular off-site back-up procedures. The overall quality management system complied with that set out in ***Chapter 10*** of this SSR. All references cited are saved in the central repository.

The activities that have been carried out with their respective links to other SSR sections/chapters and quality control requirements are presented in ***Table 5.10.18*** below.

Table 5.10.18
Summary of Activities, Links and Quality Requirements

Activity	Links		Quality Requirements
	Inputs	Outputs	
Laboratory Analysis		Water quality data will be used as input to the ***Section 5.5*** (Land and Water Use) and ***Section 5.12*** (Water Supply).	Use of approved suppliers Certificate of accreditation for selected laboratories. ***Appendix 5.10.F*** (Quality Control Data Pack) ***Sections 5.11*** (Geohydrology) and ***5.15*** (Geotechnical Characterisation)
	Soil's permeability and infiltration data from testing/analysis carried out by ***Sections 5.11*** (Geohydrology) and ***5.15*** (Geotechnical Characterisation).		
Hydrological modelling	Rainfall data from ***Section 5.8*** (Meteorology) as input parameters as well as to assess current rainfall trends against historical measurements.	***Chapter 6*** (Evaluation of External Events). Flood Peaks and Volumes.	International benchmarking, use and acceptability. Validation and verification of computer software codes used to comply with NNR requirements. Uncertainties and management/incorporation thereof. Sensitivity analysis. Peer Review. ***Appendix 5.10.F*** (Quality Control Data Pack)
Hydraulic Modelling	***Section 5.9*** (Oceanography and Coastal Engineering). Confirmation that flooding from sea and flooding from land may be calculated independently, due to absence of estuaries at site	***Chapter 6*** (Evaluation of External Events). Maximum and minimum flooding level.	International benchmarking, use and acceptability. Validation and verification of computer software codes used to comply with NNR requirements. Uncertainties and management/incorporation thereof. Sensitivity analysis. Peer Review. ***Appendix 5.10.F*** (Quality Control Data Pack)

A regulatory compliance table (***Table 5.10.19***) is given below to indicate where the relevant regulatory compliance issues have been dealt with in the section.

Table 5.10.19
Regulatory Compliance Matrix

Act/Regulation	Section / Regulation	Issue	Subsections where covered
Regulations on Licensing of Sites for New Nuclear Installations (Department of Energy, 2011)	R.927 4 (5)	Natural phenomena	***5.10.7, 5.10.10, 5.10.11***
Regulations on Licensing of Sites for New Nuclear Installations (Department of Energy, 2011)	R.927 5 (3)	a) External events of natural origin b) Meteorological	***5.10.7, 5.10.10, 5.10.11*** ***5.10.6, 5.10.7***
Regulations on Licensing of Sites for New Nuclear Installations (Department of Energy, 2011)	R.927 5 (5)	Probabilistic Risk Assessment	***5.10.11***
Interim Guidance on the Siting of Nuclear Facilities, Rev 0 (National Nuclear Regulator, 2016)	RG-0011 Section 6.1.(1) Section 6.1.(4) Section 6.6.1(1) Section 6.6.1(2) Section 6.6.1(4) Section 6.6.3.2 Section 6.6.3.3	Site Licencing Process a) External events and b) site characteristics Site characteristics (safety and environment) b) Site characteristics (design and technologies) a) external events and civil engineering issues Probabilistic Safety Assessment External events (relevant factors) External events (relevant data)	***5.10.7, 5.10.10, 5.10.11*** ***5.10.7, 5.10.10, 5.10.11*** ***5.10.7, 5.10.10, 5.10.11, 5.10.12*** ***5.10.7, 5.10.10, 5.10.11, 5.10.12*** ***5.10.7, 5.10.10, 5.10.11*** ***5.10*** ***5.10***
Interim Guidance on the Siting of Nuclear Facilities, Rev 0 (National Nuclear Regulator, 2016)	RG-0011 Section 7	Hazards Associated with External Natural and Human-Induced Events	***5.10.7, 5.10.10, 5.10.11***
National Water Act No. 36 of 26 August 1998, (Republic of South Africa, 1998) GN704	Section 21 Section 40 Section 41	Water Use License Requirements	Eskom would be required to apply for a Water Use License when site selection process and technology has been completed

Act/Regulation	Section / Regulation	Issue	Subsections where covered
National Water Act No. 36 of 26 August 1998, (Republic of South Africa, 1998) GN704	Section 144	Floodlines on plans	***5.10.10*** and ***5.10.11*** which will be dealt with during the design phase
National Water Act No. 36 of 26 August 1998, (Republic of South Africa, 1998) GN704	Section 19	Separation of 'clean' and 'dirty water' (pollution prevention)	***5.10.12*** which will form part of the non- structural BMP that will be dealt with during the design phase
(National Nuclear Regulator, 2016)	RG-0016	Modelling	***5.10.7*** and ***5.10.10***

5.10.17 Conclusions

A comprehensive investigation of the hydrology and hydraulics of the Duynefontyn site has been carried out to obtain the required level of understanding of the site characteristics in support of this SSR and the licence application. Based on the results and knowledge gained to date, the following key conclusions are drawn:

- A conservative approach has been adopted throughout the assessment. The probable maximum values have been used where applicable and where these were not available the 1:10 000 return period was considered. This relates to a 90% probability of non-occurrence in 1 000 years design life for the 1:10 000 year return period event.

  Extreme storm events were also determined (10^{-4}, 10^{-6} and 10^{-8} annual probability of exceedance for the 95th percentile) which included any increases in rainfall intensities due to climate change. This can be considered a low probability of occurrence.

- The still sea water level boundary conditions (extreme climatic events and sea level rise) for the hydraulics were analysed based on a 10^{-4}, 10^{-6} and 10^{-8} annual probability of exceedance for the 95th percentile (upper values of the 90 per cent confident intervals). This is considered a low probability of occurrence. The downstream boundary condition was the still high water levels excluding the instantaneous (wave set-up and run-up) values.

  In addition, the probability of occurrence from a site safety perspective further decreases when making the assumption that the extreme still high water levels occur simultaneously with the extreme storm event.

- Climate change has been incorporated into the hydrology and hydraulic assessment using the precipitation and extreme still water level values. The climate change approach and methodology has been explained in more detail in ***Sections 5.8*** and ***5.9***.

- The Duynefontyn site is dominated by two main vegetation types, namely Cape Flats Dune Strandveld and Cape Flats Sand Fynbos or Atlantis Sand Fynbos, both previously known as Sand Plain Fynbos (***Section 5.3***). The Cape Flats Dune on sand and limestone, and Sand Plain Fynbos on marine-derived, leached acid sand. There is also a transitional vegetation type between the two. The catchments have a low run-off coefficient due to high infiltration as a result of the sandy soils and moderate vegetation. Due to the topography and locality of the proposed nuclear installation(s), the external catchments potentially impacting the Duynefontyn site are relatively small (less than 4.0 km^2) and the water levels are controlled by the backup from the extreme high water levels. There are no perennial watercourses close to the Duynefontyn site and the closest major watercourse is Diep Rivier located approximately 15 -20 km in a different quaternary catchment. The majority of run-off occurs along drainage lines and temporary ponds within the low-lying areas between the dunes during a storm event.

- There are no significant dams upstream of the Duynefontyn site which may impact on the safety of the nuclear installation(s) and no further investigation on possible dam failure is required.

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

- Surface water quality from the virgin Duynefontyn site is currently not a concern since monitoring (albeit limited) has indicated that all constituents comply with the water quality guidelines and do not impact on the safety of the nuclear installation(s).

- The 10^{-4}, 10^{-6} and 10^{-8} annual probability of exceedance for the 95th percentile flood depths and velocities have been mapped along the drainage lines and ponding areas for the site, based on the extreme rainfall conditions and extreme downstream still water levels. Any nuclear installation(s) constructed within these areas would require a 1.5 m high berm constructed around the proposed 12 m amsl platform or alternatively raise the platform by 1.5 m and construct a 1.5 m deep channel around to cut-off off external run-off ensure safety of the nuclear installation(s). This would be subject to the final platform elevation requirements from

Section 5.9. During detailed design, the localised surface water run-off would need to be collected and diverted around any of the platforms.

- During the construction stage, a large increase in runoff peaks and volumes is expected at excavation sites due to the high run-off potential of the rock floor of the nuclear installation foundation excavations. This will be compounded by the side slopes possibly being covered by erosion control measures such as cement stabilised liners, which would cause a higher runoff due to being less permeable than the surrounding soil. The higher run-off results in localised flooding of the deep excavations but considered temporary as the wells and pumps will extract the water from the open excavation. This potential impact would need to be addressed during the detailed design.
- There is an insignificant difference in run-off peaks and volumes between the operation and the construction stage as it is assumed that most of the nuclear installation sites would be paved once the excavations have been backfilled and hence the percentage hard surface would be similar for both stages. This would also need to be addressed in the detailed design.

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

With the appropriate remedial measures in place, the safety consequence (Hazard x Vulnerability) for the nuclear installation(s) is low and suitable for the development of a nuclear installation(s) from a site safety perspective (surface water hydrology and hydraulics). The final footprint would need to be located above the 10^{-4}, 10^{-6} and 10^{-8} annual probability of exceedance (95^{th} percentile) flood levels. The recommended platform levels for the nuclear installation(s) would need to be considered during the detailed design phase. Similarly, the existing KNPS site has a low safety consequence (Hazard x Vulnerability) for the current 8 m amsl platform.

5.10.18 References

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APPENDICES

The following appendices are provided in electronic format:

Appendix 5.10 A
Meteorological Data

Appendix 5.10 B
Infiltration Data and Calculations

Appendix 5.10 C
Hydrological and Hydraulic Model Parameters

Appendix 5.10 D
Chemical Laboratory Certified Results

Appendix 5.10 E
Chemical Results Evaluation

Appendix 5.10 F
Quality Data Pack

Appendix 5.10.A
Meteorological Data

Monthly Rainfall Data Robben Island station 20649

This is just an indication of the typical monthly values and actual daily rainfall used in the modelling was obtained from ***Section 5.8***

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1850	30.2	3.4	22.4	72.3	41.1	118	67.2	60.1	41	48.7	29	6.2	**539.6**
1851	4.5	1	3.9	16.3	48	117.4	63.5	10.1	21.5	31	9.2	8.1	**334.5**
1852	2.9	4.5	19.8	21	70.7	31.3	70.8	78.2	37.8	16.2	18	4.6	**375.8**
1853	14.4	8.2	25.7	20.9	45	71.6	71.3	52.8	22.9	21.8	1.4	3.3	**359.3**
1854	5.1	10.6	19.6	19.5	37.1	56.4	53.8	57.2	44.9	18.9	11.5	6.4	**341**
1855	6.5	4.3	15.8	26.6	49.3	79.2	45.5	88.2	73.8	10.8	2.1	0.4	**402.5**
1856	6.2	5.9	14.6	8.3	62.8	59.3	51.1	53.2	26.6	19	21.7	21	**349.7**
1857	3.6	7.9	4.2	41.5	44.5	83.3	53.3	73.7	27.7	22.5	4.2	18.1	**384.5**
1858	19.1	15.4	11.9	44.1	12.7	53.2	71.6	93.9	40.5	13.3	17.3	6.3	**399.3**
1859	25.7	14.6	12.7	13	110.1	97.7	107.3	82.1	48	35.4	39.9	3.8	**590.3**
1860	12.1	15.8	9.1	19.6	104.9	87.6	80.3	15.6	75.4	30.1	3.8	8.8	**463.1**
1861	11.1	1.4	12	26.3	68.7	131	68.8	32.2	38.6	2.2	20.1	0.9	**413.3**
1862	3.9	4.2	4.9	15.3	19.9	184.3	102.1	68.1	33.7	49.8	24.7	0	**510.9**
1863	2.9	10.6	36.4	42.2	85.9	55.4	41.3	45.3	26.7	39	14.4	5	**405.1**
1864	8.3	0.4	4.8	16.9	44.3	76.5	47.8	36.7	30.3	28.4	15.3	2.4	**312.1**
1865	4.7	2.3	5.6	31.1	61.8	19.1	81.7	28.2	10.3	45.7	9	4.6	**304.1**
1866	0.9	45.4	3.3	25.5	12.5	99.8	40.6	38.2	22.8	16.7	6.3	8.2	**320.2**
1867	6.1	15.7	14	40.5	49	63.9	71	23.1	22.5	50.3	3.3	9.3	**368.7**
1868	10.4	15.7	6.8	35.7	30.1	58.8	45.6	11.7	14.7	38.8	36.7	14.5	**319.5**
1869	3.7	1.3	8.3	31.4	128	163.2	52	68.9	18.6	18.6	20.3	19.2	**533.5**
1870	10.9	1.4	4	23	69.7	91.7	108.7	74.4	20.6	26.6	7	18.8	**456.8**
1871	5.3	3.1	12.7	24.5	49.7	68.5	49	59.1	18	11.5	11.6	14.9	**327.9**
1872	10.9	10	19	4.1	108.7	82.5	43.2	128.5	32.4	15.5	16.8	9.7	**481.3**
1873	4.1	3.8	7.8	36.5	62.9	86.2	54.9	67.7	16.9	13.5	10	22	**386.3**
1874	1.6	1	18.2	79.1	31.4	55.5	79.1	63.2	23.6	30.3	40	1.6	**424.6**
1875	0	20	8.8	22.3	28.4	98.8	21.4	68.5	57.6	30.5	20	28.7	**405**
1876	2.4	0	27.3	18.3	48.6	59.9	57.7	101.7	28.4	17.4	20.2	35.3	**417.2**
1877	10.6	24.1	8.5	58.6	215	48.2	22.7	61.6	24.1	25.2	46.5	21.1	**566.2**
1878	12.3	0	0	0	0	0	0	0	0	0	0	0	**12.3**
1879	13.4	3.5	11	23.3	44.2	39.8	46.6	21.1	37.8	20.1	13.2	17.2	**291.2**
1880	25.5	7.6	13.1	28.3	20.3	30.3	44.1	56.6	0	0	0	0	**225.8**
1881	5.3	2.3	11.5	58.5	109.6	57.5	47.5	59.4	18.9	16.3	22.4	6	**415.2**
1882	2.1	3.1	50.5	33.3	44.3	59.1	102.2	41.5	32.5	44.1	6.7	38.5	**457.9**
1883	17.8	6.8	13.1	39.3	92.6	87.1	89.7	71.8	48.3	35.4	1.1	11.4	**514.4**
1884	5.6	13.6	8.4	37.9	36.9	84.3	78.5	19.6	74.3	49.2	40.5	1.4	**450.2**
1885	5.8	30.9	14.2	32	59.5	106.7	33.8	71	23.4	27.5	25.6	13.7	**444.1**
1886	4	0	38.2	11.1	38.7	132.7	41.3	65	37.8	49.7	4.8	10.7	**434**

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1887	21.1	3.4	5	35	63.7	49.1	52.1	66.8	13.4	41.1	11.9	12.4	**375**
1888	2.5	0.5	9.8	60	133.2	166.8	62.9	48.8	42.3	8	22	15.5	**572.3**
1889	1.3	17.7	18.3	83.8	85.2	60	54.7	83.7	51	9.8	7.8	19.1	**492.4**
1890	7	19.1	16	35.6	94.2	14.3	104.6	61.1	31.9	15.9	15.7	4.3	**419.7**
1891	4.8	13.2	6.3	42.5	136.7	46.2	62.6	64.4	48.2	3.1	7.9	5.9	**441.8**
1892	13.2	0.8	16.9	30.5	38.5	145.9	59.4	112.2	39.8	26.8	28.1	44.1	**556.2**
1893	0	3.3	1.8	27	47.7	93.6	49.6	81.3	56	26.2	54.9	1	**442.4**
1894	0	20.3	27.9	7.9	11	113.1	79.7	69.8	22.2	38.7	38.9	0	**429.5**
1895	2.5	0	2.5	47	64.2	50.3	34.4	51.6	54.2	24.1	13.7	10.7	**355.2**
1896	12.3	6.4	17.7	9	40.9	54.4	41.3	50.3	13.9	13.7	13.2	0.4	**273.5**
1897	6.1	9.9	13.4	2.5	26.7	31.9	94.4	48.9	51.1	39.3	11.9	7.9	**344**
1898	20.1	10.9	21.3	90.7	76.2	98.6	83.3	26.9	37.1	46.4	20.6	8.7	**540.8**
1899	8.6	7.9	6.4	38.6	46.8	32.4	58.1	215.8	20.4	34.8	11.4	24.4	**505.6**
1900	6.4	2.5	9.8	18.4	57.2	31.5	77.6	62.2	19.7	55.1	11.7	8.3	**360.4**
1901	71.4	14.9	0	10.2	98.8	28.9	76.3	9.1	45.8	16.7	43.7	16.5	**432.3**
1902	9.4	7.6	18	34.7	81.9	84.9	103.6	95.4	146.6	33	20.9	1.8	**637.8**
1903	35.1	0	30	49.8	72.1	124.5	30.5	69.2	48.6	86.4	0.5	3.5	**550.2**
1904	15.5	3	8.1	106.2	28.4	113	39.8	68.3	56	61.7	14	6.1	**520.1**
1905	11.1	6.6	9.9	1	89.7	190.9	41.4	44.4	28.5	23.5	17.2	4.3	**468.5**
1906	13.7	0	13.7	18.3	54.2	61.8	28.8	51.6	18.8	14.4	6.4	44.9	**326.6**
1907	9.6	0.5	12	56.1	101.1	34.8	14.2	25.9	40.1	20.7	20.3	27.7	**363**
1908	17.8	14.6	6.9	98.8	17.1	72.5	26.7	67	35.1	27.2	15.5	5.6	**404.8**
1909	12.7	1.3	52.2	4.8	48.8	29.2	42.4	173.5	16.5	29.7	4.8	38.3	**454.2**
1910	0	10.4	7.7	25.5	65.9	83.4	93.1	57.9	23.4	23.5	24.7	71.6	**487.1**
1911	17.6	9.9	5.1	23.1	80.5	42.6	87.5	51	55.3	28.3	14.6	30.8	**446.3**
1912	0.5	8.1	16.7	59.2	59.8	79.1	32.5	72.7	76.5	14.7	37.8	1	**458.6**
1913	2.6	8.9	0.8	22.1	50.1	72.4	65.1	79.5	40.7	21.1	34.8	19.9	**418**
1914	29.9	11.5	5.6	35.3	55.1	70.1	90.2	108	48.6	2	22.7	10.9	**489.9**
1915	0	0	37.4	59.6	38.8	91.1	112.2	40.7	53	13.6	16.3	8.4	**471.1**
1916	11	2.1	13.7	16.5	72.9	91.8	55.8	80	54.2	20.3	9.7	19.3	**447.3**
1917	20.1	0	5.9	23.2	83.2	101.7	183.1	32.6	16.1	20.1	18.6	13	**517.6**
1918	0	3.8	19.1	21.6	95	145.3	75.8	7.2	41.9	35	40.2	4.8	**489.7**
1919	33.9	8.5	5.1	32.5	22.6	65.5	99.3	37.4	48.1	5.1	18.8	1	**377.8**
1920	0	4.6	2.5	12.2	79.4	126	121.3	61.4	74.2	37.5	18.9	27.4	**565.4**
1921	21.4	18.8	11.1	38.9	7.9	220.2	80	100.8	21.9	20.9	4.8	17.8	**564.5**
1922	30.5	5.1	8.9	27.7	22	132.3	63	78.3	9.2	29.5	4.4	1.3	**412.2**
1923	16.8	1.6	7.7	40.2	117.4	126.6	73	62.7	33	17.2	62.1	2.3	**560.6**
1924	6.8	1.6	18	13.4	34.1	76.3	27.3	62	22.6	21.4	19	3.3	**305.8**
1925	14.2	1.8	0	2.3	16	187.6	98.7	12	33.2	40.7	41.4	5.4	**453.3**
1926	4.3	23.9	2.1	9	57.7	29	96.8	53.5	26.6	67.6	10.2	0	**380.7**
1927	2	16.1	4.3	29.9	69.8	32.2	29.5	87.1	23.4	4.9	33.2	17.8	**350.2**
1928	15.6	2.1	10	5.4	1.8	93.8	29.4	38.5	44.4	16.2	11.5	12.4	**281.1**
1929	0.5	9.1	4.9	37.9	40.7	36.6	54	51.2	16.6	9.2	7.2	20.1	**288**
1930	18.3	12.6	6.3	15.3	2.3	6.9	36.7	35.5	75.9	15.2	25	8.5	**258.5**
1931	0	20.8	0	62.2	37.5	14.4	24.2	72.1	40.7	29.5	3.6	10	**315**
1932	5.7	45.6	8.3	5.7	121.1	82.4	48.3	40.8	43.6	12.5	3.5	19.1	**436.6**

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1933	10.9	6.1	4.9	13.3	44.9	113.1	92.1	46.7	15.3	28	8.9	0	**384.2**
1934	13.2	4.8	12.6	12	71.2	31	38.1	52.8	24.9	32.9	9.6	0	**303.1**
1935	3.5	0.8	11.7	57.9	66.9	36	49.7	62.9	33.7	33.5	27.4	0	**384**
1936	35.8	6.8	15.6	7.8	37.3	42.8	27.5	87.3	36	2.3	0.3	10.5	**310**
1937	6.6	0	19.3	56.9	42.4	89.7	107.6	37.2	42.1	28.6	8.6	0	**439**
1938	11.4	3.9	7.4	53.8	42	39.3	28.4	34.8	23.2	7.4	12.7	25.9	**290.2**
1939	0	15	0	30.2	97.1	32.6	28.7	49.5	12.1	0	0	19.5	**284.7**
1940	0	43.5	19.3	48.5	37.2	83.3	35.5	22.8	40.8	30.2	25.3	7.6	**394**
1941	12.1	1.5	1.3	85.2	75.2	103.4	84.4	38.9	33	27.4	9.9	11.2	**483.5**
1942	6.3	1	1.3	37.8	108.2	110.7	23.4	50.2	37.1	30.5	0	4.5	**411**
1943	16.5	3.5	22.6	14.1	38.9	33.9	58.6	60.6	15.2	17.3	15.4	1.3	**297.9**
1944	15.7	0.8	3.6	8.9	63.6	138.7	48.4	94.8	34.1	23.2	13	11.9	**456.7**
1945	0	0	1.6	40.7	83	113.3	71.2	50.5	2.1	11.9	2.7	5	**382**
1946	5.9	3	8.1	64.2	41	29.7	48.2	17.6	88.9	12.4	3.8	11.7	**334.5**
1947	0	0	38	19.5	56.2	31.7	111.1	45.1	18.8	10.7	1.3	0.5	**332.9**
1948	1.8	3.3	29.7	18.7	51.6	41.6	71.4	22.9	43.7	20.1	3.3	12.5	**320.6**
1949	12.7	0	4.8	33.8	21.1	65.1	53.1	57	45.8	21.1	18.5	1.5	**334.5**
1950	5	0.8	4.3	91.9	33.5	45	176.1	25.2	44.1	23.6	30	2.3	**481.8**
1951	14.2	0	0.9	67.4	49.6	142.6	44.8	30.9	33.5	20.8	22	0.5	**427.2**
1952	0.1	2.9	16.7	23	42.7	56.6	65.2	112.1	82.6	6.6	42.4	3.2	**454.1**
1953	5.6	0	5.8	149.5	112.5	50.8	80.7	48.1	14.4	17.1	14.7	3	**502.2**
1954	28.8	61.6	8.3	50.1	136.5	83.7	149.7	69.2	25.1	22.1	3.7	19.8	**658.6**
1955	0	54.6	4.6	29	11	31.1	87.7	92.8	20.4	40.5	4.6	16	**392.3**
1956	0	4.5	21	11.5	82	98.5	67.8	75.4	18.4	40	2	9	**430.1**
1957	3.2	26.3	10.6	3.9	111.3	96.5	86.2	119.1	24.3	39.6	4.5	0	**525.5**
1958	5.6	42.5	2.4	23.5	60.5	41.1	13.2	88.1	14.4	22.2	22.9	0	**336.4**
1959	5.9	2.9	21.8	79.5	162.7	16.5	21.4	54.3	27.5	34.2	1.7	0.8	**429.2**
1960	1.1	2.1	16	21.1	40.5	95.5	25	25.6	10	6.1	0.2	15.9	**259.1**
1961	22.5	1.3	16.4	8.6	26.2	91.7	26	61.8	39	5.3	0.2	10.5	**309.5**
1962	3.9	33.4	26.4	42.7	20.3	175	49.8	54.5	16.8	98.5	12.7	0.4	**534.4**
1963	3.2	0	2.6	5	17.7	49.4	65.1	64	27.8	2.3	52.7	11.4	**301.2**
1964	0.4	34.7	0.8	11.6	34.4	84.5	58.4	74	11.7	38.4	19.1	2.1	**370.1**
1965	12.6	31.7	30.2	32.6	51.6	39.7	29	45.1	11.6	15	5.5	17.7	**322.3**
1966	1.5	5.4	55.1	25.2	31.5	30.9	76	43.4	34.3	2.1	8.5	10.2	**324.1**
1967	11.5	0	4.2	59.7	25.7	70.5	32.3	32.3	27.7	23.8	24.6	6.3	**318.6**
1968	14.5	4.5	0	35.4	58.2	111.3	76.5	55.3	4.4	62	3.9	11.8	**437.8**
1969	27.4	3.5	12.3	28.2	1.5	56.7	49.7	37.5	42.4	31.2	3.8	1.7	**295.9**
1970	5.6	16.3	2.7	4	82.1	97.9	67	73.3	41.7	36.4	3.1	27.9	**458**
1971	0.3	0	5.8	7.4	46	46.6	61	69.3	13.8	8.7	1.7	3.1	**263.7**
1972	17	6.1	10.5	30.7	65.1	43	21	54.1	22.5	9.8	0	45.7	**325.5**
1973	0.5	0	3.3	7.6	38.9	24	67	40.6	16.6	13.1	2.5	25.3	**239.4**
1974	9.2	4.2	4.2	6.5	76.4	124.5	43.2	169.9	29	33.1	20.4	6.7	**527.3**
1975	15.7	1.5	3	41.6	138.8	37.6	113.6	38.2	6	33.5	30.7	2.6	**462.8**
1976	0	0.5	10.9	21.2	26	133.6	54.6	48.9	35	1.6	30.1	29.5	**391.9**
1977	6.4	31.6	11.4	66.7	93	132.6	118.9	87.4	37	10.8	13.3	8.7	**617.8**
1978	4.4	54	22.3	56	31	8.1	9.7	75.2	50.5	25.8	2	9	**348**

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1979	17.3	26.2	1.9	1.1	49	69.3	47.7	19.2	27.2	82.1	11.2	0.1	**352.3**
1980	20.5	21	1.2	36.8	103.4	94.2	24.8	31.6	23.8	6.3	51.5	27.5	**442.6**
1981	66.5	0	31.2	32.7	5.8	41.1	148.9	45.9	97.2	9.7	8.7	31.1	**518.8**
1982	17.9	2	0	30.3	48.9	89.7	79.5	67	13.7	27.5	11.1	20.4	**408**
1983	1.4	32.9	20.1	3.2	75.7	119.4	44.5	31.3	43.4	5.9	5.5	8.2	**391.5**
1984	2.2	4.1	10.8	36	133.6	34.4	47.7	30.7	68.8	43.9	0.1	36.1	**448.4**
1985	11.5	10.1	56.5	41.3	41.5	90.3	128	75.1	30.9	7.4	1.6	7.9	**502.1**
1986	10.5	3.5	39.8	28.5	17.5	135.1	87.1	67.1	27.6	19.4	13.8	5	**454.9**
1987	12.2	8	25	29.3	72.2	66.5	133.8	83.9	45	12.7	12.7	18.2	**519.5**
1988	0.1	0.1	19.8	46.2	37.4	31	95.3	86.1	29.7	13.8	3.9	7.2	**370.6**
1989	7.1	19.3	38.5	49.4	55.9	57.1	93.9	123.2	62.9	28.8	14	2	**552.1**
1990	11.2	14.5	2.5	113	84.2	89.2	116.5	30.4	18.6	1.5	12.7	21.9	**516.2**
1991	3.8	4.1	4.5	18.1	79.1	120.9	150.5	17.9	73.1	38.4	11.1	5.7	**527.2**
1992	0.1	12.8	3.8	59	57.4	89.5	53.4	25.8	58.7	45.1	4.8	12	**422.4**
1993	3.4	25.1	5.4	91.9	120.9	37.6	94.7	49.3	2.4	1.3	11	12	**455**
1994	4.9	0	3.2	15.8	29.8	210.2	64.8	17.9	19.2	14.6	7.3	0.9	**388.6**
1995	6.6	1.9	4	13.2	54.9	82.9	81.4	47.4	13.1	39.9	5.2	20.7	**371.2**
1996	1.2	31.3	19.3	30	58.7	109.2	58	57.4	64.4	31.4	28	25.2	**514.1**
1997	8.6	2.5	1.4	30.6	65.6	104	23.3	65.3	3.2	7.8	35.4	10.4	**358.1**
1998	3	0.5	8.4	19.3	103.8	35.6	86.9	55.3	19	15.5	40.1	20.7	**408.1**
1999	0.2	0	0	33.4	16.9	64	0	0	0	1	21.1	19.6	**156.2**
2000	3.9	0	5	5.4	38.8	75.8	42.7	29.3	36.8	6.3	1.5	7.2	**252.7**
2001	0	2.1	0.1	21.6	82	35.5	184	52.6	14.8	5.5	10.5	1.5	**410.2**

Appendix 5.10.B
Infiltration Data and Calculations

Duynefontein					
Site name	**Latitude**	**Longitude**	**Soil type**	**K (cm/s)**	**K (m/d)**
DF_infil1	S34.17332	E24.72918	Sand	-	-
DF_infil2	S34.17916	E24.70774	Sand	0.0106	9.15602
DF_infil3	S34.18392	E24.71903	Sand	0.0078	6.775205
DF_infil4	S34.19094	E24.70829	Sand	0.0294	25.37859
Ave.					13.770
Median					9.156

Appendix 5.10.C
Hydrological and Hydraulic Model Parameters

Catchment	Area	Hydraulic	r	Elevation High	Elevation Low	H	S	Tc	Tc	SCS Lag
Name	(km^2)	Length (km)		(m)	(m)	(m)	(m/m)	(hrs)	(min)	
G21B_A1	0.3063	1.24	0.3	45.00	27.02	17.98	0.014527	1.02	61.29	0.61
G21B_B1	0.0941	0.72	0.3	49.00	39.00	10.00	0.013878	0.80	48.12	0.48
G21B_B2	0.0976	0.57	0.3	55.00	37.00	18.00	0.031619	0.59	35.56	0.36
G21B_B3	0.1015	0.27	0.3	54.00	39.00	15.00	0.055208	0.37	22.10	0.22
G21B_B4	0.1425	0.42	0.3	54.00	45.00	9.00	0.021549	0.56	33.66	0.34
G21B_C1	0.2421	0.77	0.3	42.00	26.00	16.00	0.020662	0.76	45.35	0.45
G21B_C2	0.1054	0.71	0.3	44.00	34.61	9.39	0.013225	0.81	48.34	0.48
G21B_C3	0.0167	0.18	0.3	42.00	37.00	5.00	0.028125	0.35	21.22	0.21
G21B_C4	0.0732	0.29	0.3	63.71	36.00	27.71	0.094322	0.34	20.23	0.20
G21B_C5	0.1580	0.40	0.3	57.00	37.00	20.00	0.049539	0.45	27.28	0.27
G21B_D1	0.1401	0.31	0.3	59.00	43.00	16.00	0.051668	0.40	23.86	0.24
G21B_DF1	0.1780	0.48	0.3	19.00	7.00	12.00	0.024899	0.58	34.79	0.35
G21B_DF2	0.1767	0.56	0.3	21.39	5.00	16.39	0.029046	0.60	36.13	0.36
G21B_DF3	0.3693	0.99	0.3	33.77	17.00	16.77	0.016949	0.89	53.25	0.53
G21B_DF4	0.2477	1.18	0.3	42.00	17.00	25.00	0.021203	0.91	54.85	0.55
G21B_DF5	0.0788	0.43	0.3	18.53	5.00	13.53	0.031405	0.52	31.27	0.31
G21B_DF6	0.2515	1.32	0.3	35.71	11.66	24.05	0.018160	1.00	60.04	0.60
G21B_DF7	0.0611	0.51	0.3	18.54	5.00	13.54	0.026673	0.58	35.08	0.35
G21B_DF8	0.1960	0.88	0.3	32.06	15.22	16.84	0.019214	0.81	48.87	0.49
G21B_E1	0.0443	0.38	0.3	41.00	22.52	18.48	0.048001	0.45	26.87	0.27
G21B_F1	0.0481	0.40	0.3	39.33	20.00	19.33	0.048609	0.45	27.20	0.27
G21B_G1	0.0451	0.28	0.3	48.56	31.00	17.56	0.062941	0.36	21.70	0.22
G21B_G2	0.1169	0.29	0.3	55.35	29.00	26.35	0.091633	0.34	20.16	0.20
G21B_G3	0.1001	0.24	0.3	62.76	35.00	27.76	0.113770	0.30	17.76	0.18
G21B_H1	0.0359	0.22	0.3	44.34	28.00	16.34	0.075559	0.31	18.47	0.18
G21B_H2	0.2406	0.83	0.3	58.00	24.00	34.00	0.040879	0.67	39.98	0.40
G21B_H3	0.0585	0.33	0.3	46.09	29.00	17.09	0.051575	0.41	24.64	0.25
G21B_H4	0.1237	0.42	0.3	38.00	23.00	15.00	0.035548	0.50	30.09	0.30
G21B_I1	0.0654	0.40	0.3	34.70	13.91	20.79	0.051510	0.45	27.02	0.27
G21B_I2	0.0334	0.21	0.3	38.77	28.00	10.77	0.051643	0.33	19.84	0.20
G21B_J1	0.0251	0.19	0.3	29.00	24.00	5.00	0.025880	0.37	22.50	0.22
G21B_K1	0.0947	0.60	0.3	27.02	7.00	20.02	0.033606	0.60	35.81	0.36
G21B_K2	0.1024	0.62	0.3	33.24	9.00	24.24	0.038861	0.59	35.37	0.35
G21B_K3	0.0506	0.17	0.3	41.00	19.00	22.00	0.128495	0.25	15.00	0.15
G21B_K4	0.0719	0.26	0.3	35.00	20.00	15.00	0.057339	0.36	21.53	0.22

Catchment	Area	Hydraulic	r	Elevation High	Elevation Low	H	S	Tc	Tc	SCS Lag
Name	(km^2)	Length (km)		(m)	(m)	(m)	(m/m)	(hrs)	(min)	
G21B_K5	0.0376	0.20	0.3	32.26	22.36	9.90	0.049900	0.33	19.54	0.20
G21B_K6	0.1331	0.58	0.3	34.81	17.00	17.81	0.030964	0.60	35.91	0.36
G21B_K7	0.0585	0.35	0.3	34.48	23.00	11.48	0.033167	0.46	27.87	0.28
G21B_M1	0.0314	0.22	0.3	32.95	21.00	11.95	0.054869	0.33	19.96	0.20
G21B_N1	0.0795	0.43	0.3	16.61	6.00	10.61	0.024651	0.55	33.08	0.33
G21B_N2	0.1677	0.94	0.3	34.81	14.00	20.81	0.022216	0.81	48.73	0.49
G21B_N3	0.0877	0.77	0.3	37.84	15.69	22.15	0.028697	0.70	41.93	0.42
G21B_N4	0.1664	0.77	0.3	32.64	18.00	14.64	0.019023	0.77	46.10	0.46
G21B_N5	0.5075	1.24	0.3	46.66	18.00	28.66	0.023049	0.92	55.14	0.55
G21B_O1	0.0673	0.37	0.3	21.00	6.00	15.00	0.040615	0.46	27.41	0.27
G21B_P1	0.0816	0.56	0.3	20.09	5.00	15.09	0.026726	0.61	36.85	0.37

Note: *r = Roughness coefficient*
H = Height difference
S = Slope
Tc = Time of concentration
SCS Lag = Index of the catchment's response time to the peak discharge

Catchment	Peak Flow (m^3/s)							Stormflow Volume (m^3)						
Name	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-8}	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-8}
G21B_A1	0	0	0.00	0.01	0.02	0.07	0.24	0	0	100	300	500	1300	3100
G21B_B1	0	0	0.00	0.00	0.01	0.02	0.08	0	0	0	100	200	400	1000
G21B_B2	0	0	0.00	0.00	0.01	0.03	0.10	0	0	0	100	200	400	1000
G21B_B3	0	0	0.00	0.00	0.01	0.03	0.14	0	0	0	100	200	400	1000
G21B_B4	0	0	0.00	0.00	0.01	0.04	0.16	0	0	100	100	200	600	1500
G21B_C1	0	0	0.00	0.01	0.02	0.06	0.23	0	0	100	200	400	1000	2500
G21B_C2	0	0	0.00	0.00	0.01	0.03	0.10	0	0	100	100	200	400	1100
G21B_C3	0	0	0.00	0.00	0.00	0.01	0.02	0	0	0	0	0	100	200
G21B_C4	0	0	0.00	0.00	0.00	0.02	0.11	0	0	0	100	100	300	800
G21B_C5	0	0	0.00	0.00	0.01	0.05	0.19	0	0	100	200	300	700	1600
G21B_D1	0	0	0.00	0.00	0.01	0.04	0.18	0	0	100	100	200	600	1400
G21B_DF1	0	0	0.00	0.00	0.01	0.05	0.19	0	0	100	200	300	800	1800
G21B_DF2	0	0	0.00	0.00	0.01	0.05	0.19	0	0	100	200	300	800	1800
G21B_DF3	0	0	0.01	0.01	0.02	0.09	0.32	0	0	200	400	600	1600	3800
G21B_DF4	0	0	0.00	0.01	0.02	0.06	0.21	0	0	100	200	400	1100	2500
G21B_DF5	0	0	0.00	0.00	0.00	0.02	0.09	0	0	0	100	100	300	800
G21B_DF6	0	0	0.00	0.01	0.02	0.06	0.20	0	0	100	200	400	1100	2600
G21B_DF7	0	0	0.00	0.00	0.00	0.02	0.07	0	0	0	100	100	300	600
G21B_DF8	0	0	0.00	0.01	0.01	0.05	0.17	0	0	100	200	300	800	2000
G21B_E1	0	0	0.00	0.00	0.00	0.01	0.05	0	0	0	0	100	200	500
G21B_F1	0	0	0.00	0.00	0.00	0.01	0.06	0	0	0	0	100	200	500
G21B_G1	0	0	0.00	0.00	0.00	0.01	0.06	0	0	0	0	100	200	500
G21B_G2	0	0	0.00	0.00	0.01	0.04	0.17	0	0	100	100	200	500	1200
G21B_G3	0	0	0.00	0.00	0.01	0.03	0.15	0	0	0	100	200	400	1000
G21B_H1	0	0	0.00	0.00	0.00	0.01	0.05	0	0	0	0	100	200	400
G21B_H2	0	0	0.00	0.01	0.01	0.06	0.24	0	0	100	200	400	1000	2500
G21B_H3	0	0	0.00	0.00	0.00	0.02	0.08	0	0	0	100	100	200	600
G21B_H4	0	0	0.00	0.00	0.01	0.04	0.14	0	0	100	100	200	500	1300
G21B_I1	0	0	0.00	0.00	0.00	0.02	0.08	0	0	0	100	100	300	700
G21B_I2	0	0	0.00	0.00	0.00	0.01	0.05	0	0	0	0	100	100	300
G21B_J1	0	0	0.00	0.00	0.00	0.01	0.03	0	0	0	0	0	100	300
G21B_K1	0	0	0.00	0.00	0.01	0.03	0.10	0	0	0	100	200	400	1000
G21B_K2	0	0	0.00	0.00	0.01	0.03	0.11	0	0	0	100	200	400	1100
G21B_K3	0	0	0.00	0.00	0.00	0.02	0.08	0	0	0	0	100	200	500
G21B_K4	0	0	0.00	0.00	0.00	0.02	0.10	0	0	0	100	100	300	700
G21B_K5	0	0	0.00	0.00	0.00	0.01	0.05	0	0	0	0	100	200	400
G21B_K6	0	0	0.00	0.00	0.01	0.04	0.14	0	0	100	100	200	600	1400
G21B_K7	0	0	0.00	0.00	0.00	0.02	0.07	0	0	0	100	100	200	600
G21B_M1	0	0	0.00	0.00	0.00	0.01	0.05	0	0	0	0	100	100	300
G21B_N1	0	0	0.00	0.00	0.00	0.02	0.09	0	0	0	100	100	300	800

Catchment	Peak Flow (m^3/s)							Stormflow Volume (m^3)						
Name	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-8}	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-8}
G21B_N2	0	0	0.00	0.00	0.01	0.04	0.15	0	0	100	200	300	700	1700
G21B_N3	0	0	0.00	0.00	0.01	0.02	0.09	0	0	0	100	200	400	900
G21B_N4	0	0	0.00	0.00	0.01	0.04	0.15	0	0	100	200	300	700	1700
G21B_N5	0	0	0.01	0.01	0.03	0.12	0.42	0	0	200	500	900	2200	5200
G21B_O1	0	0	0.00	0.00	0.00	0.02	0.08	0	0	0	100	100	300	700
G21B_P1	0	0	0.00	0.00	0.01	0.02	0.09	0	0	0	100	100	300	800

Duynefontyn Surface Water Modelling at Plant (47 ha)

Natural

Probability of Occurrence (years)	**10^{-2}**	**10^{-3}**	**10^{-4}**	**10^{-6}**	**10^{-8}**
Rainfall (mm)	95.1	124.5	154.0	212.6	271.4
***Peaks (m^3/s)**					
Nuclear installation site catchments	0.01	0.11	0.35	1.27	2.63
Volume (m^3)					
Nuclear installation site catchments	500	2 000	4 400	11 800	21 600

* Due to the small catchment areas, low rainfall depth and high infiltration rates the lower storm events generated very low to zero run-off peaks.

During Construction

Probability of Occurrence (years)	**10^{-2}**	**10^{-3}**	**10^{-4}**	**10^{-6}**	**10^{-8}**
Rainfall (mm)	95.1	124.5	154.0	212.6	271.4
Peaks (m^3/s)					
Nuclear installation site catchments	3.55	5.30	7.06	10.69	14.28
Volume (m^3)					
Nuclear installation site catchments	25 100	37 300	49 600	75 600	101 700

Operation

Probability of Occurrence (years)	**10^{-2}**	**10^{-3}**	**10^{-4}**	**10^{-6}**	**10^{-8}**
Rainfall (mm)	95.1	124.5	154.0	212.6	271.4
Peaks (m^3/s)					
Nuclear installation site catchments	4.05	5.87	7.65	11.31	14.89
Volume (m^3)					
Nuclear installation site catchments	28 500	41 300	54 100	80 700	107 200

Appendix 5.10.D
Chemical Laboratory Certified Results

P.O. Box 82124,
Southdale, 2135,
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TEL. (011) 496-2228
FAX (011) 496-2239

M&L

Registration Number 1974/001476/07 Vat Number 4780103505

M and L Laboratory Services (Pty) Ltd

Consulting Industrial Chemists, Analysts & Samplers

CONFIDENTIAL

Ref No. : **08/13263L**

Issued at : **Johannesburg**

Date : **2008.12.10**

Page : **1 of 2**

COMPANY NAME	:	SRK CONSULTING, RONDEBOSCH, CAPE TOWN
ADDRESS	:	POSTNET SUITE NO 206, PRIVATE BAG X18, RONDEBOSCH, 7700
SUBJECT	:	ANALYSIS OF 3 WATER SAMPLES
MARKED	:	ESKOM NUCLEAR: DUYNEFONTEIN AND AS BELOW
PROJECT	:	385 908
INSTRUCTED BY	:	NAEEM SUTRIA
ORDER NO	:	L 4049
RECEIVED ON	:	2008.12.02
LAB NO(S)	:	H41520 – H41522
DATE ANALYSED	:	2008.12.05

Analysis on as received basis:

Test: TPH

Test Ref.: E.P.A. 8015 B & EPA 502.2

SAMPLE MARKS:	C_6 - C_{10} GASOLINE RANGE ORGANICS	C_{10} - C_{28} DIESEL RANGE ORGANICS
KSW1	BDL	BDL
KSW2	6	BDL
KSW3	6	BDL

QUALITY CONTROL	300	2500
QUALITY CONTROL RESULTS	281	2500

Methods:

GRO – GC / FID Following Purge & Trap Technique
DRO – GC / FID Following Solvent Extraction

1) All results reported in µg/l
2) B.D.L. = Below Detection Limit (1µg/l)
3) No Field Blank Supplied

Results reported relate only to items tested

Terms and Conditions apply to Electronic Certificates / Reports (see attached file)

Mahmood Patel
OPERATIONAL MANAGER

Authorised Signature
OPERATIONAL MANAGER

P.O. Box 82124,
Southdale, 2135,
South Africa.
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M&L

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M and L Laboratory Services (Pty) Ltd

Consulting Industrial Chemists, Analysts & Samplers

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Ref No. : 08/13263L

Issued at : Johannesburg

Date : 2008.12.10

Page : 2 of 2

M&L Laboratory Services is an SANAS accredited testing laboratory. The Laboratory Accreditation Number is T0040. The Laboratory complies with ISO/IEC 17025:2005.

The following test schedule outlines only the test methods and/or techniques accredited. Uncertainties of Measurement for these accredited test methods are available upon request:

Materials/Products Tested	Types of Tests/Properties Measured, Range of Measurement	Standard Specifications, Equipment/ Techniques Used
CHEMICAL:		
Water	Total dissolved solids	W044-03-W
	pH	pH/EC Meter W044-05-W
	Electrical conductivity	pH/EC Meter W044-04-O
	pH and Electrical conductivity	DL70 ES Titrator W044-08-O
	Calcium	AAS W044-15-W
	Magnesium	AAS W044-01-W
	Potassium	AAS W044-02-W
Pharmaceutical and Veterinary Products	TECHNIQUE – HPLC Determination of Perindopril and degradation products.	PF.T.CTR.A02.R44.09490.01
MICROBIOLOGY:		
Water:	*Escherichia coli* per 100 ml	SANS 5221:2006, Edition 4.2/ ISO 7218: 1996 (E)
Borehole water	Faecal coliform bacteria per 100 ml	SANS 5221:2006, Edition 4.2/ ISO 7218: 1996 (E)
Tap water	Total coliform bacteria per 100 ml	SANS 5221:2006, Edition 4.2/ ISO 7218: 1996 (E)
Drinking water		
Environmental water	Standard (Heterotrophic) Plate Count cfu/ml	SANS 5221:2006, Edition 4.2/ ISO 7218: 1996 (E)
Sewage water		
Bottle water		
Other:		
Freshwater & seawater products	Escherichia coli per gram	SABS 758:1995
Poultry, meat products	Total coliform bacteria per gram	SABS ISO 4832:2006
Spices, herbs	Standard (Heterotrophic) Plate Count cfu/gram	SABS ISO 4833:2006
Egg & egg products		
Milk & dairy products		
Pre-prepared foods		
Vegetables & Fruit		
Pharmaceuticals		
Soils		
Beverages		
Canned products		
Sweets, cakes, dessert		
Processed food		

ENVIRONMENTAL:		
Water	G.C Technique for B.T.E.X Components	EPA 502.2
Solids	G.C Technique for B.T.E.X Components	E042-11-W (Based on EPA 8015B)
Solids	G.C Technique for D.R.O	E042-09-W (Based on EPA 8015B)
Water	G.C Technique for D.R.O	EPA 8015B
Solids	G.C Technique for G.R.O	E042-10-W (Based on EPA 8015B)
OCCUPATIONAL HYGIENE		
Water and Solids	G.C/M.S Technique for V.O.C Components	EPA 8260B

Please also refer to web site www.sanas.co.za for the full Certificate and Schedule of Accreditation

P.O. Box 82124,
Southdale, 2135,
South Africa.
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M&L

Registration Number 1974/001476/07 Vat Number 4780103505

M and L Laboratory Services (Pty) Ltd

Consulting Industrial Chemists, Analysts & Samplers

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Ref.No. : 08/13323L

Issued at : Johannesburg

Date : 05.01.2009

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COMPANY NAME	:	**SRK CONSULTING**
ADDRESS	:	**PRIVATE BAG X18, RONDEBOSCH, 7700**
SUBJECT	:	**Analysis of 3 Samples of WATER**
MARKED	:	**Eskom Nuclear, Duynefontein and as below**
INSTRUCTED BY	:	**Naeem Sutria**
PROJECT NO.	:	**385908**
ORDER NO.	:	**L4049**
RECEIVED ON	:	**01.02.2008**
LAB NO(S)	:	**E52642-E52644**
DATE ANALYSES	:	**18-22.12.2008**

Analysis on an as received basis:

Lab No:	**52642**	**52643**	**52644**
SAMPLE MARKS	**KSW 1**	**KSW 2**	**KSW 3**
pH Value @ 22°C	**8.1**	**7.5**	**8.6**
Conductivity mS/m @ 25°C	**225**	**240**	**1748**
Calcium,Ca	**130**	**111**	**230**
Magnesium, Mg	**13.5**	**14.4**	**471**
Sodium,Na	**329**	**378**	**3046**
Potassium,K	**17.5**	**20**	**70**
Free and Saline Ammonia, N	**<0.1**	**<0.1**	**<0.1**
Total Alkalinity as CaCO3	**142**	**124**	**351**
P Alk as CaCO3	**Nil**	**Nil**	**Nil**
Bicarbonate,HCO3	**173**	**151**	**428**
Carbonate, CO3	**Nil**	**Nil**	**Nil**
Chloride,Cl	**364**	**401**	**5179**
Sulphate,SO4	**467**	**528**	**1464**
Nitrate,NO3	**22**	**122**	**3.1**
Nitrate,N	**5.0**	**28**	**0.7**
Fluoride,F	**0.2**	**0.2**	**0.7**

Sum of Cations meq/ℓ	**22.356**	**23.678**	**184.504**
Sum of Anions meq/ℓ	**23.190**	**26.757**	**183.628**
% Error	**-1.831**	**-6.106**	**0.238**

The results are expressed in mg/l where applicable.

The sample marked KSW2 is not in chemical Balance

Method reference: list is appended.

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COMPANY NAME	**: SRK CONSULTING**
ADDRESS	**: POSNET SUITE NO 206, Private Bag X18, Rondebosch 7700**
SUBJECT	**: Analysis of 3 samples of water**
MARKED	**: Eskom Nuclear: Dynefontein and as below**
INSTRUCTED BY	**: Naeem Sutria**
ORDER NO.	**: L4049**
DATE RECEIVED	**: 2008.12.03**
DATE ANALYSED	**: 2008.12.10**
LAB NO(S)	**: E52642 – E52644**

Analysis on an as received basis:

Lab number	**E52642**	**E52643**	**E52644**
Sample marks	**KSW 1**	**KSW 2**	**KSW 3**
Manganese, Mn	**0.02**	**0.02**	**0.008**
Iron, Fe	**0.004**	**<0.001**	**0.007**
Zinc, Zn	**0.05**	**<0.005**	**<0.005**
Lead, Pb	**<0.001**	**<0.001**	**<0.001**
Cobalt, Co	**<0.001**	**<0.001**	**<0.001**
Copper, Cu	**0.009**	**<0.002**	**<0.002**
Total Chromium, Cr	**<0.003**	**<0.003**	**<0.003**
Cadmium, Cd	**<0.001**	**<0.001**	**<0.001**
Phosphorus as PO_4	**0.79**	**<0.12**	**<0.12**

- **The results are expressed in mg/l**
- **Method: Quantitative ICP scan (A.P.H.A 3120 B)**

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DETERMINANT	METHOD	METHOD REFERENCES
pH Value	Electrometric	W044-08-W (A.P.H.A. 4500-H^+ B)
Conductivity	Potentiometric	W044-04-0 (A.P.H.A. 2510 B)
Total Dissolved Solids	Gravimetric	W044-03-W (A.P.H.A. 2540 C)
Total Solids and Loss On Ignition	Gravimetric	A.P.H.A. 2540 BE
Total Alkalinity	Titrimetric	Auto Analyser or A.P.H.A. 2320 B
Calcium	Atomic Absorption Spectrophotometry	W044-15-W (A.P.H.A. 3111 B)
Magnesium	Atomic Absorption Spectrophotometry	W044-01-W (A.P.H.A. 3111 B)
Potassium	Atomic Absorption Spectrophotometry	W044-01-W (A.P.H.A. 3111 B)
Sodium	Atomic Absorption Spectrophotometry	A.P.H.A. 3111 B
Colour Hazen Units	Lovibond Comparator	B.D.H. Nessleriser Method
Turbidity N.T.U.	Comparator	A.P.H.A. 2130 B
Odour	Physical Testing	A.P.H.A. 2150 B
Carbonate Hardness	By Calculation	A.P.H.A. 2340 A
Chloride	Titrimetric or Mercuric Nitrate Titration	Auto Analyser or A.P.H.A. 4500-Cl C
Sulfate	Gravimetric	A.P.H.A. 4500-SO_4 C
Sulfate	Turbimetric	A.P.H.A. 4500-SO_4 E
Sulfite,	Titrimetric	A.P.H.A. 4500-SO_3 B
Settle-able Solids	Volumetric Measurement	A.P.H.A. 2540-F
Nitrate	Colorimetric	EPA 352.1
Nitrate	Nitrate Electrode	Auto Analyser (A.P.H.A. 4500-NO_3 D)
Nitrite	Colorimetric	A.P.H.A. 4500-NO_2 B
Fluoride	Ion Selective Electrode	A.P.H.A. 4500-F C
Mercury	Cold Vapour Generation A.A.S.	A.P.H.A. 3112 B
Hexavalent Chromium	Colorimetric – Diphenyl Carbazide	A.P.H.A. 3500-Cr D
Total Cyanide	Titrimetric following distillation	A.P.H.A. 4500-CN CD
Phenolic Compounds as Phenol	Colorimetric following distillation	A.P.H.A. 5530 BC
Biochemical Oxygen Demand	Titrimetric	A.P.H.A. 5210 B
Chemical Oxygen Demand	Titrimetric	A.P.H.A. 5220 C
Total Suspended Solids	Gravimetric	A.P.H.A. 2540 D
Soap, Oil & Grease	Gravimetric	S.A.B.S. 1051
Sulfide Sulfur	Lead Acetate Method	S.A.B.S. 1056
Sulfide Sulfur	Titrimetric	A.P.H.A. 4500-S^2 F
Free & Saline Ammonia	Titrimetric following distillation	A.P.H.A. 4500-NH_3 BC
Kjeldahl Nitrogen	Titrimetric following distillation	A.P.H.A. 4500-Norg B
Acidity/ P Alkalinity	Titrimetric	Auto Analyser or A.P.H.A. 2310/2320 B
Dissolved Oxygen	Titrimetric	A.P.H.A. 4500-O C
Oxygen Absorbed (Permanganate Value)	Titrimetric	S.A.B.S. 220
Residual/Free Chlorine	Colorimetric	A.P.H.A. 4500-Cl G
Bromide	Ion Chromatograph	A.P.H.A. 4110 C
Calcium Carbonate Saturated pH	Potentiometric	P.C.I. 9.28

Free Carbon Dioxide	**Nomographic**	**A.P.H.A. 4500-CO_2 B**
Free Carbon Dioxide	**Titrimetric**	**A.P.H.A. 4500-CO_2 C**
Arsenic, Selenium, Titanium, Aluminium, Nickel, Manganese, Iron, Vanadium, Zinc, Antimony, Lead, Cobalt, Copper, Total Chromium, Silicon, Tin, Zirconium, Bismuth, Thallium, Beryllium, Cadmium, Boron, Phosphorus, Phosphorus as Phosphate, Uranium, Molybdenum, Barium, Silver, Thorium, Lithium, (also Ca, Mg, Na, K)	**ICP Quantitative Scan**	**A.P.H.A. 3120 B**

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M&L Laboratory Services is an SANAS accredited testing laboratory. The Laboratory Accreditation Number is T0040. The Laboratory complies with ISO/IEC 17025:2005.

The following test schedule outlines only the test methods and/or techniques accredited. Uncertainties of Measurement for these accredited test methods are available upon request:

Materials/Products Tested	Types of Tests/Properties Measured, Range of Measurement	Standard Specifications, Equipment/ Techniques Used
CHEMICAL:		
Water	Total dissolved solids	W044-03-W
	pH	W044-05-W
	Electrical conductivity	W044-04-O
	Calcium by AAS	W044-15-W
	Magnesium by AAS	W044-01-W
	Potassium by AAS	W044-02-W
Pharmaceutical and Veterinary Products	TECHNIQUE – HPLC Determination of Perindopril and degradation products.	PF.T.CTR.A02.R44.09490.01
	Determination of Abamectin, Amitraz and Cypermethrim in Veterinary products.	HP040-54-W and HP040-55-W
MICROBIOLOGY:		
Water	Escherichia coli per 100 ml	SANS 5221:2006, Edition 4.2/ ISO 7218: 1996 (E)
	Faecal coliform bacteria per 100 ml	SANS 5221:2006, Edition 4.2/ ISO 7218: 1996 (E)
	Total coliform bacteria per 100 ml	SANS 5221:2006, Edition 4.2/ ISO 7218: 1996 (E)
	Standard (Heterotrophic) Plate Count cfu/ml	SANS 5221:2006, Edition 4.2/ ISO 7218: 1996 (E)
Pre-prepared foods Pharmaceuticals Soils	Escherichia coli per gram Total coliform bacteria per gram Standard (Heterotrophic) Plate Count cfu/gram	SABS 758:1975 SABS ISO 4832:1991 (E) SABS ISO 4833:1991 (E)
ENVIRONMENTAL:		
Water	GC for BTEX	EPA 502.2
Solids	GC for BTEX	EPA 8015B
Water	GC for DRO	EPA 8015B
Solids	GC for DRO	EPA 8015B
Solids	GC for GRO	EPA 8015B
OCCUPATIONAL HYGIENE		
Water	GC/MS for VOC	EPA 8260B
Solids		EPA 8260B

Please also refer to web site www.sanas.co.za for the full Certificate and Schedule of Accreditation

Appendix 5.10.E
Chemical Results Evaluation

SAMPLE MARKS	KSW 1	KSW 2	KSW 3	Water Quality Guidelines	Comments
	S33 38'	**S33 38'**	**S33 40'**		
	E 18 24'	**E 18 24'**	**E 18,27'**		
pH Value @ 22°C	8.1	7.5	8.6		pH values should not be allowed to vary from the range of the background pH values for a specific site and time of day, by > 0.5 of a pH unit, **or** by > 5 %, **and should be assessed by whichever estimate is the more conservative**.
	mg/l	**mg/l**	**mg/l**		
Conductivity	225	240	1748		
Calcium, Ca	130	111	230	Ns	
Magnesium, Mg	13.5	14.4	471	Ns	
Sodium, Na	329	378	3046	Ns	
Potassium, K	17.5	20	70	Ns	
Total Alkalinity as	142	124	351	Ns	
P. Alkalinity as	Nil	Nil	Nil	Ns	
Bicarbonate,	173	151	428	Ns	Very Hard water
Carbonate, CO3	Nil	Nil	Nil	Ns	
Chloride, Cl	364	401	5179	Ns	
Sulfate, SO4	467	528	1464	Ns	
Nitrate, NO3	22	122	3.1	• Inorganic nitrogen concentrations should not be changed by more than 15 % from that of the water body under local unimpacted conditions at any time of the year; and • The trophic status of the water body should not	In South Africa, inorganic nitrogen concentrations in unimpacted, aerobic surface waters are usually below 0.5 mg N/R but may increase to above 5 - 10 mg N/R in highly enriched waters Oxidised forms of inorganic nitrogen (usually nitrate) can sometimes be present in very high concentrations (> 150 mg NO -N/R) in ground water. Such high concentrations can occur 3 under natural conditions (e.g., mineral salts derived from rocks and soil, not due to man's
Nitrate as N	5.0	28	.7		
Fluoride, F	0.2	0.2	0.7	1,5mg/l	
Free and Saline	<0.1	<0.1	<0.1	0.7 mg/l N	Single measurements of ammonia are of limited use. Preferably, weekly ammonia
Manganese, Mn	0.2	0.2	0.2	0.37mg/l	
Iron, Fe	0.004	<0.001	0.007	The iron concentration should not be allowed to vary by more than 10 % of the background dissolved iron concentration for a particular site or case, at a specific time.	The toxicity of iron depends on whether it is in the ferrous or ferric state, and in suspension or solution. Although iron has toxic properties at high concentrations, inhibiting various enzymes, it is not easily absorbed through the gastro-intestinal tract of vertebrates. On the basis of iron's limited toxicity and bio-availability, it is classified as a non-critical element.
Zinc, Zn	0.05	<0.005	<0.005	0,0036 mg/l	The lethal effect of zinc on fish is thought to be from the formation of insoluble compounds in the mucus covering the gills. Sub-lethal concentrations at which toxic effects are evident depend on the concentration ratio of zinc to copper, since zinc interferes with copper absorption.
Lead, Pb	<0.001	<0.001	<0.001	The TWQR and criteria for dissolved lead at different water hardness < 60: 0.0005 mg/l 60-120 (medium): 0.001 120-180: 0.002 mg/l >180 (Very: 0.0024 mg/l	Decreasing pH increases the bioavailability of divalent lead, which is accumulated by aquatic biota. At a constant pH, solubility decreases with increasing alkalinity. Soluble lead is removed from solution by association with sediments and suspended particulates of inorganic and organic material, such as hydrous oxides and clays and humic acids, respectively
Cobalt, Co	<0.001	<0.001	<0.001	Ns	

Copper, Cu	0.009	<0.002	<0.002	Copper toxicity increases:				Copper is easily adsorbed and precipitated in sediments at alkaline pH. Less than 1 % of total copper exists in the free ionic form in natural waters. At pH levels and inorganic carbon concentrations characteristic of natural fresh waters, most of the soluble copper is present as complexes of cupric carbonate. Adsorption and precipitation are therefore important in determining the abiotic fate of copper in the aquatic environment. In reducing acidic environments, remobilisation of sorbed or co-precipitated copper can occur. In the presence of soluble organic matter, adsorption of copper onto particles may be ineffective, resulting in an increase in soluble copper forms (complexed with the dissolved organic carbon) in the water column
				< 60	60-	120-180	180	
				0.053 mg/l	0.0015 mg/l	0.0024 mg/l	0.0028 mg/l	
Total Chromium, Cr	<0.003	<0.003	<0.003	Cr (III)		Cr(VI)		Water hardness and pH affect the toxicity of both chromium(III) and chromium(VI). Limited data available indicate that acute toxicity decreases as water hardness and pH increase. There are reports that sodium chromate is more toxic in water with low concentrations of dissolved oxygen.
				0,014 mg/l		0.024 mg/l		
Cadmium, Cd	<0.001	<0.001	<0.001					Cadmium is a metal element which is highly toxic to marine and fresh water aquatic life. Elemental cadmium is insoluble in water though many of its organic and inorganic salts are highly soluble. Cadmium occurs primarily in fresh waters as divalent forms including free cadmium (II) ion, cadmium chloride and cadmium carbonate, as well as a variety of other inorganic and organic compounds. The toxicity of cadmium in water is dependent upon its hardness and chemical speciation, which is influenced by pH, water temperature, ligands and coexisting metal cations present in the water.
				< 60	60-	120-180	180	
				0.0003 mg/l	0.0005 mg/l	0.0007 mg/l	0.0008 mg/l	
Phosphorus,	0.79	<0.12	,0.12	Ns				

- Chronic values has been used rather than Target

Wetland Monitoring

SAMPLE MARKS	SW 1	SW 2		Water Quality Guidelines	Comments
	S33 38' 41	**S33 41'**			
	E 18 26'	**E 18 26'**			
pH Value @ 22°C	8.2	7.5			pH values should not be allowed to vary from the range of the background pH values for a specific site and time of day, by > 0.5 of
	mg/l	**mg/l**			
Conductivity mS/m	881	1433			
Calcium, Ca	181	383		Ns	
Magnesium, Mg	144	277		Ns	
Sodium, Na	1450	1985		Ns	
Potassium, K	32	78		Ns	
Total Alkalinity as	500	288		Ns	
P. Alkalinity as	Nil	Nil		Ns	
Bicarbonate, HCO3	610	351		Ns	Very Hard water
Carbonate, CO3	Nil	Nil		Ns	
Chloride, Cl	2370	3990		Ns	
Sulfate, SO4	509	960		Ns	

SAMPLE MARKS	SW 1	SW 2		Water Quality Guidelines	Comments
Nitrate, NO3				• Inorganic nitrogen concentrations should not be changed by more than 15 % from that of the water body under local unimpacted conditions at any time	In South Africa, inorganic nitrogen concentrations in unimpacted, aerobic surface waters are usually below 0.5 mg N/R but may increase to above 5 - 10 mg N/R in highly enriched waters Oxidised forms of inorganic nitrogen (usually nitrate) can sometimes be present in very high concentrations (> 150 mg NO -N/R) in ground water. Such high concentrations can occur 3 under natural conditions (e.g., mineral salts derived from rocks and soil, not due to man's activity).
Nitrate as N					
Fluoride, F				1,5mg/l	
Free and Saline				0.7 mg/l N	Single measurements of ammonia are of limited use. Preferably, weekly ammonia
Manganese, Mn				0.37mg/l	
Iron, Fe				The iron concentration should not be allowed to vary by more than 10 % of the background dissolved iron	The toxicity of iron depends on whether it is in the ferrous or ferric state, and in suspension or solution. Although iron has toxic properties at high concentrations, inhibiting various enzymes, it is not easily absorbed through the gastro-intestinal tract of vertebrates. On the basis of iron's limited toxicity and bio-availability, it is classified as a non-critical element.
Zinc, Zn				0,0036 mg/l	The lethal effect of zinc on fish is thought to be from the formation of insoluble compounds in the mucus covering the gills. Sub-lethal concentrations at which toxic effects are evident depend on the concentration ratio of zinc to copper, since zinc interferes with copper absorption.
Lead, Pb				The TWQR and criteria for dissolved lead at different water hardness (mg CaCO /R) in 3	Decreasing pH increases the bioavailability of divalent lead, which is accumulated by aquatic biota. At a constant pH, solubility decreases with increasing alkalinity. Soluble lead is removed from solution by association with sediments and suspended particulates of inorganic and organic material, such as hydrous oxides and clays and humic acids, respectively
				< 60 | 60-120 | 120-180 | >	
				0.0005 | 0.001 | 0.002 mg/l | 0	
Cobalt, Co				Ns	
Copper, Cu	0.009	<0.002	<0.002	Copper toxicity increases: • with a decrease in water hardness; • with a decrease in dissolved oxygen; and	Copper is easily adsorbed and precipitated in sediments at alkaline pH. Less than 1 % of total copper exists in the free ionic form in natural waters. At pH levels and inorganic carbon concentrations characteristic of natural fresh waters, most of the soluble copper is present as complexes of cupric carbonate. Adsorption and precipitation are therefore important in determining the abiotic fate of copper in the aquatic environment. In reducing acidic environments, remobilisation of sorbed or co-precipitated copper can occur. In the presence of soluble organic matter, adsorption of copper onto particles may be ineffective, resulting in an increase in soluble copper forms (complexed with the dissolved organic carbon) in the water column
				< 60 | 60-120 | 120-180 | 1	
				0.053 | 0.0015 mg/l | 0.0024 mg/l | 0	

SAMPLE MARKS	SW 1	SW 2		Water Quality Guidelines				Comments
Total Chromium, Cr	<0.003	<0.003	<0.003	Cr (III) 0,014 mg/l		Cr(VI) 0.024 mg/l		Water hardness and pH affect the toxicity of both chromium(III) and chromium(VI). Limited data available indicate that acute toxicity decreases as water hardness and pH increase. There are reports that sodium chromate is more toxic in water with low concentrations of dissolved oxygen.
Cadmium, Cd	<0.001	<0.001	<0.001	< 60 0.0003 mg/l	60-120 0.0005 mg/l	120-180 0.0007 mg/l	1 0 .	Cadmium is a metal element which is highly toxic to marine and fresh water aquatic life. Elemental cadmium is insoluble in water though many of its organic and inorganic salts are highly soluble. Cadmium occurs primarily in fresh waters as divalent forms including free cadmium (II) ion, cadmium chloride and cadmium carbonate, as well as a variety of other
Phosphorus, PO4	0.79	<0.12	0.12	Ns				

Note: *Ns = No standard*

Parameter	Water Quality Guideline	Guidelines					
		Bathing	Laundry	Irrigation	Livestock watering	Industry	Aquatic ecosystems
Aluminium as Al (mg/l)	5	Ns	Ns	5	**5**	Ns	0.01
Arsenic as As (mg/l)	0.1	0.2	0.2	**0.1**	1.5	Ns	0.02
Boron as B (mg/l)	0.5	Ns	Ns	**0.5**	5	Ns	Ns
Cadmium as Cd (mg/l)	0.01	0.02	0.05	**0.01**	**0.01**	Ns	0.0003-0.0008 depending on hardness
Chromium as Cr (mg/l)	0.1	Ns	Ns	**0.1**	1	Ns	0.014
Cobalt as Co (mg/l)	0.05	Ns	Ns	**0.05**	1	Ns	Ns
Copper as Cu (mg/l)	0.2	1.3	1.3	**0.2**	0.5	Ns	0.00053-0.0028 depending on hardness
Iron as Fe (mg/l)	0.2	5	**0.2**	**0.2**	10	10	0.32
Mercury as Hg (mg/l)	0.001	Ns	Ns	Ns	**0.001**	Ns	0.00008
Manganese as Mn (mg/l)	0.02	0.1	0.1	**0.02**	10	Ns	0.37
Molybdenum as Mo (mg/l)	0.01	Ns	Ns	0.01	**0.01**	Ns	Ns
Nickel as Ni as (mg/l)	0.2	Ns	Ns	**0.2**	2	Ns	0.025-0.15 depending on hardness2
Lead as Pb (mg/l)	0.1	Ns	Ns	0.2	**0.1**	Ns	0.0005-0.0024 depending on hardness
Selenium as Se (mg/l)	0.05	Ns	Ns	0.02	**0.05**	Ns	0.005
Vanadium as Va (mg/l)	0.1	Ns	Ns	**0.1**	1	1	Ns
Zinc as Zn (mg/l)	1.0	No effects	No effects	**1.02**	20	Ns	0.0036

Note: *Ns = No standard*

iThemba LABS GAUTENG

Environmental Isotope Group (EIG)

Postal address: Private Bag 11, Wits, 2050, South Africa.
Physical Address: Empire Road (between Jan Smuts Avenue and Yale Road)
Tel ++27 11 351 7000/1 (switchboard/secretary), Fax ++27 11 351 7053

Report
Reference: SRK049

Date: 3rd February 2009

Isotope analyses on three (3) water samples

Submitted by: Naeem Sutria
SRK
Eskom Nuclear: Duynefontein. Proj. No. 385908

M.J. Butler, O.H.T. Malinga, M.J. Mabitsela

confidential

1. General

Three water samples were submitted by Naeem Sutria of SRK for tritium analysis. The samples were received on the 2nd of December 2008.

2. Tritium Analysis

The samples were distilled and subsequently enriched by electrolysis. The electrolysis cells consist of two concentric metal tubes, which are insulated from each other. The outer anode, which is also the container, is of stainless steel. The inner cathode is of mild steel with a special surface coating. Some 500 ml of the water sample, having first been distilled and containing sodium hydroxide, is introduced into the cell. A direct current of some 10–20 ampere is then passed through the cell, which is cooled because of the heat generation. After several days, the electrolyte volume is reduced to some 20 ml. The volume reduction of some 25 times produces a corresponding tritium enrichment factor of about 20. Samples of standard known tritium concentration (spikes) are run in one cell of each batch to check on the enrichment attained.

For liquid scintillation counting samples are prepared by directly distilling the enriched water sample from the now highly concentrated electrolyte. 10 ml of the distilled water sample is mixed with 11 ml Ultima Gold and placed in a vial in the analyser and counted 2 to 3 cycles of 4 hours. Detection limits are 0.2 TU for enriched samples.

3. Results

The analytical results are presented in Table 1.

4. References

Craig, H. (1961). Isotopic variations in meteoric waters. *Science*, **133**, 1702–1703.

Table 1: Analytical Results

			Tritium	
Lab No	Field Name	Description	TU	±
SRK 355	KSW1	2008/12/01	2.0	0.3
SRK 356	KSW2	2008/12/01	1.9	0.3
SRK 357	KSW3	2008/12/01	4.5	0.4

Appendix 5.10.F
Quality Control Data Pack