SECTION 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.** **Name:** MJ Sim *Pr Tech Eng* Principal Engineering Technologist **Name:** MJ Morris *Pr Eng* Principal Engineer	SRK Consulting - Certified Electronic Signature srk consulting 599270/45654/Report 6179-7412-3262-SIMM-30/12/2024 This signature has been printed digitally. The Author has given permission for its use for this document. The details are stored in the SRK Signature Database SRK Consulting - Certified Electronic Signature srk consulting 599270/45636/Report 4288-7044-207-MORI-12/12/2024 This signature has been printed digitally. The Author has given permission for its use for this document. The details are stored in the SRK Signature Database	**Date:** 30/12/2024 **Date:** 12/12/2024
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Technical Writer Review:	**Name:** H van Graan		**Date:** 9/01/2025
Project Partner Authorisation:	**Name:** B Engelsman *Pr Eng Pr CPM*	SRK Consulting - Certified Electronic Signature srk consulting 599270/45634/Report 7365-806-1862-ENGE-10/12/2024 This signature has been printed digitally. The Author has given permission for its use for this document. The details are stored in the SRK Signature Database	**Date:** 10/12/2024
Eskom NSS Technical Lead Acceptance:	**Name:** M van Zyl		**Date:** 27/03/2026
Eskom NSS Employer's Agent Acceptance:	**Name:** F van Mosseveld pp		**Date:** 2026-03-27

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AMENDMENT RECORD			
Rev	**Draft**	**Date**	**Amendments**
0		April 2015	First issue.
0a		Nov 2024	Section updated to address NNR comments.
0b		March 2026	Section updated to align with new format and make minor editorial corrections.

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EXECUTIVE SUMMARY

Thyspunt site is located approximately 12 km to the west of Cape St. Francis in the Eastern Cape Province, South Africa. The site is situated on the coastline between Oyster Bay and Cape St. Francis, 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 (***Section 5.8***), Oceanography and Coastal Engineering (***Section 5.9***) and Geohydrology (***Section 5.11***) 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 where these were not available the 10 000 year return period was considered. This equates to a 90% probability of non-occurrence in 1 000 years design life for the 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 western portion of the site is drained by the Slang and Klipdrif rivers. The northern and eastern portions of the site drain via the Sand River into the Krom River. Wetlands in the north-eastern portion of the site are considered the most significant hydrological features and the site comprises marine, freshwater and terrestrial environments. Five major vegetation types occur on the site: Algoa Dune Strandveld, Southern Cape Dune Fynbos, Tsitisikama Sandstone Fynbos, Cape Seashore Vegetation and Cape Lowland Freshwater Wetlands.

- There are no significant dams or defined watercourses situated within the quaternary catchment K80F which drain towards the Thyspunt site. There is a catchment divide (Northern and Southern zone) and the Northern zone drains into the dunes and does not reach the enveloping footprint. The existing water bodies create natural storage areas which would not result in significant backup of headwater. There are no man-made embankments crossing the watercourse which could significantly 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. In view of the above, there are no significant dams upstream of the 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.

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- Due to the extensive inter-dune temporary ponding areas, low peak flows and velocities, there is minimal erosion and damage 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 Thyspunt 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 Forestry, 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 21 metres above mean sea level (m amsl) platform or alternatively raising of the platform by 1.5 m constructing 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 derived in ***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 to occur in excavation areas 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(s) 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

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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 downstream still high water levels rather than water levels generated by the upstream minor catchments.

With the appropriate remedial measures in place, the safety consequence (Hazard times 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).

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.

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5.10 HYDROLOGY AND HYDRAULICS

5.10.1 Introduction

This section of the Thyspunt Site Safety Report (TSSR) presents the overall site characterisation and results of the evaluation of the hydrological and hydraulic aspects of the site. These aspects cover existing watercourses, ponding areas and flow paths which could have a negative impact on the planned nuclear installation(s) under flood conditions. The site locality is shown in ***Drawing 5.10.1***, and includes 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 could 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 potential 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 (drainage lines and sheet flow areas);
- groundwater quality and levels and their influence on surface water features and infrastructure;
- 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) during extreme storm events.

Hydrological and hydraulics modelling and evaluation have been performed on the site as well as the regional drainage area consisting of quaternary catchments, namely: K80F, K90D, K90E and K90F (see ***Drawing 5.10.1***).

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5.10.3 Regulatory Framework

Chapter 2 of the TSSR presents the legal and regulatory basis for the evaluation of the site and the development of a new nuclear installation(s) on the Thyspunt 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/legislation 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 Regulations on Licensing of Sites for New Nuclear Installations (Department of Energy, 2011) – The national regulations relevant to a surface water investigation for an SSR.
- 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 2). Section 5.10: Hydrology and Hydraulics (Eskom, 2022);
- RG-0016: Guidance on the Verification and Validation of Evaluation and Calculation Models used in Safety and Design Analyses (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);

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- 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 regions K80F, K90D, K90E and K90F 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 K80F, K90D, K90E and K90F, as shown in ***Drawing 5.10.1***;
- quantification of possible safety risk 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 10 000 year return period was considered. This relates to a 90% probability of non-occurrence in 1 000 years design life for the 10 000 year return period event.

Extreme storm events were also extrapolated (up to a 10^{-8} annual probability of exceedance for the 95th 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.

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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, 2011)
2	Detailed site survey	Flown site survey for the Nuclear-1 Environmental Impact Assessment (EIA) Study and updated Topographical (LiDAR) survey (Southern Mapping Geospatial, 2011)
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 5.15*** (Geotechnical) and infiltration test results (***Appendix 5.10.B***)
6	Tidal and still high water level 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 proposed site and the adjacent catchments which could have an impact on the nuclear installation(s) (see ***Drawing 5.10.1***).

5.10.7.2 Description of the Site and Surrounding Major Catchments

Quaternary and Major Catchments

The site comprises marine, freshwater and terrestrial environments. The site is located approximately 12 km to the west of Cape St. Francis in the Eastern Cape Province, South Africa. The site is situated on the coastline

[1] Eskom Holdings, further referred to as Eskom

between Oyster Bay and Cape St. Francis and the quaternary catchments in the area are as follows:

- catchment K80F, within which the site is located and drained by the Klipdrif and Slang rivers to the west of the site;
- catchments K90D and K90E, to the north and east of the site drained by the Krom River; and do not impact on the proposed site as all run-off from these catchments drains in a northerly direction away from the site;
- catchment K90F, north and east of the Krom River catchment drained by the Seekoei River and does not impact on the proposed site as all run-off from this catchment drains in a southwesterly direction away from the site.

Five major vegetation types occur on the site: Algoa Dune Strandveld, Southern Cape Dune Fynbos, Tsitisikama Sandstone Fynbos, Cape Seashore Vegetation and Cape Lowland Freshwater Wetlands.

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

Other (local) Sub-Catchments

Run-off occurs during high intensity rainfall events to the north/northeast of the site, draining eastwards away from the site. The Sand River and a smaller (unnamed) river drain towards the St. Francis Golf Course and do not impact on the nuclear installation(s) site safety but may impact on the design of site access roads. This is, however, outside the scope of this SSR.

5.10.7.3 Surface Water Resources

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

Surrounding Area Outside Thyspunt Site

The surrounding quaternary catchments are characterised by significant surface water resources, in particular with a few large dams on the Krom River. The most notable of these dams is Impofu Dam which was established from the Tsitsikamma to Coega Internal Strategic Perspective. Unfortunately, most of the available surface water in this region is already allocated to Gqeberha and Humansdorp. The RSA Department of Water and Sanitation (DWS) has flow and water quality monitoring stations in quaternary catchments K90D and K90F. These stations are approximately 30 km from the site and located in a different catchment and therefore not regarded as relevant from a water quality perspective.

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There are no dams or well-defined watercourses that may cause a safety threat to the site within the K80F quaternary catchment (***Drawing 5.10.1*** and ***Drawing 5.10.2***).

The Thyspunt Site

Wetlands are prominent on the site and although 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 (Chapter **5.11.6.7**)).

5.10.7.4 Terrain and Site Proximity to Major Watercourses

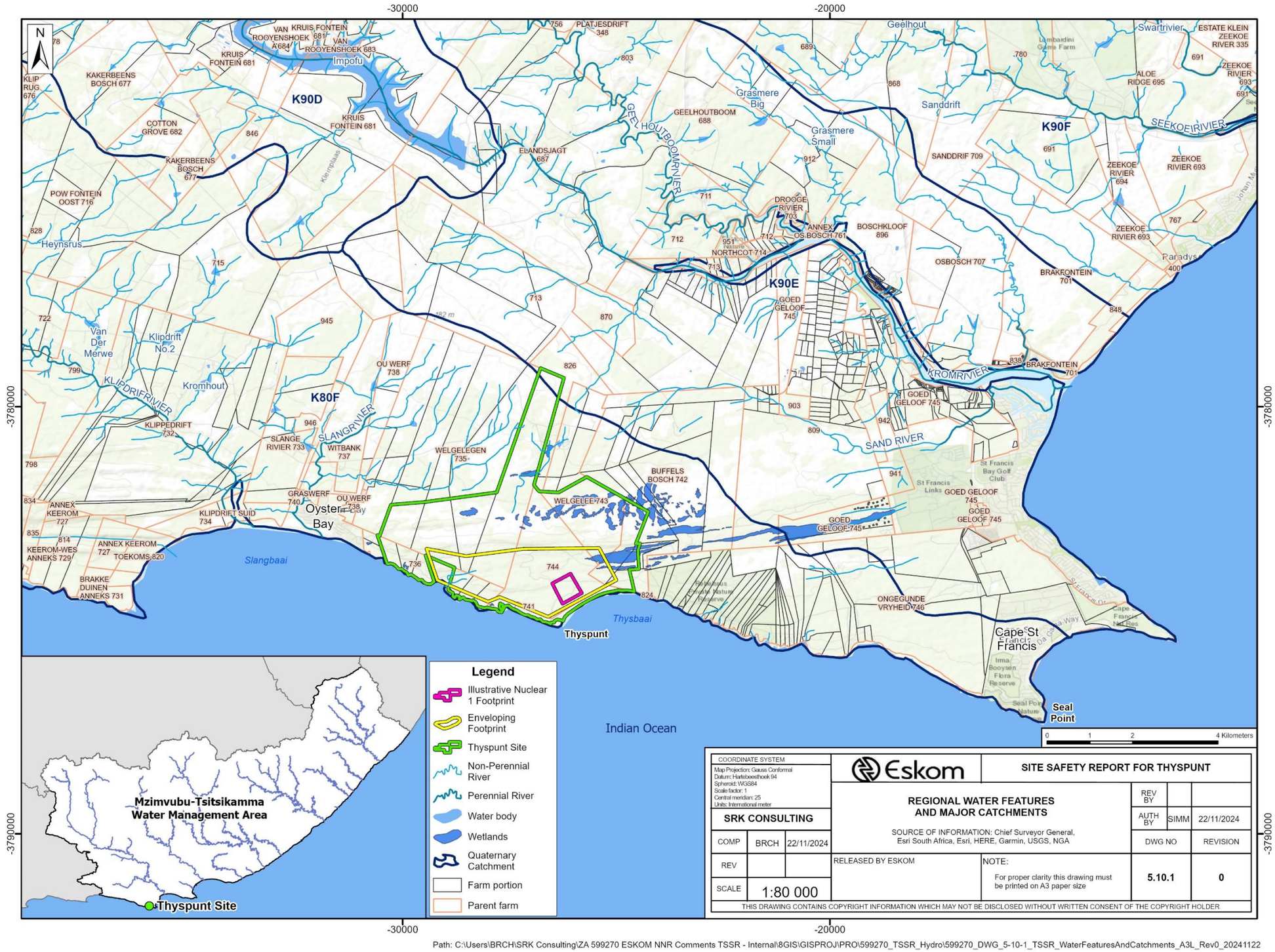
The Thyspunt site is located along the coastline and falls within the K80F quaternary catchment (Water Research Commission, 2012). There are a few drainage lines within the area which are addressed in the subsequent sections.

The closest minor watercourse within catchment K80F is the Slang Rivier located approximately 4 to 5 km northwest of the site flowing in a westerly direction.

The closest major watercourse is Klipdrif River, approximately 25 km west of the site on a different quaternary catchment (K80E), flowing in a southerly direction. The next closest major watercourse is the Krom Rivier, approximately 7 km north of the site on a different quaternary catchment (K90E), flowing in an easterly direction.

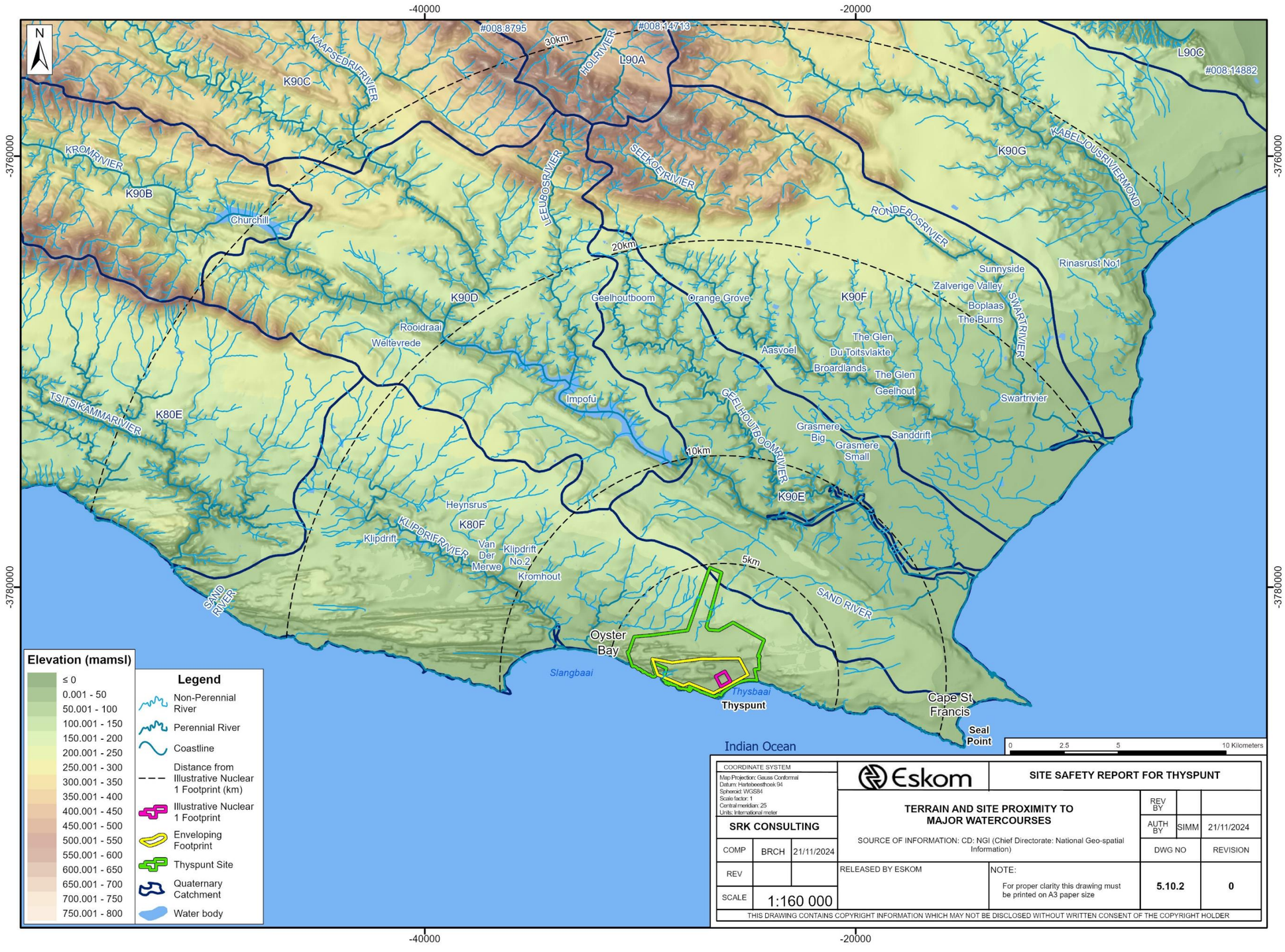
The terrain and proximity of the site to major watercourses is presented in ***Drawing 5.10.2***.

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5.10.7.5 Catchment Characteristics

The catchment is currently expected to have a low run-off coefficient due to sandy soils and moderate vegetation. This also correlates with the preliminary determined infiltration rates of approximately 5 m per day (208 mm/h). These values were considered for the coastal sand and dunes and more details on infiltration rates are given in ***Appendix 5.10.B***. The existing catchment characteristics are uniform in terms of soils (permeability) and vegetation cover for the coastal sand and dune areas. A graduated approach regarding permeability was applied to the different land use types (***Section 5.5***) as input parameters for the model run-off coefficients.

5.10.7.6 Precipitation

At present there are no long-term local rainfall monitoring data available for the site since the on-site rainfall station was only established in January 2008 (see ***Section 5.8***). This data period is too short to carry out any longer-term rainfall predictions except by including additional stations and applying statistical analyses.

Existing rainfall data with the required reliability and length of record were originally 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 have been updated for long-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)
Humansdorp [0017422 5]	146 (1878-2022)	17.3	109	685.6
Cape St. Francis [0017582 07]	104 (1881-1984)	9.3	7	673.0
Cape St. Francis [0017582 07]	19 (1985-2003)	9.3	7	660.9
Cape St. Francis [0017582A1]	20 (2004-2023)	9.3	7	595.0
Thyspunt site	6 (2008-2013 & 2017-2019)	-	51	780.8

Based on 146 years of observations at the SAWS' Humansdorp WS

[2] Metres above mean sea level

(1878-2022) (SAWS, 2024b) (SAWS, 2024c), the mean annual precipitation (MAP) was estimated to be 685.6 mm. However, this station is approximately 17.3 km inland from Thyspunt and may not reflect identical rainfall conditions. The Cape St. Francis WS (SAWS, 2024c) is closer to Thyspunt (approximately 9.3 km east), however, this location is very close to the shoreline and may be influenced by this proximity.

The selected Humansdorp station has significantly less than the record duration required for estimating the Probable Maximum Precipitation (PMP) or 10^{-8} annual probability of exceedance design rainfall depth, required for determining the estimated run-off flows and volumes. The extreme runoff flows and volumes for the higher recurrence interval events for the site are estimated using 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 together with rainfall distribution curves.

The 24-hour extreme rainfall depths (defined as the total expected precipitation in a 24-hour period) were originally calculated using a statistical approach. A statistical analysis using the Annual Maximum Series (AMS) was undertaken using various probability distributions from Flood Risk Reduction Measures (Alexander, 2001) and updated 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)	Present Base Case (mm)		Including Climate Change (mm)	
	Extreme	95th Percentile	Extreme	95th Percentile
10^{-1}	99.0	119.8	108.9	129.7
10^{-2}	151.4	190.2	166.6	205.4
10^{-3}	202.9	259.7	223.2	280.0
10^{-4}	254.3	329.2	279.7	354.6
10^{-5}	305.6	398.6	336.2	429.2
10^{-6}	357.0	468.1	392.7	503.8
10^{-8}	459.7	607	505.7	653.0

According to the 5th Assessment Report (AR5) on climate change (Intergovernmental Panel on Climate Change (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 Change (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 was 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 (Intergovernmental Panel on Climate Change, 2013). RCPs are scenarios depicting the evolution of emissions and concentrations of the most important 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/m². Therefore RCP8.5 implies radiative forcing higher than 8.5 W/m² by 2100, whereas radiative forcing stabilises at approximately 6 W/m², 4.5 W/m ² and 2.6 W/m ² 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 stabilisation scenario in which total radiative forcing is stabilised shortly after 2100, without overshoot, by the application of a range of technologies and strategies for reducing GHG emissions.
- RCP4.5 is a stabilisation scenario in which total radiative forcing is stabilised shortly after 2100, without overshooting the long-run radiative forcing target level.

[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.

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 3.1 W/m² by mid-century and returns to 2.6 W/m² by 2100. To reach such radiative forcing levels, GHG emissions (and indirectly emissions of air pollutants) are reduced substantially, over time.

The associated management of uncertainties for the rainfall has been addressed in ***Section 5.8***.

For the hydrology modelling, RCP8.5 was used to account for climate change over an approximate 100-year lifetime of the nuclear installation(s). 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] for hydrology modelling 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}	129.7
10^{-2}	205.4
10^{-3}	280.0
10^{-4}	354.6
10^{-5}	429.2
10^{-6}	503.8
10^{-8}	653.0

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 has been extracted from ***Section 5.9*** for use in the hydraulic model which calculates the relevant flood levels. 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)	1.08	1.08
	Sea level rise	(m)	3.28	3.28
	Storm surge	(m)	1.28	1.43
	Still high-water level	**(m amsl)**	**5.64**	**5.79**
10^{-6}	90th Percentile of high tides	(m amsl)	1.08	1.08
	Sea level rise	(m)	3.28	3.28
	Storm surge	(m)	1.55	1.78
	Still high-water level	**(m amsl)**	**5.91**	**6.14**
10^{-8}	90th Percentile of high tides	(m amsl)	1.08	1.08
	Sea level rise	(m)	3.28	3.28
	Storm surge	(m)	1.81	2.12
	Still high-water level	**(m amsl)**	**6.17**	**6.48**

The above data were obtained from ***Section 5.9*** and list ***still*** high-water levels due to storm events and are 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 5.79 m amsl;
- 10^{-6} year event is 6.14 m amsl;
- 10^{-8} year event is 6.48 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)	Forest Area (km^2)	Irrigation Area (km^2)	Evaporation Zone	MAE (mm)	Rain Zone	MAP (mm)	MAR (mm)	NET MAR (m^3 x 10^6)
K80F	221	0	2.1	24C	1 400	K8	769	154	34.0

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

The location of catchment K80F 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 769 mm in ***Table 5.10.6*** is higher than the MAP derived from the Humansdorp station of 687 mm. WR2012 MAP represents weather stations in the entire regional catchment K80F whereas Humansdorp values are specific to that weather station. 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 K80F data bearing in mind that the proposed nuclear installation(s) is situated along the coastline. Based on ***Table 5.10.6*** and the data for catchment K80F, an MAR of approximately 154 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 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).

5.10.7.9 Regional Hydrological Modelling

The regional hydrology includes all catchments that naturally drain towards

[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

and/or through the site/site vicinity and which may therefore have an impact on the site. The regional catchments are divided into the Northern and Southern region with the Northern draining into the dunes and the Southern towards 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.

In addition to the assessment of the drainage lines, possible temporary ponding areas have also been identified. These areas consist primarily of low points with no natural outlet. During a storm event these areas would accumulate excess run-off from the surrounding catchment which would cause temporary ponding. The locality of the ponding areas has been determined using a Geographic Information System (GIS) tool which defined all low-lying areas based on the current topographical information of the area of investigation. The 1:10 000-year return period for the low-lying areas and surface water sampling points are presented in ***Drawing 5.10.3*** and the sub-catchments for the Northern and Southern region in ***Drawings 5.10.4*** to ***5.10.5***. 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.

The model predicts run-off peaks based on a 24-hour rainfall distribution using the SCS-SA 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 (National Nuclear Regulator, 2016).

The determination of the run-off flows and volumes are based on NRC NUREG/CR-7046 (United States Nuclear Regulatory Commission, 2011) and the NNR RG-0011 (National Nuclear Regulator, 2016) recommendations, which require the 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 10 000 year return period as this provides reasonable assurance of non-exceedance for a 1 000 year period. For a 1 000 year design period, there

[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.

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will be a 90 per cent probability of non-occurrence for a 10 000 year return period event.

External Events for New Nuclear Installations (National Nuclear Regulator, 2014) position paper was also considered throughout the modelling. Extreme storm events were also extrapolated (up to a 10^{-8} annual probability of exceedance for the 95^{th} 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 (Eskom, 2022).

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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***.

Table 5.10.7
SCS-SA Deterministic 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) 129.7 205.4 280.0 354.6 429.2 503.8 653.0	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	Arable Land ……...70 Coastal Sand & Dunes. 27 Crops Non-Pivot ……68 Crops Rain-fed ……...70 Dense Forest ……..42 Low Forest ……..35 Natural Grassland ……39 Shrubland ……..30 Waterbodies ……100 Wetland ……100	Sandy soil, SCS Type ‘A’ with high infiltration rate (208 mm/h) (***Appendix 5.10.B***) for the site specific coastal sand & dunes. Graduated values for remainder of site based on land use type ***Section 5.5*** (Land & Water Use).
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.

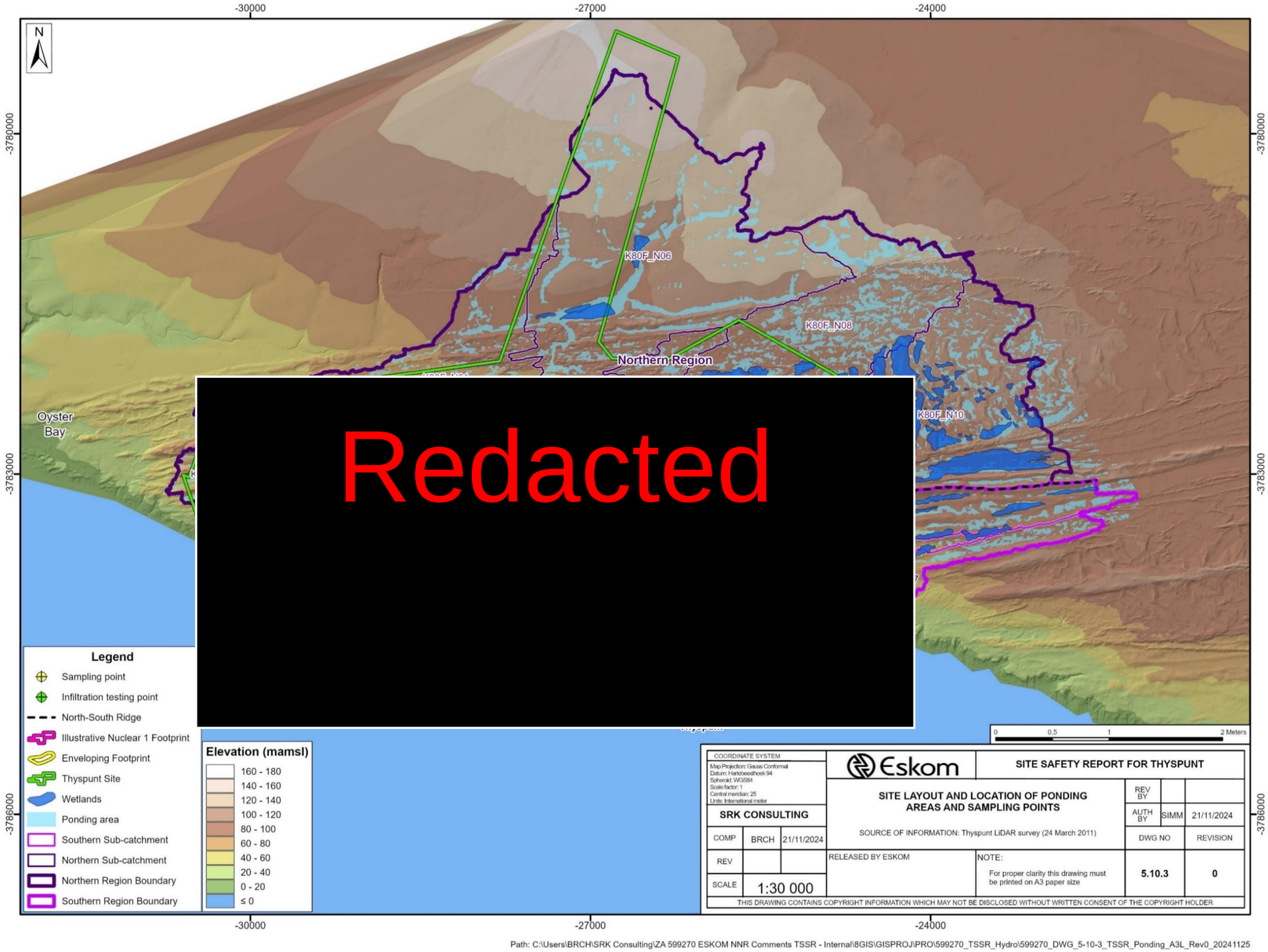
The Northern catchments are cut off from draining to the site therefore only the Southern catchments draining towards the site were assessed in detail. Based on the above approach and model input parameters, the estimated peak flow rates for all catchments covering the site as shown in ***Drawings 5.10.4*** to ***5.10.5***. are summarised in ***Table 5.10.8*** below.

Table 5.10.8
Result of Regional Hydrological Modelling

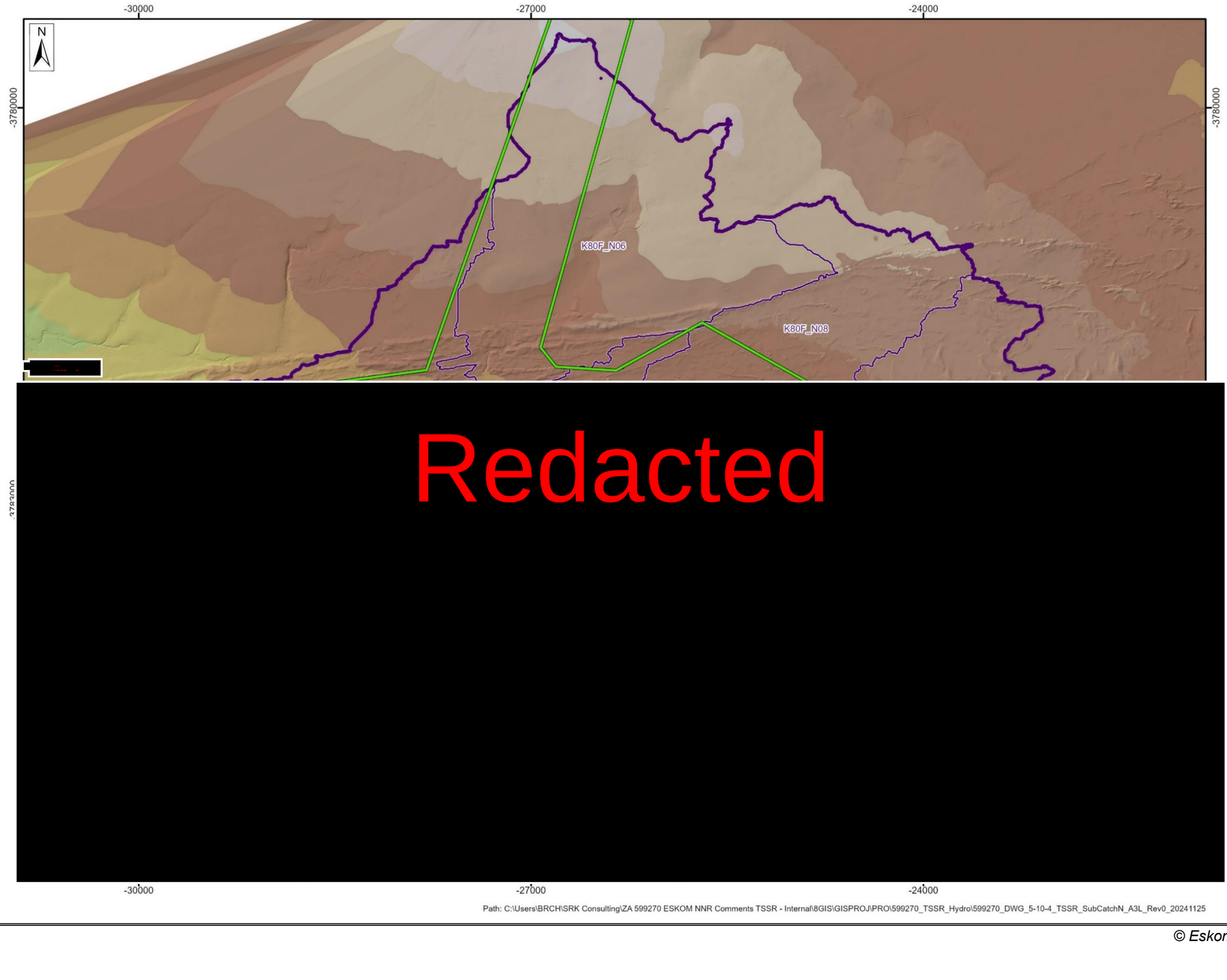
Catchment Name	Area (km^2)	* Peak Flow (m^3/s) for Various Probability of Occurrence (yrs)						
		10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-8}
K80F_S01	0.18	0.50	1.80	3.50	5.50	7.60	10.00	14.90
K80F_S02	1.44	2.20	8.00	16.00	25.50	35.90	47.20	71.30
K80F_S03	1.92	6.90	18.10	31.90	47.10	63.20	80.20	115.10
K80F_S04	0.84	1.60	5.80	11.70	18.70	26.30	34.60	52.20
K80F_S05	0.56	1.80	5.20	9.50	14.40	19.50	25.00	36.40
K80F_S06	0.88	2.00	6.80	13.20	20.70	28.90	37.70	56.30
K80F_S07	0.59	1.10	4.00	7.80	12.40	17.30	22.70	34.10
K80F_S08	0.17	0.50	1.60	3.00	4.60	6.40	8.30	12.30
K80F_S09	0.24	0.70	2.30	4.40	7.00	9.70	12.70	19.00
K80F_S10	0.55	1.20	4.10	8.00	12.60	17.50	22.90	34.20
K80F_S11	0.37	1.10	3.90	7.80	12.30	17.20	22.60	33.90
K80F_S12	0.11	0.20	0.90	1.70	2.70	3.80	5.00	7.50

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

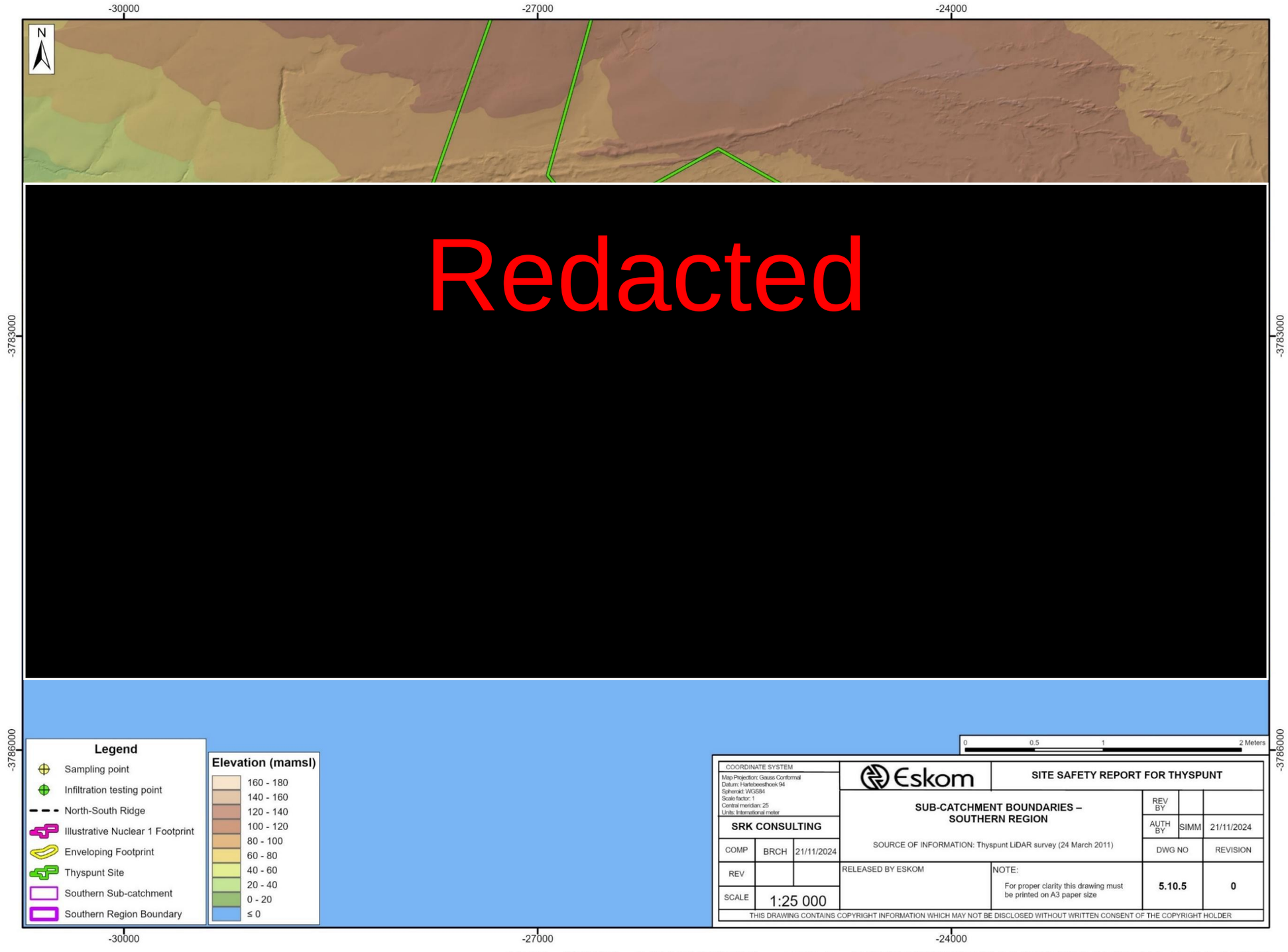
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The following conclusions for the regional peak flows can be made based on the results presented above:

- 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 Northern catchments drain towards the dunes and are disconnected (surface water perspective) from the Southern catchments draining towards the site/site vicinity.
- Five major vegetation types occur on the site: Algoa Dune Strandveld, Southern Cape Dune Fynbos, Tsitisikama Sandstone Fynbos, Cape Seashore Vegetation and Cape Lowland Freshwater Wetlands (***Section 5.5. and Section 5.3 Figure 5.3.1***).
- The majority of the local 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.
- Due to the small catchment areas, low rainfall depth and high infiltration rates, the lower storm events generated very low run-off peaks.

5.10.8 Watercourse Sedimentation Dynamics

The site falls within small, localised catchments (low lying areas) with the cumulative catchments having an area of <8.0 km^2 and therefore the runoff volumes and peak flows are low. There are no major watercourses within the site boundary and negligible amounts of sediment are expected within the enveloping footprint due to the small catchments and high infiltration rate and are not regarded as concern related to primary impacts. The final location (localised) of the illustrative nuclear island footprint is not yet known. Although sedimentation is not considered a primary impact, once the on-site terracing layout is known, the need for a sedimentation study can be considered.

5.10.9 Dam Break Modelling

It is observed in ***Drawing 5.10.1*** that no significant dams or associated defined watercourses are situated within the quaternary catchment K80F which drains towards the Thyspunt site. There is a catchment divide (Northern and Southern zone) and the Northern zone drains into the dunes and does not reach the enveloping footprint. The existing water bodies create natural storage areas which would not result in 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

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maximum wall height > 5 m. There are no existing dams of this nature within the catchment draining towards the nuclear installation(s).

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 run-off 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 drainage lines and potential ponding areas which can be seen in ***Drawing 5.10.1*** and are described as follows:

- a minor watercourse along the western boundary of the site - The watercourse is non-perennial and well vegetated draining into a small bay.
- a low-lying area and a non-perennial watercourse along the south-eastern corner of the site discharging into the Indian Ocean.
- a minor drainage line to the north of the site parallel to the enveloping footprint - However, this watercourse does not have a natural outlet and hence will function more like a low-lying ponding area than a river.

5.10.10.2 Description of Hydraulic Model

Several hydraulic modelling software packages 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). This model has been used for any defined watercourses and the 2D component for low-lying areas experiencing sheet flow with limited defined outlets. For the potential to partially retain run-off, the hydraulic modelling using the dynamic wave analysis of 2D-PCSWMM (Computational Hydraulics International, 2020) was used where required.

HEC-RAS uses standard backwater calculations and is adequate to model the natural watercourses which, due to their small sizes, do not have a large storage potential (hence a one-dimensional model adequately predicts the water levels). The model has been used in the market for over 30 years and has hence been tested sufficiently for all types of watercourse conditions.

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The model uses the standard Manning's Equation and energy balance and covers both sub-critical and super-critical flow regimes. The model calculates the high-water level in a water course based on cross sections along the water course abstracted from the existing survey information at the site. For sheet flow and ponding conditions, the 2D component is better suited.

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

SWMM is a dynamic rainfall run-off simulation model that computes run-off quantity. The run-off component of SWMM operates on a collection of sub-catchment areas that receive precipitation and generate run-off. The routing portion of SWMM transports this run-off through a system of channels. SWMM tracks the quantity of run-off 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 storm water run-off.

The HECRAS and 2D-PCSWMM computer software packages for the hydraulic calculations have been verified and validated over many years by the software vendor, as required by the NNR guidelines RG-0016 (National Nuclear Regulator, 2016). The expected peak flow hydrographs as determined by the SCS-SA model have been used in the HECRAS and 2D-PCSWMM model which calculates the expected high-water level (depths) and velocities based on the peak flow rates.

5.10.10.3 Approach and Boundary Conditions

The approach adopted was to utilise the existing topographic information to define the existing watercourse/drainage 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 HECRAS model makes use of open channel flow to compile river levels for a given flow rate. It uses a mixed flow regime as some of the water courses are steep while others have a flat gradient. This causes the flow of water to be both super-critical in steep areas and sub-critical in flat areas. For sheet flow and ponding conditions, the 2D component is better suited.

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 in the ocean 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 HECRAS (2D) and 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 run-off) was used to model the drainage lines for the current natural conditions and boundary conditions as shown in ***Table 5.10.9***.

A typical section has been provided for 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 cross section through the future illustrative nuclear island footprint is given in ***Figure 5.10.1*** below.

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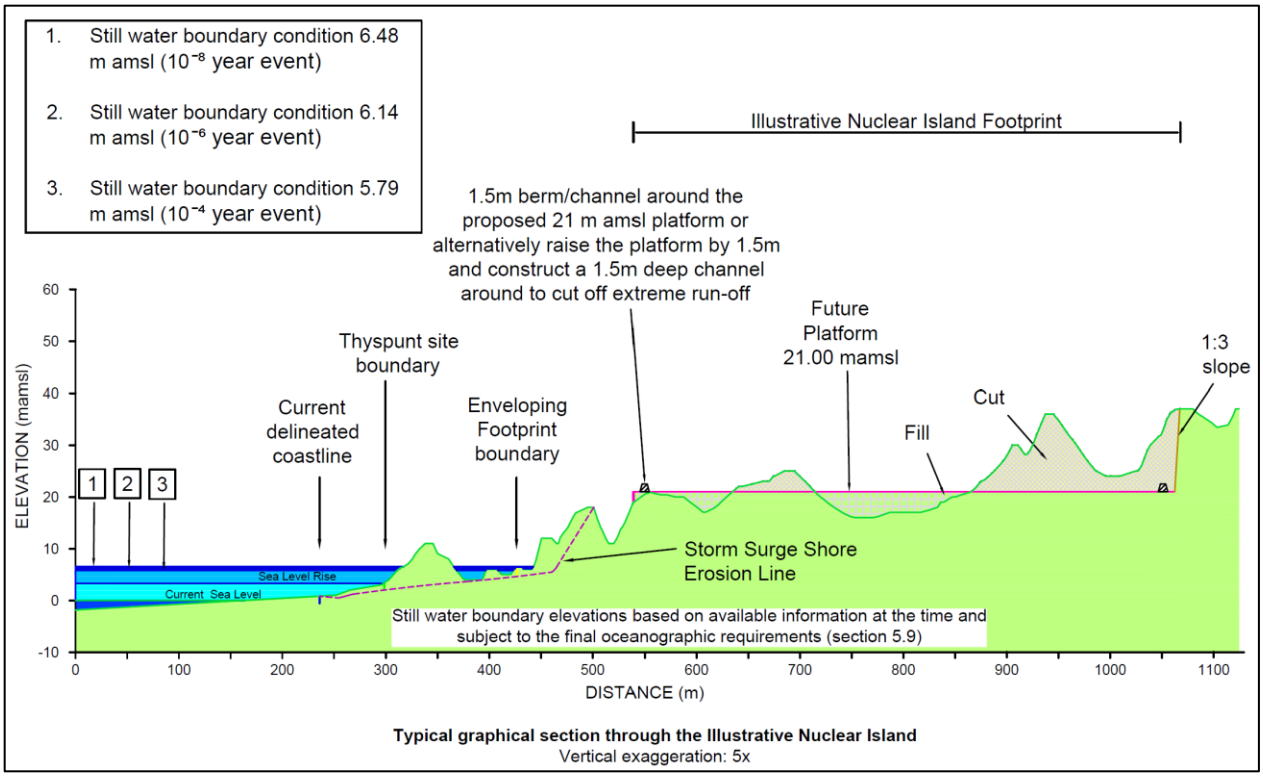


Figure 5.10.1 Typical Graphical Cross Section – Illustrative Nuclear Island

From the oceanographic study (***Section 5.9***) there is potential for cross-shore erosion during storm surge cases which may extend inland for approximately 250 – 300 m as indicated in ***Figure 5.10.1*** above. The surface water models used a maximum still high-water level of 6.48 m amsl (10^{-8} year event).

The platform level has been based on the storm surge and wave heights for instantaneous conditions from the oceanographic study and therefore would need to be assessed during detailed design. Due to the small surface water flows generated from the inland catchments the final platform level recommended by the oceanographic study takes preference over the upstream surface water elevations. This would be determined during the detailed design.

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Table 5.10.9
Hydraulic Model Input Parameters

Parameter	Value	Reason
Manning's 'n' (roughness coefficient)	0.040 – 0.060	Moderately vegetated drainage line and floodplains - HECRAS Manual (Hydrologic Engineering Centre, 2010) and 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	5.79 m amsl (10^{-4}) 6.14 m amsl (10^{-6}) 6.48 m amsl (10^{-8})	Abstracted from oceanographic study ***Section 5.9***
Topography (DEM shape file from latest Lidar survey (Southern Mapping Geospatial, 2011)	2D geo-referenced grid mesh created from Lidar survey	Sheet flow modelling required
Surface water runoff	Flows for each sub-catchment from Visual SCS-SA	Hydrographs generated and compared with model for the sub-catchments

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 define flood lines along the drainage lines. No outputs were therefore provided for the lower return periods. The locality of the expected maximum flooding depths and velocities are shown in ***Drawing 5.10.6*** to ***5.10.23*** for the 10^{-4}, 10^{-6} and 10^{-8} annual probabilities of exceedance respectively.

A summary of the average 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.

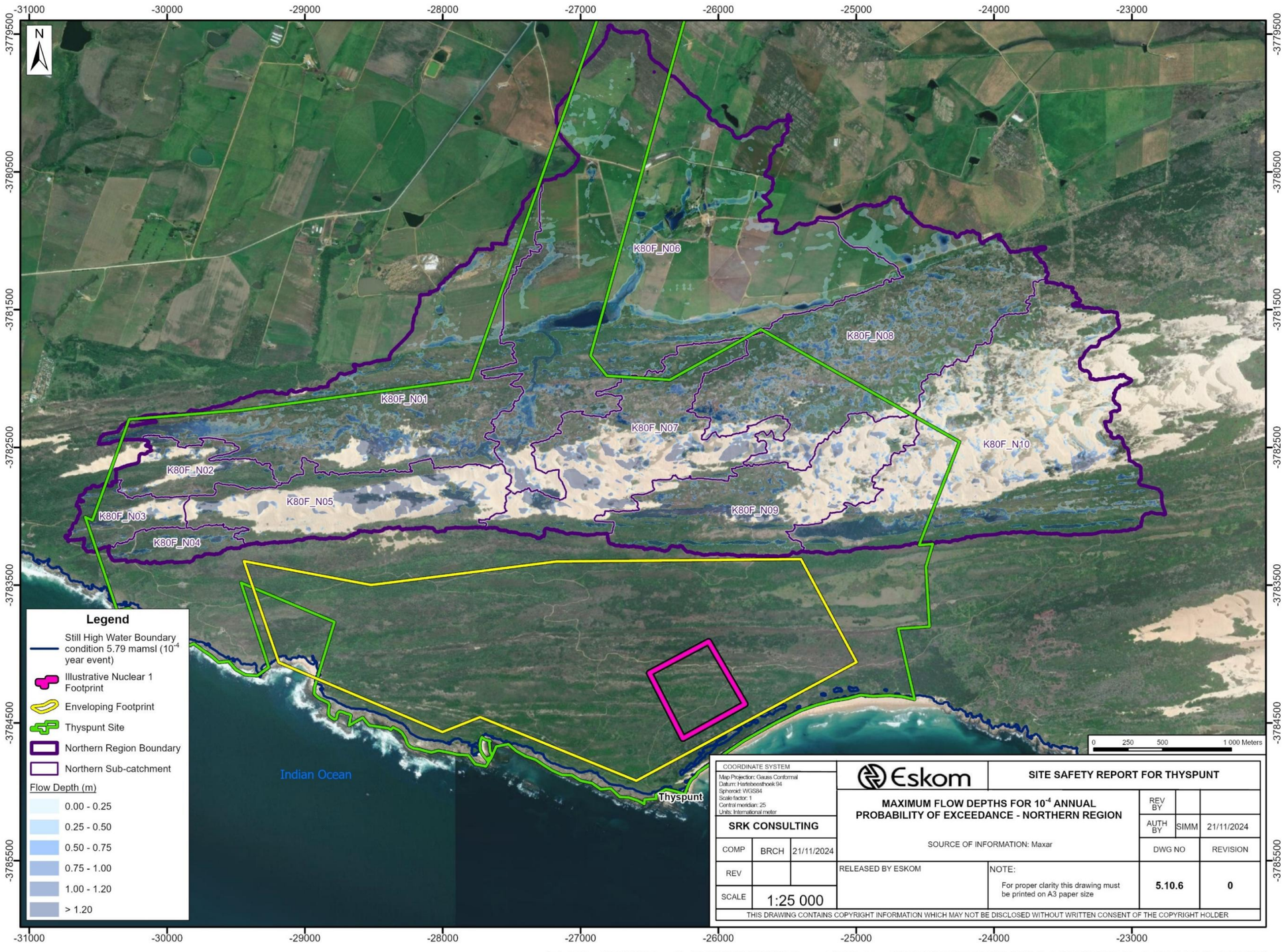
Table 5.10.10
Summary of Average Maximum Flow Depths and Velocities

Catchment Name	Average Maximum Flow Depth (m)			Average Maximum Velocity (m/s)		
	10^{-4} (yrs)	10^{-6} (yrs)	10^{-8} (yrs)	10^{-4} (yrs)	10^{-6} (yrs)	10^{-8} (yrs)
K80F_S01	0.28	0.34	0.40	0.54	0.64	0.74
K80F_S02	0.63	0.83	0.97	0.46	0.58	0.68
K80F_S03	0.92	1.20	1.22	0.55	0.64	0.72
K80F_S04	0.46	0.54	0.62	0.39	0.46	0.54
K80F_S05	0.86	1.10	1.26	0.58	0.62	0.67
K80F_S06	0.75	1.04	1.82	0.49	0.58	0.69

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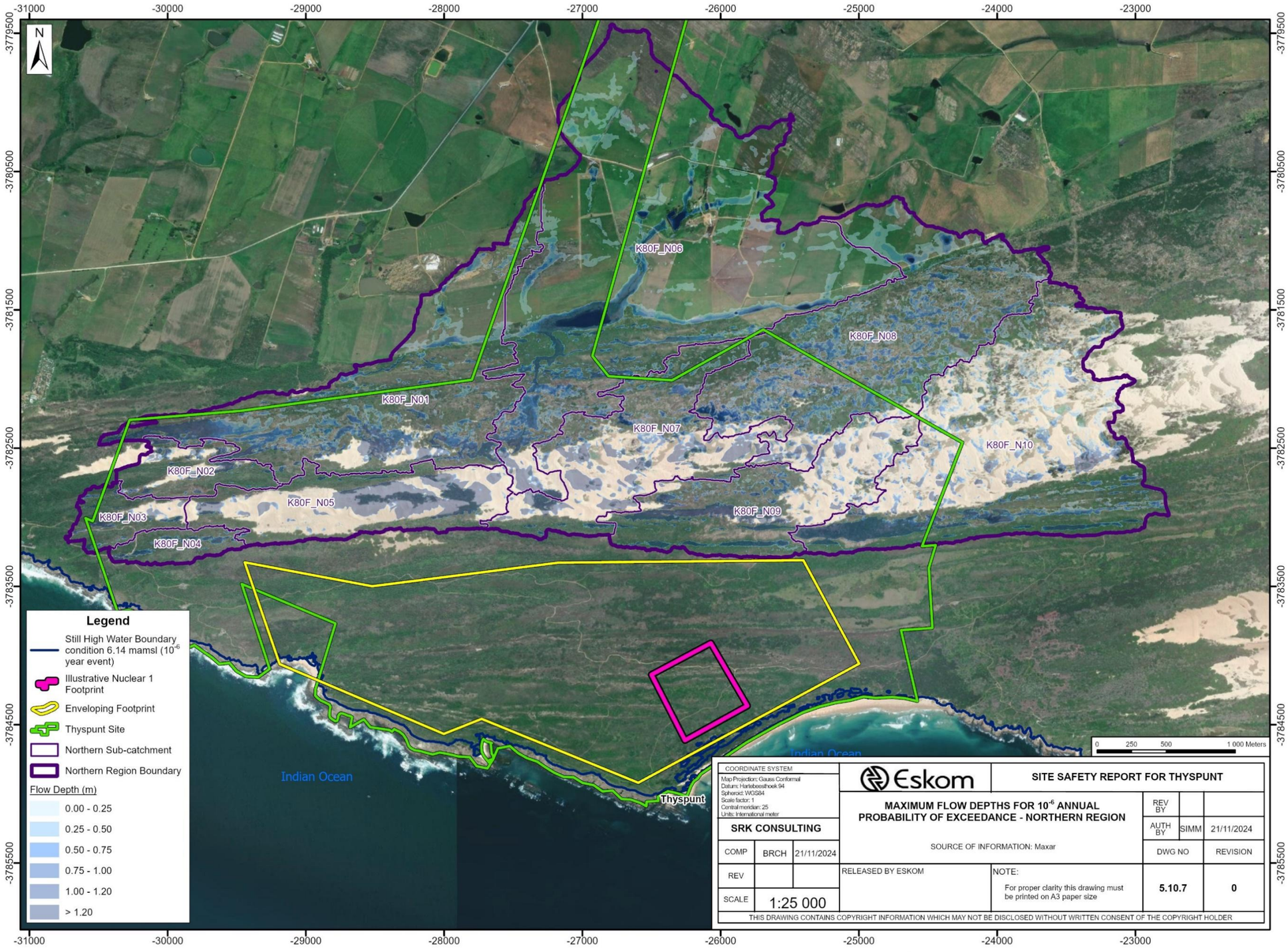
Catchment Name	Average Maximum Flow Depth (m)			Average Maximum Velocity (m/s)		
	10^{-4} (yrs)	10^{-6} (yrs)	10^{-8} (yrs)	10^{-4} (yrs)	10^{-6} (yrs)	10^{-8} (yrs)
K80F_S07	0.35	0.43	0.51	0.31	0.41	0.49
K80F_S08	0.82	0.85	0.90	0.45	0.54	0.63
K80F_S09	0.60	0.67	0.72	0.28	0.31	0.35
K80F_S10	0.70	0.95	1.07	0.33	0.36	0.42
K80F_S11	0.63	0.85	0.96	0.28	0.32	0.36
K80F_S12	0.79	1.32	1.50	0.32	0.34	0.38

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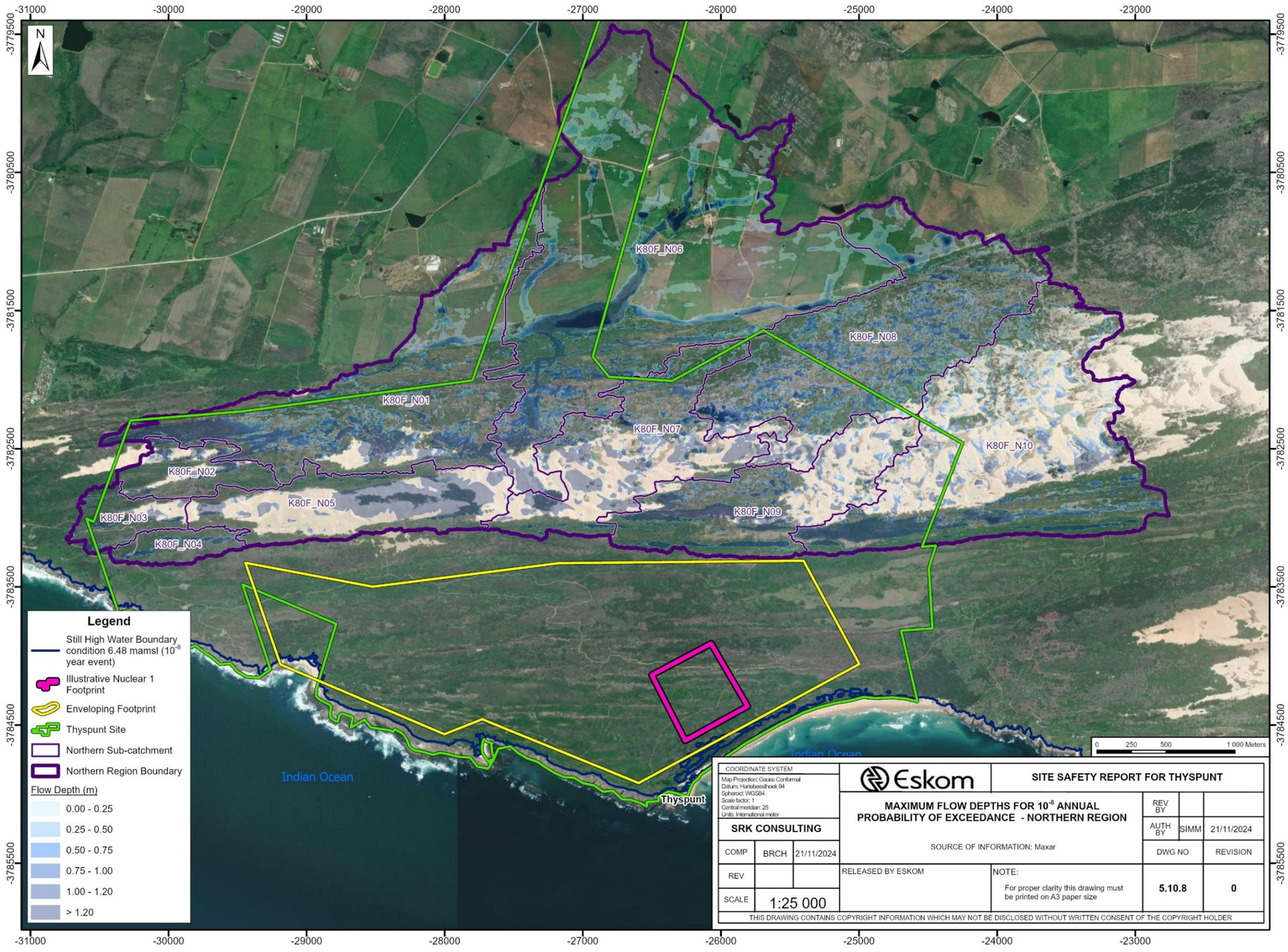
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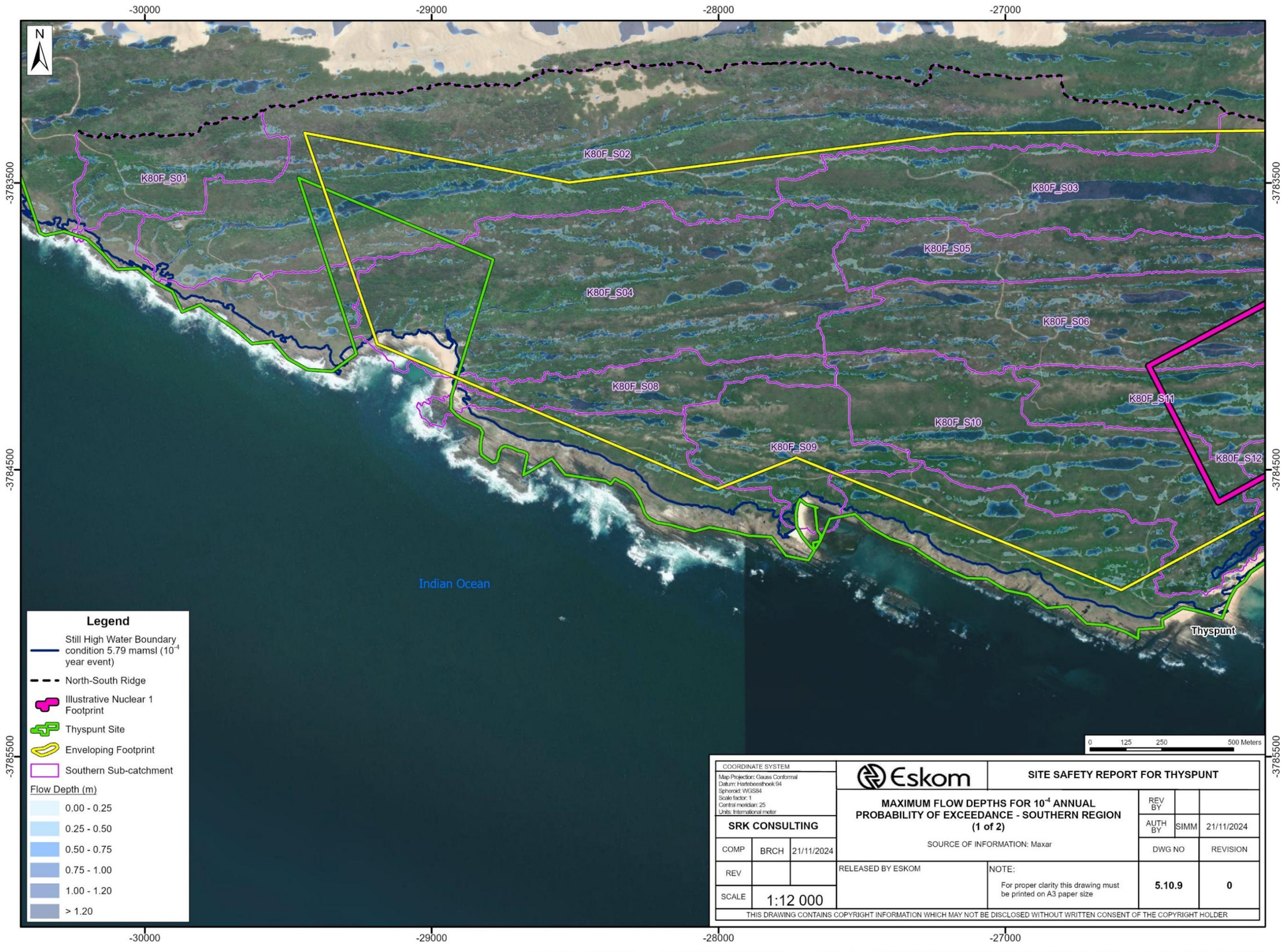
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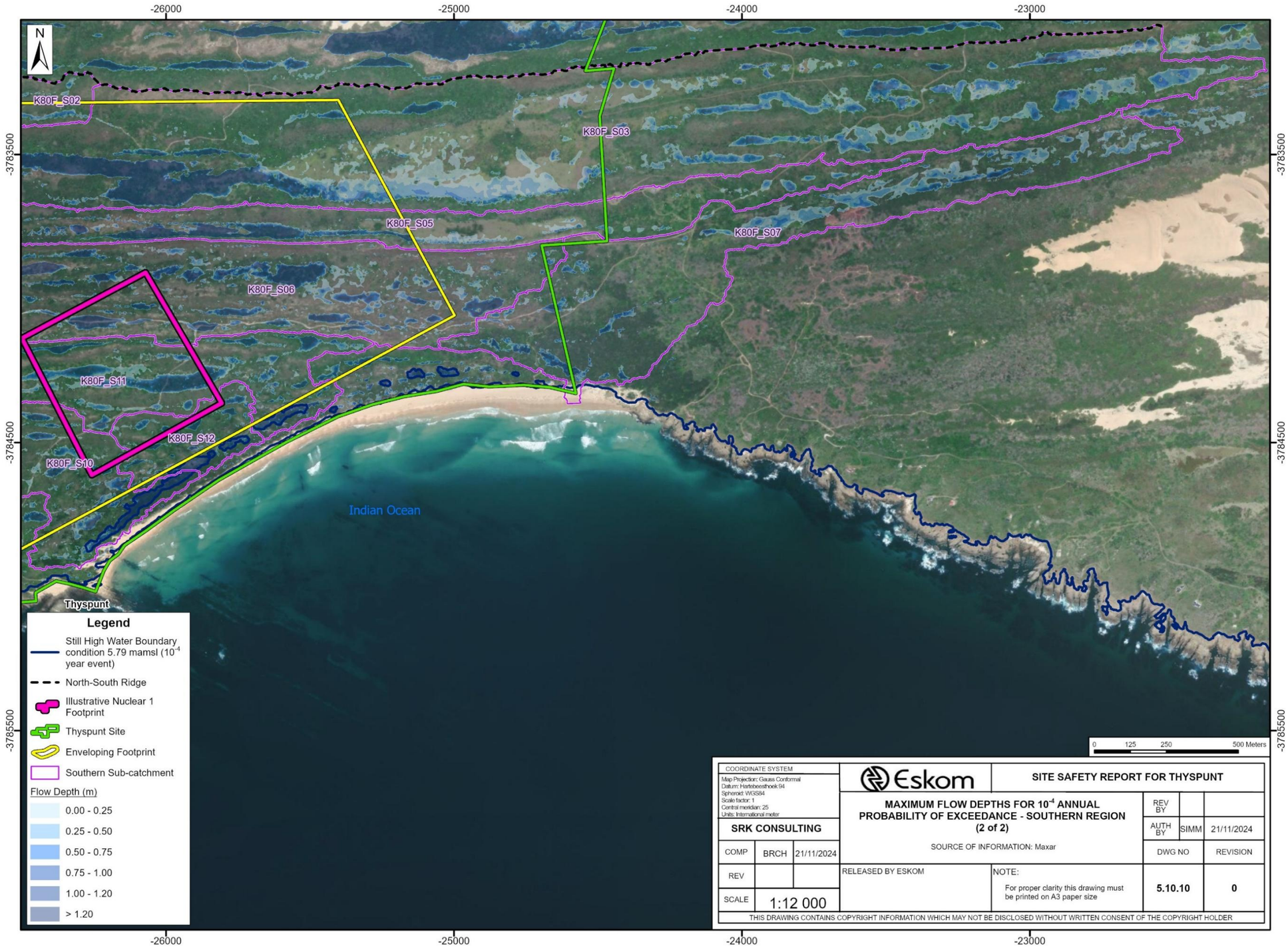
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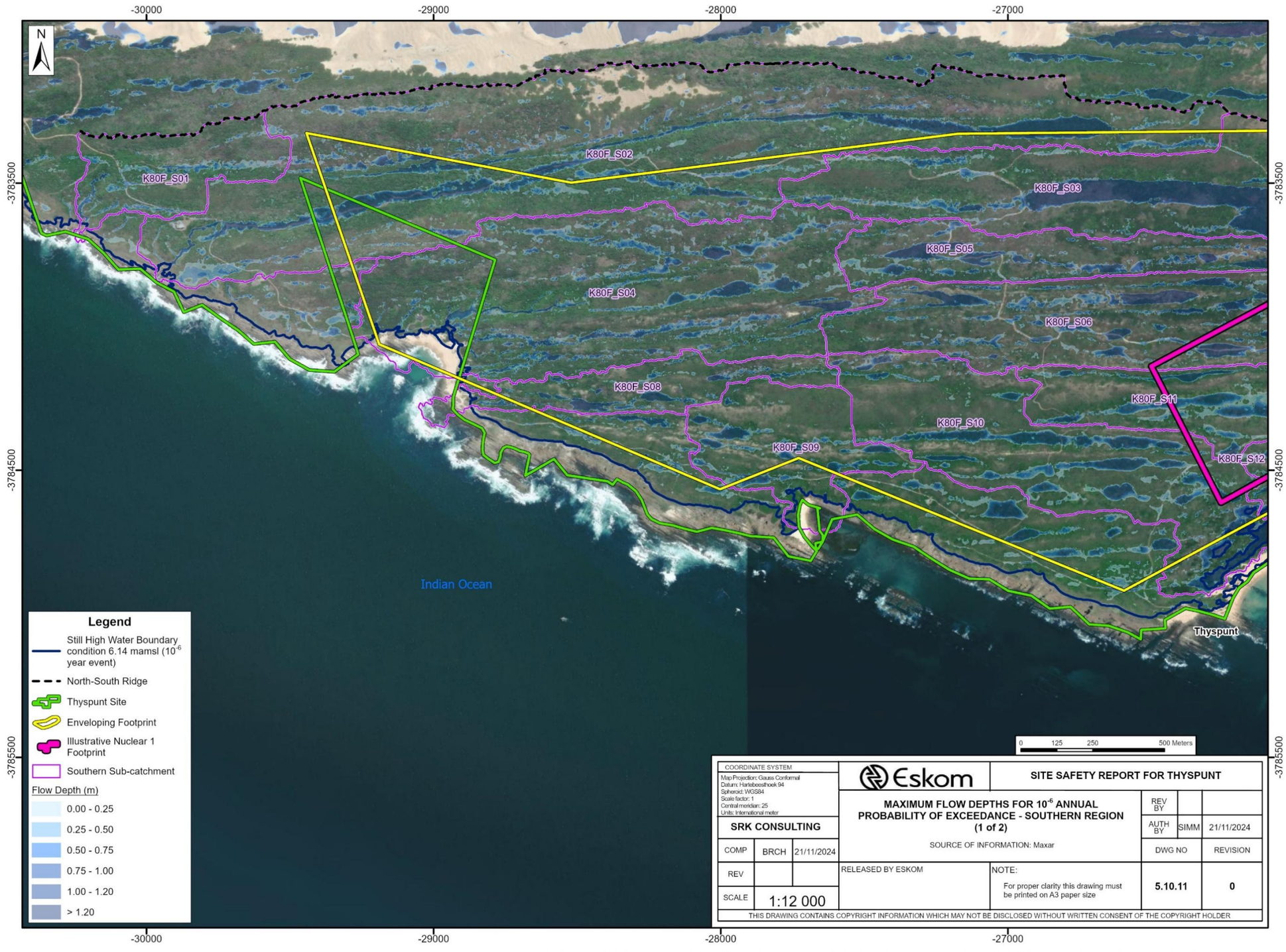
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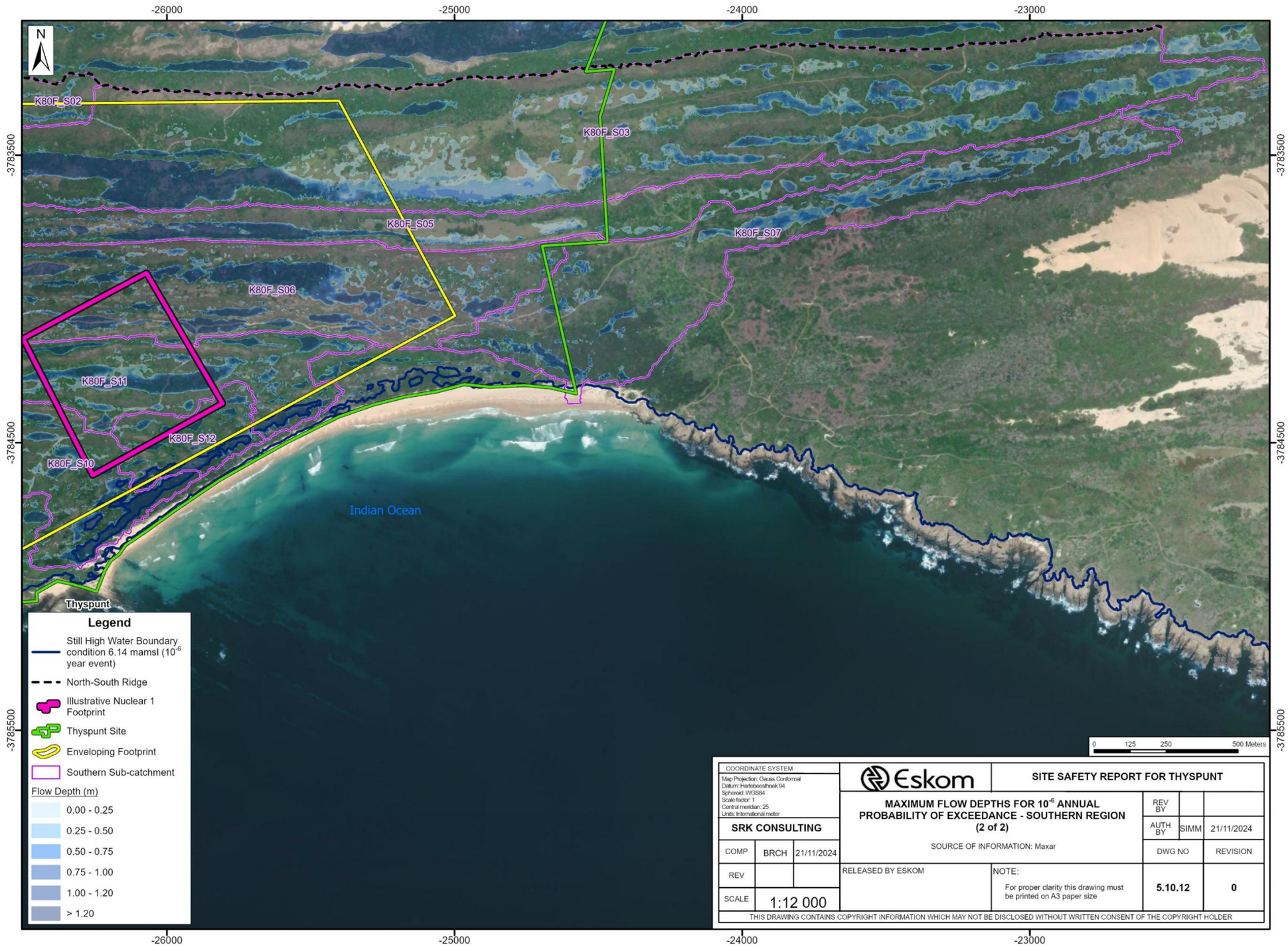
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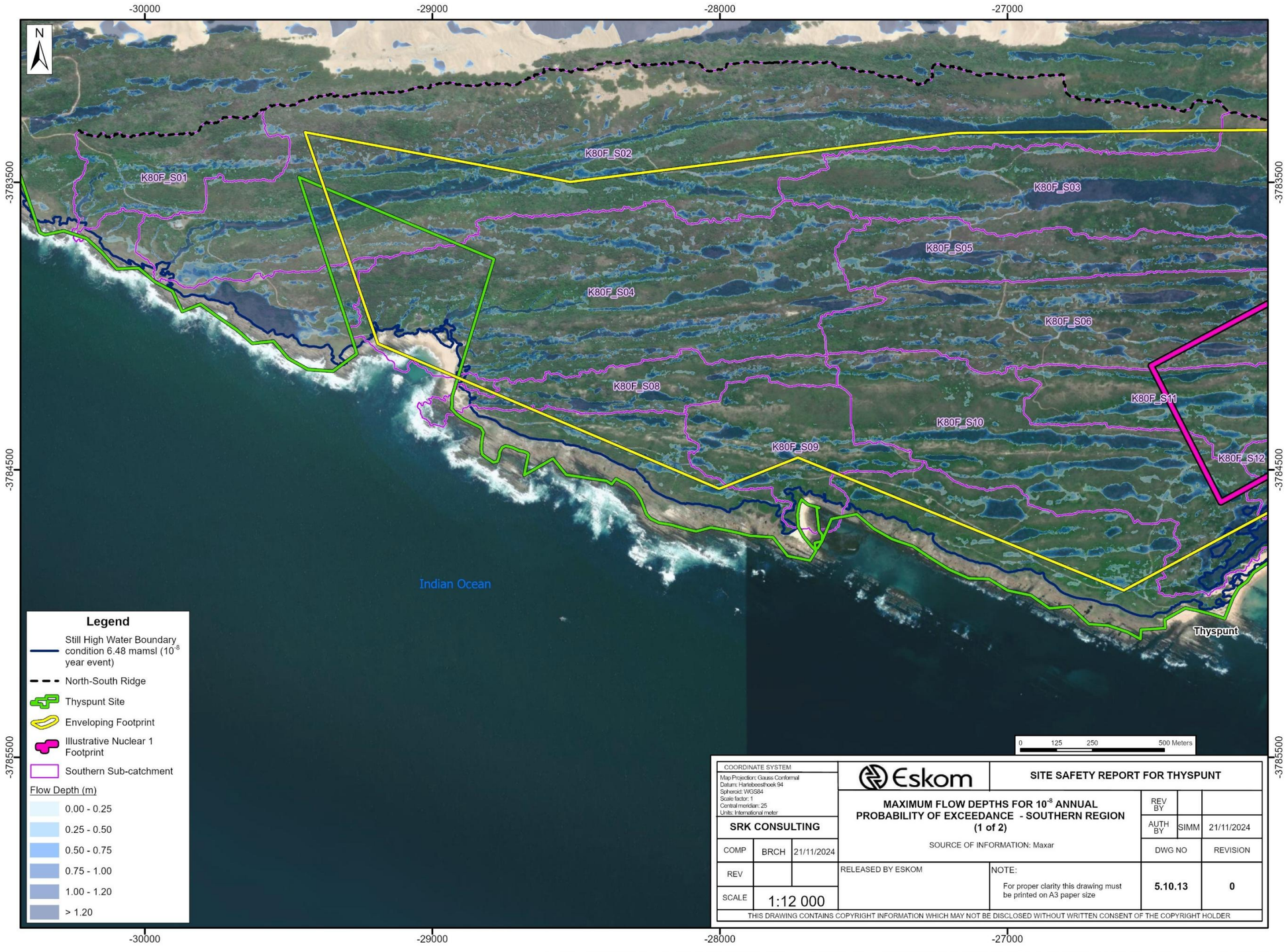
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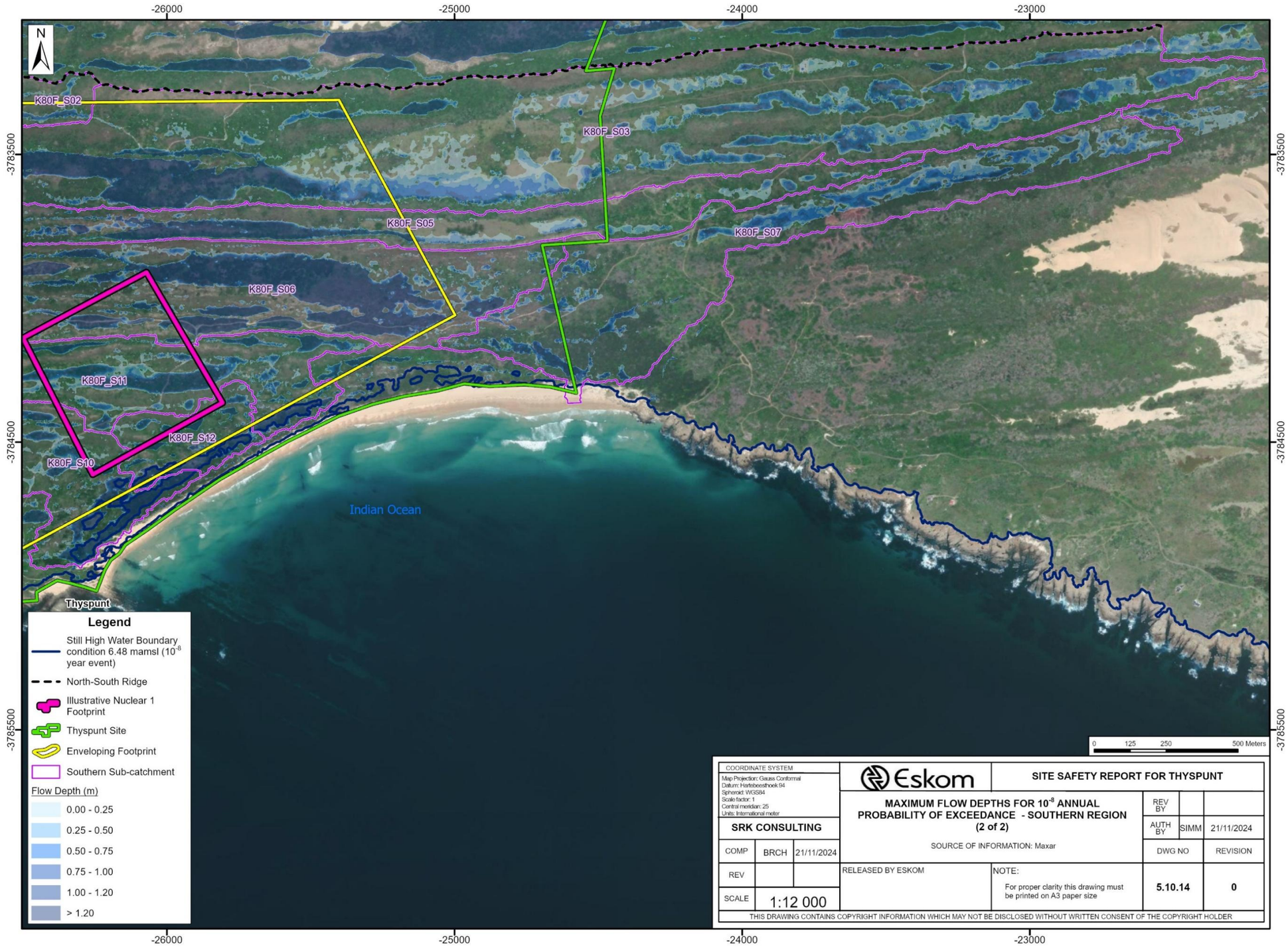
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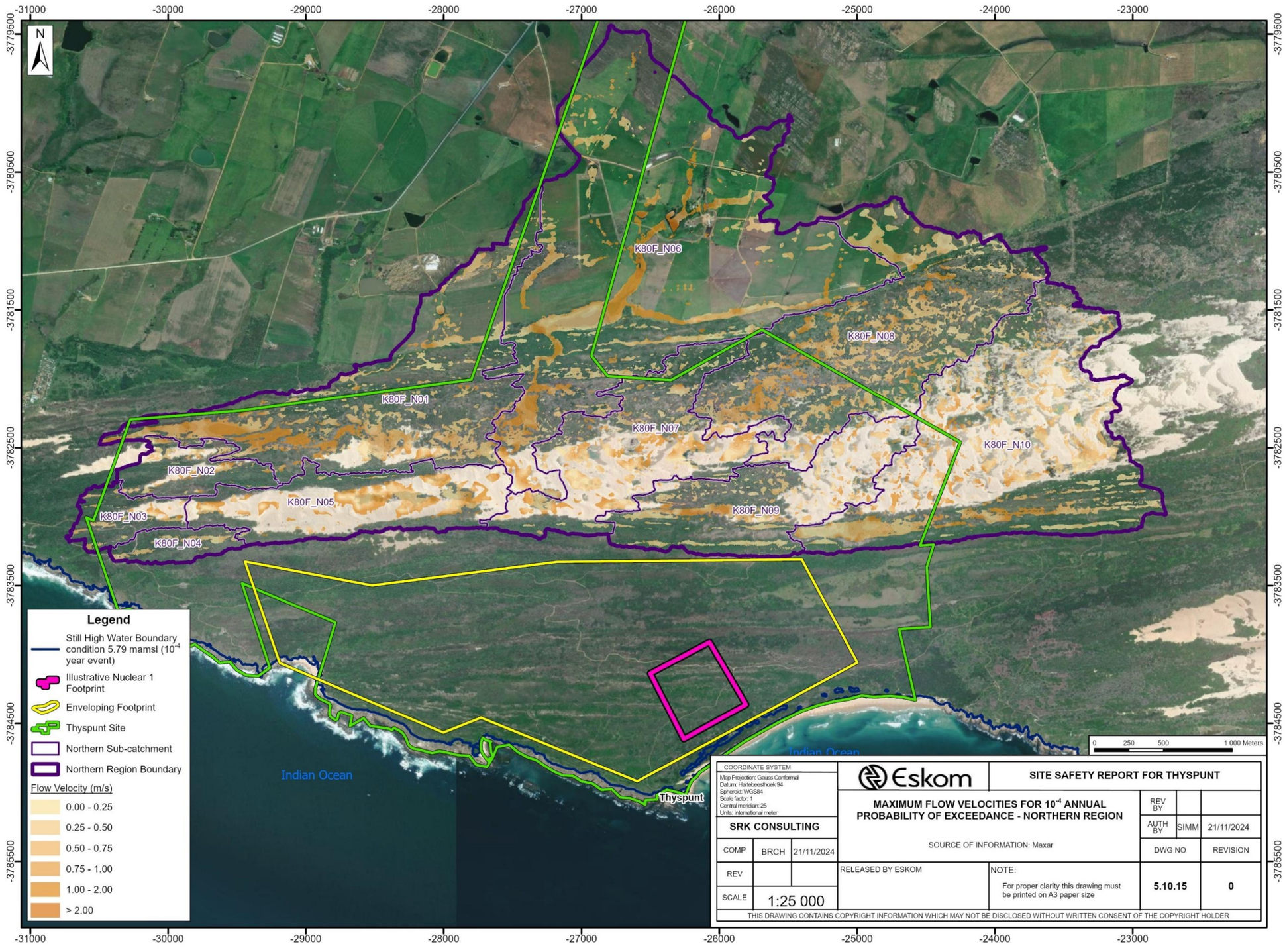
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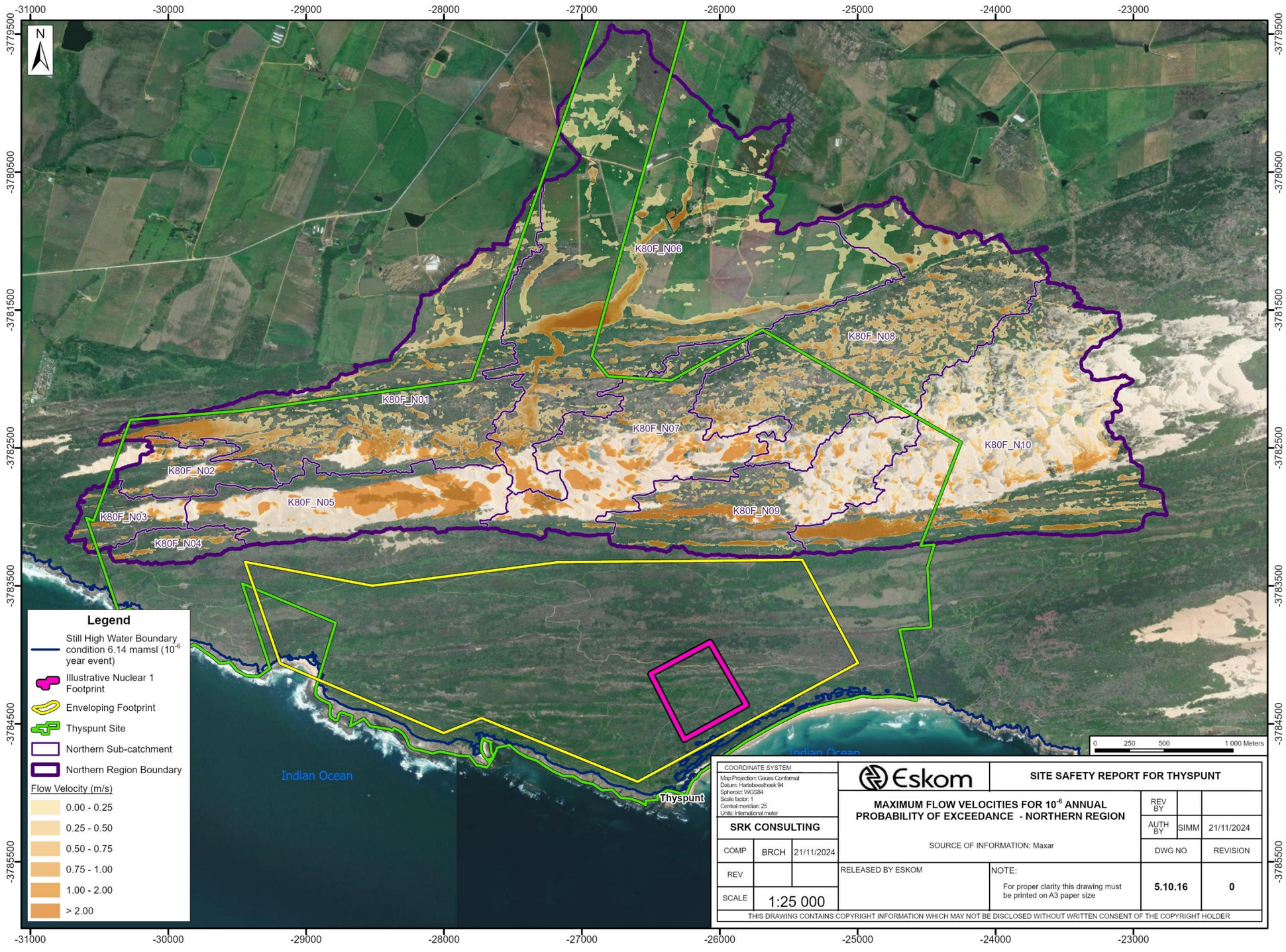


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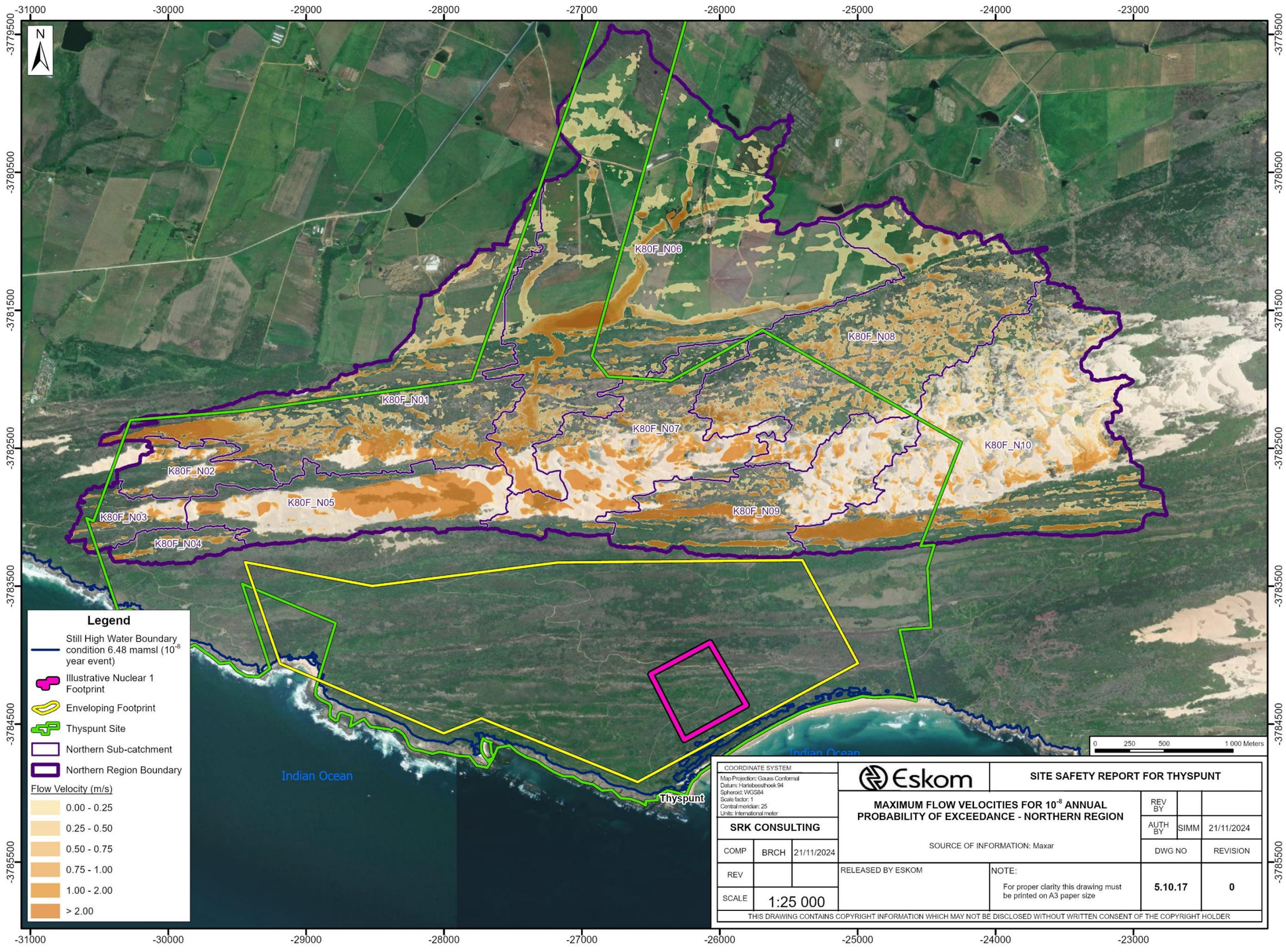


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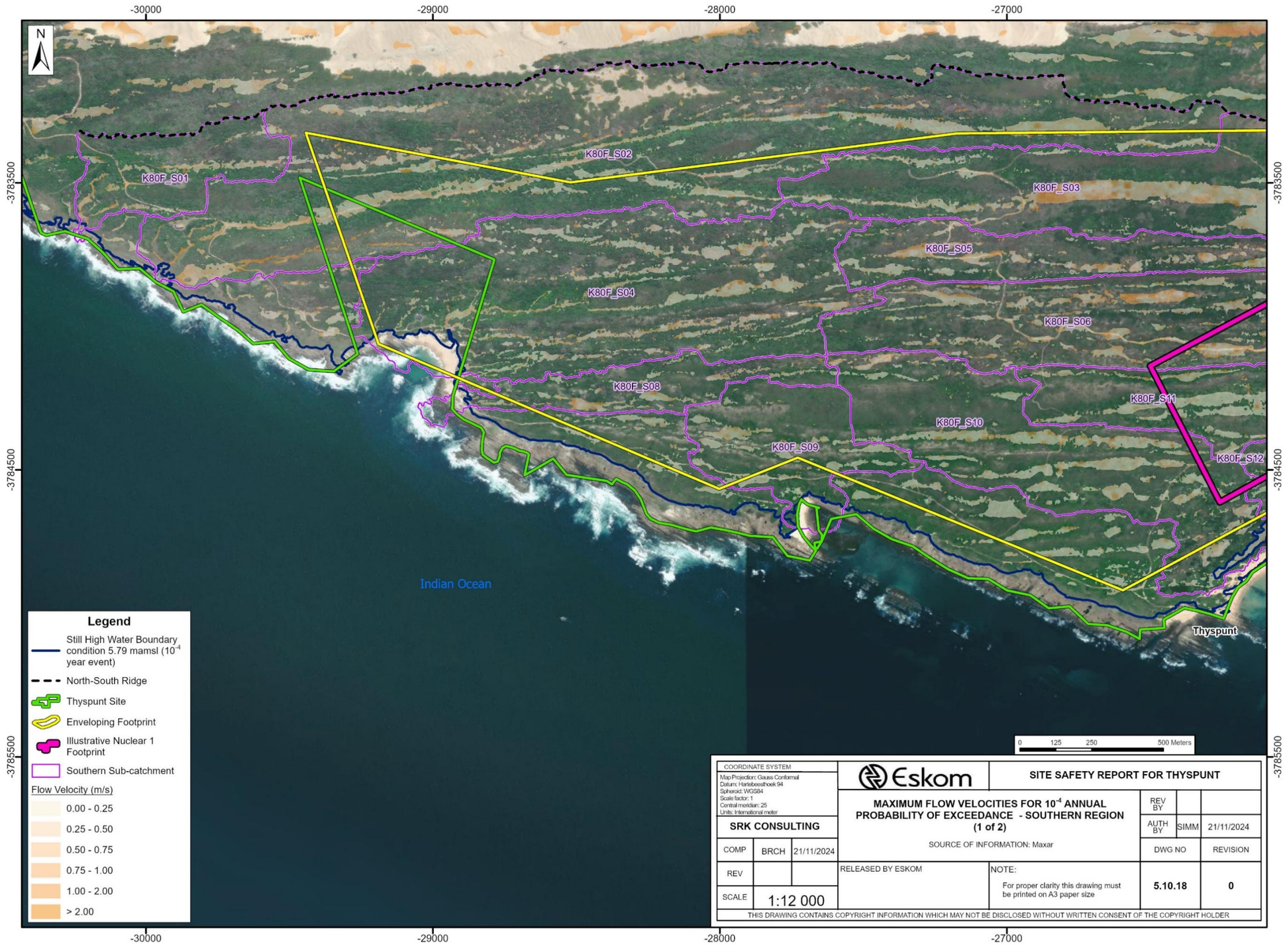
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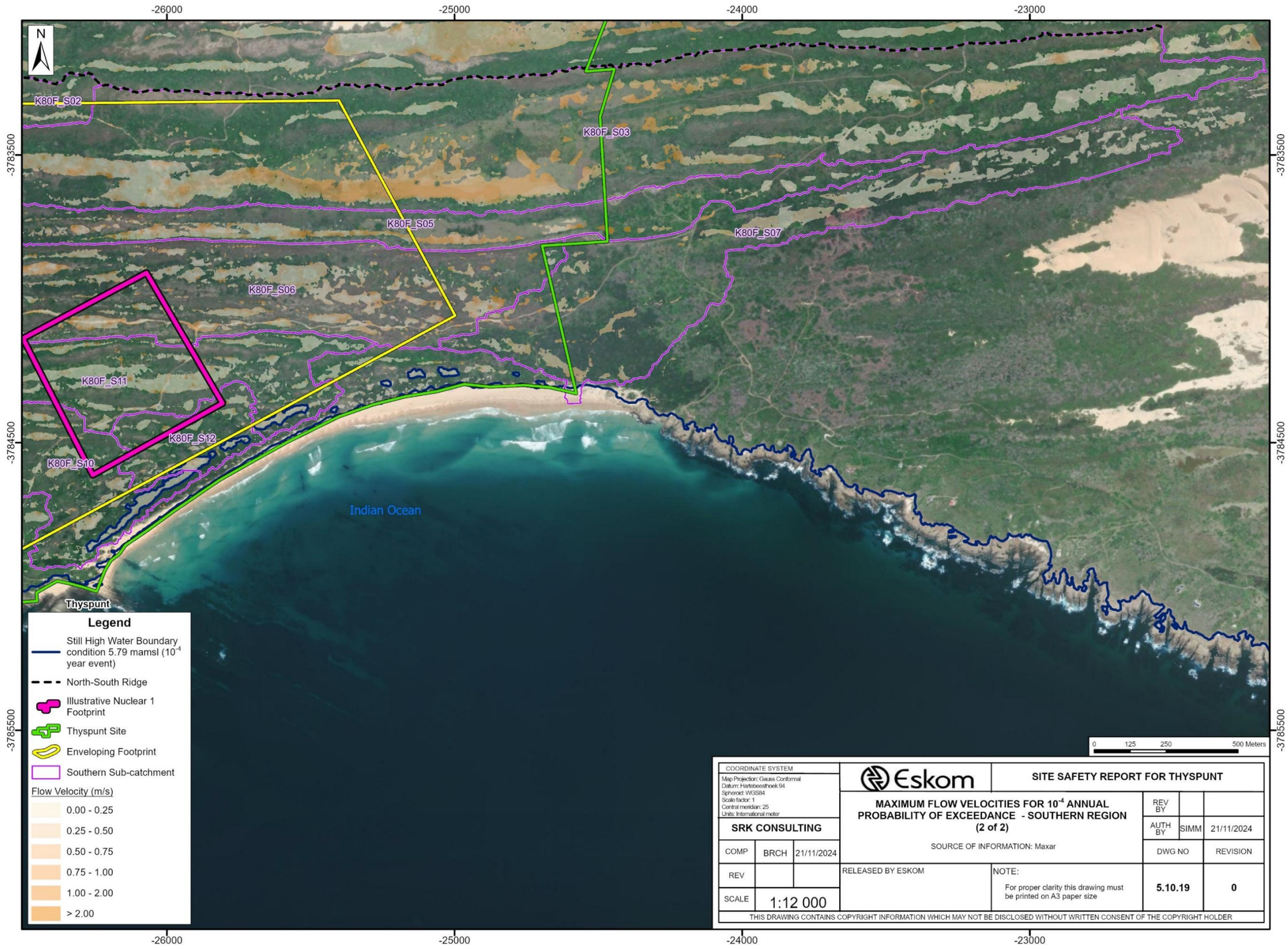
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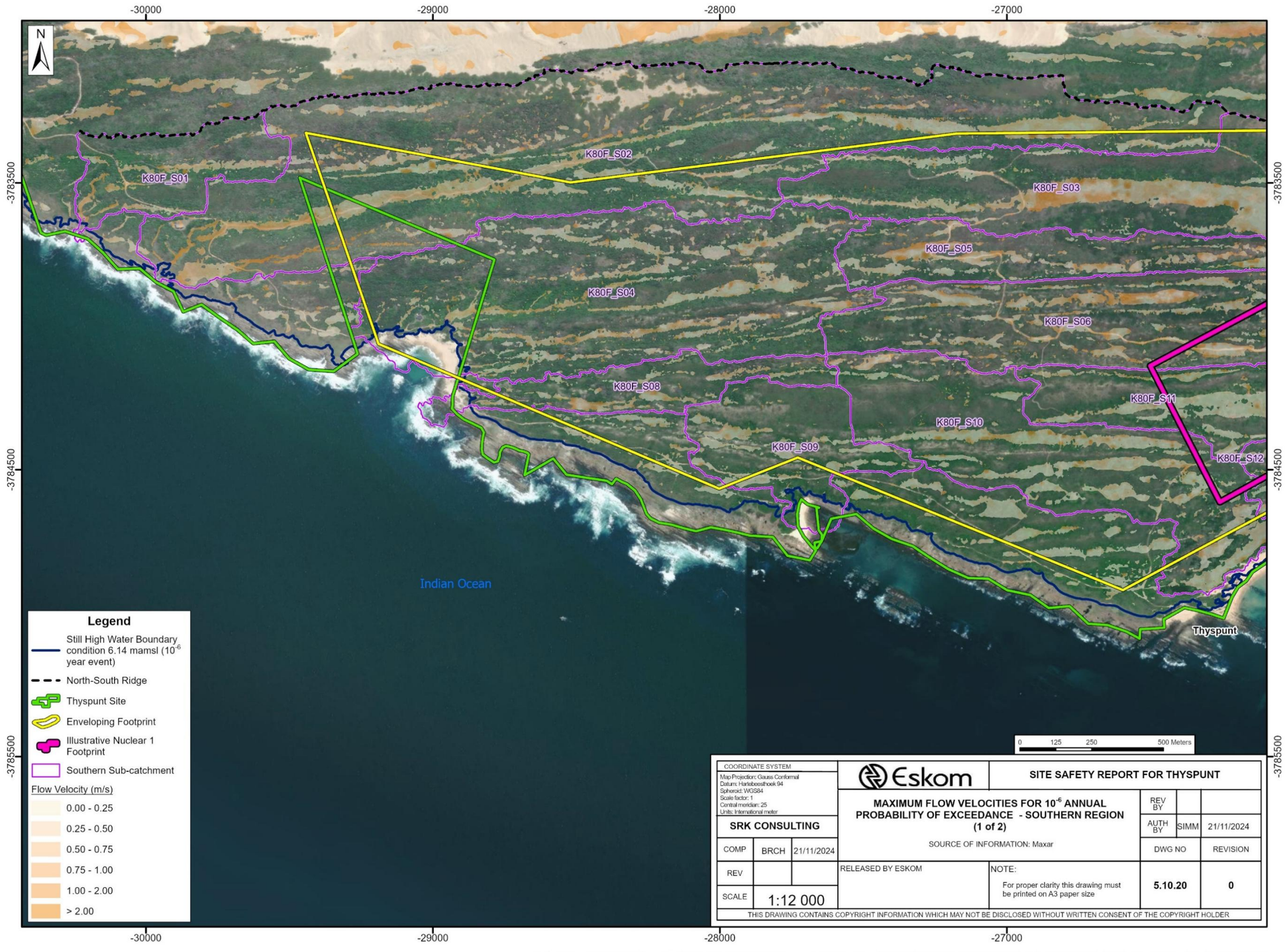
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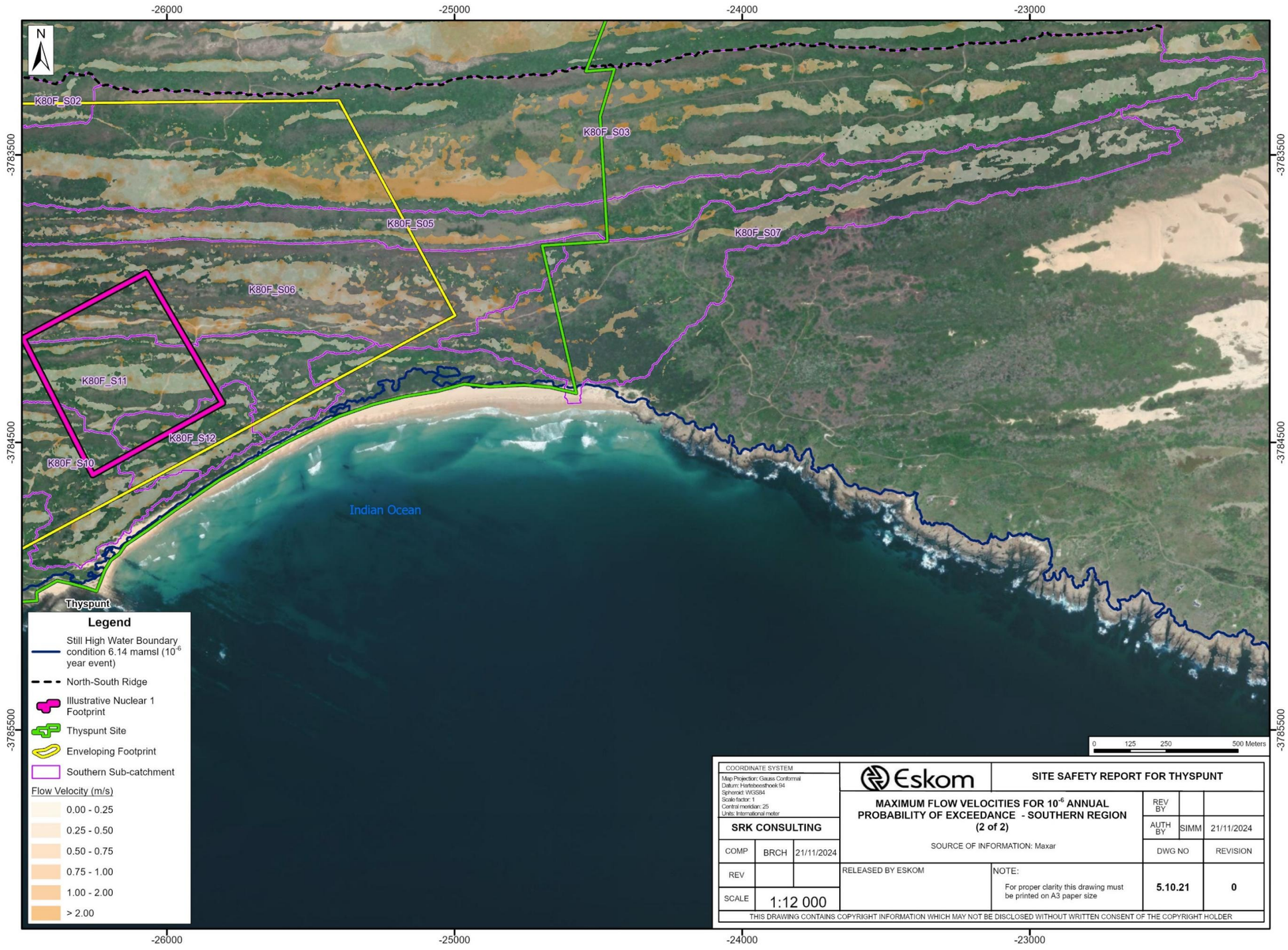
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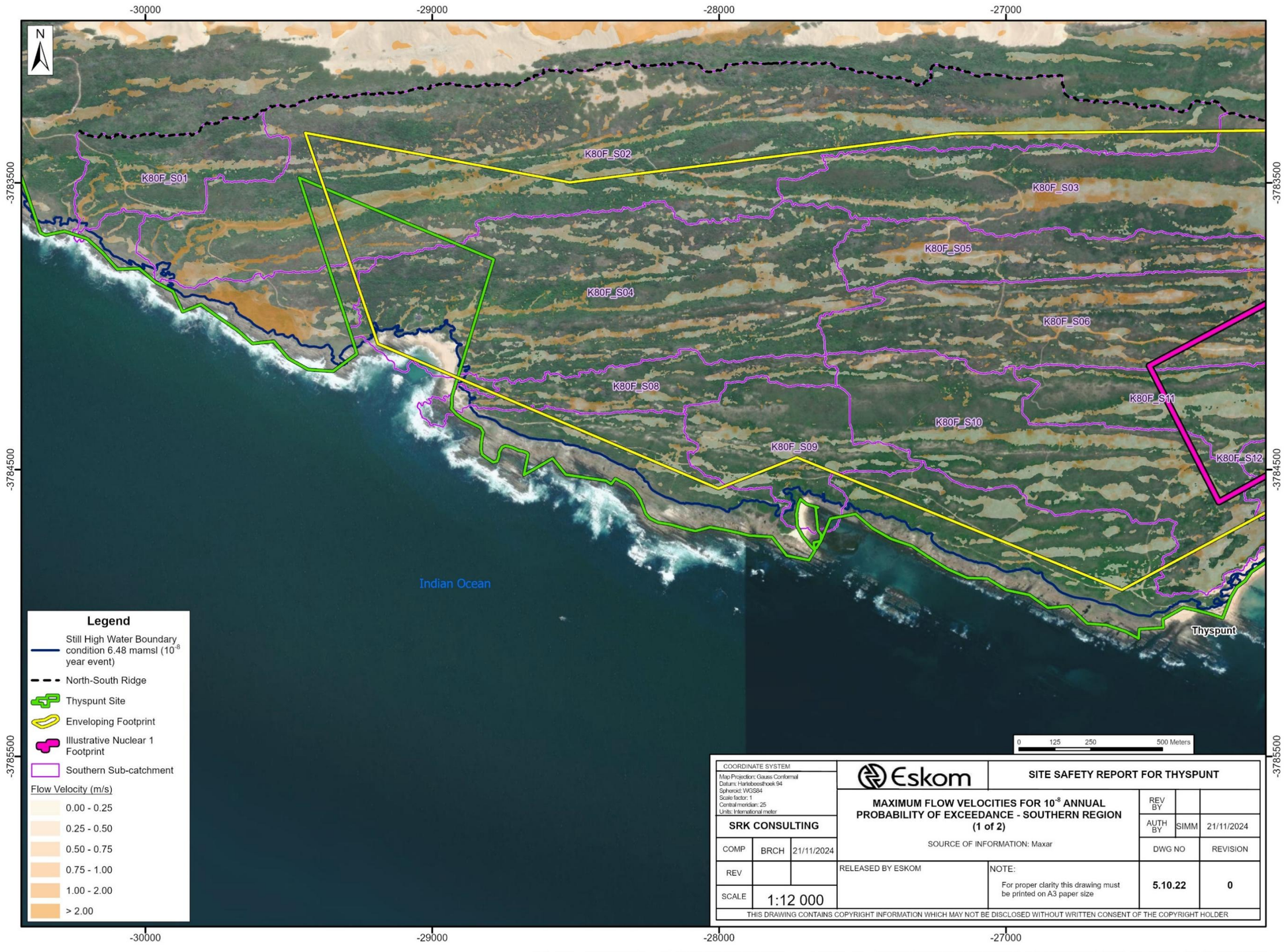
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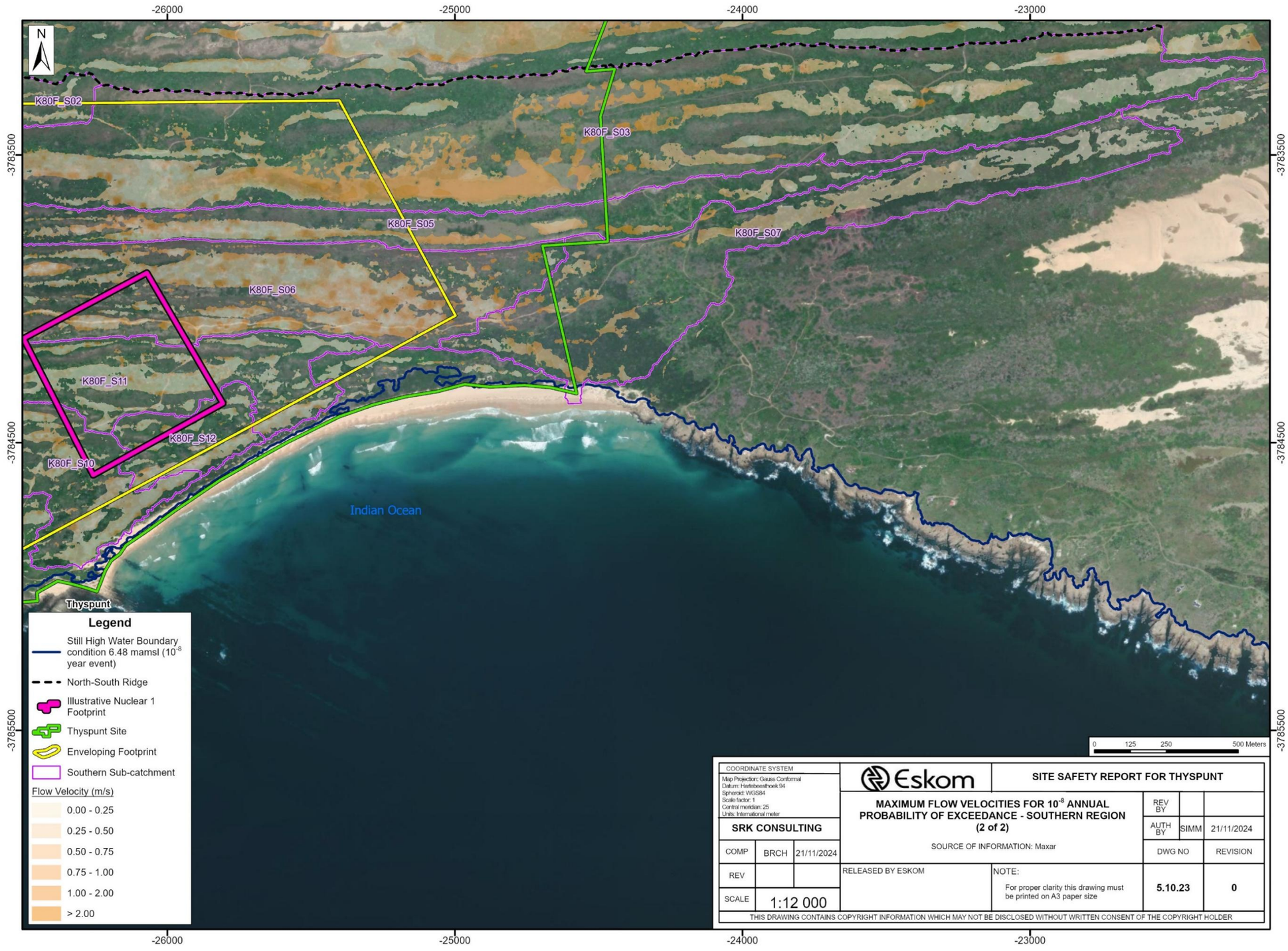
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The following is observed assuming current conditions:

Southern Region

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 0.28 – 0.92 m, 0.34 – 1.32 m and 0.35 – 1.82 m for the 10^{-4}, 10^{-6} and 10^{-8} annual probability of exceedance respectively.

The average maximum flow velocities across the site vary from 0.28 – 0.58 m/s, 0.31 – 0.64 m/s and 0.36 – 0.74 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 is shown in ***Drawings 5.10.6*** to ***5.10.23***. 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 5.79 m amsl.
- The expected still high-water level (boundary condition) for a 10^{-6} year event is 6.14 m amsl.
- The expected still high-water level (boundary conditions) for a 10^{-8} year event is 6.48 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 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 illustrative nuclear island footprint including the surrounding area.

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

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- prior to development (current topography);
- during construction (20 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 21 m amsl platform or alternatively raising the platform by 1.5 m and constructing a 1.5 m deep channel around to cut-off external run-off.
- during operation (21 m amsl platform with 1.5 m high berm wall around platform or alternatively raising the platform by 1.5 m and constructing 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 (21 m amsl platform with 1.5 m high berm wall around platform or alternatively raising the platform by 1.5 m and constructing 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 safety 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 flood hazard is based on expected flow depth and flow velocity values based on 10^{-4}, 10^{-6} and 10^{-8} annual probability of exceedance for the 95th percentile (upper values of the 90 per cent confident intervals) relationship as shown in ***Figure 5.10.2***.

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 21.0 m amsl. If further details on the position and level of the nuclear installation(s) become known, the risk assessment would be revised.

The flood hazard is rated in terms of a high, medium and low category based on ***Figure 5.10.2***. This figure is used to define where, within the hazard

rating, a particular site is situated. This information is abstracted from the HECRAS (2D) and *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 a qualitative 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 ponding areas it becomes difficult to model and a conservative approach was adopted. The expected hazard categories and locality thereof are shown in ***Drawing 5.10.24*** to ***Drawing 5.10.41***.

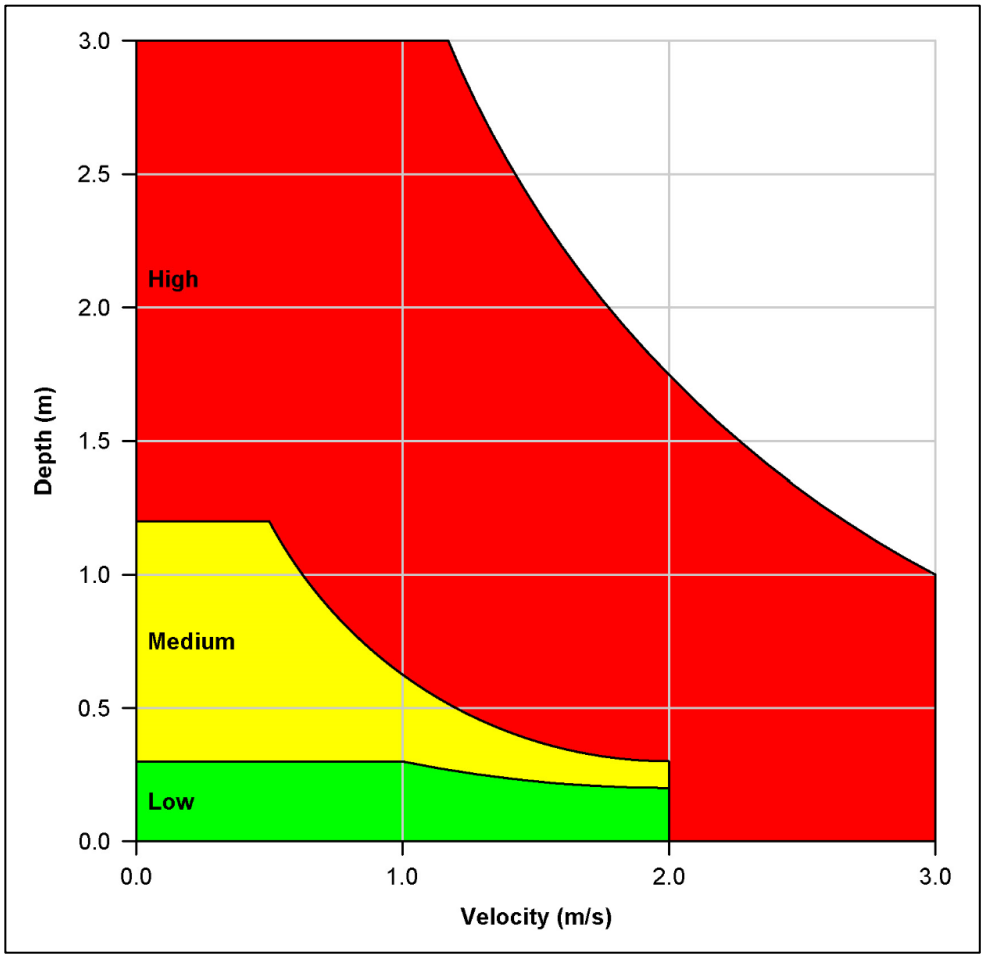


Figure 5.10.2 Flood Hazard Category

5.10.11.3 Regional Major Catchments and Sub-Catchments

In this section, both the regional catchments draining towards the enveloping footprint and the sub-catchments within the enveloping footprint have been investigated (***Drawing 5.10.24*** to ***5.10.41***). 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, Section 5.10: Hydrology and Hydraulics (Eskom, 2022).

The expected safety consequence is now classified by considering the safety hazard values and vulnerability categories. 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.

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Table 5.10.11
Expected Site Safety Consequences – Prior to Development

Catchment Name	Average Hazard Within Catchment			[7]Vulnerability			Average Safety Consequence		
	10^{-4}	10^{-6}	10^{-8}	10^{-4}	10^{-6}	10^{-8}	10^{-4}	10^{-6}	10^{-8}
K80F_S01	LH	LH	LH	N	N	N	N	N	N
K80F_S02	LH	LH	HH	N	N	N	N	N	N
K80F_S03	LH	MH	HH	N	N	N	N	N	N
K80F_S04	LH	LH	MH	N	N	N	N	N	N
K80F_S05	LH	HH	HH	N	N	N	N	N	N
K80F_S06	LH	HH	HH	H	H	H	H	H	H
K80F_S07	LH	MH	MH	N	N	N	N	N	N
K80F_S08	HH	HH	HH	N	N	N	N	N	N
K80F_S09	HH	H	H	N	N	N	N	N	N
K80F_S10	MH	MH	HH	H	H	H	H	H	H
K80F_S11	MH	MH	MH	H	H	H	H	H	H
K80F_S12	MH	HH	HH	H	H	H	H	H	H

Table 5.10.12
Expected Site Safety Consequences – During Construction

Catchment Name	Average Hazard Within Catchment			Vulnerability			Average Safety Consequence		
	10^{-4}	10^{-6}	10^{-8}	10^{-4}	10^{-6}	10^{-8}	10^{-4}	10^{-6}	10^{-8}
K80F_S01	LH	LH	LH	N	N	N	N	N	N
K80F_S02	LH	LH	HH	N	N	N	N	N	N
K80F_S03	LH	M	HH	N	N	N	N	N	N
K80F_S04	LH	LH	MH	N	N	N	N	N	N
K80F_S05	LH	HH	HH	N	N	N	N	N	N
K80F_S06	LH	HH	HH	H	H	H	H	H	H
K80F_S07	LH	MH	MH	N	N	N	N	N	N
K80F_S08	HH	LH	HH	N	N	N	N	N	N
K80F_S09	HH	MH	HH	N	N	N	N	N	N
K80F_S10	MH	MH	HH	H	H	H	H	H	H
K80F_S11	MH	MH	MH	H	H	H	H	H	H
K80F_S12	MH	HH	HH	H	H	H	H	H	H

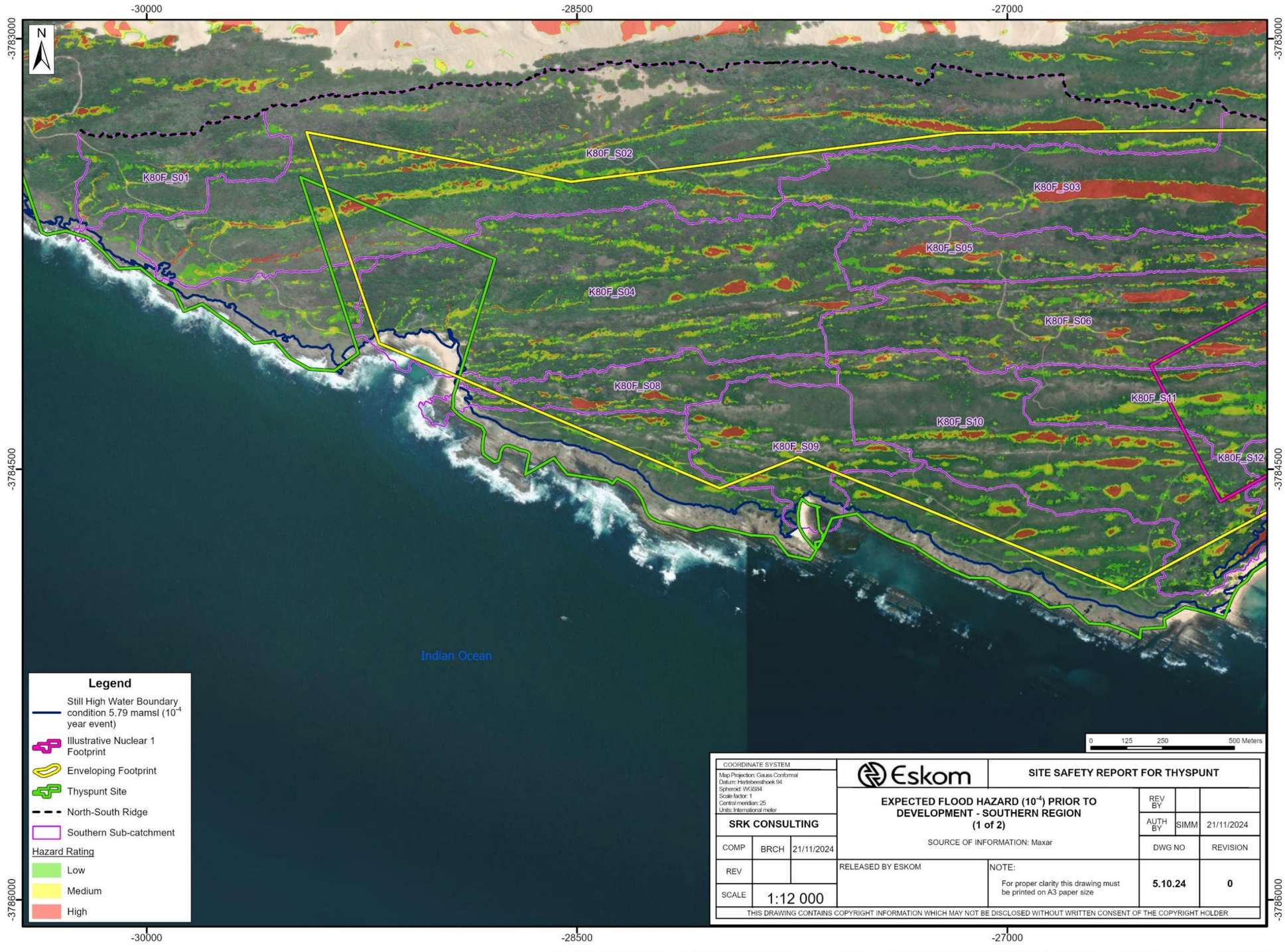
[7] Vulnerability – how vulnerable the site is to the flood hazard which includes the still high water boundary condition from the sea

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Table 5.10.13
Expected Site Safety Consequences – During Operation

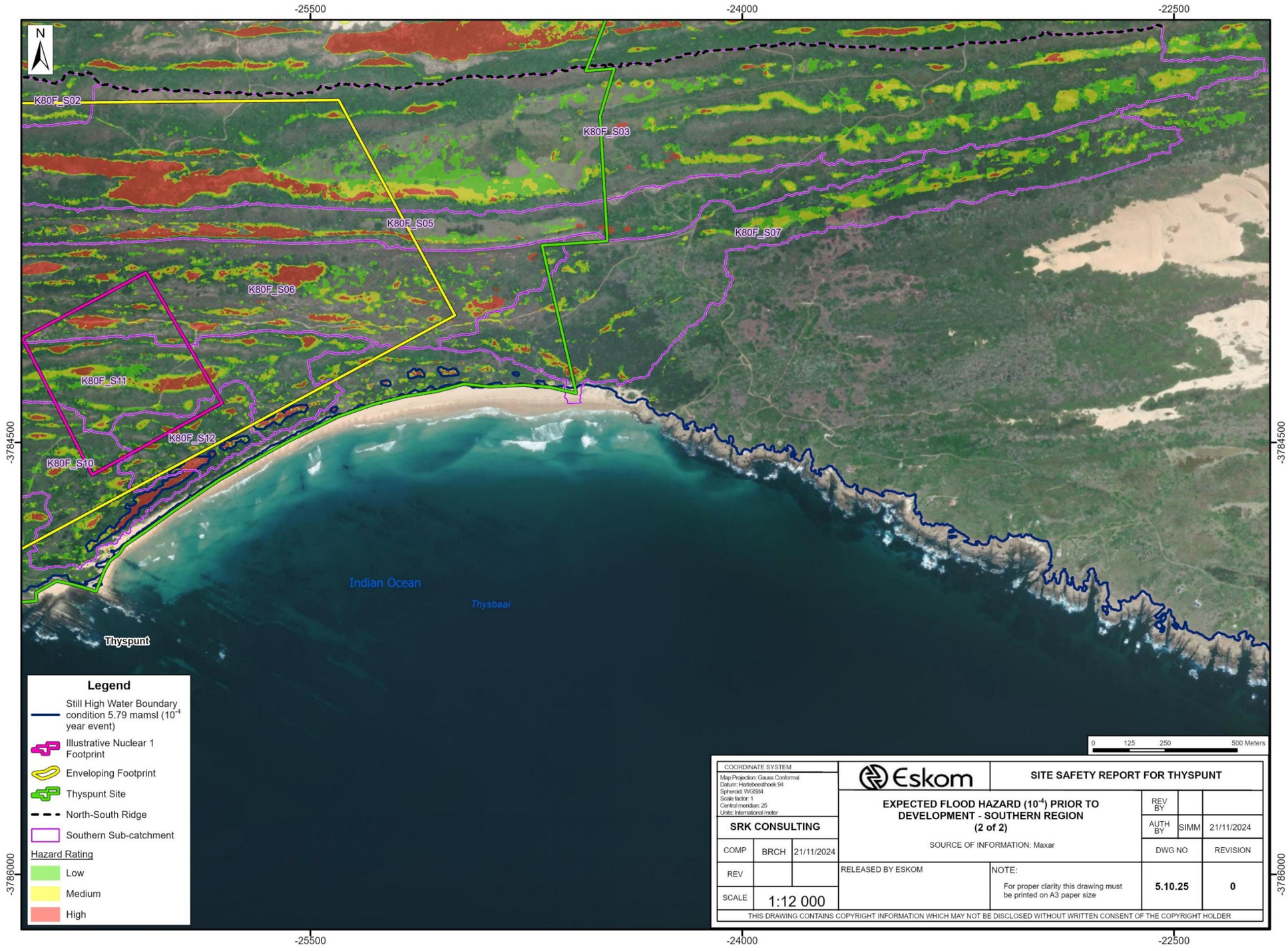
Catchment Name	Average Hazard Within Catchment			Vulnerability			Average Safety Consequence		
	10^{-4}	10^{-6}	10^{-8}	10^{-4}	10^{-6}	10^{-8}	10^{-4}	10^{-6}	10^{-8}
K80F_S01	LH	LH	LH	N	N	N	N	N	N
K80F_S02	LH	LH	HH	N	N	N	N	N	N
K80F_S03	LH	MH	HH	N	N	N	N	N	N
K80F_S04	LH	LH	MH	N	N	N	N	N	N
K80F_S05	LH	HH	HH	N	N	N	N	N	N
K80F_S06	LH	HH	HH	L	L	L	L	L	L
K80F_S07	LH	MH	MH	N	N	N	N	N	N
K80F_S08	HH	LH	HH	N	N	N	N	N	N
K80F_S09	HH	MH	HH	N	N	N	N	N	N
K80F_S10	MH	MH	HH	L	L	L	L	L	L
K80F_S11	MH	MH	MH	L	L	L	L	L	L
K80F_S12	MH	HH	HH	L	L	L	L	L	L

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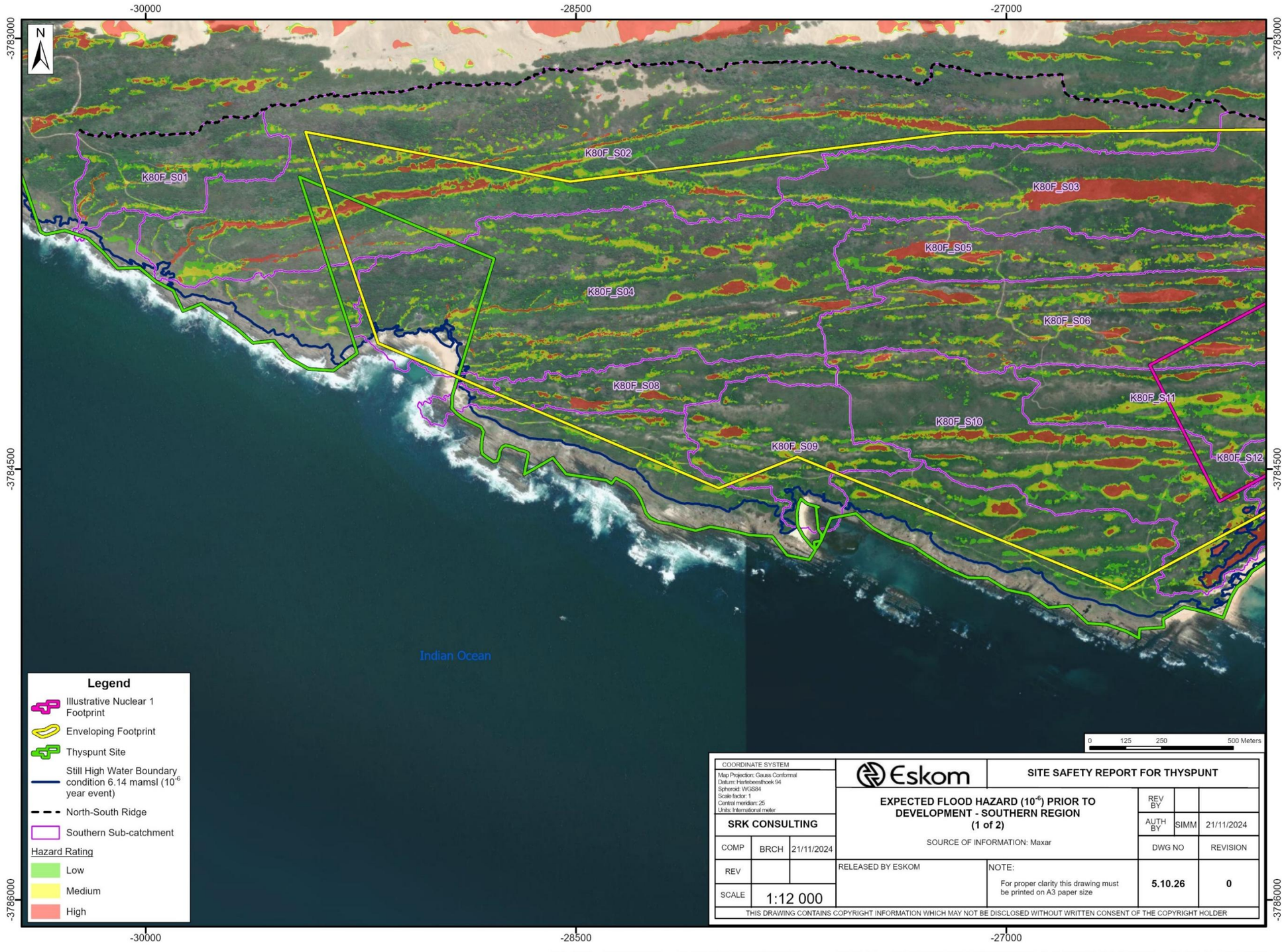
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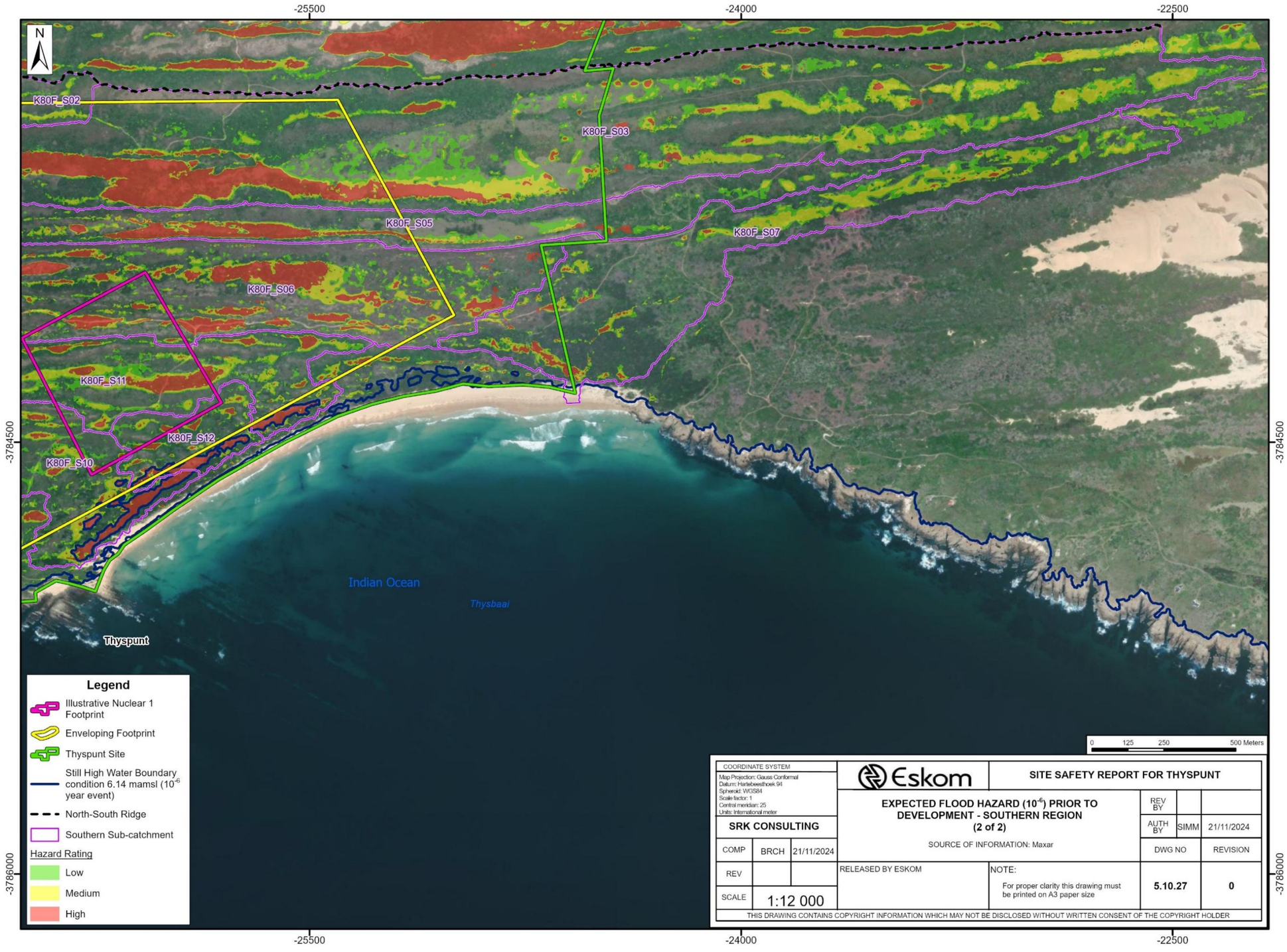
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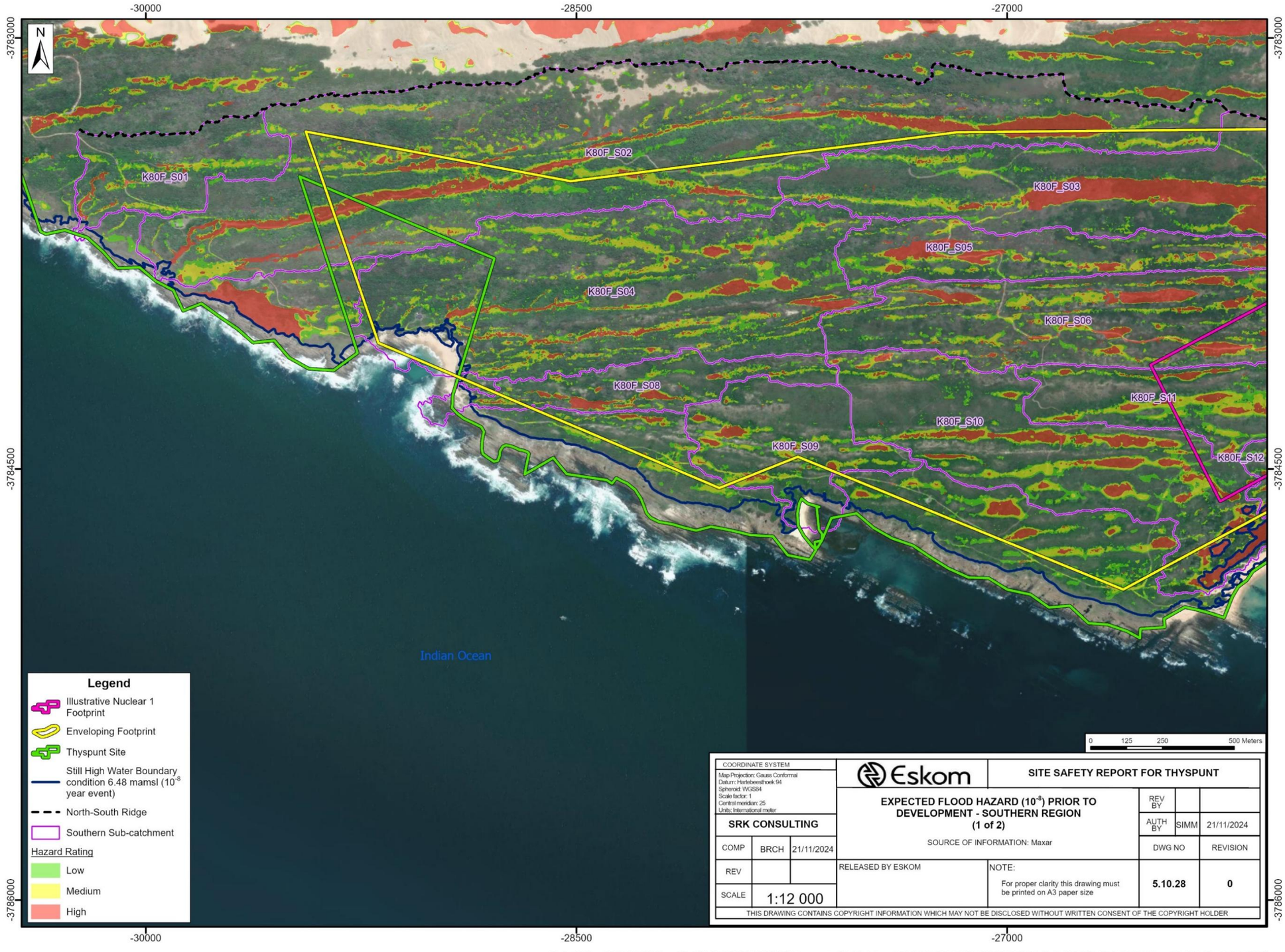
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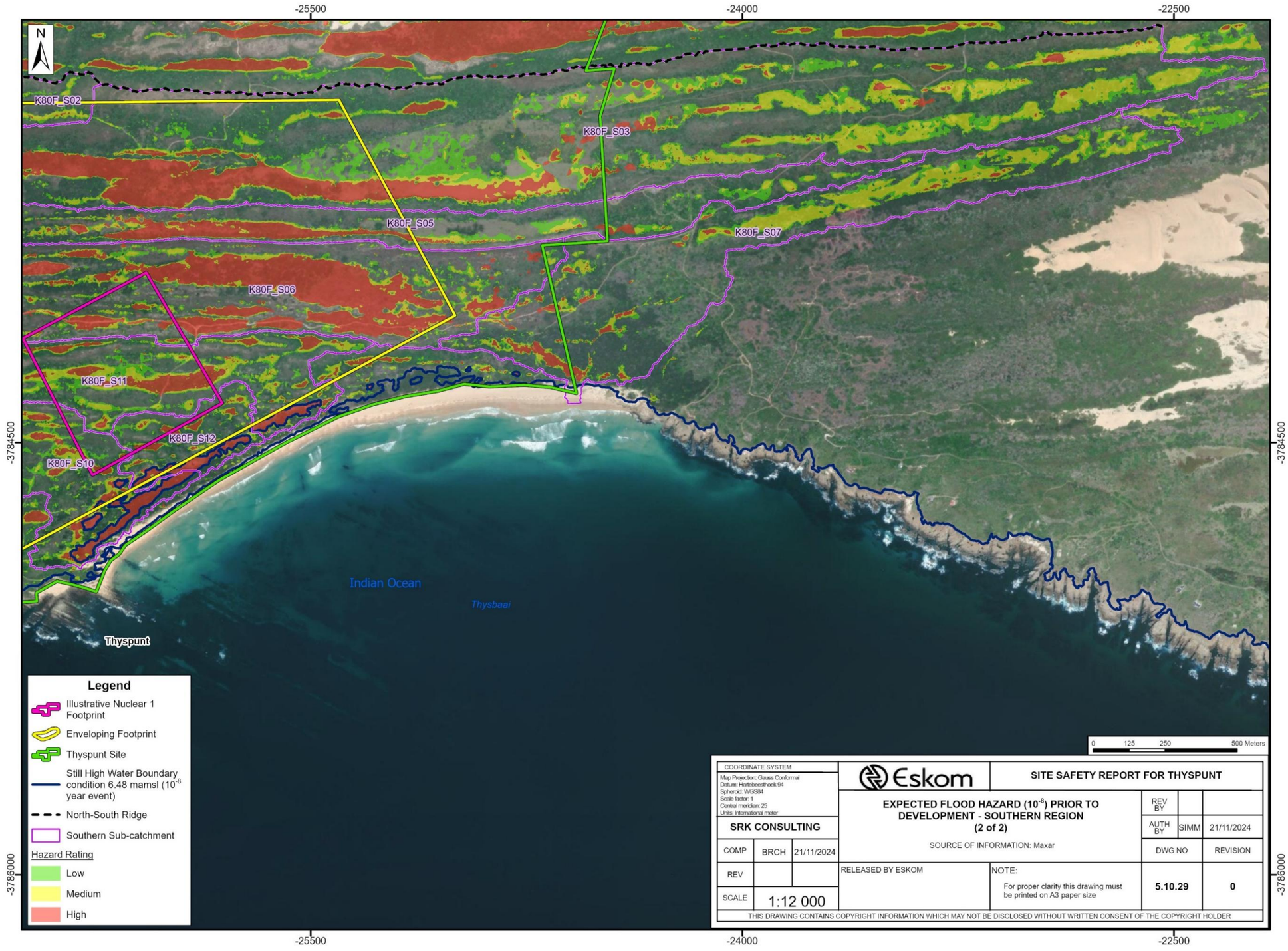
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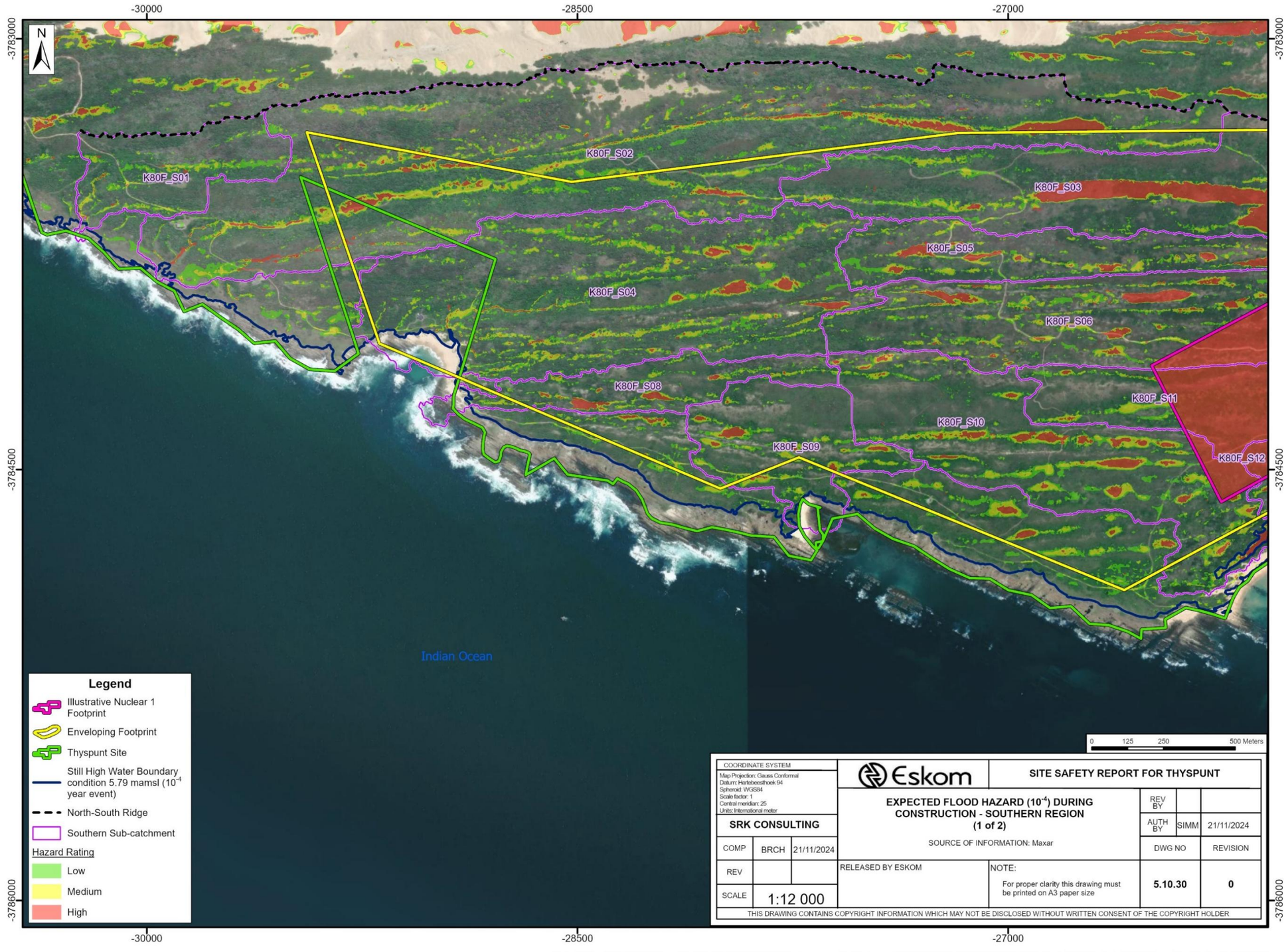
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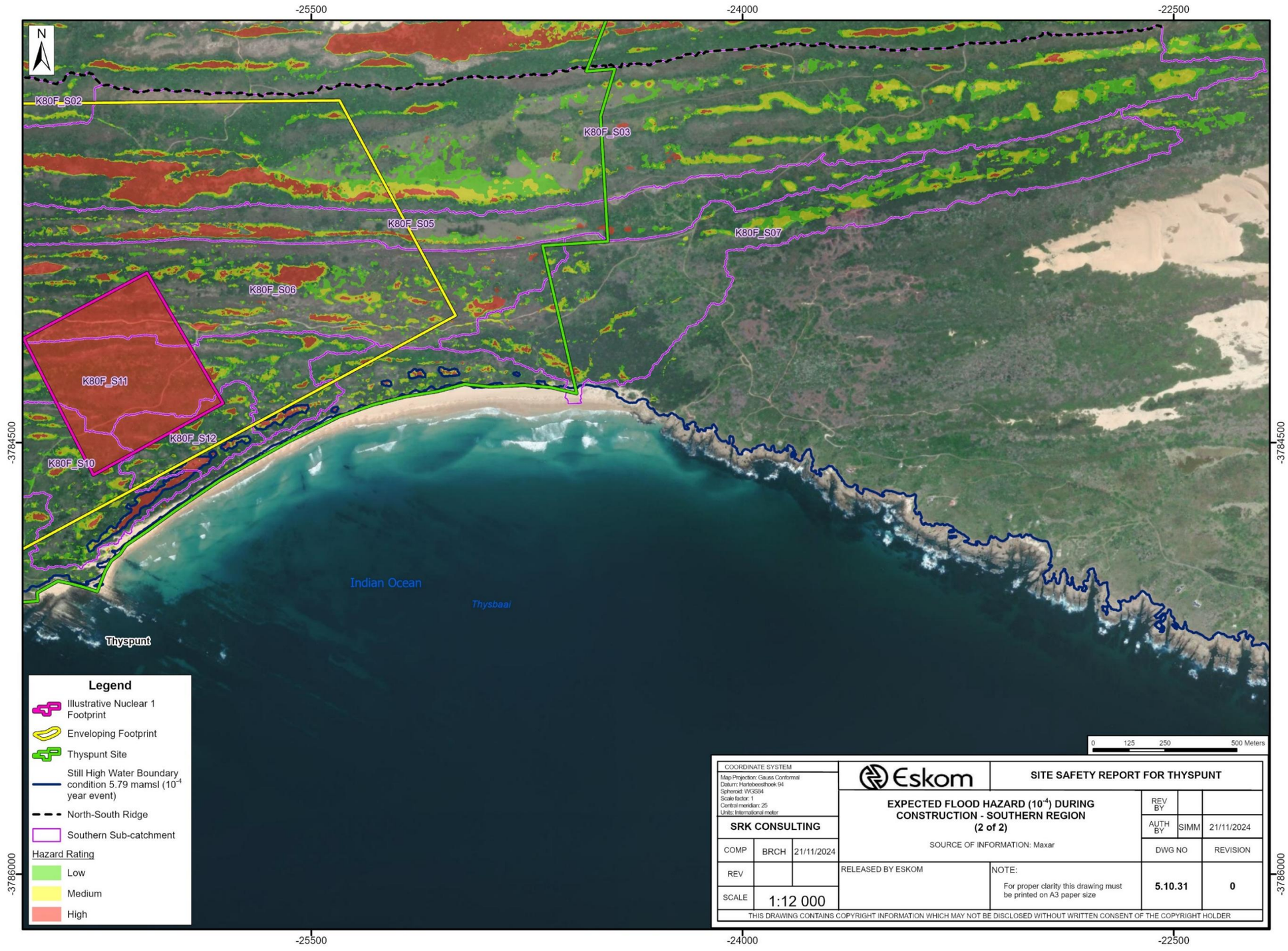
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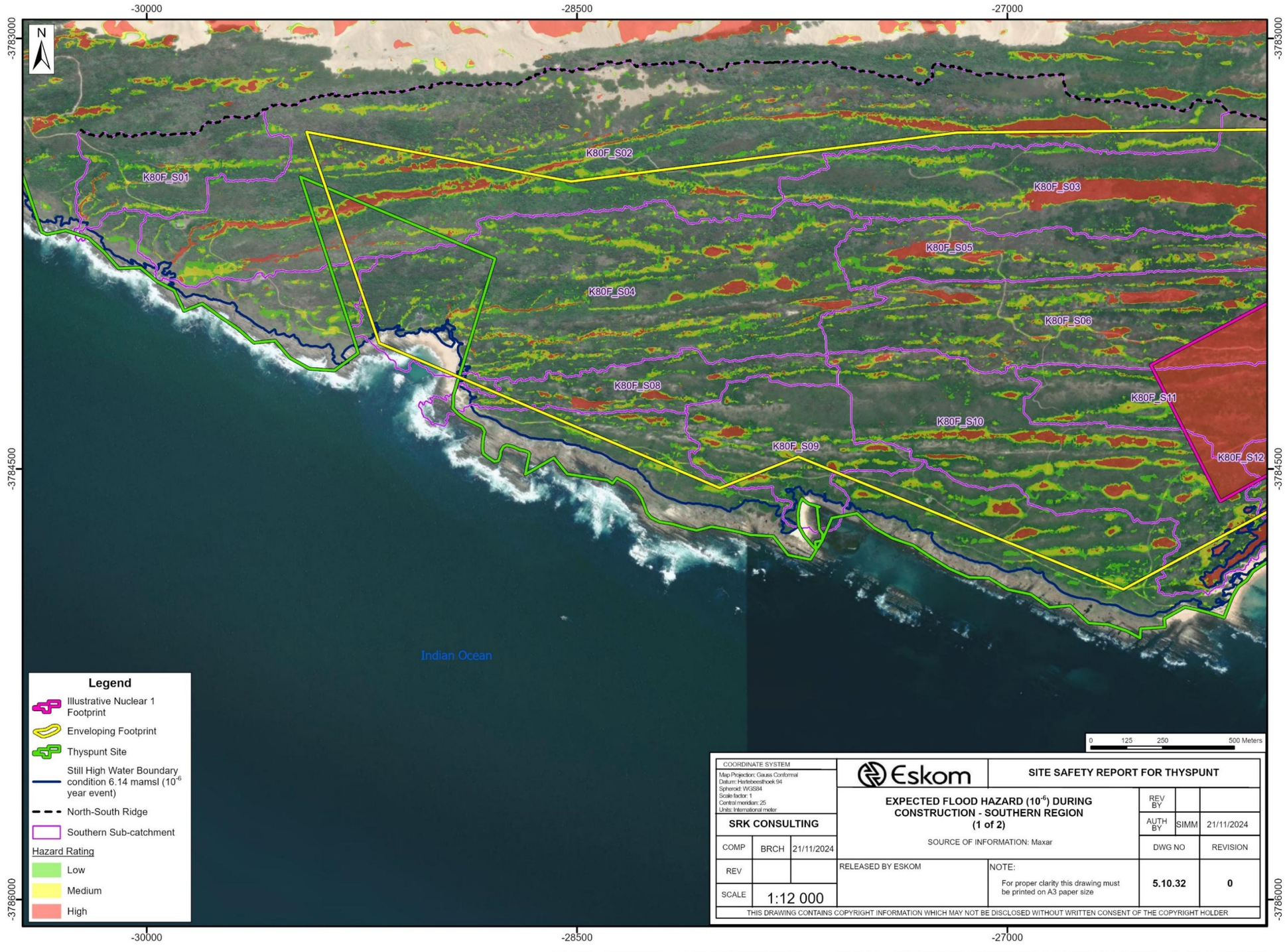
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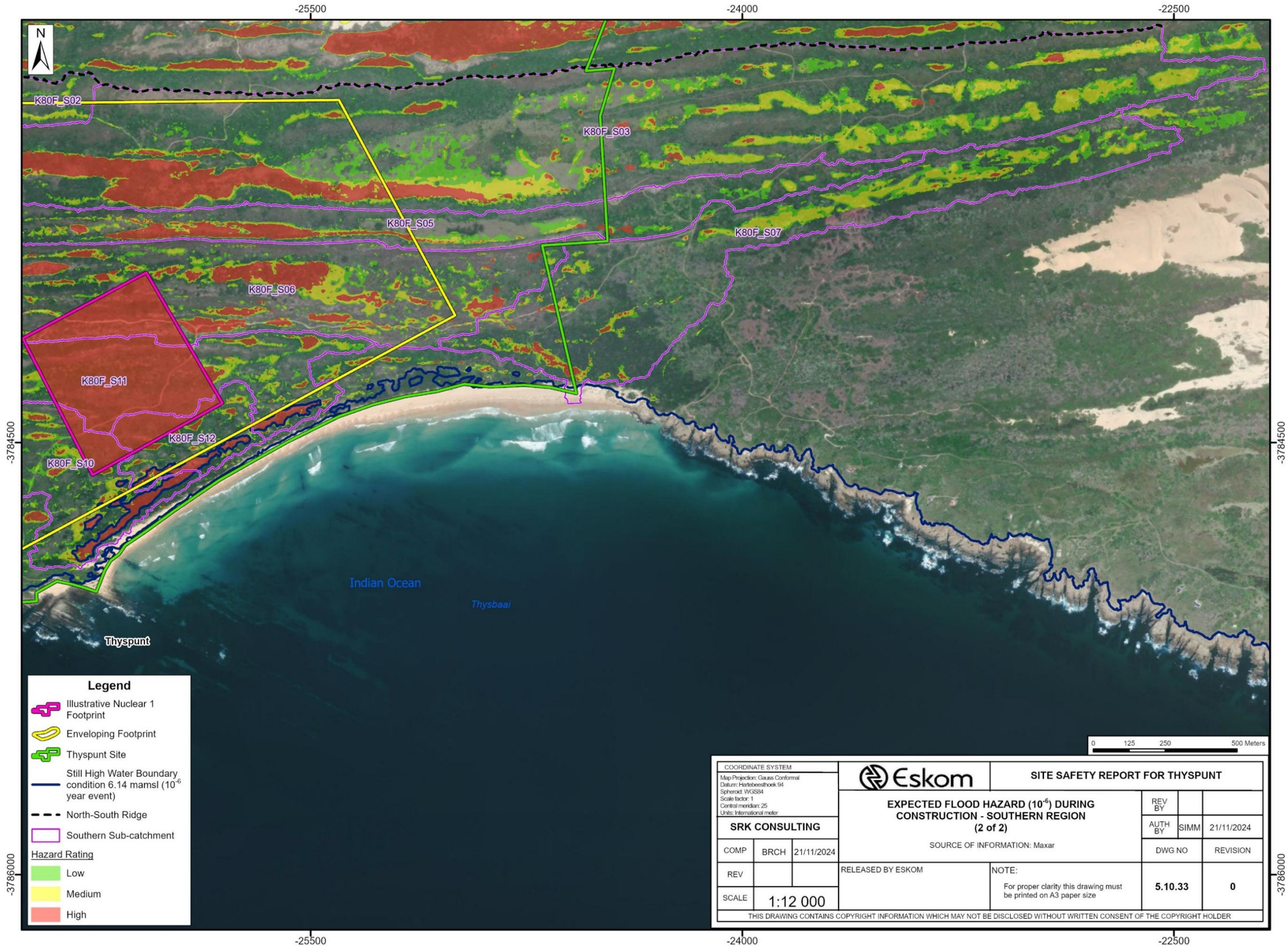
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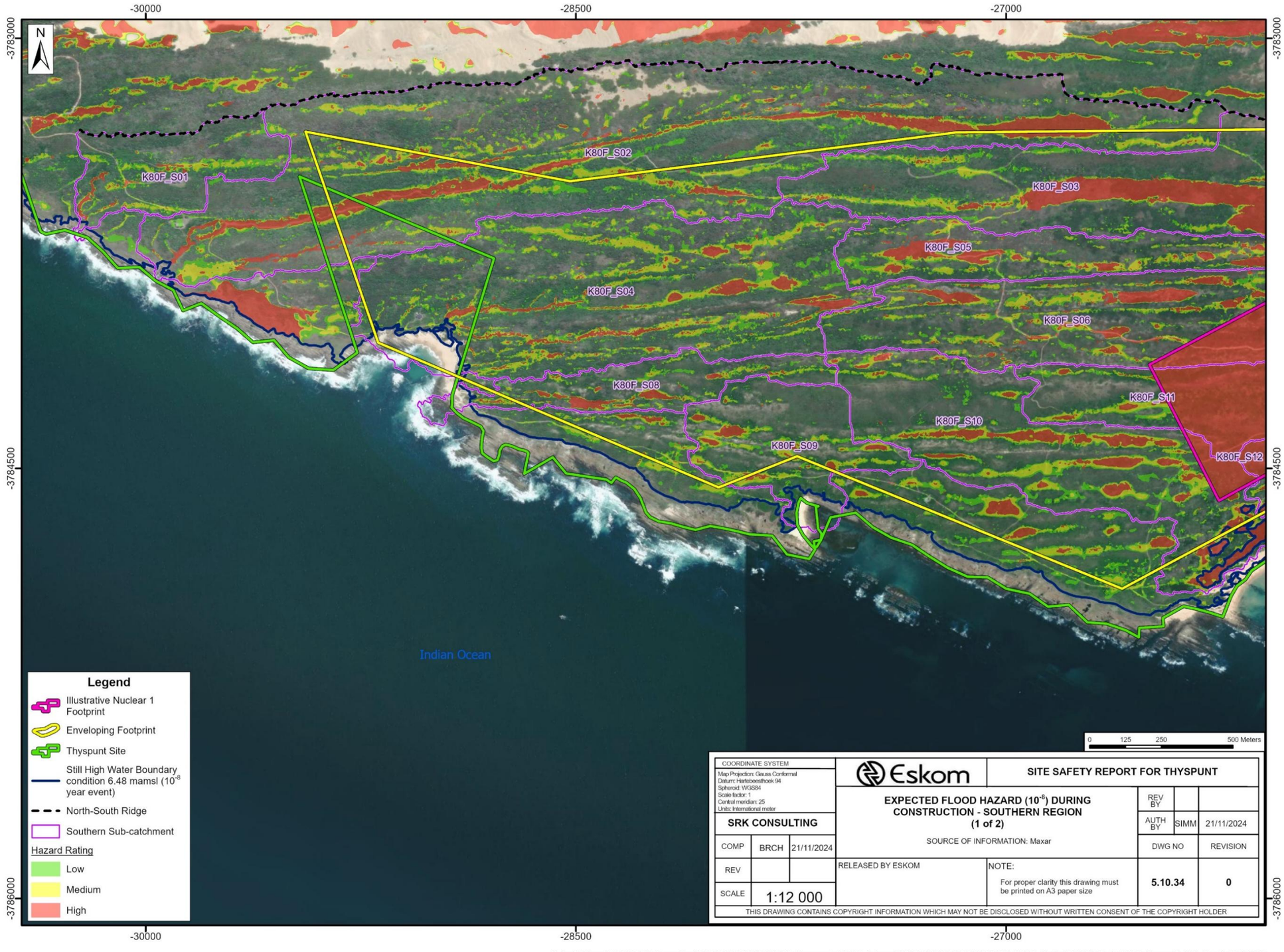
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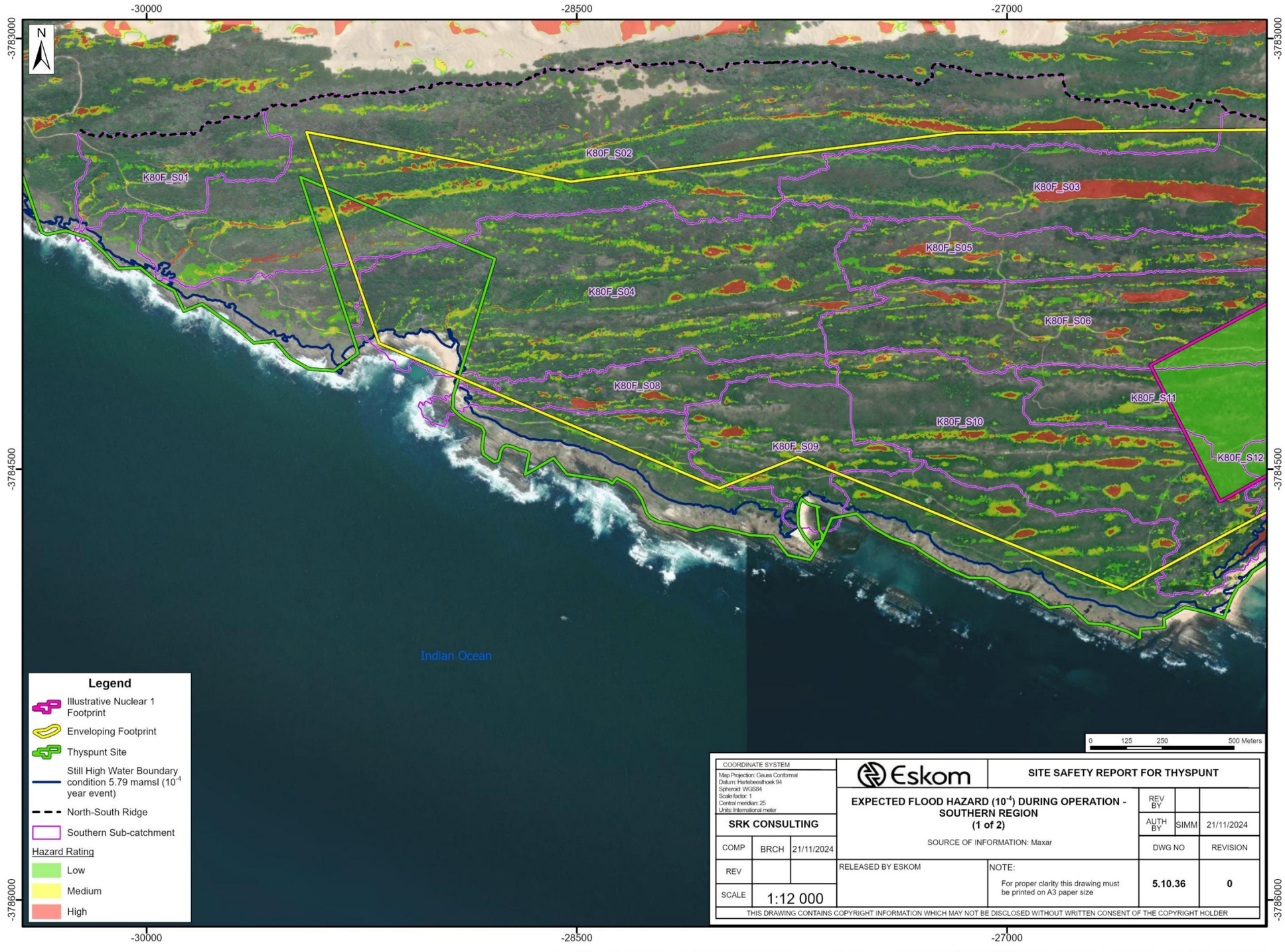
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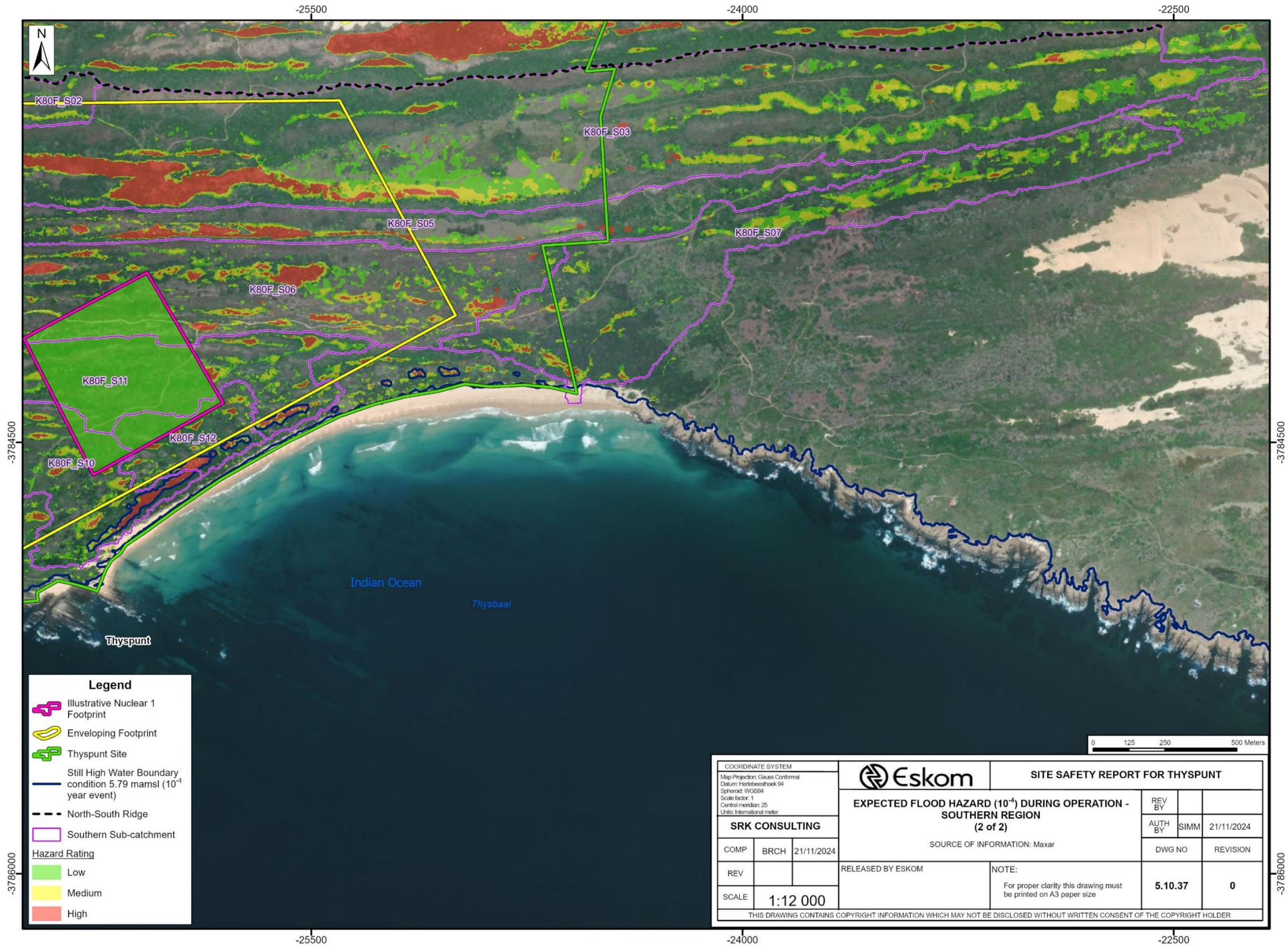


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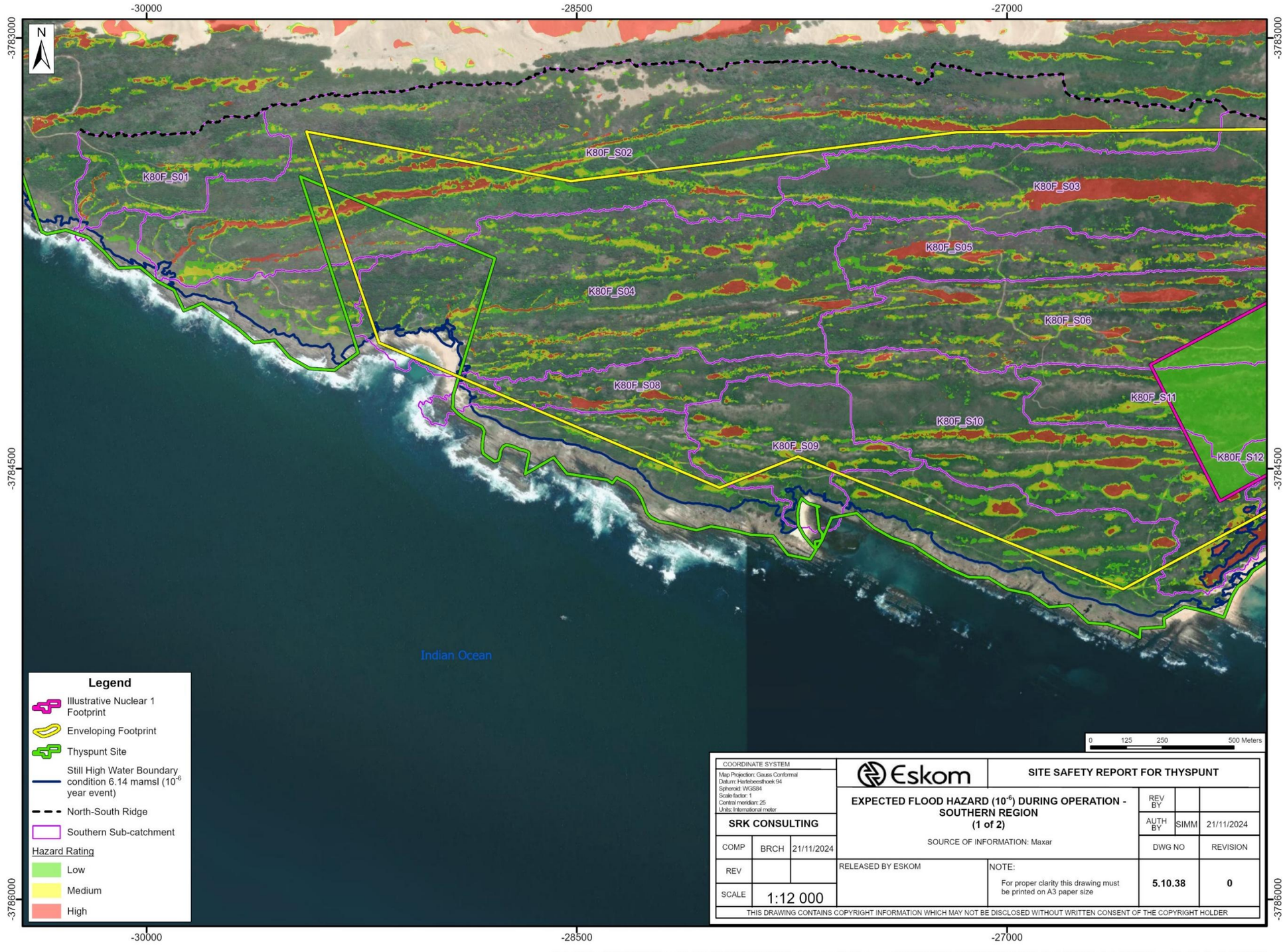
Drawing 5.10.36 Expected Flood Hazard 10^{-4} (During Operation) (1 of 2)

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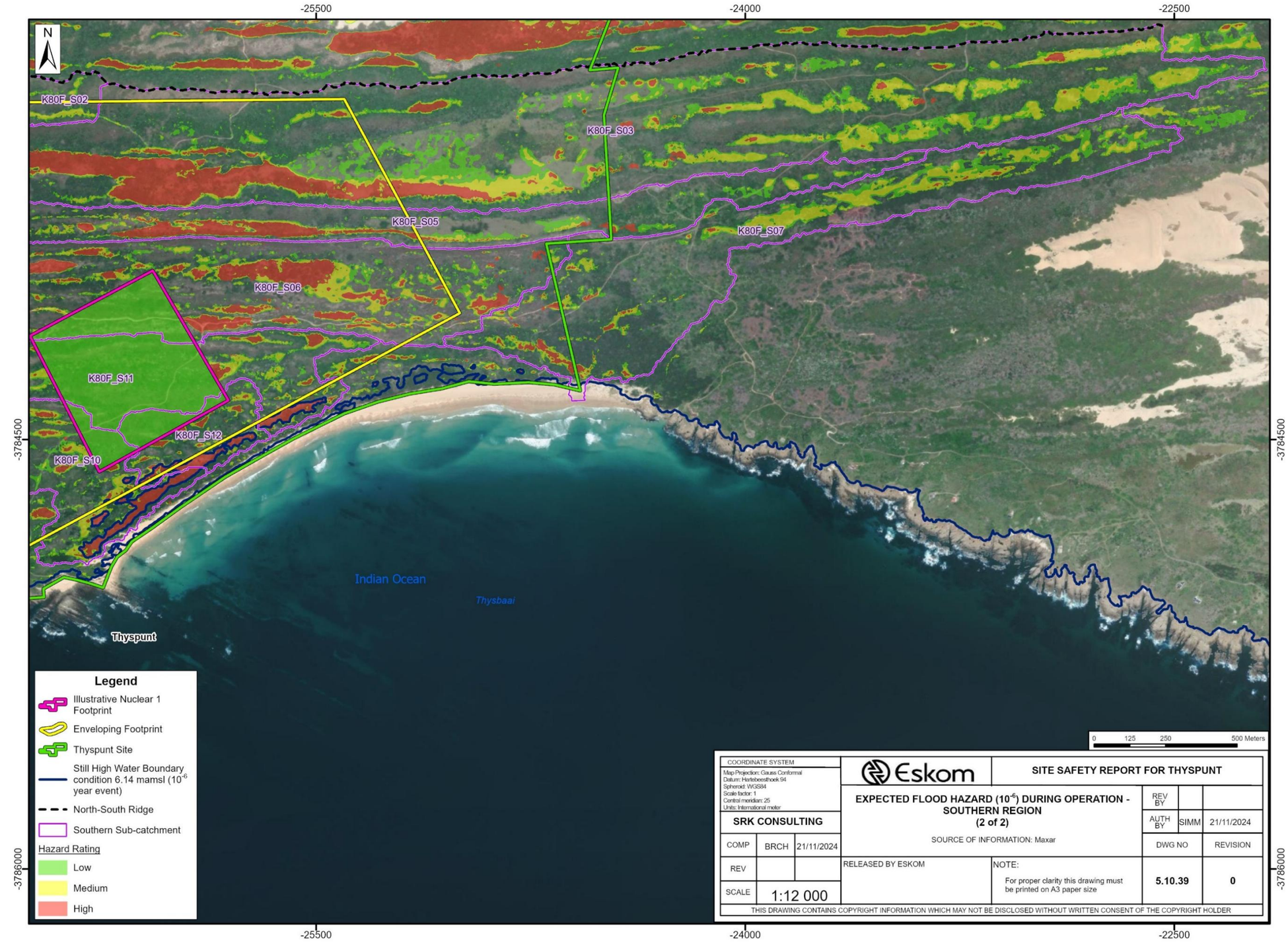
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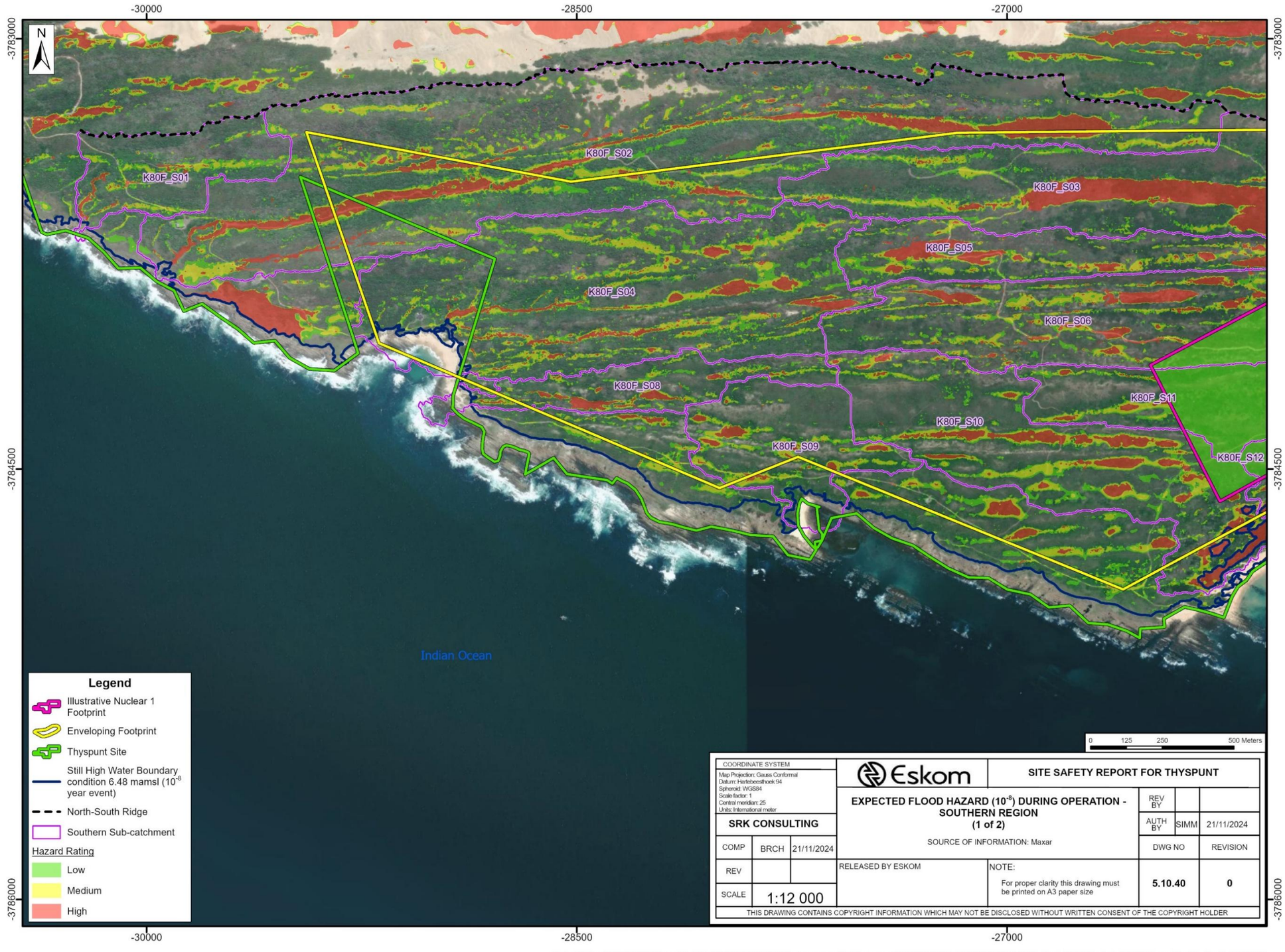
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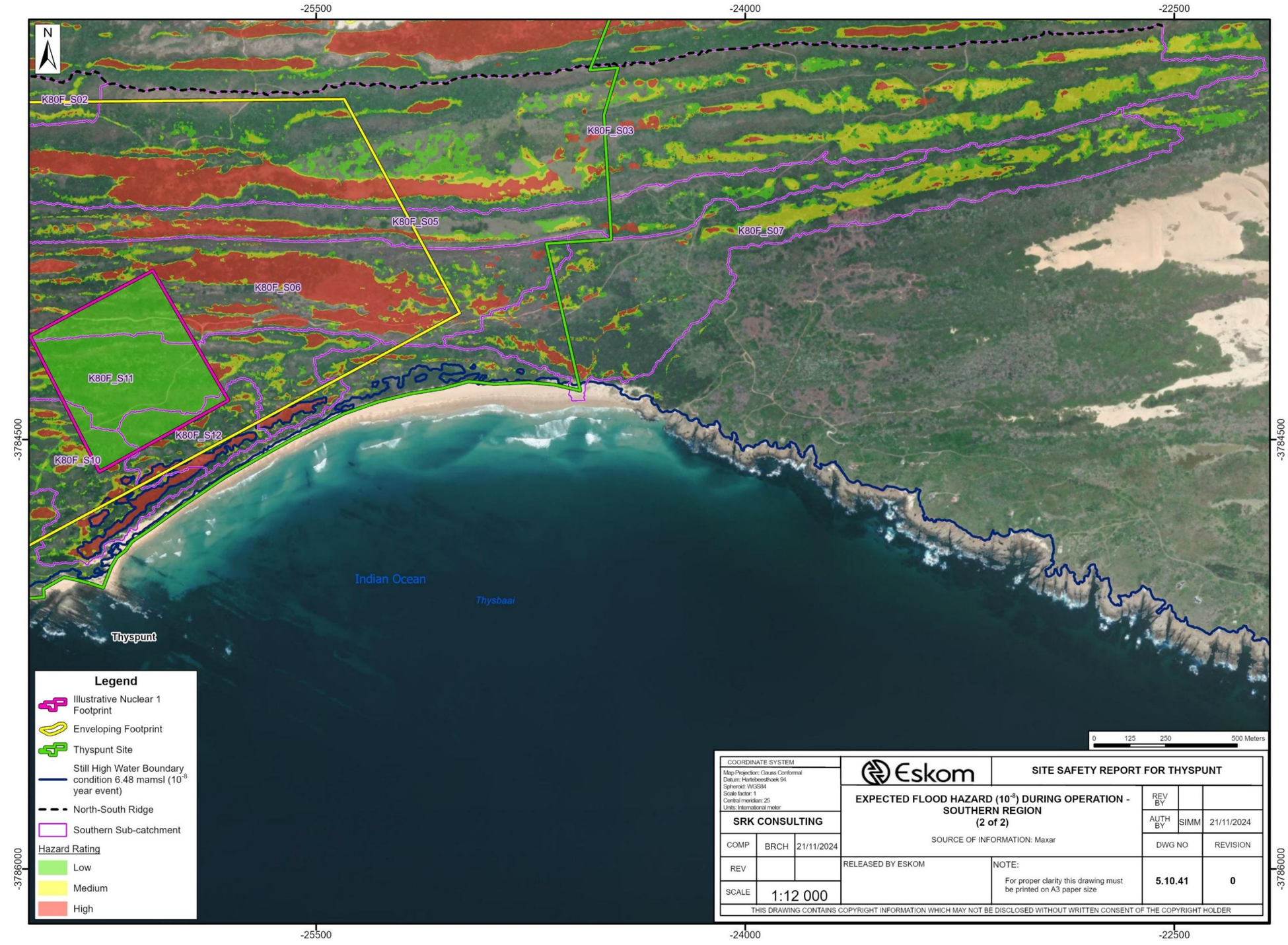
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The following conclusions for the expected flooding safety consequence can be made based on the results presented above:

Southern Sub-Catchments

Prior to any development, the catchment has a medium to high average hazard value and maximum low/medium/high hazard value in isolated areas within the sub-catchments (K80F_S01-S12). The average vulnerability and safety consequences (K80F_S06, S10-S12) are high across the catchment which includes the still high-water boundary condition from the sea. The still high sea water levels (5.79 m amsl, 6.14 m amsl and 6.48 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 21.0 m amsl (see ***Section 5.9***).

During construction of a new nuclear installation(s), the catchment has a medium-high average hazard value and maximum low/medium/high hazard value in isolated areas within the sub-catchments. The average vulnerability and safety consequences (K80F_S06, S10-S12) are high within the 20 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 medium-high average hazard value and maximum low/medium/high hazard value in isolated areas within the sub-catchments. The average vulnerability and safety consequences (K80F_S06, S10-S12) 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 raising the platform by 1.5 m and constructing 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.

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(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 20 m. This includes the 1.5 m high berm constructed around the proposed 21 m amsl platform or alternatively raising the platform by 1.5 m and constructing 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 21 m amsl platform or alternatively raising the platform by 1.5 m and constructing a 1.5 m deep channel around to cut-off external run-off.
- during the decommissioning phase of the nuclear installation(s).

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 5.10.24*** to ***Drawing 5.10.41***.

The illustrative nuclear island footprint terrace level is assumed to be approximately 21 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 27 ha. The anticipated site conditions during various stages of the development are presented below.

5.10.12.2 Prior to Construction

The site is situated on the coastline between Oyster Bay and Cape St. Francis. It is covered mainly by fynbos and a few wetlands within the valley 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 between the sand dunes parallel to the coastline. This is mainly based on the topographic information which shows that there are several low-lying areas in which storm water will pond.

5.10.12.3 During Construction

Based on previous experience gained from the Koeberg Nuclear Power

Station (KNPS) as well as other deep excavation sites, a large excavation will be required in order to get to bedrock for the foundations of the nuclear installation(s). It is expected that the site illustrative footprint will have a surface area of approximately 27 ha and the depth would be about 20 m on average for the current site positions.

Groundwater is discussed in detail in ***Section 5.11,*** however, based on the presence of wetlands, it is likely that dewatering would be required during construction.

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 21 m amsl. This includes the 1.5 m high berm constructed around the proposed 21 m amsl platform or alternatively raising the platform by 1.5 m and constructing a 1.5 m deep channel around to cut-off external run-off.

The detailed design of the infrastructure for the operational phase must consider the requirements for the water management infrastructure, its configuration and maintenance to ensure the risks are acceptable for extreme storm events.

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 similar to those 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) 129.7 205.4 280.0 354.6 429.2 503.8 653.0	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 5.10.7.6*** 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	 39 81 85	Sandy soil, SCS Type 'A' with high infiltration rate (208 mm/h) (***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(s) could be determined for the following stages:

- prior to development (current topography);
- **during construction** (20 m deep open excavation for a portion of the illustrative nuclear island footprint);
- **during operation** (21 m amsl platform for illustrative nuclear island

footprint) - This includes the 1.5 m high berm constructed around the proposed 21 m amsl platform or alternatively raising the platform by 1.5 m and constructing a 1.5 m deep channel around to cut-off external run-off.

- **decommissioning** (21 m amsl platform for illustrative nuclear island footprint) - This includes the 1.5 m high berm constructed around the proposed 21 m amsl platform or alternatively raising the platform by 1.5 m and constructing a 1.5 m deep channel around to cut-off off external run-off.

The results of the SCS-SA model for the nuclear installation(s) are summarised in ***Table 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}	0.60	4.50	3.90	22.60	4.30	25.00	4.30	25.00
10^{-2}	2.10	13.10	7.20	41.40	7.60	44.20	7.60	44.20
10^{-3}	4.10	24.40	10.40	60.80	10.80	64.00	10.80	64.00
10^{-4}	6.40	37.70	13.70	80.50	14.10	83.90	14.10	83.90
10^{-5}	9.00	52.00	16.90	100.10	17.20	103.70	17.20	103.70
10^{-6}	11.70	67.60	20.10	120.10	20.40	123.80	20.40	123.80
10^{-8}	17.50	100.50	26.40	160.00	26.70	163.80	26.70	163.80

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

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

- During the stage prior to the nuclear installation 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.

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- 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 21 m amsl platform or alternatively raising the platform by 1.5 m and constructing a 1.5 m deep channel around to cut-off external run-off, 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.
- 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 similar to 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 potentially 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 Best Management Practices (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;
- restricting construction to low rainfall periods;
- 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 (detention and retention), filters, surfaces and devices located on site.

Storm water management on the site will require the maximum practical use of the following non-structural strategies at the site and will only be considered 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

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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 unrestricted subsurface drainage systems;
- provide preventative source controls.

5.10.14 Monitoring

Although not part of site safety, recording of daily rainfall will enhance future modelling of the site hydrology and will continue as is presented in ***Table 5.10.16*** 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***.

Two sampling points (TSW 4 and TSW 5) were dry and could therefore not be sampled. 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:

- TSW 1 Slang River;
- TSW 2 Klipdrif River;
- TSW 3 small tributary on enveloping footprint;
- TSW 4 low lying area upstream of enveloping footprint;
- TSW 5 low lying on enveloping footprint.

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.

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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. 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. Certificate 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 will 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 ***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 5.15*** (Geotechnical).
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).
Still high water data	Sea level rise and storm surge has been addressed and the uncertainty managed in ***Section 5.9*** (Oceanography & Coastal Engineering)
Climate change	The sea level rise due to climate change, 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, 2022), 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*** – Historical 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;

Electronic records have been stored in a secure central repository with regular off-site back-up procedures. The overall quality management system complied with is 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. ***Sections 5.15*** (Geotechnical Characterisation)
	Soils permeability and infiltration data from testing/analysis carried out by ***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.
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.

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

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	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***

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Act/Regulation	Section / Regulation	Issue	Subsections where covered
National Water Act No. 36 of 26 August 1998, (Republic of South Africa, 1998) GN704	Section 21 Section 40 Section 41	Water Use License Requirement	Eskom would be required to apply for a Water Use License when site selection process and technology has been completed
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 Thyspunt site has been carried out in order to obtain the required level of understanding of the site characteristics in support of this SSR and a 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 10 000 year return period was considered. This relates to a 90% probability of non-occurrence in 1 000 years design life for the 10 000 year return period event.

  Extreme storm events were also extrapolated (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 site and surrounding catchments are currently all moderately vegetated, with five major vegetation types occurring on the site, *viz*: Algoa Dune Strandveld, Southern Cape Dune Fynbos, Tsitisikama Sandstone Fynbos, Cape Seashore Vegetation and Cape Lowland Freshwater Wetlands. 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 site the external catchments impacting the site are relatively small (less than 2.0 km^2) and the water levels are controlled by the backup from the extreme high water levels. There are two non-perennial drainage lines close to the site. One is situated along the western boundary of the site and the other along the eastern boundary of the site.

- There are no significant dams upstream of the Thyspunt 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 Thyspunt 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 95^{th} 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 21 m amsl platform or alternatively raising the platform by 1.5 m and constructing 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.

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- During the construction stage, a large increase in run-off 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 site 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.

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.

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5.10.18 References

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APPENDICES

The following appendices are provided in electronic format:

Appendix 5.10.A
Historical 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 Certificates

Appendix 5.10.E
Chemical Results Evaluation

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Appendix 5.10.A
Historical Meteorological Data

Monthly Rainfall Data Humansdorp Station 0017542 (1878-2001).This is just an indication of the historical monthly values and actual daily rainfall used

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1934	44.6	37.8	46.2	25.4	41	45.8	110.9	67.7	16.3 1	60.5	24.9	11.4	632.5
1935	44.7	30.8	36.5	76.2	236.7	45.5	69	48.3	51.4	53.9	63.3	54.7	811
1936	27.7	10.9	38	62.4	43.7	16.5	33.9P	0	53.3 1	2.3	160.8	40.8	590.3
1937	11.5	28.2	60.2	11.4	4.6	89	50.5	21.8	100.4	46.3	68.6	68.6	561.1
1938	37.6	15.2	33	58.2	29.2	38.4	25.5	16.5	63.7P	72	61	28	478.3
1939	13.2	118	78.4	52.1	40.9	22.8	67.3	162.3	32.2	64.6	77.7	58.4	787.9
1940	68.1	65.7	74.8	36.3	39.8	39.7	57.1	0	65.8	26.2	63.7	14.8	552
1941	28.8	18.3	41.4	38.4	17.8	115.8	10.2	50.8	49.0 1	7.3	29.2	122.9	629.9
1942	116.2	6.9	P 21.3	39.5	107.7	65.9	28.7	49.2P	30.0 1	5.6	32	40.6	643.6
1943	65.7	27.2	32	48	8.8	106.2	70.2	111.2	103	10.2	107	60.9	750.4
1944	30.7	65.5	124.7	99	261.2	28.3	39.3	22.9	95.4	58	10.6	25.9	861.5
1945	32.5	34.9	11.5	15.4	138.9	97.7	25.4	124.8	30.4 1	66.3	5.1	24.2	707.1
1946	34	36.5	173	21.6	4.8	34.3	72.9	79.7	31.5	40.9	17.8	9.4	556.4
1947	23.8	32.6	98	31.5	72	P 91.2	107.3	0	40.3	22.9	56.3	56.9	632.8
1948	23.6	10.2	54.7	145.4	3	49.1	16.4	44.1	43.9 1	46.3	39.7	30	606.4
1949	18.5	33.2	5.1	31.5	18.8	0.8	20.4	29.3	36.9	13.6	219.6	33.5	461.2
1950	20.8	34.5	25.4	95	26.1	3.3	76.9	113.8	43.6	74.2	128.3	67.1	709
1951	152.7	46.8	21.9	13.3	59.4	56	105.2	42.2	184.6	33.2	17.8	59.6	792.7
1952	63.3	69.2	15.3	28.2	90.3	51.1	30.5	89.9	156.2	41.4	73.7	54.1	763.2
1953	24.7P	52.6	13.4P	27.9	22.6	50.3	P 238.3	137.9	145.3 4	87.7	74	P 56.6	1331.3
1954	22.1	13.9	P 192.8	67.2P	178.3	127.5	64.1P	106.6P	138.7	74.9	232.4	58.2	1276.7
1955	47.7P	160.8	P 85.1	34.8	31	P 36.6	P 64.5	180.6	61.2P 1	22.2P	178.5	P 50.8	1053.8
1956	20	53.5	76.2	28.5	174.5	30.5	57.5	48.5	140.5 1	74.8	86.4	122.7	1013.6
1957	18.5	89	60.1	49.5	47.2	99.7	64.3	90	160.2	89	10.5	16.5	794.5
1958	8	8.5	86.5	45	164.2	46.5	19.2	120.7	38.7	77.8	18.5	46.5	680.1
1959	106.5	22.5	97.5	107.5	57	52.5	49.5	80	51.5	79.5	22	49	775
1960	82.5	17.8	36	42.9	93	52.7	106.5	41.2	52.5	29.5	48.5	14	617.1
1961	62	66	102.5	93	110	37	74	30.3	18.6	53.9	37	43	727.3
1962	40.5	42.3	81.2	93.1	16.6	15.6	30.8	144.2	17.8	67.7	30.4	5.4	585.6
1963	91.1	12.5	125	83.4	73.1	7.7	56	51	29	39.5	51	97.5	716.8
1964	79.3	39	52.6	43.8	17.5	147.2	31.4	46	162	51.5	96.9	18	785.2
1965	41.5	13.4	31.3	62	87.3	33.2	42.3	14.5	50.8 1	24	123.5	28.5	652.3
1966	71.3	60.5	37	38	53	7.5	37	75.8	55	42.5	72	46	595.6
1967	37.8	49.5	54.4	90.8	97.2	45	54	68.4	66.5	36.8	37.2	25.3	662.9
1968	10.9	46.8	38.3	107.7	66.3	249	24	72	96.2	42.9	42.1	17.5	813.7
1969	48.7	32.1	57.1	36	15.6	46.7	32	33.8	41.1	49	30	23.9	446
1970	47.4	41	12.1	20.1	1.8	21.1	30.5	64.6	47.5	73.7	13.3	88.1	461.2
1971	24.3	43	55.3	193.3	95.4	52.3	139.2	167.5	18	43.3	73.7	21.5	926.8
1972	24.1	52.6	38.7	56.6	50	26.7	46	57.2	6	23.3	26.2	8	415.4
1973	23	52.6	46.2	56	71.8	3.5	11.5	32.2	48.2	45.1	74.9	14.7	479.7
1974	86.5	72.5	150.7	31.8	84.5	54.5	8	107	121.5	18	22.5	37	794.5
1975	68.5	20	56	9	1.1	21	82.5	59.5	97	13.1	47.5	42	517.2
1976	31	28.2	85.1	171	48	63	133.5	51.5	28.5 1	31	67.8	14	852.6
1977	17	97	40	80	149.5	45.5	15	34.6	177.5	30.1	102.5	63.2	851.9
1978	2.8	1.8	116.8	89	58.1	70	P 32.0P	50.3	29.6	87.8	113.5	38.9	690.6
1979	85.6	46.9	51.9	31.7	56.8	51.3	114.9	196.3	69.6	43.2	7.7	54.3	810.2
1980	62.2	9.1	15	76	17	55.1	14.3	26.1	48.5 1	9.2	58.5	27.4	518.4
1981	132	11.5	235	28.3	95.2	57.2	38.1	130.6	24.0 1	26.7	37	33.3	948.9
1982	46.8	22.4	54.3	96.4	1.4	24.5	62.5	64.6	39.2	50.7	8.5	19.5	490.8
1983	22.4	31.5	8.1	16.5	35.9	38.3	234.7	24.4	43.2	46.5	48.2	14.2	563.9
1984	13.5	13.2	59	15.2	15.9	45.4	79.5	15.7	51.2	2.4	41.8	P 53.9P	406.7
1985	102.1P	37.9	P 27.5P	78.0P	8.8	P 82.1	67.7P	7.3	6.9	72.6	85.4	60.6P	636.9
1986	24.7P	14.8	42.5	15.1	11.5	41.1	P 14.1P	85.2P	45.6 1	32.7	75.7	47.4	550.4
1987	13.1	32.6	31.7	64.3	10.2	110	7.1	44	99.2	12	15.7	27.3	467.2
1988	21	77.5	37	72.9	33.1	P 74.6	26.8	47.5	23	38	34	56	541.4
1989	43.9	51	11	52.5P	26.5	14.5	35	11	63.5 2	0.5	142	0	651.4

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Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1878	22.9	53.8	-99.9M	-99.9M	57.8	61.9	57.7	-99.9M	72.6	61.6	55.1	57.9	501.3U
1879	37.6	39.1	180.4	49.3	19.3	80	35.5	64	53.1	45	16.8	35	655.1
1880	41.5	68.7	197.7	108.6	47.5	20.9	4.9	130.3	17.7	58.3	151.8	18.8	866.7
1881	33.5	8.6	80.3	108.2	160.8	72.6	79.6	80.1	44.7	29.6	43	31.5	772.5
1882	32.2	17.6	45.3	29	114.1	3.3	56.9	33.2	74.6	57.3	47.8	67	578.3
1883	18.5	10.9	45.6	77	50.5	19.3	49.7	122.3	21.4	91.7	5.1	33.5	545.5
1884	75.7	51.1	47.8	40.2	16.3	97.1	35.7	21	89.4P	59.5	31	31.5	596.3
1885	39.4	32.4	22.6	40.5	113.3	10.9	41.5	58.7	70.4	20.5	52.3	11.4	513.9
1886	32.7	66.4	58.5	80.1	24.4	0	123.3	31	33.1	46.6	52.8	70.6	619.5
1887	36.7	69.7	66.6	97.1	48.1	19.1	14	85.9	10.3	29.8	66.8	20.4	564.5
1888	21.7	34.6	143.1	42.1	129	58.6	57.2	142.9	81	67.6	56.3	50.6	884.7
1889	80.8	11.6	28	11.4	0.5	47.5	78.2	43	30.1	56	57.9	244.3	689.3
1890	22.1	99.6	27.5	20.3	30.2	56.2	48.8	4.9	29.8	83.9	37.5	29.8	490.6
1891	55.8	33.8	28.7	5.9	44.2	269.6	17.9P	113.6	26.3	57.4	229.4	45.8	928.4
1892	25.6	63.4	95.3	191.3	26.4	95.8	65.8	15.2	132.5	96.5	6.8	20.6	835.2
1893	49.8	39.9	79.1	46.8	148.1	7.7	32.1	28.2	114.5	39.9	181.1	34.5	801.7
1894	46.7	11.5	115.9	42.4	85.7	11.1	42.2	43.2	21.1	52.1P	69.8	22	563.7
1895	102.9	28	15.5	56.1	30.7	50.3	31.8	58.5	37.5	79	29	56.9	576.2
1896	14.7	32.2	13.6	77.5	15	32.9	41.1	215.6	37.7	7.6	125.6	56.4	669.9
1897	15.2	35.3	46.3	9.9	181.7	60.7	83.4	39.7	147.5	77.8	57.4	21.1	776
1898	77.2	26.2	21.7	12.2	71.6	23.4	44.8	25.1	62.7P	69.7	49	43.6	527.2
1899	12.8	40.1	50.1	87.7	41	43.5	6.3	21.2	28.2	31.8	25.5	37.1	425.3
1900	64.5	22.6	50.1	19.3	22.6	45.5	15	72.9	20.6	59.8	49	123.2	565.1
1901	61.5	81	44.7	59.2	41	51.6	7.7	14.5	145.8	79.3	59.4	16.8	662.5
1902	33	80.4	115.4	11.2	28.2	99	55.2	212.7	104.9	31.3	35.1	84.4	890.8
1903	20.8	22.2	42.4	46	21.3	80.3	53.6	88.3	20.4 1	29.6	191.2	19.3	735.4
1904	5.6	104.2	80.3	2.3	19.3	13.5	73.3	80.6	75.7 1	61.7	31.7	66.6	714.8
1905	18.3P	44.5	P 45.5P	137.2P	66	P 55.4	P 16.6P	68.6P	182.3P	76.6P	28	P 23.9P	762.9
1906	13.2P	55.5	P 72.5P	137.3P	163.7	P 48.6	P 29.9P	29.5P	88.7P 1	11.5P	58.7	P 165.3P	974.4
1907	24.7P	21.8	P 102.9P	57.0P	119.4	P 23.2	50.3	37.6	86.6 1	1.9	71.5	66.7	763.6
1908	78.8	25.9	66.3	160.1	17.8	74.9	33.9	91.2	19.0 1	46.8	44.1	37.4	796.2
1909	58.5	42.5	35.9	64.3	25	1.5	55.4	71.9	107.6	73.6	28.2	139.5	703.9
1910	18.9	109.8	120.1	35.6	63.5	30.8	P 8.1	17	67.3P 1	41.7	52.8	56.5	722.1
1911	176.1	42.5	54.6P	25	83.2	18.6	P 48.2	59.5	132.7	57.2	10.6	13.2	721.4
1912	74.8	44	35.7	182.8	32.3	66	31.7	41.5	145.5	57.7	29.7	39.2	780.9
1913	23.6	55.1	62	8.1	58.7	10.4	68.4	92.4P	144	19.9	17.3	13.3	573.2
1914	85.3	71.8	38	58	48.9	64.7	51.4	86.6	14.8	54.4	91	52	716.9
1915	77.7	16.6	23.6	98.3	48.5	43	P 65.6	18.3	45	58.6	101.4	68.9	665.5
1916	52.5	11.6	93.4	71	152.8	25.9	52.9	79.8	35.2	30.3	24.7	57.5	687.6
1917	36	38.2	78.2	115.8	31	127.3	81.1	58.5	67.2 1	12	50.5	16.2	812
1918	61.5	19.6	126.4	30.4	148.8	21.3	48.7	30.2	62	70.5	13	39.4	671.8
1919	29.5	207.1	48.1	90.7	73	59.4	29.7	74.1	32.5	16	40.5	49	749.6
1920	20.7	51.1	95.3	26.8	36.5	41.2	34.6	29.2	20.8	75.4	20	63	514.6
1921	30.0P	58.8	72.1	66.9P	45.5	62.4	73.9	71.2	66.1	24.9	74.9	P 96.6	743.3
1922	28.5P	54	P 37.3	83.8P	79	46.7	96.4P	20.8	30.2	51.2	231.1	22.3	781.3
1923	86.5	32.9	P 34.1P	107.2P	93	72.9	78.4	35.8	37.1	52.3	70.3	P 41.4	741.9
1924	44.4	34.6	P 28.1	14.7	52.2	P 68.2	35.1	111.0P	56.5	38.6P	64.3	69.8	617.5
1925	21.5	9.4	67.4	91.4	70.4	108.7	P 31.7	44.7P	103.9	73.2	35.3	94.8P	752.4
1926	14	43.1	P 15.4	34.7P	65.9	14.1	155.4	66.8P	60.2P 1	10.6	96.5	13.4	690.1
1927	46.9P	34.7	P 86.9P	5.9P	81.2	19.8	19.3	94.1	22.3	22.6	68.1	P 50.8	552.6
1928	32.5	43.6	250.3	31.1P	12.2	83.1	9.7	66.2P	91.1	63.8	95.5	39.9	819
1929	15.3	28.4	28.7	40	69.7	39	88	23.7	129.9	40.9	20.5	43	567.1
1930	18.5	65.3	96.8	49.3	32.6	47.6	17.6	75.8	42.7	67.8	5.2	43.8	563
1931	42.7	10.4	74.4	49.3	12.5	21.7	113.4	18.3	91.7 1	95.9	4.8	145.3	780.4
1932	46.1	26	61.9	11	24.8	43.9	85.8	49.3	341.5	79.6	149.1	37.6	956.6
1933	23.1	34	23.2	17.3	75.3	23.3	14.7	149.4	22.4	22.1	104.9	41.1	550.8

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Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1990	26	81.5	69.7	114	55	111.5	12	52.5	45.5 1	24.5	24	17.5	733.7
1991	40.5	44.5	20.5	14.5	36.5	51	8	63.5	32	95.5	32.5	81	520
1992	15	217	17	43	53	68.5	60.5	141.5	21.5 1	86	145	2.5	970.5
1993	17.5	13	0	103.5	32.5	270.2	10.5	57	221.5	20	41	94	880.7
1994	25	63.5	43.5	26.5	37.5	50	72.5	119	25.5	54.5	10.5	95	623
1995	31.3P	95	89.5	88.3P	43.7	P 6.1	P 15.5	64.2P	28.5	49.2P	45.5	65.0P	621.8
1996	34.5	25.5	28.5	3.5P	14	0	68.0P	71.5	36.5 2	18.9P	263.5	15.5	779.9
1997	9	25	64.8	184.5	46.5	53	32.8P	77.5	22	6	18	2.5	541.6
1998	69.5	28	113.5	11.5	3	15	47.5	68.5	37.5	25	61.5	36.5	517
1999	27	47.5	39.5	67	18.2	P 4.5	100	24	0	0	0	86	413.7
2000	81.5	99.5	136.3	54	13	3.5	23.5	2.5	46	49	53	5	566.8
2001	124	18	73	75.5	6	20	38.5	66	-84.5	99.9M	72	18	595.5U

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Appendix 5.10.B
Infiltration Data and Calculations

Thyspunt Mini Disk Infiltration Test Results					
Site name	**Latitude**	**Longitude**	**Soil type**	**K (cm/s)**	**K (m/d)**
THY_infil1	S34.17332	E24.72918	Sand	0.0210	18.103
THY_infil2	S34.17916	E24.70774	Sand	0.0059	5.081
THY_infil3	S34.18392	E24.71903	Sand	0.0045	3.861
THY_infil4	S34.19094	E24.70829	Sand	-	
Ave.					9.015
Median					5.081

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Appendix 5.10.C
Hydrological and Hydraulic Model Parameters

Inputs Southern Region

Catchment Name	Area (km^2)	Hydraulic Length (km)	r	CN	S (m/m)	Tc (hrs)	SCS Lag
K80F_S01	0.18	1.01	0.3	39	0.288	0.46	0.28
K80F_S02	1.44	4.09	0.3	37	0.244	0.92	0.55
K80F_S03	1.92	3.82	0.3	49	0.177	0.96	0.58
K80F_S04	0.84	2.07	0.3	37	0.270	0.66	0.39
K80F_S05	0.56	2.72	0.3	45	0.230	0.77	0.46
K80F_S06	0.88	2.14	0.3	39	0.263	0.67	0.40
K80F_S07	0.59	2.43	0.3	38	0.198	0.76	0.46
K80F_S08	0.17	1.59	0.3	41	0.286	0.57	0.34
K80F_S09	0.24	0.94	0.3	39	0.218	0.48	0.29
K80F_S10	0.55	2.13	0.3	39	0.204	0.71	0.43
K80F_S11	0.37	0.54	0.3	38	0.227	0.36	0.22
K80F_S12	0.11	1.62	0.3	38	0.287	0.58	0.35

Note: *r = Roughness coefficient*
CN = SCS Curve Number
S = Average catchment slope
Tc = Time of concentration
SCS Lag = Index of the catchment's response time to the peak discharge

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Outputs Southern Region (Flows)

Catchment	Peak Flow (m^3/s)						
Name	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-8}
K80F_S01	0.50	1.80	3.50	5.50	7.60	10.00	14.90
K80F_S02	2.20	8.00	16.00	25.50	35.90	47.20	71.30
K80F_S03	6.90	18.10	31.90	47.10	63.20	80.20	115.10
K80F_S04	1.60	5.80	11.70	18.70	26.30	34.60	52.20
K80F_S05	1.80	5.20	9.50	14.40	19.50	25.00	36.40
K80F_S06	2.00	6.80	13.20	20.70	28.90	37.70	56.30
K80F_S07	1.10	4.00	7.80	12.40	17.30	22.70	34.10
K80F_S08	0.50	1.60	3.00	4.60	6.40	8.30	12.30
K80F_S09	0.70	2.30	4.40	7.00	9.70	12.70	19.00
K80F_S10	1.20	4.10	8.00	12.60	17.50	22.90	34.20
K80F_S11	1.10	3.90	7.80	12.30	17.20	22.60	33.90
K80F_S12	0.20	0.90	1.70	2.70	3.80	5.00	7.50

Outputs Southern Region (Volumes)

Catchment	Stormflow Volume ($m^3 x\ 10^3$)						
Name	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-8}
K80F_S01	3.10	8.90	16.70	25.70	35.40	46.00	68.50
K80F_S02	20.80	63.30	120.40	187.80	261.50	341.80	513.00
K80F_S03	56.00	138.30	238.50	349.80	466.80	590.50	846.50
K80F_S04	12.20	37.00	70.40	109.70	152.80	199.60	299.70
K80F_S05	13.40	34.90	61.90	92.50	125.00	159.60	231.90
K80F_S06	14.70	42.70	79.70	122.80	169.50	220.20	327.50
K80F_S07	9.20	27.40	51.50	79.80	110.70	144.20	215.40
K80F_S08	3.20	8.90	16.30	24.80	33.90	43.80	64.60
K80F_S09	4.00	11.60	21.60	33.30	46.00	59.80	88.90
K80F_S10	9.30	26.90	50.20	77.30	106.70	138.60	206.20
K80F_S11	5.80	17.20	32.40	50.20	69.70	90.80	135.60
K80F_S12	1.70	5.00	9.50	14.70	20.40	26.60	39.70

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Outputs Southern Region - Nuclear Footprint (27 Ha)

Phase	Peak Flow (m^3/s)						
	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-8}
Natural	0.50	1.80	3.50	5.50	7.60	10.00	14.90
During Construction	2.20	8.00	16.00	25.50	35.90	47.20	71.30
During Operation	6.90	18.10	31.90	47.10	63.20	80.20	115.10

Phase	Stormflow Volume (m^3)						
	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-8}
Natural	0.50	1.80	3.50	5.50	7.60	10.00	14.90
During Construction	2.20	8.00	16.00	25.50	35.90	47.20	71.30
During Operation	6.90	18.10	31.90	47.10	63.20	80.20	115.10

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Appendix 5.10.D
Chemical Laboratory Certificates

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

Registration Number 1974/001476/07 Vat Number 4780103505
M and L Laboratory Services (Pty) Ltd
Consulting Industrial Chemists, Analysts & Samplers
CONFIDENTIAL

Ref No. : 08/13472L
Issued at : Johannesburg
Date : 2009.01.16
Page : 1 of 5

COMPANY NAME	:	SRK CONSULTING – PORT ELIZABETH
ADDRESS	:	PO BOX 21842, PORT ELIZABETH, 6000
SUBJECT	:	ANALYSIS OF 5 WATER SAMPLES
MARKED	:	ESKOM NUCLEAR: THYSPUNT AND AS BELOW
INSTRUCTED BY	:	JOHAN DU PLOOY
PROJECT NO.	:	385 924
ORDER NO	:	L 3817
RECEIVED ON	:	2008.12.15
LAB NO(S)	:	E52983 – E52987

Analysis on an as received basis:

Lab No:	52983	52984	52985	52986
SAMPLE MARKS	TSW 1	TSW 2	TSW 3	TSW 4
pH Value @ 22°C	8.2	8.1	8.1	8.2
Conductivity mS/m @ 25°C	141	126	85.1	68
Calcium,Ca	48	50	81	77
Calcium Hardness as CaCO3	120	125	202	192
Magnesium, Mg	43	40	28	15.8
Magnesium Hardness as CaCO3	177	165	115	65
Total Hardness as CaCO3	297	290	318	257
Sodium,Na	138	124	66	27
Potassium,K	9.7	7.1	4.1	2.4
Free and Saline Ammonia, NH4	<0.1	<0.1	<0.1	<0.1
Total Alkalinity as CaCO3	117	110	218	185
P Alk as CaCO3	Nil	Nil	Nil	Nil
Bicarbonate,HCO3	143	134	266	226
Carbonate, CO3	Nil	Nil	Nil	Nil
Chloride,Cl	335	299	122	80
Sulphate,SO4	46	45	100	20
Nitrate,NO3	0.3	1.1	4.1	0.8
Nitrate,N	0.1	0.2	0.9	0.2
Fluoride,F	0.1	0.1	0.2	0.2
Sum of Cations meq/l	12.183	11.360	9.320	6.378
Sum of Anions meq/l	12.752	11.590	9.955	6.392
% Error	-2.285	-0.999	-3.290	-0.114

The results are expressed in mg/l where applicable.

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Page : 2 of 5

Analysis on an as received basis:

Lab No:	52987
SAMPLE MARKS	TSW 7
pH Value @ 22°C	7.8
Conductivity mS/m @ 25°C	236
Calcium,Ca	78
Calcium Hardness as CaCO3	195
Magnesium, Mg	50
Magnesium Hardness as CaCO3	206
Total Hardness as CaCO3	401
Sodium,Na	315
Potassium,K	15.6
Free and Saline Ammonia, NH4	<0.1
Total Alkalinity as CaCO3	242
P Alk as CaCO3	Nil
Bicarbonate,HCO3	295
Carbonate, CO3	Nil
Chloride,Cl	553
Sulphate,SO4	122
Nitrate,NO3	11.5
Nitrate,N	2.6
Fluoride,F	0.2
Sum of Cations meq/l	22.106
Sum of Anions meq/l	23.166
% Error	-2.342

The results are expressed in mg/l where applicable.

Method Reference: List Appended.

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MARKED	:	ESKOM NUCLEAR: THYSPUNT AND AS BELOW
INSTRUCTED BY	:	JOHAN DU PLOOY
PROJECT NO.	:	385 924
ORDER NO	:	L 3817
RECEIVED ON	:	2008.12.15
LAB NO(S)	:	E52983 – E52987
DATE ANALYSED	:	2008.12.12

Analysis on an as received basis:

Lab number	E52983	E52984	E52985	E52986	E52987
Sample marks	TSW 01	TSW 02	TSW 03	TSW 04	TSW 07
Manganese, Mn	<0.001	<0.001	<0.001	<0.001	<0.001
Iron, Fe	0.61	0.45	0.04	0.48	1.0
Zinc, Zn	<0.005	<0.005	<0.005	<0.005	<0.005
Lead, Pb	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt, Co	<0.001	<0.001	<0.001	<0.001	<0.001
Copper, Cu	<0.002	<0.002	<0.002	<0.002	<0.002
Total Chromium, Cr	<0.003	<0.003	<0.003	<0.003	<0.003
Cadmium, Cd	<0.001	<0.001	<0.001	<0.001	<0.001
Phosphorus as PO_4	1.9	<0.12	1.1	4.2	3.4

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

Results reported relate only to items tested

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

Mahmood Patel
OPERATIONAL MANAGER

Authorised Signature

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Page : 4 of 5

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

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

Registration Number 1974/001476/07 Vat Number 4780103505
M and L Laboratory Services (Pty) Ltd
Consulting Industrial Chemists, Analysts & Samplers
CONFIDENTIAL

Ref No. : 08/13472L
Issued at : Johannesburg
Date : 2009.01.16

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-ClC
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-$S^{=}$ 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-OC
Oxygen Absorbed (Permanganate Value)	Titrimetric	S.A.B.S. 220
Residual Free Chlorine	Colorimetric	A.P.H.A. 4500-ClG
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 and L Laboratory Services (Pty) Ltd

Consulting Industrial Chemists, Analysts & Samplers
CONFIDENTIAL

Ref.No. : 09/02007L
Issued at : Johannesburg
Date : 12.06.2009
Page : 1 of 4

COMPANY NAME	:	SRK CONSULTING – PORT ELIZABETH
ADDRESS	:	P.O. BOX 21842, PORT ELIZABETH, 6000
SUBJECT	:	Analysis of 3 samples of WATER
MARKED	:	Eskom nuclear: Thyspunt and as below
INSTRUCTED BY	:	Karen Burger
PROJECT NO.	:	385924
ORDER NO.	:	L7582
RECEIVED ON	:	14.05.2009
LAB NO(S)	:	E56418-E56420
DATE ANALYSED	:	26.05.2009

Analysis on an as received basis:

Lab No:	56418	56419	56420
SAMPLE MARKS	TSW01	TSW02	TSW03
pH Value @ 18°C	7.6	7.9	7.4
Conductivity mS/m @ 25°C	100	136	80.5
Calcium,Ca	36	94	75
Magnesium, Mg	28	35	14.9
Sodium,Na	123	138	67
Potassium,K	10.6	6.1	5.6
Total Alkalinity as CaCO3	98	251	192
P Alk as CaCO3	Nil	Nil	Nil
Bicarbonate,HCO3	119	306	234
Carbonate, CO3	Nil	Nil	Nil
Chloride,Cl	219	230	111
Sulphate,SO4	42	73	23
Nitrate,NO3	1.2	11.8	7.6
Nitrate,N	0.3	2.7	1.7
Fluoride,F	0.1	0.1	0.2
Free and Saline Ammonia as NH_4	<0.1	1.2	<0.1
Sum of Cations meq/l	9.721	13.728	8.026
Sum of Anions meq/l	9.033	13.216	7.578
% Error	3.668	1.899	2.867

The results are expressed in mg/l where applicable.

Method reference: list appended.

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Ref.No. : 09/02007L
Issued at : Johannesburg
Date : 12.06.2009
Page : 2 of 4

COMPANY NAME : SRK CONSULTING
ADDRESS : P.O Box 21842, Port Elizabeth, 6000
SUBJECT : Analysis of 3 samples of water
MARKED : Eskom Nuclear (Thyspunt) and as below
INSTRUCTED BY : Karen Burgers
ORDER NO. : L7582
RECEIVED ON : 2009.05.18
DATE ANALYZED : 2009.06.19
LAB NO(S) : E56418 – E56420

Analysis on an as received basis:

Lab number	E56418	E56419	E56420
Sample marks	TSW01	TSW02	TSW03
Manganese, Mn	0.03	0.007	<0.001
Iron, Fe	0.80	0.68	0.64
Zinc, Zn	<0.005	<0.005	<0.005
Lead, Pb	<0.001	<0.001	<0.001
Cobalt, Co	<0.001	<0.001	<0.001
Copper, Cu	<0.002	<0.002	<0.002
Total Chromium, Cr	0.07	0.10	0.08
Cadmium, Cd	<0.001	<0.001	<0.001
Phosphorus as PO_4	0.59	<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 C D
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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Ref.No. : 09/02007L
Issued at : Johannesburg
Date : 12.06.2009
Page : 4 of 4

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.

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Appendix 5.10.E
Chemical Results Evaluation

Sample Markings	**TSW01**		**TSW02**		**TSW03**		**TSW04**		**TSW05**		
Determinant	**S34 10' 16.32"**		**S34 10' 15.88"**		**S34 11' 1.716"**		**S34 10' 4.044"**		**S34.10' 15.708"**		**Comments**
	E24 37' 55.56"		**E25 38' 56.040"**		**E24 41' 10.14"**		**E24 41' 51.0"**		**E24 38' 56.04"**		
	Dec 08	**May 09**	**Dec 08**	**May 09**	**Dec 08**	**May 09**	**Dec 08**	***May 09**	**Dec 08**	***May 09**	
pH Value @ 22°C	8.2	7.6	8.1	7.9	8.1	7.4	8.2		7.8		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**.
Conductivity mS/m @ 25°C	141	100	126	136	85.1	80.5	68				
	mg/l		**mg/l**		**mg/l**		**mg/l**	**mg/l**	**mg/l**		
Calcium, Ca	48	36	50	94	81	75	77		78		
Magnesium, Mg	43	28	40	35	28	14.9	15.8		50		
Sodium, Na	138	123	124	138	66	67	27		315		
Potassium, K	9.7	10.6	7.1	6.1	4.1	5.6	2.4		15.6		
Total Alkalinity as $CaCO_3$	117	98	110	251	218	192	185		242		
P. Alkalinity as $CaCO_3$	Nil	Nil	Nil	Nil	Nil	Nil	Nil		Nil		
Total Hardness CaCO3	297		290		318		257		401		
Bicarbonate, HCO_3	143	119	134	306	266	234	226		295		Very Hard water
Carbonate, CO_3	Nil	Nil	Nil	Nil	Nil	Nil	Nil		Nil		
Chloride, Cl	335	219	299	230	122	111	80		553		
Sample Markings	**TSW01**		**TSW02**		**TSW03**		**TSW04**		**TSW05**		
Determinant	**S34 10' 16.32"**		**S34 10' 15.88"**		**S34 11' 1.716"**		**S34 10' 4.044"**		**S34 10' 15.708"**		**Comments**
	E24 37' 55.56"		**E25 38' 56.040"**		**E24 41' 10.14"**		**E24 41' 51.0"**		**E24 38' 56.04"**		
	Dec 08	**May 09**	**Dec 08**	**May 09**	**Dec 08**	**May 09**	**Dec 08**	***May 09**	**Dec 08**	***May 09**	
Sulfate, SO_4	46	42	45	73	100	23	20		11.5		
Nitrate, NO_3	0.3	1.2	1.1	11.8	4.1	7.6	0.8		2.6		In South Africa, inorganic nitrogen concentrations in un-impacted, 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 under natural conditions (e.g., mineral salts derived from rocks and soil, not due to man's activities).
Nitrate as N	0.1	0.3	0.2	2.7	0.9	1.7	02				Nitrates are low and should not cause eutrophication
Fluoride, F	0.1	0,1	0.1	0.1	0.2	0.2	0.2				

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Sample Markings	**TSW01**		**TSW02**		**TSW03**		**TSW04**		**TSW05**		
Free and Saline Ammonia as NH_4	<0.1	<0.1	<0.1	1.2	<0.1	<0.1					Single measurements of ammonia are of limited use. Preferably, weekly ammonia concentrations, averaged over a period of at least 4 weeks, with the minimum and maximum values reported, should be compared with the Target Water Quality Range (TWQR). Interpretation of the ammonia criteria is based on the free ammonia concentrations. The potential effect of ammonia on the aquatic environment is modified by the chemical species present, the relative proportions of each, and other factors such as pH, temperature and dissolved oxygen concentration.
Manganese, Mn	<0.001	0.3	<0.001	0.007	<0.001	<0.001	<0.001		<0.001		
Sample Markings	**TSW01**		**TSW02**		**TSW03**		**TSW04**		**TSW05**		
Determinant	**S34 10' 16.32"**		**S34 10' 15.88"**		**S34 11' 1.716"**		**S34 10' 4.044"**		**S34 10' 15.708"**		**Comments**
	E24 37' 55.56"		**E25 38' 56.040"**		**E24 41' 10.14"**		**E24 41' 51.0"**		**E24 38' 56.04"**		
	Dec 08	**May 09**	**Dec 08**	**May 09**	**Dec 08**	**May 09**	**Dec 08**	***May 09**	**Dec 08**	***May 09**	
Iron, Fe	0.61	0.80	0.45	0.68	0.04	0.64	0.48		1.0		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	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005		<0.005		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. In most natural waters zinc exists mainly as the divalent cation, which is the potentially toxic form. The proportion of other forms such as inorganic compounds like ZnCO ; stable organic complexes like Zn- 3 cysteinate; or colloids like Zn2+-clay or Zn2+-humic acid, depends on the chemistry of the water. The greatest dissolved zinc concentrations will occur in water with low pH, low alkalinity and high ion strength.

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Sample Markings	TSW01		TSW02		TSW03		TSW04		TSW05		
Determinant	**S34 10' 16.32"**		**S34 10' 15.88"**		**S34 11' 1.716"**		**S34 10' 4.044"**		**S34 10' 15.708"**		**Comments**
	E 24 37' 55.56"		**E25 38' 56.040"**		**E24 41' 10.14"**		**E24 41' 51.0"**		**E24 38' 56.04"**		
	Dec 08	**May 09**	**Dec 08**	**May 09**	**Dec 08**	**May 09**	**Dec 08**	***May 09**	**Dec 08**	***May 09**	
Lead, Pb	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		<0.001		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 Lead uptake by aquatic organisms is dependent on the action of calcium; therefore, hardness is an important factor determining the toxicity of lead in aquatic systems.
Cobalt, Co	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		<0.001		
Copper, Cu	<0.002	<0.002		<0.002		<0.002	<0.002		<0.002		Copper is easily absorbed and precipitated in sediments at alkaline pH. Less than 1 % of total copper exists in the free 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. Absorption and precipitation are therefore important in determining the abiotic fate of copper in the aquatic environment. In reducing acidic environments, remobilisation of absorbed or co-precipitated copper can occur. In the presence of soluble organic matter, absorption 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.
Sample Markings	**TSW01**		**TSW02**		**TSW03**		**TSW04**		**TSW05**		
Determinant	**S34 10' 16.32"**		**S34 10' 15.88"**		**S34 11' 1.716"**		**S34 10' 4.044"**		**S34 10' 15.708"**		**Comments**
	E 24 37' 55.56"		**E25 38' 56.040"**		**E24 41' 10.14"**		**E24 41' 51.0"**		**E24 38' 56.04"**		
	Dec 08	**May 09**	**Dec 08**	**May 09**	**Dec 08**	**May 09**	**Dec 08**	***May 09**	**Dec 08**	***May 09**	
Total Chromium, Cr	<0.003	0.07	<0.003	0.1	<0.003	0.08	<0.003		<0.003		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	<0.001	<0.001	<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 co-existing metal cations present in the water.
Phosphorus, PO4	1.9	0.59	<0.12	<0.12	1.1	<0.12	4.2		3.4		

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