Richards Bay PHSHDA

Climate Risk Profile Report

16OCTOBER 2023

Report compiled by the CSIR
Funded by the GIZ
DFFE, DHS and the HDA as collaborative partners

Title:	Richards Bay PHSHDA: Climate Risk Profile Report
Authors:	Melanie Lück-Vogel, Amy Pieterse, Chantel Ludick & Lethabo Chilwane
Project lead:	Willemien van Niekerk (CSIR) & Michelle Hiestermann (GIZ)
Date:	16 October 2023
Citation:	CSIR, 2023. Richards Bay PHSHDA: Climate Risk Profile Report. GIZ, DFFE, DHS, the HDA & uMhlathuze Local Municipality.
Version:	Draft 1

Table of Contents

Figures

Tables

List of Acronyms and Abbreviations

°C	Degree Celsius
AFF	Agriculture, Forestry, and Fisheries
AR5	Fifth Assessment Report
CABLE	CSIRO Atmosphere Biosphere Land Exchange model
CCAM	Conformal-cubic atmospheric model
CDRF	Climate and Disaster Resilience Fund
CMIP5	Coupled Model Intercomparison Project 5
CRVA	Climate Risk and Vulnerability Assessment
CSIR	Council for Scientific and Industrial Research
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DHS	Department of Human Settlements
DM	District Municipality
DRR	Disaster risk reduction
DWS	Department of Water and Sanitation
EcVI	Economic Vulnerability Index
EnVI	Environmental Vulnerability Index
GCM	General circulation model
GDP	Gross Domestic Product
GRiMMS	Groundwater Drought Risk Mapping and Management System
GVA	Gross Value Added
IDRC	International Development Research Centre
IPCC	Intergovernmental Panel on Climate Change
km	Kilometre
l/p/d	Litres Per Person Per Day
LM	Local Municipality
LRT	Let's Respond Toolkit
mm	Millimetre
NDMC	National Disaster Management Centre
PHSHDA	Priority Human Settlement and Housing Development Area
PHS	Priority Human Settlement
PHDA	Priority Housing Development Area

PVI	Physical Vulnerability Index
RCP	Representative Concentration Pathways (mitigation scenarios)
SCIMAP	Sensitive Catchment Integrated Modelling and Prediction
SEVI	Socio-Economic Vulnerability Index
SPI	Standardised Precipitation Index
SPLUMA	Spatial Planning and Land Use Management Act, 2013 (Act No.16 of 2013)
THI	Temperature Humidity Index
WMAs	Water Management Areas
WMO	World Meteorological Organisation
WRYM	Water Resources Yield Model
WUI	Wildland-Urban Interface

Glossary of Terms

Adaptation actions	A range of planning and design actions that can be taken by local government to adapt to the impacts of climate change, reduce exposure to hazards, and exploit opportunities for sustainable development (CSIR, 2023).
Adaptation planning	The process of using the basis of spatial planning to shape built-up and natural areas to be resilient to the impacts of climate change, to realise co-benefits for long-term sustainable development, and to address the root causes of vulnerability and exposure to risk. Adaptation planning assumes climate change as an important factor while addressing developmental concerns, such as the complexity of rapidly growing urban areas, and considers the uncertainty associated with the impacts of climate change in such areas – thereby contributing to the transformational adaptation of urban spaces. Adaptation planning also provides opportunities to climate proof urban infrastructure, reduce vulnerability and exploit opportunities for sustainable development (National Treasury, 2018; Pieterse, 2020).
Adaptive capacity	"The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences" (IPCC, 2022, p. 2899).
Climate change adaptation	"In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects" (IPCC, 2022, p. 2898).
Climate change mitigation	"A human intervention to reduce emissions, or enhance the sinks, of greenhouse gases (GHGs)" (IPCC, 2022, p. 2915). The goal of climate change mitigation is to achieve a reduction of emissions that will limit global warming to between 1.5°C and 2°C above preindustrial levels (Behsudi, A, 2021).

Climate hazards	Climate hazards are a sub-set of natural hazards and a grouping of hydrological, climatological, and meteorological hazards. This includes the spatial extent and frequency of, among others, floods, fires, and extreme weather events such as extreme rainfall and extreme heat. Sometimes referred to as hydrometeorological hazards. The potential occurrence of a climate hazard may cause loss of life, injury, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources (IPCC, 2022). Climate hazards can increase in intensity and frequency with climate change (Pieterse et al., 2023).
Climate risk	Risk implies the potential for adverse consequences resulting from the interaction of vulnerability, exposure, and a hazard. Relevant adverse consequences include those on "lives and livelihoods, health and well-being, economic and sociocultural assets, infrastructure and ecosystems" (IPCC, 2022, p. 144). In the IPCC's 6th Assessment Report, it is confirmed that risks may result from "dynamic interactions between climate-related hazards with the exposure and vulnerability of the affected human or ecological system" (IPCC, 2022, p. 132).
Coping capacity	"The ability of people, institutions, organizations and systems, using available skills, values, beliefs, resources and opportunities, to address, manage, and overcome adverse conditions in the short to medium term" (IPCC, 2022, p. 2904).
Disaster risk reduction	"Denotes both a policy goal or objective, as well as the strategic and instrumental measures employed for anticipating future disaster risk; reducing existing exposure, hazard or vulnerability; and improving resilience" (IPCC, 2022, p. 2906).
Exposure	Exposure implies the physical exposure of elements to a climate hazard. It is defined as the "presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected [by climate hazards]" (IPCC, 2022, p. 2908).
Mainstreaming	The process of integrating climate change adaptation strategies and measures into existing planning instruments and processes as opposed to developing dedicated adaptation policies and plans (Pieterse et al., 2021).

Resilience	"The capacity of interconnected social, economic and ecological systems to cope with a hazardous event, trend or disturbance, responding or reorganising in ways that maintain their essential function, identity and structure. Resilience is a positive attribute when it maintains capacity for adaptation, learning and/or transformation" (IPCC, 2022, pp. 2920–2921).
Sensitivity	"The degree to which a system or species is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea level rise)" (IPCC, 2022, p. 2922).
Vulnerability	Vulnerability is defined as the "propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including, sensitivity or susceptibility to harm and lack of capacity to cope and adapt" (IPCC, 2022, p. 2927). Vulnerability refers to the characteristics or attributes of exposed elements, i.e., elements that are exposed to potential climate-related hazards. Vulnerability is a function of sensitivity and (coping or adaptive) capacity (Pieterse et al., 2023).

1. Introduction

This Climate Risk Profile report, as well as the accompanying Adaptation Actions Plan, were developed specifically for the Richards Bay Priority Human Settlement Area and Housing Development Area (PHSHDA) in the uMhlathuze Local Municipality in KwaZulu-Natal, to support its strategic climate change response agenda. Both documents are primarily informed by the GreenBook, which is an open-access online planning support system that provides quantitative scientific evidence in support of local government's pursuit in the planning and design of climate-resilient, hazard-resistant settlements. The GreenBook is an information-dense resource and planning support system offered to South African local governments to better understand their risks and vulnerabilities in relation to population growth, climate change, exposure to hazards, and vulnerability of critical resources. In addition to this, the GreenBook also provides appropriate adaptation measures that can be implemented in cities and towns, so that South African settlements are able to minimise the impact of climate hazards on communities and infrastructure, while also contributing to developmental goals (see GreenBook - Adapting settlements for the future).

The purpose and strategic objectives of the Climate Risk Profile and the Adaptation Actions Plan are to:

- Build and further the climate change response agenda,
- Inform strategy and planning in the Priority Human Settlement Area and Housing Development Area (PHSHDA),
- Identify and prioritise risks and vulnerabilities,
- Identify and prioritise interventions and responses, as well as
- Guide and enable the mainstreaming of climate change response, particularly adaptation.

1.1. Approach followed

The approach used in the GreenBook and the Climate Risk Profile report is centred around understanding climate-related risk. Climate-related risk implies the potential for adverse consequences resulting from the interaction of vulnerability, exposure, and the occurrence of a climate hazard (see Figure 1). "Relevant adverse consequences include those on lives, livelihoods, health and wellbeing, economic, social and cultural assets [as well as] investments, infrastructure, and services (including ecosystem services, ecosystems and species)" (Chen et al., 2021, p. 64).

The components of risk are dynamic. Climate hazards are driven by natural climate variability and anthropogenic climate change. Human activity contributes to Greenhouse Gas emissions that increase temperatures, which in turn affects changes in the occurrence of climate hazards such as drought, flooding, coastal flooding, and heat extremes. Planned as well as unplanned development and growth of our settlements drive the exposure of people, as well as the built- and natural environment to climate hazards. Vulnerability includes the inherent characteristics that make systems sensitive to the effects and impacts of climate hazards. Municipal risk is driven by vulnerability and exposure to certain climate-related hazards.

Figure 1: The interaction between the various components of risk, indicating the opportunity to reduce risk through adaptation (based on IPCC, 2014 and IPCC, 2021)

To understand climate risk, the exposure of a settlement to certain climate hazards and its vulnerability to climate change are unpacked. In this Climate Risk Profile report, multiple vulnerability indices are provided, as well as variables for the current and future projected climate. Climate-related hazards such as drought, heat extremes, wildfire, flooding and coastal flooding and erosion and the impact of climate on key resources are also set out for the uMhlathuze Local Municipality in which the Richards Bay PHSHDA falls.

All information contained in this report is based on the GreenBook, unless otherwise specified. The information in the GreenBook is provided at local municipal level and settlement level. In case that the PHSHDA falls within a settlement, the local municipal and settlement level risk profile will be utilised. Information and data were derived using GIS analysis and modelling techniques using secondary data and is not based on local surveys.

1.2. Policy framework

There are various regulatory and legislative requirements for climate change response [planning] in South Africa, at local government level. For instance, the Disaster Management Amendment Act of 2015, which aims to provide measures to reduce disaster risks through climate change adaptation and the development of early warning systems, requires each organ of state, provincial government, and municipality to identify measures for, as well as indicate plans to invest in disaster risk reduction (DRR) and climate change adaptation. The Spatial Planning and Land Use Management Act, No. 16 of 2013 (SPLUMA) outlines five principles intended to guide spatial planning, land development and land use management at all levels of planning, including local government level. Amongst them are the principles of (1) spatial resilience, which encourages "flexibility in spatial plans, policies and land use management systems, to ensure sustainable livelihoods in communities most likely to suffer the impacts of economic and environmental shocks" (Republic of South Africa, 2013, p. 20) – some of which may be induced by the impacts of climate change, and (2) spatial sustainability, which sets out requirements for municipal planning functions such as spatial planning and land use management to be carried out in ways that consider protecting vital ecosystem features such as agricultural land, i.e., from both anthropogenic and natural threats, including the impacts of climate change, as well as in ways that consider current and future costs of providing infrastructure and social services in certain areas (e.g., uninformed municipal investments may lead to an increase in the exposure of people and valuable assets to extreme climate hazards). Furthermore, the National Climate Change Response White Paper – which outlines the country's comprehensive plan to transition to a climate resilient, globally competitive, equitable and low-carbon economy and society through climate change adaptation and mitigation, while simultaneously addressing the country's key priorities, including job creation, poverty reduction, social equality and sustainable development, amongst others – identifies local governments as critical role players that can contribute towards effective climate change adaptation through their various functions, including "[the] planning [of] human settlements and urban development; the provision of municipal infrastructure and services; water and energy demand management; and local disaster response, amongst others." (Republic of South Africa, 2011, p. 38). The Climate Change Bill takes it further by setting out reporting requirements on climate change response needs and interventions for every municipality in the country.

The National Climate Change Adaptation Strategy outlines several actions that are applicable at municipal level, including the development and implementation of adaptation strategies and vulnerability reduction programmes targeting communities and individuals that are most at risk to the impacts of climate change; the development of municipal early warning systems; as well as the integration of climate change adaptation into municipal development plans and relevant sector plans, i.e., mainstreaming. The National Climate Risk and Vulnerability Assessment Framework – which is aimed at all actors, including local governments – guides the development and review of climate risk and vulnerability assessments (CRVAs) to enable alignment, aggregation and comparison across all CRVAs, in an effort to inform an integrated and effective climate change adaptation response across all scales and sectors.

In response to the national call to advance spatial transformation and consolidation in human settlement development, the National Department of Human Settlements (DHS) has identified a total of 136 Priority Human Settlements and Housing Development Areas (PHSHDAs). The PHSHDAs were declared to ensure that housing delivery is used to restructure and revitalise towns and cities, strengthen the livelihood prospects of households, and overcome apartheid spatial patterns by fostering integrated urban forms (DHS, 2020). PHSHDAs were designated using national criteria which includes an area or settlement's potential to support sustainable environmental management (which plays a critical role in mitigating the negative impacts of climate change), as well as its potential to accommodate the integration of land uses and amenities, i.e., in addition to other criteria.

The DHS has identified two key objectives for PHSHDAs, namely (1) targeting and prioritising areas for integrated housing and human settlements development to ensure the delivery of housing for a diverse range of income groups within an integrated mixed-use development, as well as (2) transforming spatial patterns which have historically exacerbated social inequality and economic inefficiency (DHS, 2020). As part of the second objective, this initiative aims to develop post-apartheid cities and city patterns that ensure urban access, as well as achieve a balance between spatial equity, economic competitiveness, and environment sustainability (DHS, 2020). As the impacts of climate change become more severe, the latter outcome (i.e., ensuring and maintaining environmental sustainability) will become increasingly important. Furthermore, as part of the implementation approach for housing and human settlement development in PHSHDAs, the DHS has identified the provision and maintenance of ecological infrastructure to support development in priority areas as a key avenue for integrating climate considerations and mainstreaming climate responses (DHS, 2022).

1.3. Local Municipal context

The Richards Bay PHSHDA is located in the uMhlathuze Local Municipality within the King Cetshwayo District in KwaZulu-Natal. uMhlathuze's climate is characterized by a warm to hot and humid subtropical climate, with warm moist summers. Average daily maximum temperatures range from 29°C in January to 22°C in July, and extremes can reach more than 40°C in summer. The average annual rainfall is 1 200 mm and most (~80%) of the rainfall occurs in the summer, from October to March, although rainfall also occurs in winter (~20%). The Richards Bay area is generally very flat and is situated on a coastal plain and whilst going west towards Empangeni the terrain rises and becomes undulating (uMhlathuze, 2022).

The uMhlathuze Local Municipality was established on 5 December 2000 after the demarcation process and the local government elections of that date. As such it encompasses the towns of Empangeni, Richards Bay, eSikhaleni, Ngwelezane, Nseleni, Vulindlela and Felixton as well as the Traditional Authority areas under Amakhosi Dube, Mkhwanazi, Khoza, Mbuyazi, Zungu, Mthembu, Cebekhulu and small portions of Biyela (Obuka) (uMhlathuze, 2022).

The city of uMhlathuze has identified various development nodes within its area of jurisdiction. The identified nodes contain opportunities for development and constraints to development. Richards Bay is classified as a Primary Node based on the type of facilities and services it currently offers to the local people and the rest of uMhlathuze inhabitants (Figure 2). The city is facing an imbalance of spatial development and is aiming for restructuring the major settlement areas in Richards Bay, Empangeni and along the Vulindlela-Esikhaleni corridor (Figure 3). The development corridor between Richards Bay and Nseleni/Mkhoma, also a Priority Human Settlement Housing Development Area (PHSHDA) is the focus of this Risk Profiling Report. Nseleni/Mkhoma is classified as a tertiary socio-economic node "offering sustainable mixed use development opportunities based on a human scale principle such as educational, low income residential (urban & periurban living), health facilities, and small-scale commercial facilities (uMhlathuze, 2021).

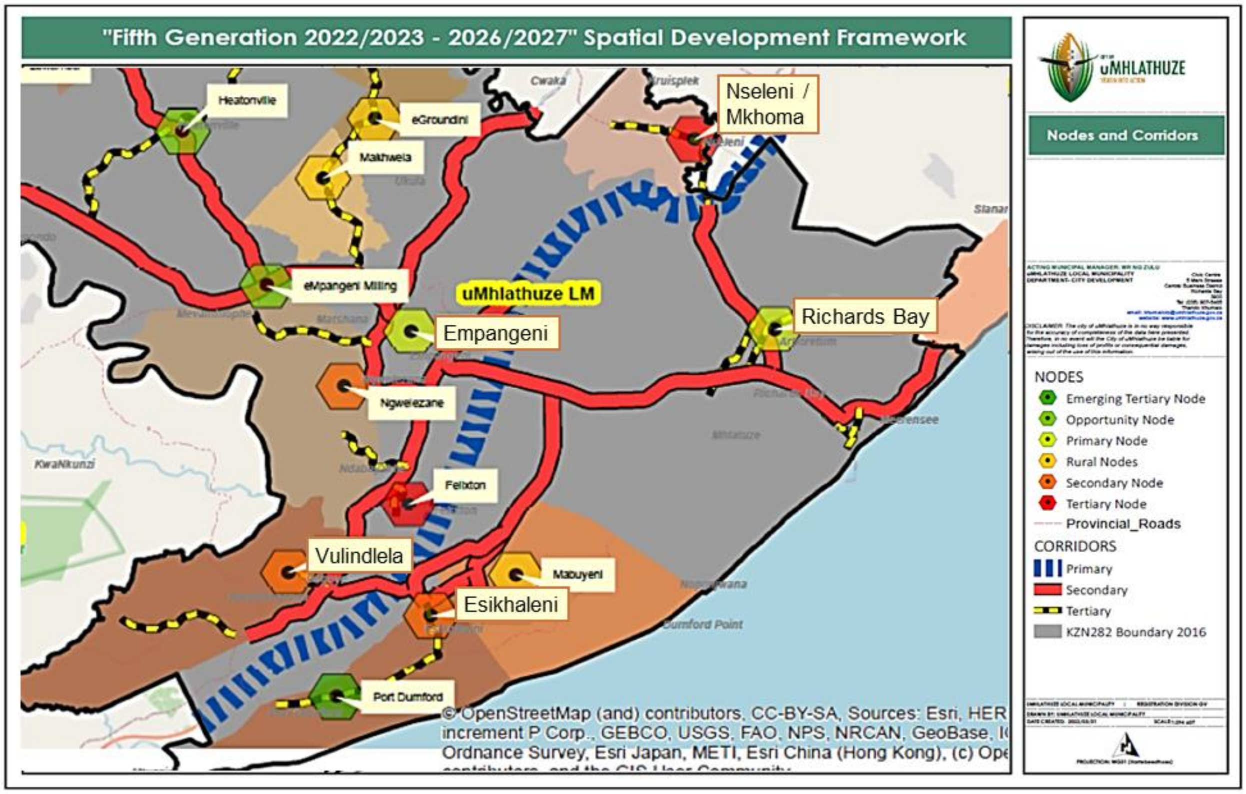


Figure 2: Development nodes and Corridors in uMhlathuze (adopted from: uMhlathuze 2022).

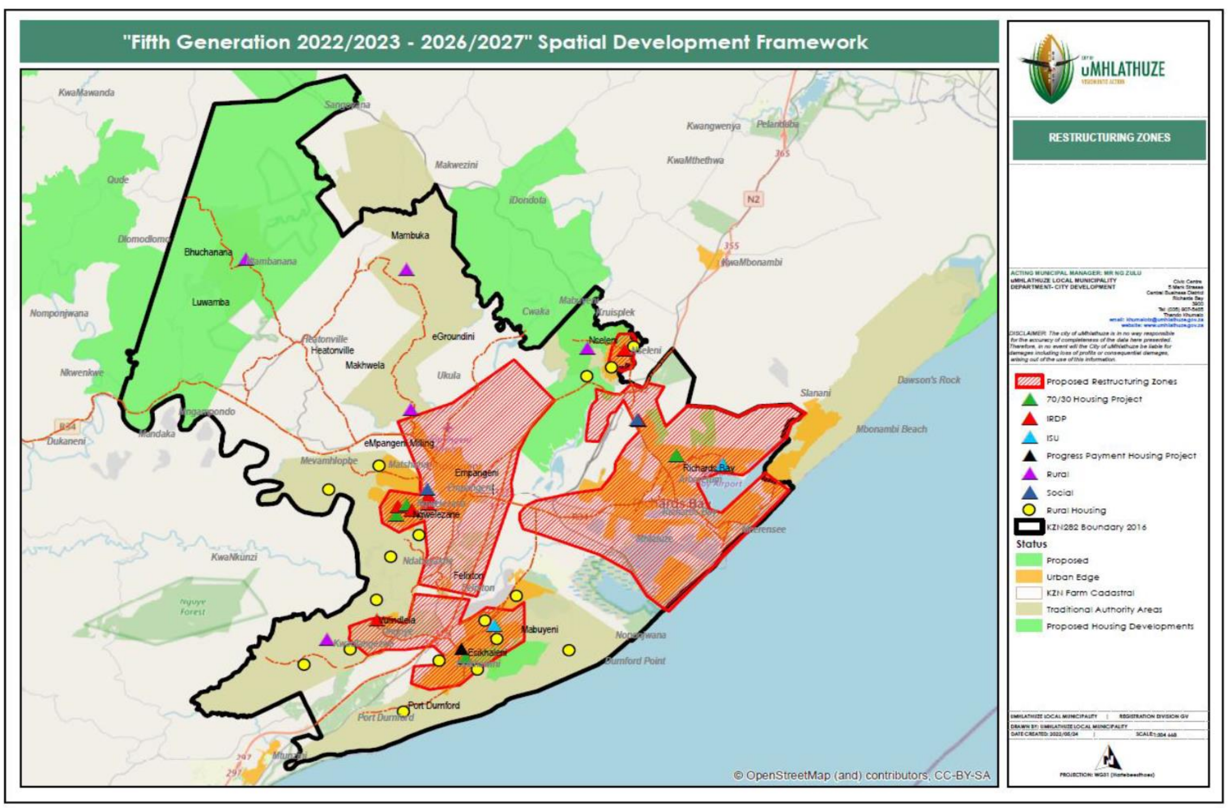


Figure 3: Geographical context and proposed restructuring zones in the uMhlathuze LM (Source: uMhlathuze, 2022).

Figure 4: Satellite image of the Richards Bay PHSHDA (zoom in for details). Source: GoogleEarth

The settlements of Mkhoma and Nseleni are located just north the N2 route. Mkhoma is a traditional settlement with a population of 5,360. 63.9% thereof are working age, 67.2% are living in formal dwellings. The population density is 1,719 people/km^2. The majority of the households (27.4%) do not have formal income[1].

Nseleni is a low to medium income formal settlement bordering Mkhoma in the north. The total population is 8,379, thereof 69.7 in working age. The population density is with 6,186 persons/km^2

---

[1] https://www.statssa.gov.za/?page_id=4286&id=7779

very high. Both settlements are inhabited by more than 99% of Black Africans, with isiZulu being the predominant language.

The city of Richards Bay has a total population of about 57,387, thereof 72% at working age. The population density is with 402 persons / km^2 relatively low. Black African is the main ethnic group (48%), followed by White (30.1%) and Indian/Asian with 18.2%. isiZulu, English and Afrikaans are the dominant languages. 24.1% of the population have received higher education, in contrast to Nseleni with 8.1% higher education and 1.6% in Mkhoma[1].

Land ownership within the Richards Bay PHSHDA is to about equal parts municipal (southeastern part), private (central part) and Ingonyama Trust owned (Nseleni/Mkhoma area). The agricultural quality of the land is largely secondary (uMhlanga, 2022).

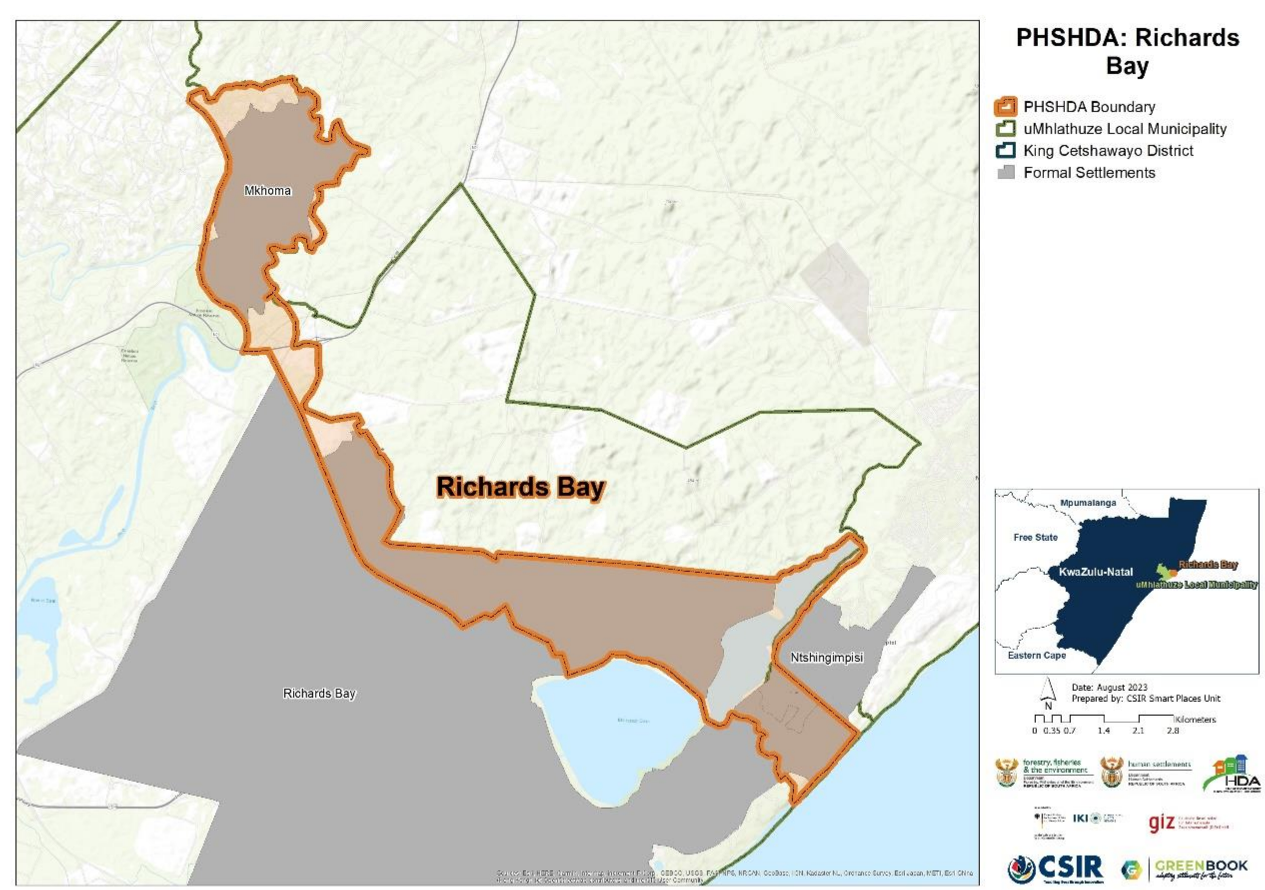


Figure 5: Location of the Richards Bay PHSHDA

2. Baseline and future climate risk

This section starts with an overview of vulnerability and population change projections, unpacking the components of vulnerability on both the municipal and settlement level as well future population pressures. Thereafter the current and future climate is discussed in terms of temperature and rainfall. Current as well as future exposure to drought, heat, wildfire, rainfall related flooding and coastal flooding and erosion are also set out. Together, this information provides an overview of current and future climate risk for the Richards Bay PHSHDA to inform responsive planning and adaptation.

2.1. Vulnerability and population change

There are many factors that influence the vulnerability of our municipalities and settlements, some of which are unpacked in the following section. The current vulnerabilities for the Richards Bay PHSHDA are profiled using a framework which sets out indicators that can be used to profile the multi-dimensional and context-specific inherent vulnerability of settlements and municipalities in South Africa. The framework describes and quantifies, where possible, the inherent vulnerability of people, infrastructure, services, economic activities, and natural resources by setting out context and location-specific indicators that were specifically designed to support vulnerability risk assessments of South African municipalities. Population changes drives vulnerability into the future, and therefore population growth and decline of settlements across the local municipality are projected to 2050. Spatial population projections are integral in determining the potential exposure and vulnerability of a population to hazards.

2.1.1. uMhlathuze municipal vulnerability

Municipal vulnerability is unpacked in terms of four vulnerability indices, each of which are described below, and in Table 1 the vulnerability scores are provided for the uMhlathuze LM.

The Socio-Economic Vulnerability Index (SEVI) shows the vulnerability of households living in the municipality with regards to household composition, income composition, education, mobility, health, access to basic services, access to social government services, political instability, and safety and security of households. A high vulnerability score indicates that the municipality houses a high number of vulnerable households with regards to their ability to withstand adverse shocks from the external environment.

The Economic Vulnerability Index (EcVI) speaks toward the economic resilience of the municipality, and considers economic sector diversification, the size of economy, labour force, the GDP growth/decline pressure experienced in the municipality, and the inequality present in the municipality. The higher the economic vulnerability the more susceptible the municipality is to being adversely affected by external shocks.

The Physical Vulnerability Index (PVI) relates to the built environment and the connectedness of the settlements in the local municipality. It is a composite indicator that considers road infrastructure, housing types, the maintenance of the infrastructure, densities, and general accessibility. A high physical vulnerability score highlights areas of remoteness and/or areas with structural vulnerabilities.

The Environmental Vulnerability Index (EnVI) highlights municipalities where there is a high conflict between preserving the natural environment and accommodating the growth pressures associated with population growth, urbanisation, and economic development. The index considers the human influence on the environment, the amount of ecological infrastructure present that needs protection, the presence of critical water resources, environmental health, and environmental governance. A high vulnerability score highlights municipalities that experience increasing pressure relating to protecting the environment and allowing land use change due to growth pressures.

uMhlathuze LM is provided with a score out of 10 for each of the vulnerability indices. A score higher than 5 indicates an above national average, and a score lower than 5 indicates a below national average for vulnerability. Scores are provided for both 1996 and 2011, where a lower score in 2011 compared to 1996 indicates an improvement and a higher score indicates worsening vulnerability. Trend data is only available for Socio-Economic Vulnerability and Economic Vulnerability.

Table 1: Vulnerability indicators across uMhlathuze Local Municipality

MUNICIPALITY	SEVI 1996	SEVI 2011	Trend	EcVI 1996	EcVI 2011	Trend	PVI	Trend	EnVI	Trend
uMhlathuze	4.7	3.9	↘	5.0	5.6	↗	6.2	N/A	4.4	N/A

In terms of socio-economic vulnerability, uMhlathuze ranked 76th out of 213 LMs nationally, and 4th out of 44 LMs on a provincial level in 2011. This means that uMhlathuze is among the least socio-economically vulnerable LMs in KwaZulu-Natal, and among the least vulnerable 30% of LMs nationally. As outlined in Table 1, uMhlathuze's socio-economic vulnerability has decreased, i.e. improved between 1996 and 2011, thus indicating that the number of vulnerable households has decreased, particularly in terms of their lack of access to basic and social services, and essential resources that influence their ability to withstand adverse shocks from the external environment, including those induced by climate change.

However, the LM's economic vulnerability has slightly increased (worsened) within the same period, therefore indicating the municipality's susceptibility to being adversely affected by external shocks. The LM's economic vulnerability ranks 110th out of 213 LM nationally and 34th out of 44 LMs in KwaZulu-Natal. This means, its economic vulnerability is comparatively high. uMhlathuze has a relatively high physical vulnerability score; this alludes to some structural vulnerabilities in the LM, particularly when considering the municipality's buildings and infrastructure. In 2011, the LM's physical vulnerability ranks 132nd out of 213 LMs in South Africa and 28th out of 44 LMs in the province. uMhlathuze's environmental vulnerability ranks 131st out of 213 nationally and 17th out of 44 in KwaZulu-Natal.

2.1.2. Settlement vulnerability

The unique set of indicators outlined below highlight the multi-dimensional vulnerabilities of the settlement in which the PHSHDA is to be found within the uMhlathuze LM with regards to six composite indicators. This enables the investigation of the relative vulnerabilities of the settlement (PHSHDA) within the LM compared to other settlements.

A high vulnerability score (closer to 10) indicates a scenario where an undesirable state is present e.g., low access to services, high socio-economic vulnerabilities, poor regional connectivity, environmental pressure or high economic pressures. An indicator of growth pressure, providing a temporal dimension (15-year trend), was added to show which settlements are experiencing growth pressures on top of the other dimensional vulnerabilities.

The Socio-economic Vulnerability Index comprises of three indicators (and eight variables) that show the vulnerability of households occupying a specific settlement with regards to their (1) household composition (household size, age dependency, female/child headed household), (2) income composition (poverty level, unemployment status, and grant dependency of the households), as well as (3) their education (literacy and level of education).

The Economic Vulnerability Index comprises of five variables grouped into three indicators that highlight the economic vulnerability of each settlement with regards to (1) its size (GDP per capita and GDP production rates), (2) the active labour force (taking note of unemployed and discouraged work seekers), and (3) the GDP growth rate for the past 15 years.

The Environmental Vulnerability Index considers the footprint composition of the settlement taking the ration of built-up versus open spaces into account.

The Growth-Pressure Vulnerability Index shows the relative (1996-2011 growth rates) and anticipated pressure on settlements.

The Regional Economic Connectivity Vulnerability Index looks at the regional infrastructure of each settlement (measured through a remoteness/accessibility index), as well as the role of the town in terms of its regional economy.

The Service Access Vulnerability Index comprises of 10 variables grouped into four indictors, that show the level of services offered and rendered within a settlement and includes the settlement's (1) access to basic services (electricity, water, sanitation, and refuse removal), (2) settlement's access to social and government services (health access, emergency service access, access to schools, and early childhood development), (3) access to higher order education facilities, and (4) access to adequate housing.

For the Richards Bay PHSHDA, settlement vulnerability data are available for Mkhoma and Richards Bay. Figure 6 displays the distribution of vulnerability across the six indices for Mkhoma and Richards Bay. The average settlement vulnerability for Richards Bay across the six indices mentioned above, is 2.2 which is the lowest of all settlements in the uMhlathuze LM. This is in stark contrast to Mkhoma's overall settlement vulnerability which is with 7.0 the second highest of all settlements in uMhlathuze. Here, service access and economic vulnerability scoring the highest possible vulnerability of 10, socio-economic and environmental vulnerability are with 7.89 and 7.42 respectively of high concern as well. Growth pressure is with 4.89 moderate and regional connectivity is of least concern, given the proximity to the N2 highway.

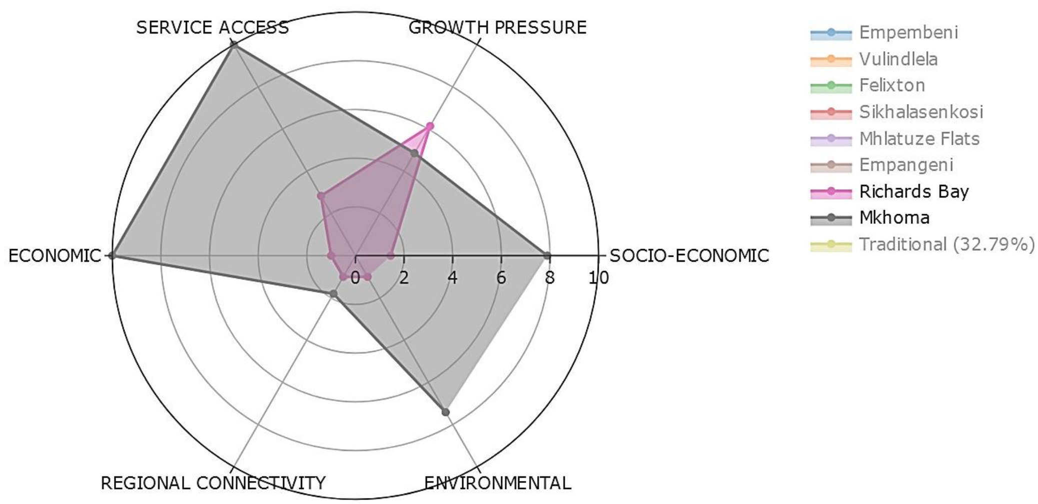


Figure 6: Settlement vulnerability for Mkhoma and Richards Bay

While no explicit settlement vulnerability data exist for Nseleni, it can be assumed that its vulnerability lies between that of Mkhoma and Richards Bay. The stark contrast of settlement vulnerability between Mkhoma and Richards Bay implies that Richards Bay will adopt much easier to climate change challenges than the population of Mkhoma which will be significantly limited in resources to adapt technologically or to resettle into areas under less climate pressure.

2.1.3.Future population growth pressure

The core modelling components of the settlement growth model are the demographic model and the population potential gravity model. The demographic model produces the long-term projected population values at the national, provincial and municipal scale using the Spectrum and Cohort-Component models. The spatially-coarse demographic projections were fed into the population potential gravity model, a gravity model that uses a population potential surface to downscale the national population projections, resulting in 1x1 km resolution projected population grids for 2030 and 2050. The availability of a gridded population dataset for past, current, and future populations enables the assessment of expected changes in the spatial concentration, distribution, and movement of people.

Using the innovative settlement footprint data layer created by the CSIR, which delineates built-up areas, settlement-scale population projections were aggregated up from the 1 x 1 km grids of South African projected population for a 2030 and 2050 medium and high growth scenario. These two population growth scenarios (medium and high) are differentiated based on their in- and out-migration assumptions. The medium growth scenario assumes that the peak of population influx from more distant and neighbouring African countries into South Africa has already taken place. The high growth scenario assumes that the peak of migrant influx is yet to happen.

Table 2: Population growth pressure across uMhlathuze Local Municipality

Growth scenario	2011	2030	2050
Medium Growth Scenario	363 327	541 697	727 333
High Growth scenario	363 327	554 280	763 172

Table 2 indicates that under either, medium and high growth scenario, the population in the LM is likely to double between 2011 and 2050. The similarity between these scenarios indicates that the current influx of people is going to continue for the next decades. This extreme growth puts all settlements in the municipality under an extreme growth pressure (Figure 7), apart from Mkhoma which is expected to experience “only” a high growth pressure and the rural area of uMhlathuze Flats which is projected to stay stable in its population (Table 3). Table 3 provides an overview of the expected population growth pressure and expected population development per settlement.

Table 3: Settlement-level population growth pressure across uMhlathuze Local Municipality

uMhlathuze Local Municipality				
Town	Pressure	2011	2030	2050
Empembeni	Extreme	1,764	2,657	3,567
Vulindlela	Extreme	12,778	19,387	26,265
Felixton	Extreme	1,140	2,018	2,930
Sikhalasenkosi	Extreme	101,485	152,693	205,979
Mhlathuze Flats	No Change	62	62	62
Empangeni	Extreme	59,466	92,400	126,621
Richards Bay	Extreme	56,112	85,882	116,757
Mkhoma	High	31,319	41,827	52,564

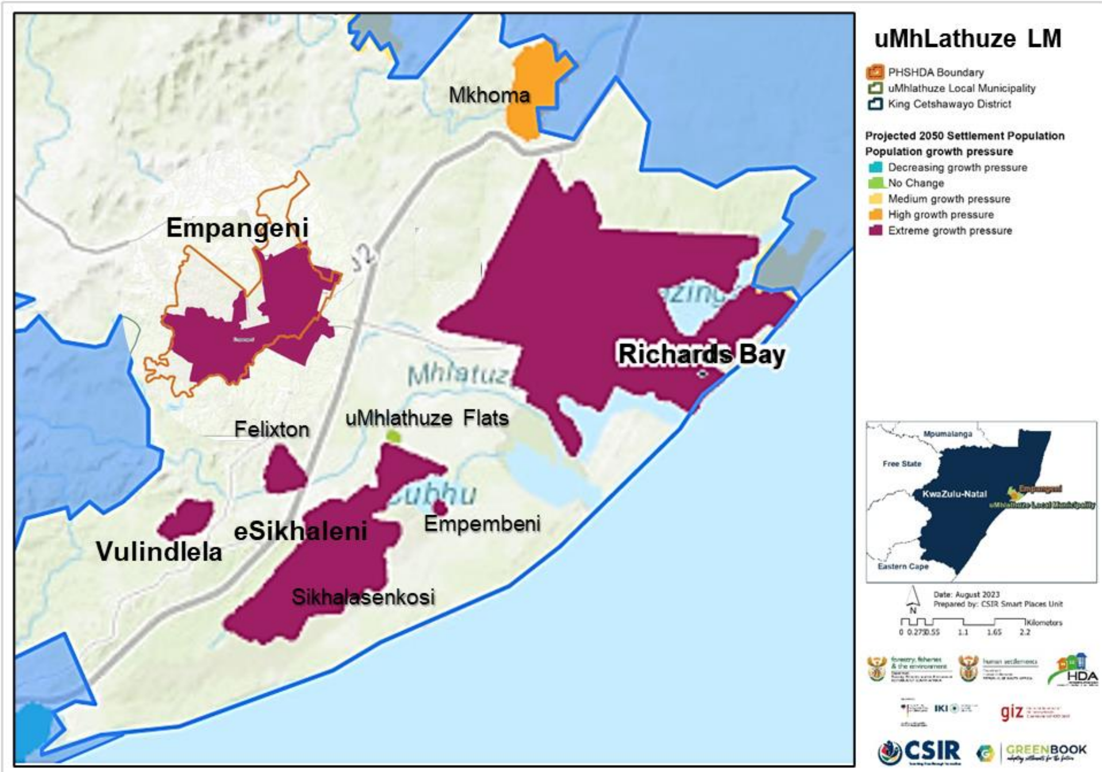


Figure 7: Settlement-level population growth pressure across uMhlathuze

2.2. Climate

An ensemble of very high-resolution climate model simulations of present-day climate and projections of future climate change over South Africa has been performed as part of the GreenBook. The regional climate model used is the Conformal-Cubic Atmospheric Model (CCAM), a variable-resolution Global Climate Model (GCM) developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO). CCAM runs coupled to a dynamic land-surface model CABLE (CSIRO Atmosphere Biosphere Land Exchange model). GCM simulations of the Coupled Model Inter-Comparison Project 5 (CMIP5) and the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC), obtained for the emission scenarios described by Representative Concentration Pathways 4.5 and 8.5 (RCP 4.5 and RCP 8.5) were first downscaled to 50 km resolution globally. The simulations span the period 1960–2100. RCP 4.5 is a high mitigation scenario (assuming a reduction in CO_2 emissions into the future), whilst RCP 8.5 is a low mitigation scenario (assuming "business as usual" emissions).

After completion of the 50 km resolution simulations described above, CCAM was integrated in stretched-grid mode over South Africa, at a resolution of 8 x 8 km (approximately 0.08° degrees in latitude and longitude). The model integrations performed at a resolution of 8 km over South Africa offer several advantages over the 50 km resolution simulations:

a) Convective rainfall is partially resolved in the 8 km simulations, implying that the model is less dependent on statistics to simulate this intricate aspect of the atmospheric dynamics and physics.

b) Important topographic features such the southern and eastern escarpments are much better resolved in the 8 km resolution simulations, implying that the topographic forcing of temperatures, wind patterns and convective rainfall can be simulated more realistically.

For more information on the climate simulations, see the GreenBook Climate Change Story Map and the full technical report.

For each of the climate variables discussed below:

a) The simulated baseline (also termed "current" climatological) state over South Africa calculated for the period 1961–1990 is shown (note that the median of the six downscaled GCMs are shown in this case).
b) The projected changes in the variable are subsequently shown, for the time-slab 2021–2050 relative to the baseline period 1961-1990.
c) An RCP 8.5 scenario (low mitigation: worst case scenario) is shown.

2.2.1. Temperature

The model was used to simulate annual average temperatures (°C) for the baseline (current) period of 1961–1990, and the projected change for period 2021–2050 under a RCP8.5 mitigation scenario. According to Figure 8, the average annual temperature in the Richards Bay area currently lies at 22°C. Figure 9 indicates that the annual temperature will increase between 1.5°C and 2°C between 2021 and 2050.

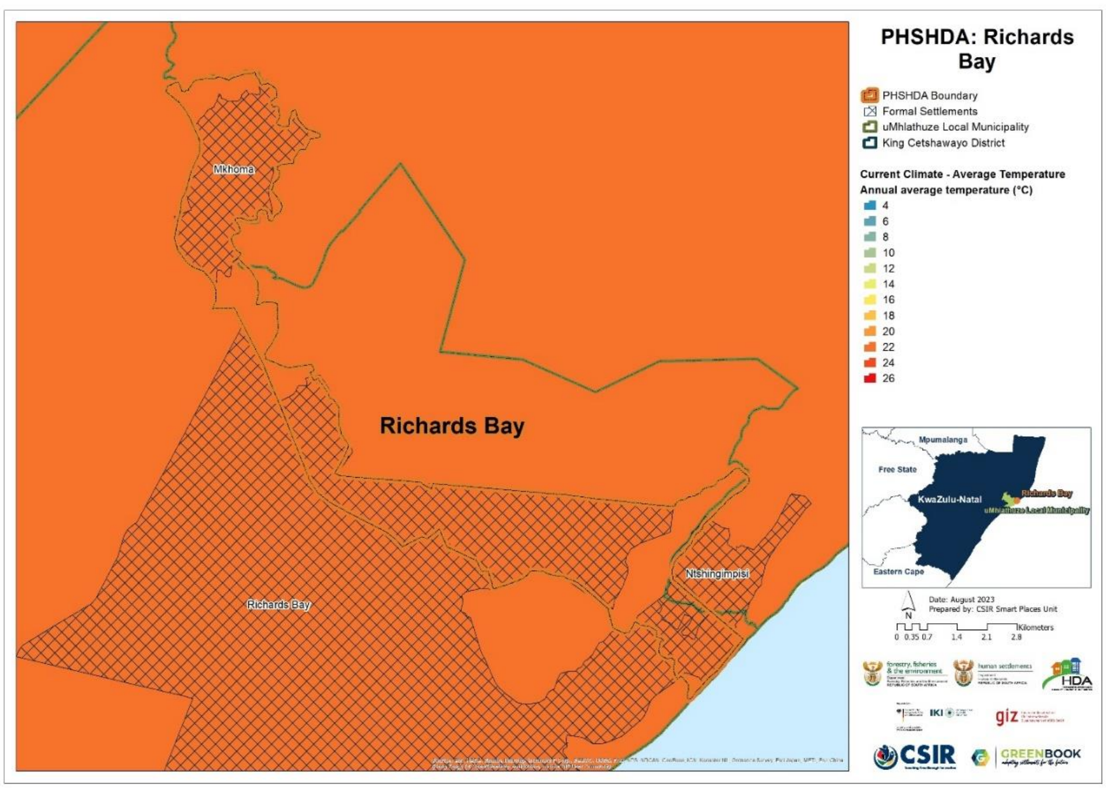


Figure 8: Average annual temperature (°C) for the baseline period 1961 – 1990 for Richards Bay

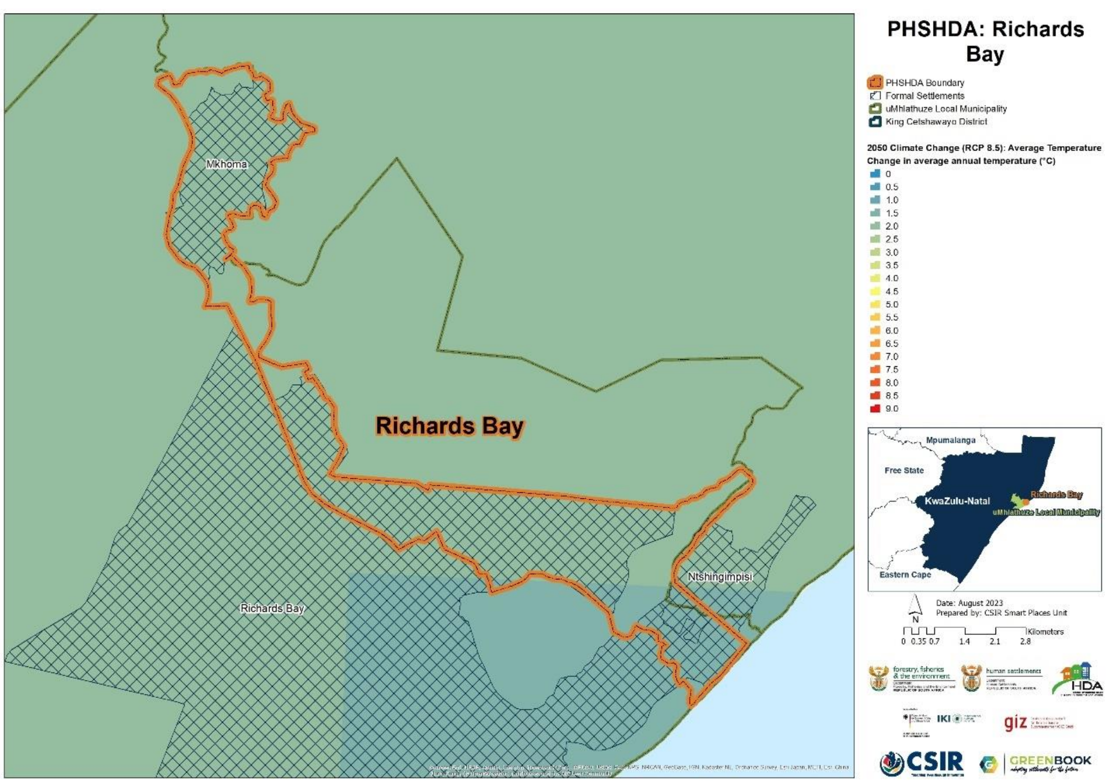


Figure 9: Projected change in average annual temperature (°C) from the baseline period to the period 2021 – 2050 for Rochards Bay, assuming an (RCP 8.5) emissions pathway

This range of average temperature increase is representative of the expected degree of warming for most of uMhlathuze, with the exception of the coastal belt where an increase of 1.5°C is expected between 2021 and 2050, due to the cooling effect of the ocean.

2.2.2. Rainfall

The multiple GCMs were used to simulate average annual rainfall (depicted in mm) for the baseline (current) period of 1961–1990, and the projected change from the baseline to the period 2021–2050 under an RCP8.5 emissions scenario. Model projections of precipitation manifest uncertain due to several factors, including model sensitivity to spatial resolution at which processes are resolved. At 8x8 km horizontal resolution, for example, some processes (such as convective systems) that contribute to rainfall are not adequately resolved by the climate models. The precipitation projections therefore could reflect uncertainty in some locations since fine-scale processes that contribute to precipitation and its extremes are not captured. When the modelling ensemble approach used in the online GreenBook is considered, and the 10^{th}, 50^{th} and 90^{th} percentiles, per grid point, agree on the directional change relative to the reference period, the signal is considered well developed and conclusive. In the case where the respective model percentiles show conflicting signs, the model ensemble manifest uncertainty and therefore reflect low confidence on which future model realisation/outcome is more likely. It is therefore critical to consider the ensemble distribution uncertainty when devising long-term adaptation strategies.

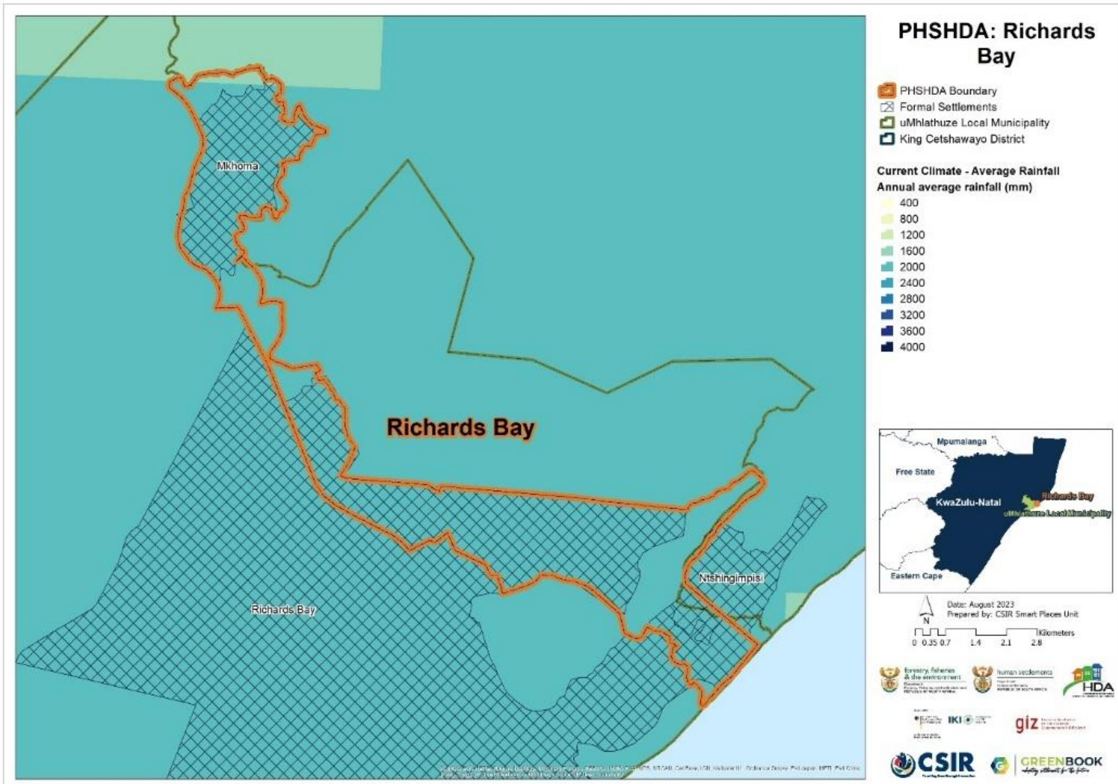


Figure 10: Average annual rainfall (mm) for the baseline period 1961 – 1990 for Richards Bay

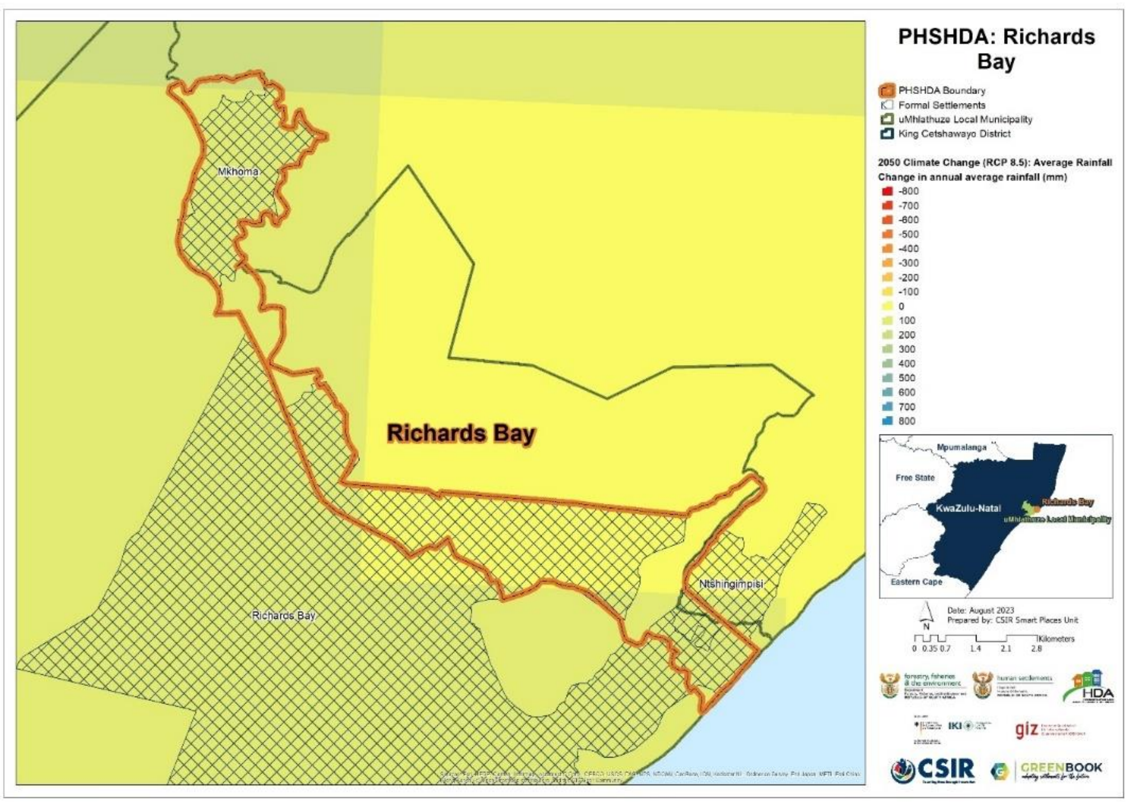


Figure 11: Projected change in average annual rainfall (mm) from the baseline period to the period 2021 – 2050 for Richards Bay, assuming an (RCP 8.5) emissions pathway

According to these, spatially relatively coarse models, between 1961 and 1990, Richards Bay was receiving up to 1600 mm of rain annually (Figure 10). A slight increase in annual rainfall of about 74 mm is expected for parts of Richards Bay in the future using the RCP8.5 scenario (Figure 11). However, the RCP4.5 scenario predicts a decrease in rainfall for the wider uMhlathuze area of about 70 mm per year. These contradicting trends allude to some degree of uncertainty in the rainfall future of the area.

2.3. Climate Hazards

This section showcases information with regards to the uMhlathuze Local Municipality's exposure to climate-related hazards.

2.3.1. Drought

The southern African region (particularly many parts of South Africa) is projected to become generally drier under enhanced anthropogenic forcing, with an associated increase in dry spells and droughts. However, downscaled models for the region also predict an increase in average and extreme rainfall which can lead to extended wet spells. To characterise the extent, severity, duration, and time evolution of drought and wet spells over South Africa, the GreenBook uses primarily the Standardised Precipitation Index (SPI), which is recommended by the World Meteorological Organisation (WMO) and is also acknowledged as a universal meteorological drought index by the Lincoln Declaration on Drought. The SPI, with a two-parameter gamma distribution fit with maximum likelihood estimates of the shape and scale parameters, was applied on monthly rainfall accumulations for a 3-, 6-, 12-, 24- and 36-months base period. The SPI severity index is interpreted in the context of negative values indicating droughts and positive values indicating wet spells, potentially leading to floods. These values range from exceptionally drier (<-2.0) or wetter (>2.0) to near-normal (region bounded within -0.5 and 0.5).

When compared to the 1986-2005 baseline period, the period 1995-2004, the coastal zone of uMhlathuze has been experiencing a slight decrease in drought tendencies (SPI index between 0.0 – 0.4) under an RCP 8.5 “business as usual” emissions scenario. However, under the low mitigation “business as usual” emissions scenario (RCP 8.5), an increase in drought tendencies per 10 years (more frequent than baseline) is expected for the period 2015–2044, relative to the 1986–2005 baseline period. Figure 12 below depicts that uMhlathuze settlements, including Richards Bay and the wider Mkhoma area, are at moderate risk of increases in drought tendencies into the future.

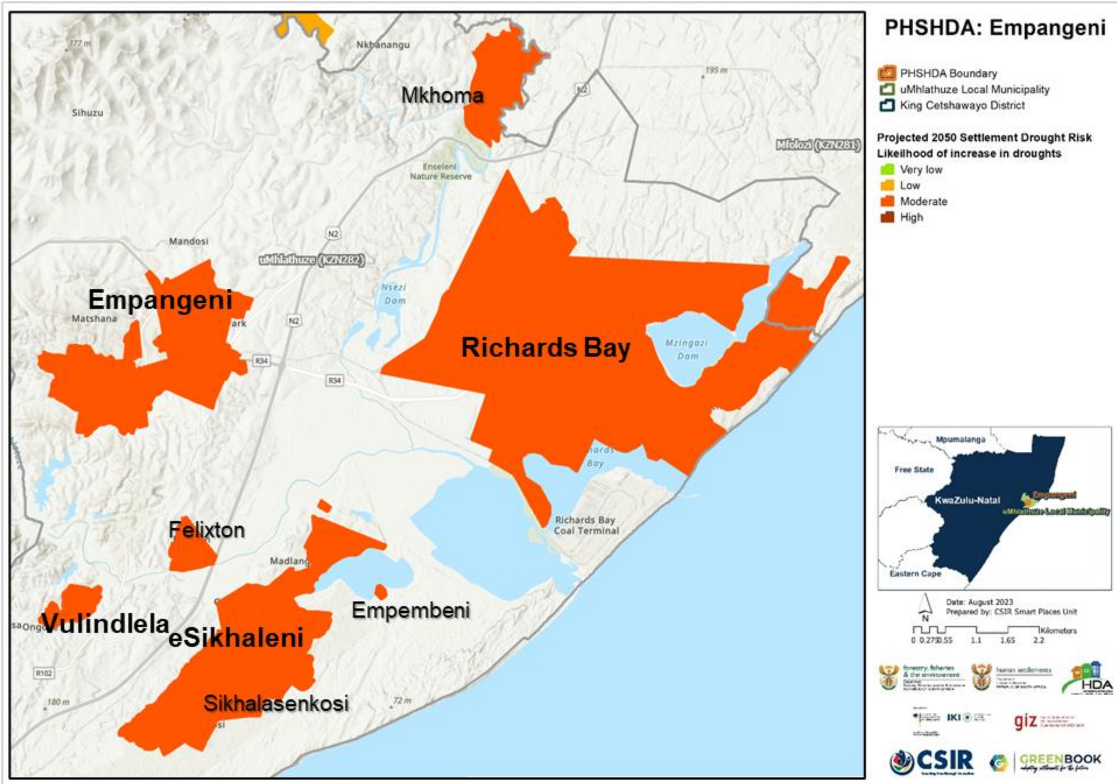


Figure 12: Settlement-level drought risk for uMhlathuze settlements

2.3.2. Heat

The GCMs were used to simulate bias-corrected, annual average number of very hot days, defined as days when the maximum temperature exceeds 35°C per GCM grid point for the baseline (current) period of 1961–1990 (Figure 13), and for the projected change for period 2021–2050 (Figure 14), assuming a "business as usual" (RCP 8.5) emissions pathway. According to these data, Richards Bay currently experiences between zero and 12 very hot days per year, with a tendency of more very hot days towards Mkhoma. In 2050, the likely range of very hot day increases to 11 to 20 days per year for the area.

The annual heatwave days map under baseline conditions (Figure 15) depicts the number of days (per 8x8 km grid point) where the maximum temperature exceeds the average maximum temperature of the warmest month of the year at that location by at least 5°C, for a period of at least three consecutive days. Under current climate conditions, Richards Bay is experiencing between zero and 2 heatwave days per year. The projected change for the period 2021–2050 (Figure 16), assuming a "business as usual" (RCP 8.5) emissions pathway is also shown. According to this projection, this area will experience up to 4 more days belonging to a heatwave in 2050. In the national comparison, this is a very slight increase in heatwave days.

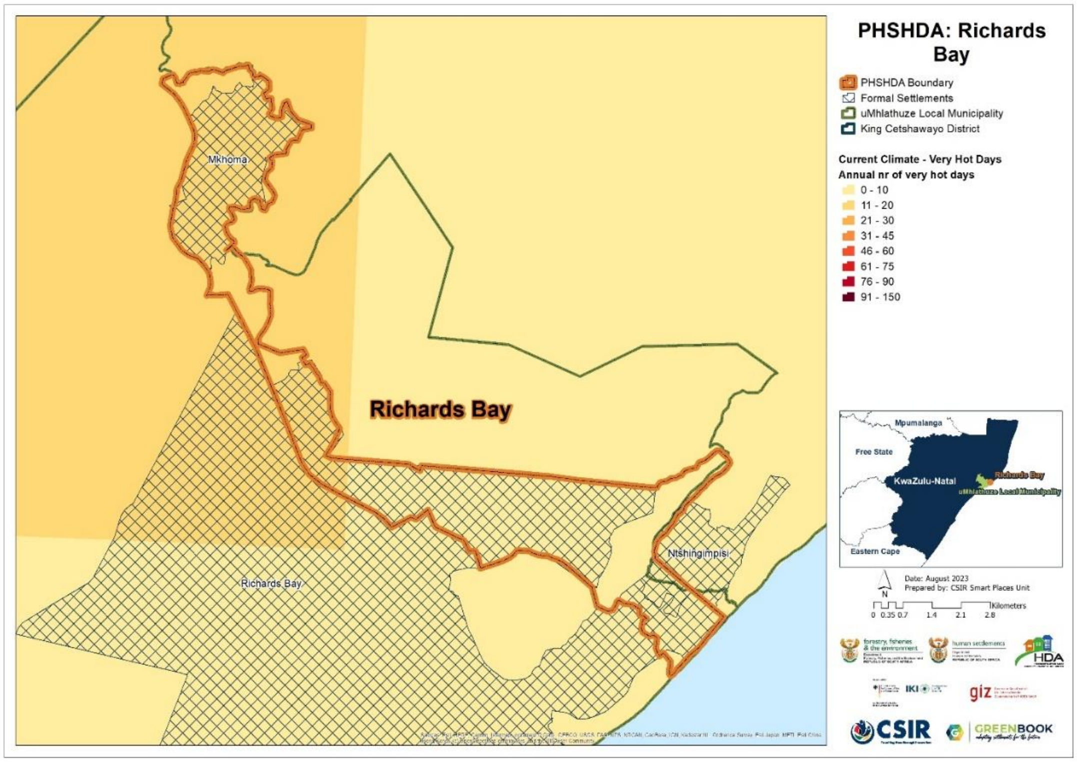


Figure 13: Annual number of very hot days under baseline climatic conditions in Richards Bay with daily temperature maxima exceeding 35°C

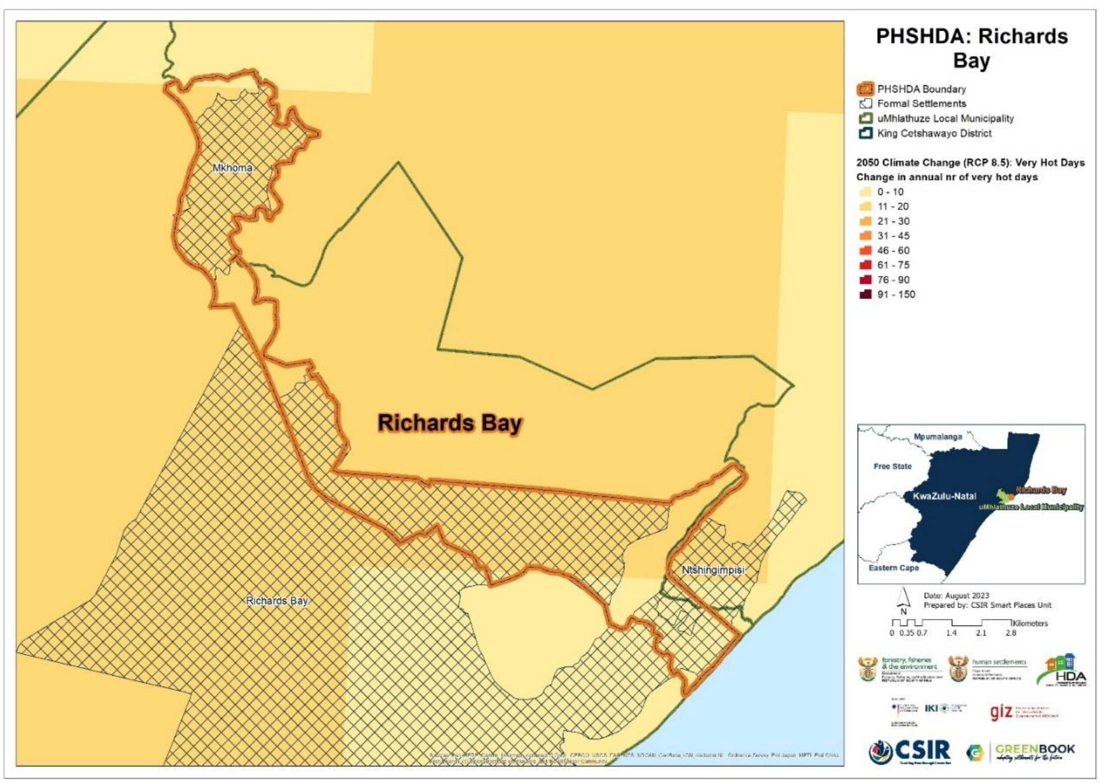


Figure 14: Projected change in annual number of very hot days in Richards Bay with daily temperature maxima exceeding 35°C, assuming an (RCP 8.5) emissions pathway

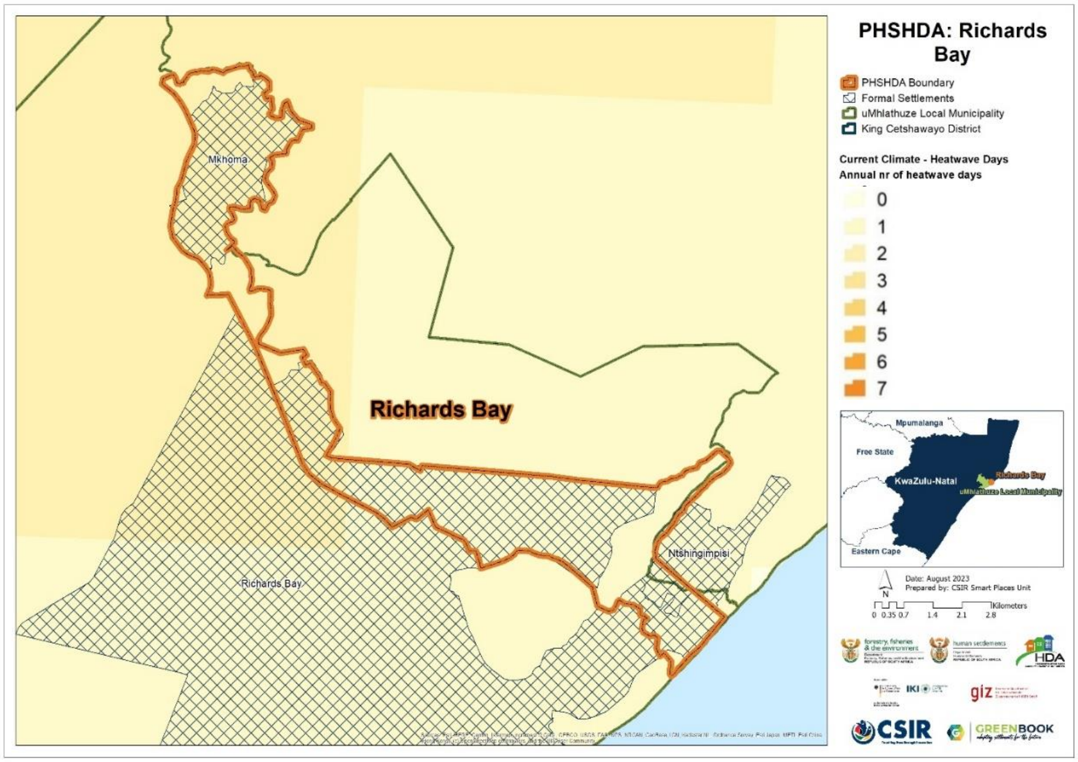


Figure 15: Annual number of heatwave days under baseline climatic conditions in Richards Bay

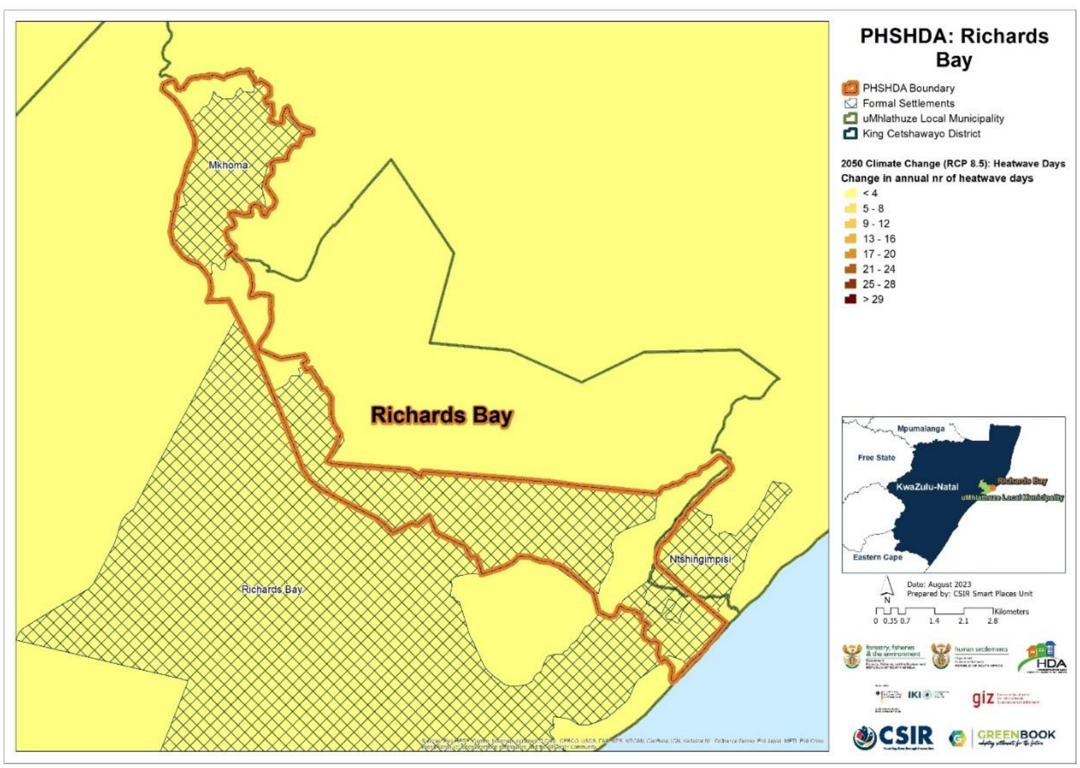


Figure 16: Projected change in annual number of heat wave days in Richards Bay, assuming an (RCP 8.5) emissions pathway

Consequently, the likelihood of increase of extreme heat in Richards Bay and Mkhoma is very low (Figure 17), probably due to the cooling influence of the ocean.

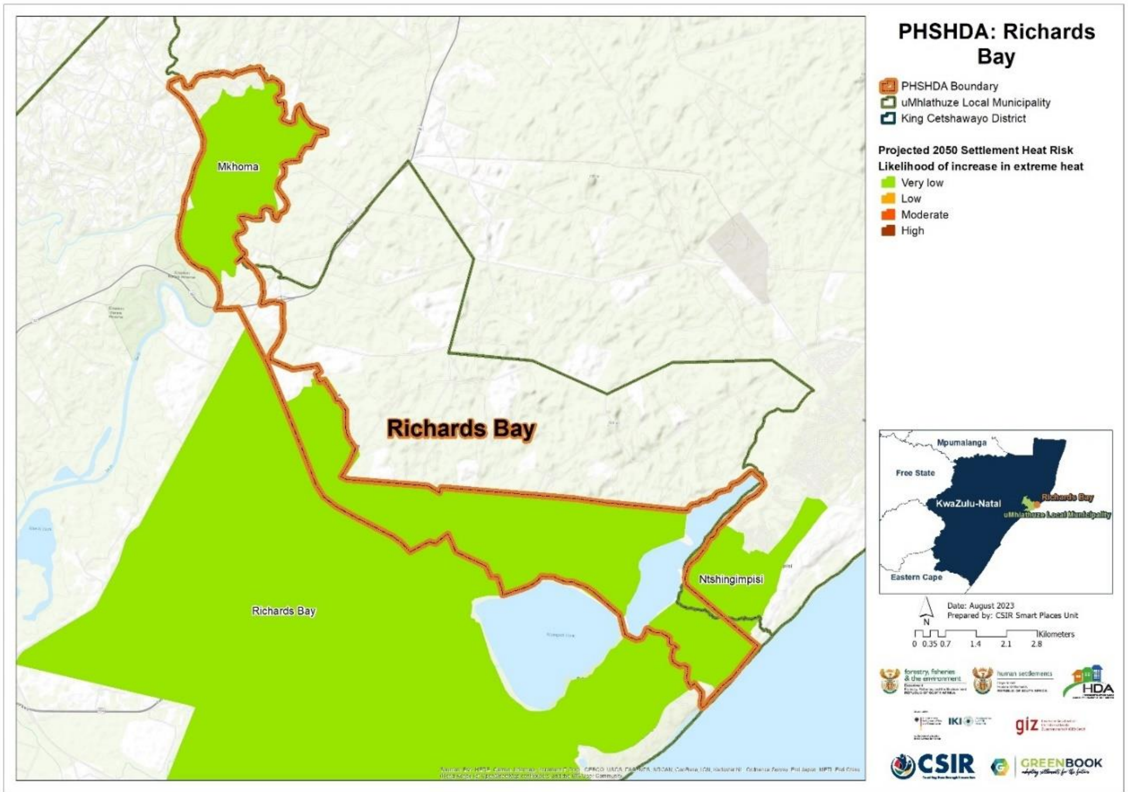


Figure 17: Heat stress risk across Richards Bay at settlement level in the 2050s

2.3.3. Wildfire

Wildfires occur regularly in South Africa and often cause significant damage. Fires are a threat to human lives, livelihoods, and infrastructure. Increasing numbers of people, assets and infrastructure are placed on the boundary or interface between developed land and fire-prone vegetation – what we call the wildland-urban interface (WUI) – where they are exposed to wildfires. The combination of vegetation characteristics and agricultural practices that use fires, and growing human exposure, results in significant wildfire risk across the country, especially in the southern and eastern parts.

Many settlements in South Africa are exposed to high fire risks, especially economic risks, and experience considerable losses every year. The risks are increased by the fact that many fires are the result of human actions, whether deliberate or inadvertent. For these areas of high risk, it is not a question of if there will be a fire, but when there will be a fire.

Fire risk is determined by combining the typical fire hazard for a fire-ecotype (i.e., likelihood, fire severity) and the social and economic consequences (i.e., the potential for economic and social losses). The typical fire hazard was used to develop a plausible fire scenario for each fire-ecotype, i.e., what a typical wildfire would be like. The fire scenarios were then combined with the vulnerability to estimate the economic and social consequences. We used a scale where the likelihood was rated from 'rare' to 'almost certain' and the consequences were rated from 'insignificant' to 'catastrophic' to determine a level of fire risk which ranged from 'low' to 'high'. The risks were then summarised for all the settlements within a local authority. Changes in the fire risk in future were accommodated by adjusting either the fire scenarios or the likelihood, or both. Figure 18 shows that currently the risk of wildfires occurring in the wildland-urban interface (the boundary or interface between developed land and fire-prone vegetation) for the inland area of Richards Bay is "likely", due to the expected high fuel load on the urban boundary. However, for the coastal belt of Richards Bay, being dominated by swamp forests and wetlands, currently the occurrence of wildfires is rare.

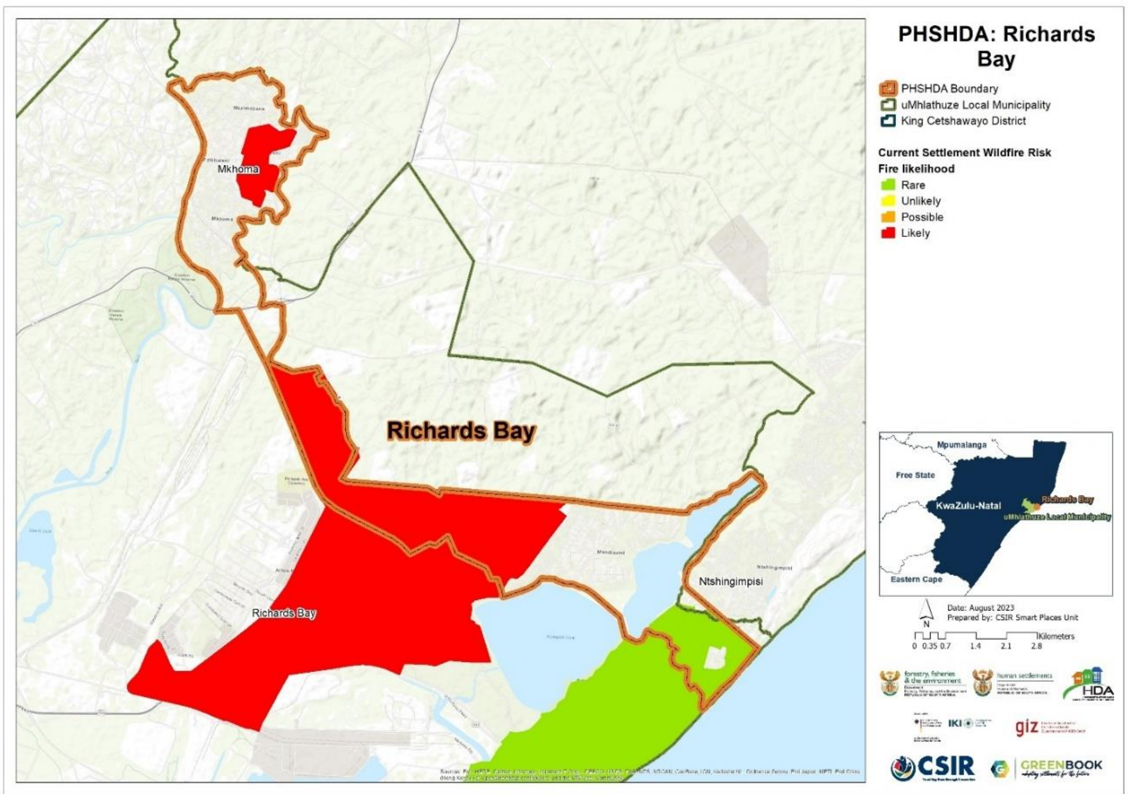


Figure 18: The likelihood of wildfires under current climatic conditions across settlements in the Richard Bay PHSHDA Corridor

The projected number of fire danger days for an 8 x 8 km grid-point under an RCP 8.5 "business as usual" emissions scenario was calculated. A fire danger day is described as a day when the McArthur fire-danger index exceeds a value of 24. The index relates to the chances of a fire starting, its rate of spread, its intensity, and its difficulty of suppression, according to various combinations of air temperature, relative humidity, wind speed and both the long and short-term drought effects. Future settlement risk of wildfires is informed by the projected change in the number of fire danger days. Figure 19 shows that there is a "very low" likelihood of increases in wildfires in Richards Bay by the year 2050 and a "moderate" increase in the Mkhoma area. Altogether, the actual number of high fire danger days in the municipality is, with less than 10 days annually, currently and in the future, very low in the national comparison.

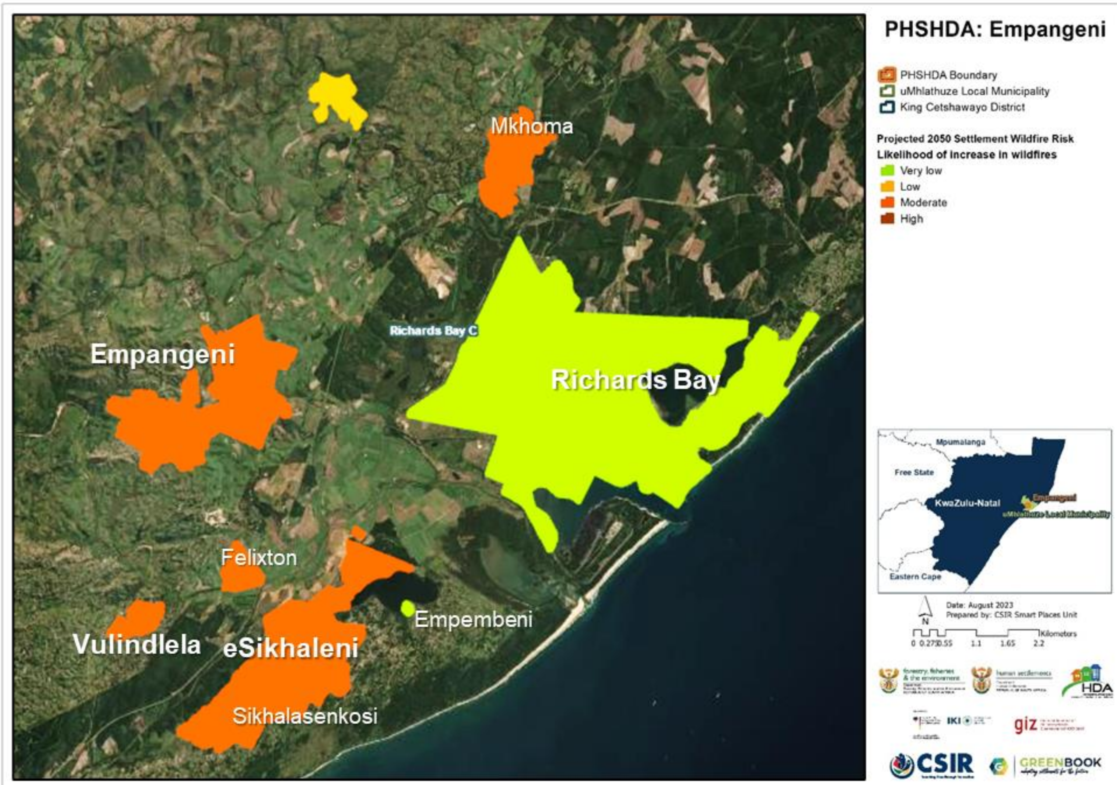


Figure 19: The likelihood of wildfires under projected climatic conditions across settlements in uMhlathuze

2.3.4. Flooding

The flood hazard assessment combines information on the climate, observed floods, and the characteristics of water catchments that make them more or less likely to produce a flood. The climate statistics were sourced from the South African Atlas of Climatology and Agrohydrology, and a study of river flows during floods in South Africa (Schulze et al. 2008). The catchment characteristics that are important are those that regulate the volume and rate of the water flowing down and out of the catchment. The SCIMAP model was used to analyse the hydrological responsiveness and connectivity of the catchments and to calculate a Flood Hazard Index. Changes in land cover, such as urbanisation, vegetation and land degradation, or poorly managed cultivation, reduce the catchment's capacity to store or retain water. More dynamic changes in land cover could not be considered in this analysis, such as for example, recent informal settlements that may increase exposure and risk. Additional local and contextual information should be considered to further enrich the information provided here.

Since the magnitude and intensity of rainfall are the main drivers of floods and rainfall intensity is likely to increase into the future, estimates of extreme daily rainfall into the future were obtained from high-resolution regional projections of future climate change over South Africa. The settlements that are at risk of an increase in floods were calculated using a risk matrix, that considered the flood hazard index and the change in extreme rainfall days from the baseline period of 1961-1990, to the 2050s.

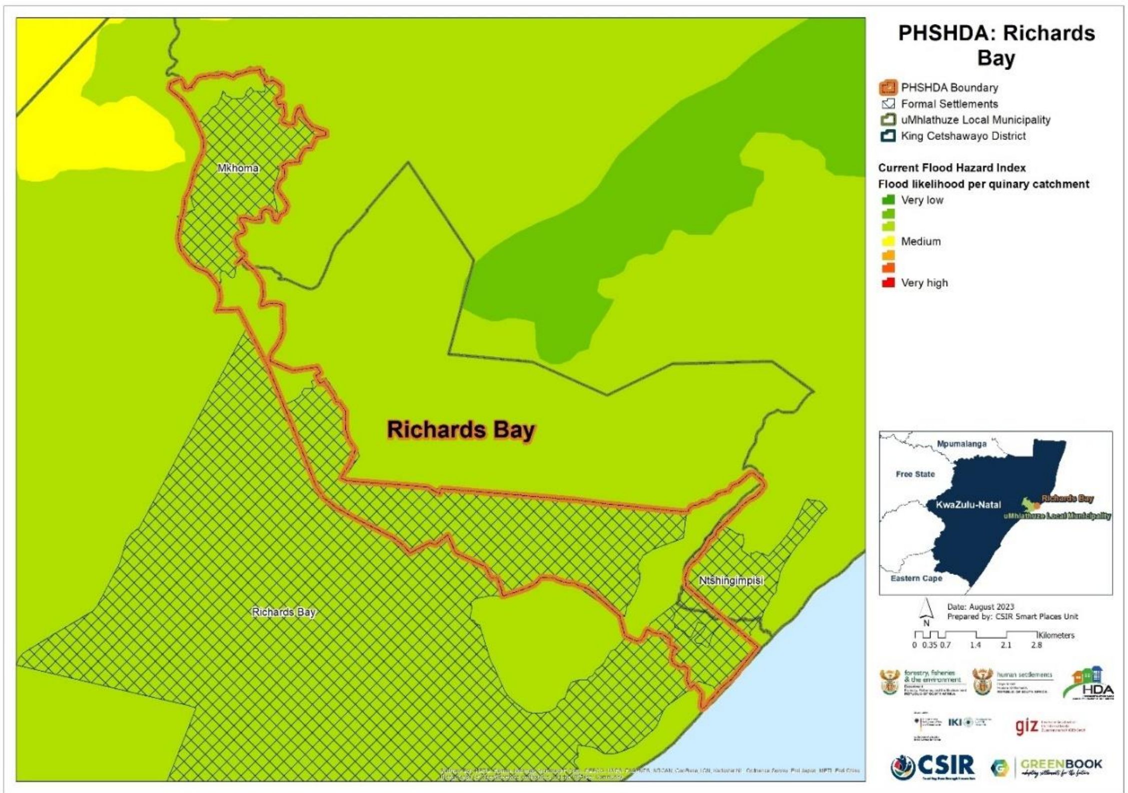


Figure 20: The flood hazard index for Richards Bay under current (baseline) climatic conditions

Figure 20 depicts the flood hazard index of the individual quinary catchments present or intersecting with the local municipality. The flood hazard index is based on the catchment characteristics and design rainfall, averaged at the quinary catchment level. Green indicates a low flooding hazard, while red indicates a high flood hazard. The map shows that Richards Bay and Mkhoma are currently facing a low to very low flood hazard.

Figure 21 depicts the projected change for the year 2050 in extreme rainfall days for an 8 x 8 km grid. This was calculated by assessing the degree of change when future rainfall extremes (e.g., 95^{th} percentile of daily rainfall) are compared with those under the current rainfall. A value of more than one indicates an increase in extreme daily rainfalls. The map shows that statistically, the area of the Richards Bay PHSHDA will be facing a very slight increase of 0-2 days of extreme rainfall by 2050.

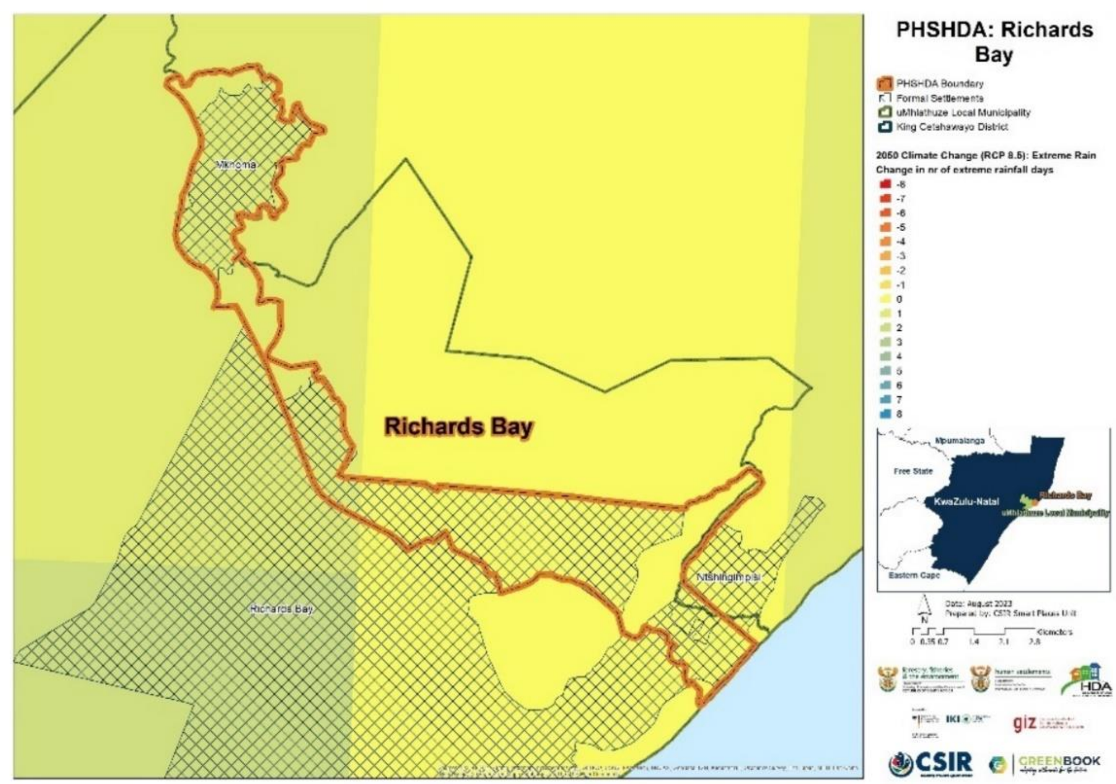


Figure 21: Projected change into the future in extreme rainfall days in Richards Bay

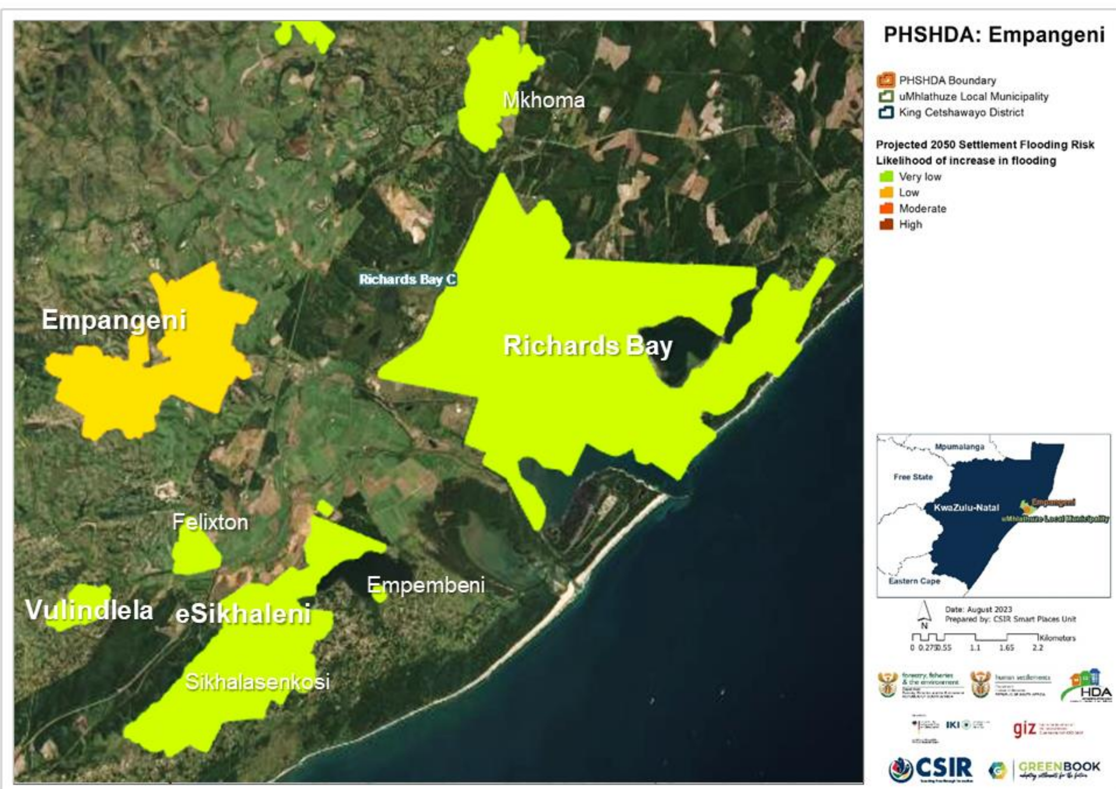


Figure 22: Flood risk into a climate change future at settlement level across uMhlathuze

Figure 22 depicts the projected risk trends for urban flooding in the major uMhlathuze settlements under an RCP 8.5 low mitigation (worst case of greenhouse gas emissions) scenario. The map shows that for most settlements in uMhlathuze, including Richards Bay and Mkhoma, there is a "very low" risk of increase in urban flooding, and only for Empangeni a "low" risk.

2.3.5. Coastal flooding and erosion

Section 2.2 illuminated that the major changes in climate expected for the Richards Bay area is an increase in average temperature, while the rainfall regime stays more or less the same. However, according to IPCC-6 (2021), the warming oceans are likely to lead to more severe and more frequent coastal storms and cyclones. Therefore, erosion and flooding risk is considered for coastal settlements as well.

The modelling of the flood extents followed a two-step approach. First, hydrodynamic modelling determined the water-level height on the coastline, based on statistically determined offshore wave conditions for the 1:10, 1:30, 1:50 and 1:100 years storm events, in combination with a medium-future sea-level rise (0.3 m) and a long-term sea-level rise scenario (1.0 m). Those water-level heights were then extrapolated inland, using the "enhanced Bathtub Model" in ArcGIS (DEFF 2020). The spatial accuracy for the flood extent maps depends greatly on the spatial detail of the used digital elevation model used, and for this project a Digital Surface Model at 5 x 5 m pixel size was used which was generated from LiDAR data.

Figure 23 shows that the area at risk of coastal flooding in the Richards Bay PHSHDA is very small. According to the flood risk modelling conducted by DEFF (2020), only a very narrow strip of coast will be directly affected by flooding originating from coastal storm surges and wave runup, due to the high coastal foredunes in the area of the Richards Bay PHSHDA. However, the unconsolidated sandy shoreline and dunes are very vulnerable to erosion caused by wave impact during coastal storms.

The modelling of the erosion extent followed a two-step approach. First, hydrodynamic modelling determined the water level height and wave energy on the coastline, based on statistically determined offshore wave conditions for the 1:10, 1:30, 1:50 and 1:100 years storm events. Then, engineering-based equations were used to determine the expected "erosion distance" i.e., the amount the coastline would move "inland", in combination with protection provided by coastal vegetation, dune height and seawalls. It should be noted that for rocky shores, or for sandy shores with underlying solid rock, the modelling might have over-estimated the erosion distance (DEFF 2020).

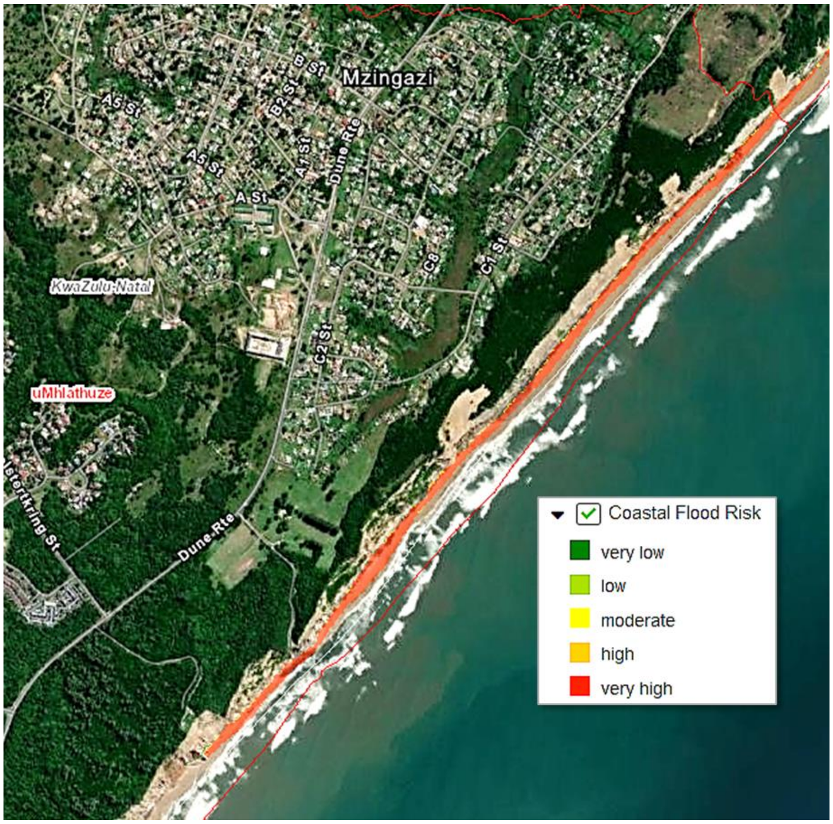


Figure 23: Coastal flood risk in the Richards Bay PHSHDA (zoom in for details)

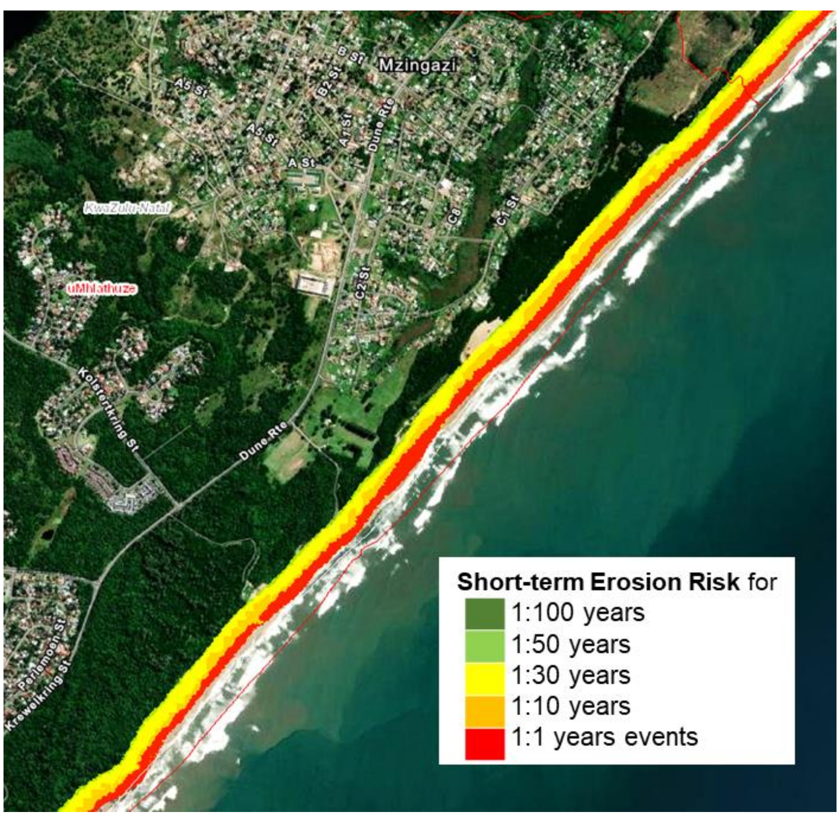


Figure 24: Coastal short-term (i.e. storm-related) erosion risk in the Richards Bay PHSHDA (zoom in for details)

Figure 24 shows that the area affected by coastal erosion is more extensive than the area affected by coastal flooding. However, currently only one existing property is located in the coastal erosion risk zone (and has reportedly been affected by coastal erosion in the past). Consequently, the coastal erosion risk for the Richards Bay PHSHDA currently is very low.

As for future coastal flood and erosion risk, the magnitude of risk is largely dependent on the spatial development of the Richards Bay PHSHDA: the risk will increase with increasing expansion of urban development into the delineated coastal risk zones. If this development can be avoided, then coastal risk will remain very low.

3. Climate impacts on key resources and sectors

To understand the impact that climate change might have on major resources, this section explores the impact that climate change is likely to have on the resources and economic sectors of uMhlathuze LM.

3.1. Water resources and supply vulnerability

To obtain a high-level first order assessment of the relative climate change risks for water supply to different towns and cities across South Africa, a general risk equation was developed to determine the current and future surface water supply vulnerability that combines both climate change and development risks (i.e., due to an increase in population and demand). The current vulnerability of individual towns was calculated based on the estimated current demand and supply as recorded across the country by the Department of Water and Sanitation's (DWS) All Towns study of 2011. The future vulnerability was calculated by adjusting the water demand for each town proportional to the increase in population growth for both a high and medium growth scenario. The level of exposure was determined as a factor of the potential for increasing evaporation to result in increasing demands, and for changes in precipitation to impact directly on the sustainable yield from groundwater, and the potential for impacts on surface water supply. These were then multiplied by the proportion of supply from surface and groundwater for each town. Exposure to climate change risk for surface water supply was calculated in two ways. The first was by assuming surface water supply was directly related to changes in streamflow in the catchment in which the local municipality was located (E1) and alternatively (E2) taking into account the potential benefits offered by being connected to a regional water supply system by using the result from a national study of climate change impacts on regional water supply derived from a high level national configuration of the Water Resources Yield Model (WRYM) that calculated the overall impacts on urban, industrial and agriculture water supply to each of the original 19 (now 9) Water Management Areas (WMAs) in South Africa.

The Richards Bay Water Supply System (RBWSS) supplies water to the City of uMhlathuze Local Municipality (CoMLM), which comprises the towns of Richards Bay, Empangeni, Ngwelezane and Esikhaweni, as well as a number of rural villages. The RBWSS's supply area is within the Mhlathuze River Catchment, which is the major water resource. The Mhlathuze River Catchment receives inter-catchment transfers from the Umfolozi River and Thukela (Tugela) River

Catchments and, as a result, these catchments are also part of the Water Supply System Area. Water is also sourced from various natural lakes within the Catchment such as Lake Nhlabane, Lake Mzingazi and Lake Cubhu. The Catchment also serves as the resource for agriculture, both irrigated and dryland, afforestation, as well as ecological requirements (DWA 2021).

While uMhlathuze therefore is not ground-water dependent, groundwater plays a key strategic role in South Africa in supporting economic development and sustaining water security in several rural and urban settlements that are either entirely or partially dependent on groundwater supply. Groundwater is a natural resource the availability and distribution of which are highly influenced by climate variability and change. An analysis of the impact of climate change on potential groundwater recharge was conducted for the period 2031 to 2050. The Villholth GRiMMS (Groundwater Drought Risk Mapping and Management System) formulation (Vilholth et al. 2013), which implemented a composite mapping analysis technique to produce an explicit groundwater recharge drought risk map, was adapted to formulate a series of potential groundwater recharge maps for the far-future across South Africa. Finally, the future period 2031 to 2050 was compared with the historical period 1961 to 1990. In line with DWA (2021), Figure 25 indicates that all settlements with the uMhlathuze LM are surface water dependent. Groundwater currently does not play a role in water supply.

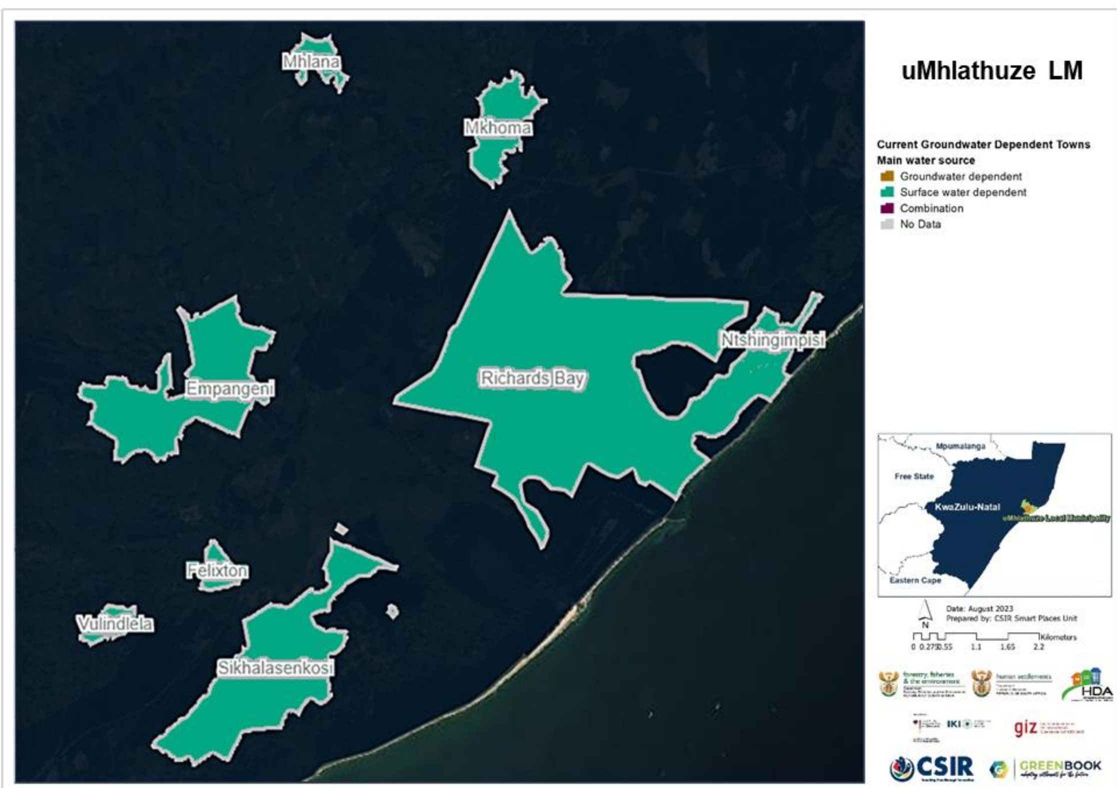


Figure 25: Main water source for settlements in uMhlathuze

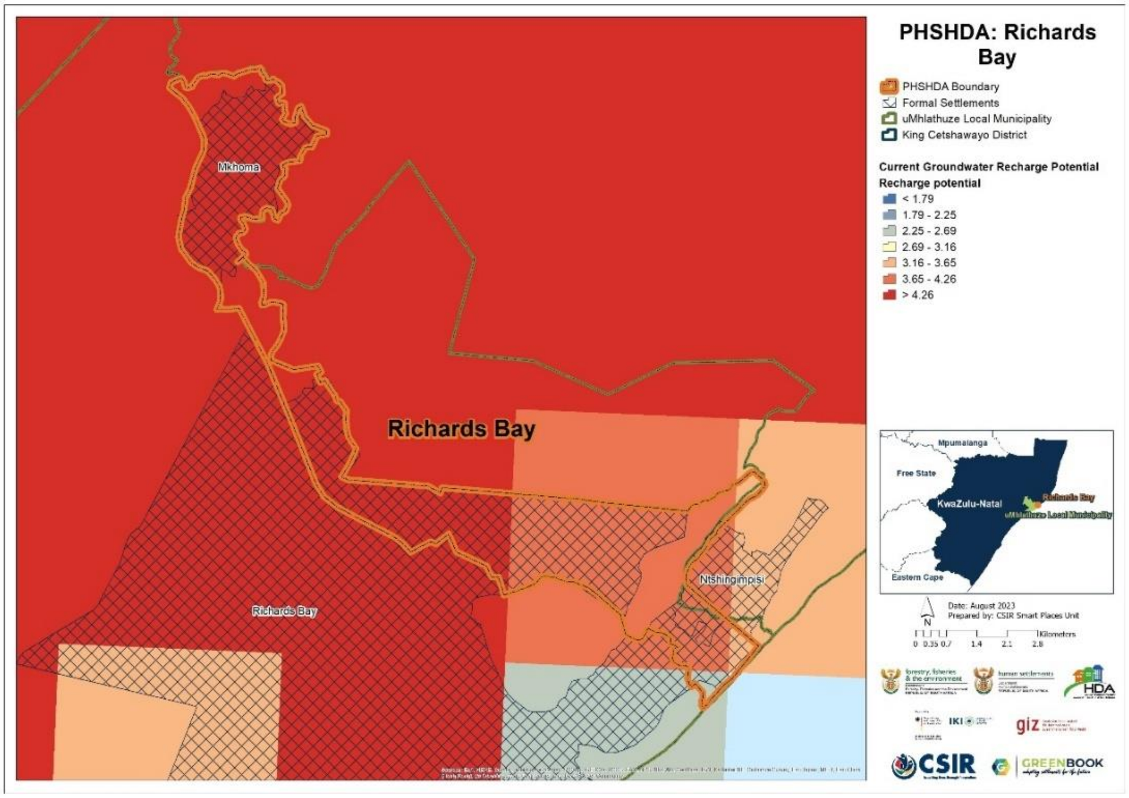


Figure 26: Groundwater recharge potential in Richards Bay under current (baseline) climatic conditions

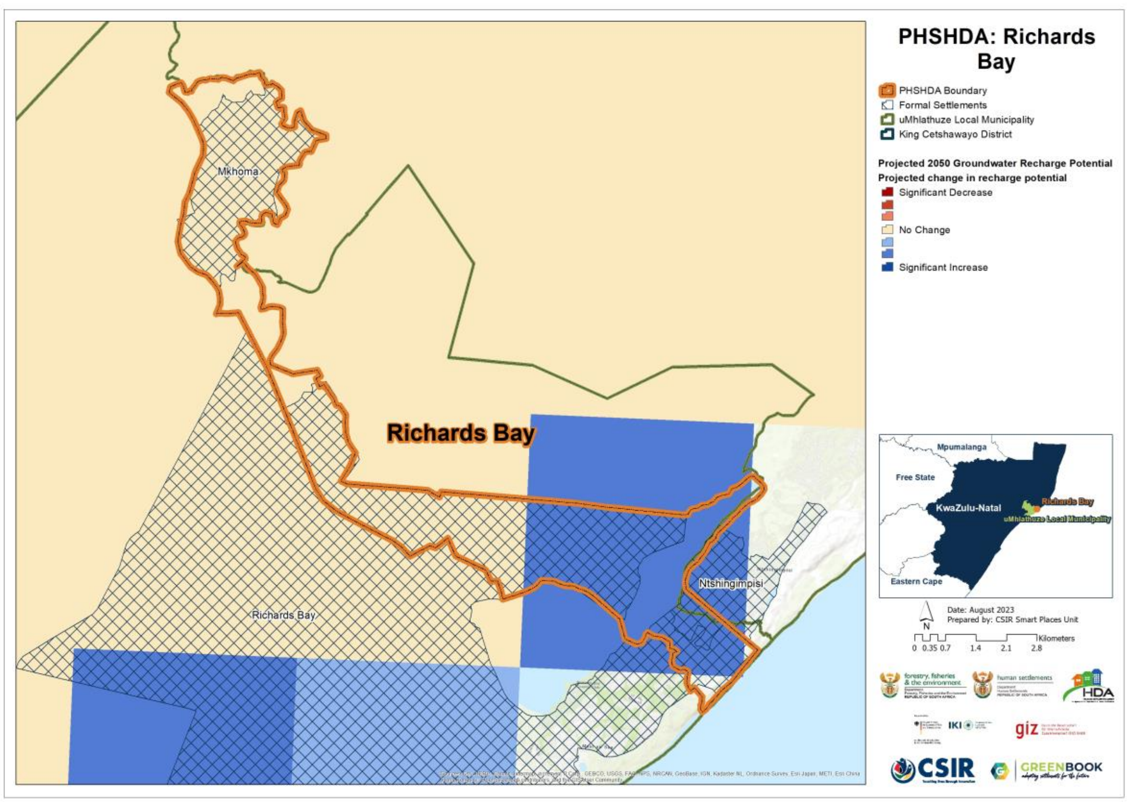


Figure 27: Projected changes in groundwater recharge potential from baseline climatic conditions to the future in Richards Bay

While the natural water availability in the area is good, according to uMhlathuze (2022, p.185), the municipality faces challenges with regards to water supply in eSikhaleni, Vulindlela and other areas due to failing infrastructure and under-capacitated sewage treatment systems. For future development it might be worth mentioning however that, given the high annual rainfall and the porosity of the largely unconsolidated sediment-based (coastal belt) soils and fissured geology (inland), the current groundwater recharge potential in Richards Bay of >4.26 is very high (Figure 26). Figure 27 indicates that the projected groundwater recharge potential is likely to remain unchanged. Therefore, groundwater may be explored as an alternative source of water.

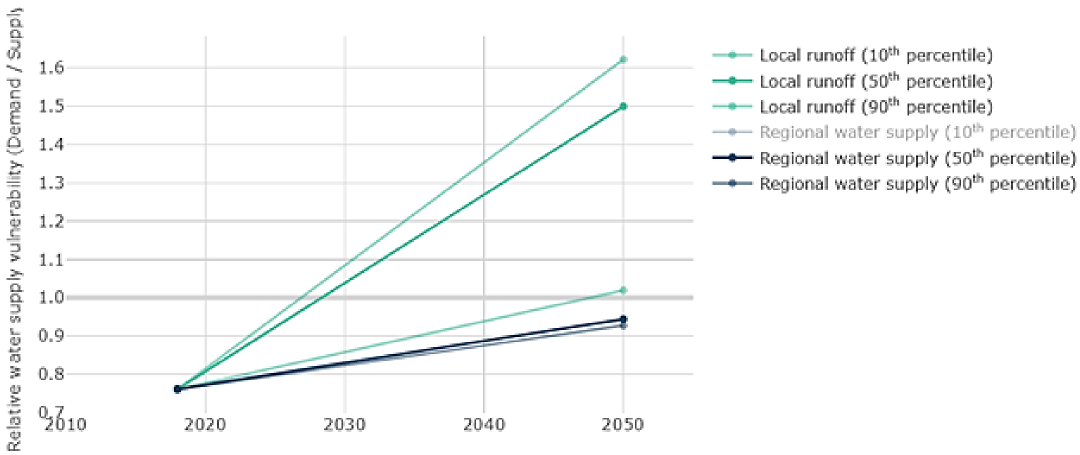
Table 4 provides and overview of current water supply vulnerability (i.e., demand versus supply) in the uMhlathuze Local Municipality based on the data compiled for the Department of Water and Sanitation's (DWS) All Town's Study (Cole, 2017). A water supply vulnerability score above 1 indicates that demand is more than supply, while a score below 1 indicates that supply is meeting demand.

Table 4: Current water supply and vulnerability across uMhlathuze LM

Local Municipality	Water Demand per Capita (l/p/d)	Water Supply per Capita (l/p/d)	Current Water Supply Vulnerability
uMhlathuze	151.87	199.53	0.76

Current and future water supply vulnerability estimations are based on: 1) a local water supply perspective incorporating changes to population growth coupled with exposure to climate risk and 2) a regional water supply perspective, based on impacts of regional water supply assuming supply is part of the integrated regional and national bulk water supply network. The water supply vulnerability estimations do not consider current state of water supply and reticulation infrastructure. The current context and conditions within each of the local municipalities need to be considered when interpreting the information provided in this report. Figure 28 shows the estimated current and future water supply vulnerability for the uMhlathuze LM.

uMhlathuze's water demand currently is lower than the actual supply, indicated by a current water supply vulnerability of 0.76 (Table 4). However, the LM's water supply vulnerability is projected to increase to between 0.92 to 1.6 (Figure 28). This increase in vulnerability, especially for the Local runoff (10^{th} percentile) and Local runoff (50^{th} percentile), is primarily caused by a massive increase in population (66.82%), which is potentially insufficiently compensated by a regional urban water supply growth of 48.22%. Further, a slight decrease in mean annual precipitation and mean annual runoff, as well as a slight increase in annual evaporation contribute to the worsening of uMhlathuze's water supply vulnerability.



VULNERABILITY CONTRIBUTION FACTORS	PERCENTAGE CHANGE
Mean annual precipitation	-2.55%
Mean annual evaporation	4.18%
Mean annual runoff	-13.53%
Regional urban water supply	48.22%
Population growth	66.82%

Figure 28: Future water supply vulnerability in uMhlathuze Local Municipality, under a medium population growth scenario

3.2. Agriculture, forestry, and fisheries

In 2019, manufacturing was with 20.58% the strongest sector of the King Cetshwayo district while agriculture, forestry and fishing (AFF) contributed 6.9% to the Gross Value Added (KZN 2019). AFF contributes 2.44% to uMhlathuze GVA production and 4.96% to uMhlathuze total employment. The total AFF GVA production of uMhlathuze Municipality contributes 0.86% to the national AFF GVA, ranking them as the 30th biggest contributor. The main commodities in uMhlathuze are sugarcane, citrus and chicken. Poultry is a popular subsistence farming activity among small-scale farmers; in the City of uMhlathuze there are approximately 30 emerging poultry farmers that are currently trading as informal commercial farmers (uMhlathuze, 2020).

Climate change, through increased temperature and changing rainfall patterns, can have fundamental impacts on agriculture if the climatic thresholds of the commodities being farmed are breached. However, the nature and extent of these impacts depends on the type of commodity being farmed and the relative geographic location of the farmer in relation to the industries served, and on the resources available to the farmer. The same climate impact can have different impacts on different commodities and farms. Overall, climate change could make it more difficult to grow crops, raise animals, and catch fish in the same ways and same places as we have done in the past.

The methodological approach to understanding the impact of climate and climate change on AFF consisted of four components. Firstly, the most important areas in terms of Gross Value Added (GVA) and employment for the AFF sector relative to the other sectors of the South African economy were determined. Secondly, an analysis of climate change scenarios was done using historical climate variables, as well as multi-model projections of future climates to help identify specific climate-related risk factors for agriculture within specific regions. Thirdly, crop suitability modelling was done to indicate how the area suitable for crop production under the present climate conditions might shift or expand under the scenarios of future climate change, in addition to using the Temperature Humidity Index (THI) to assess heat stress in livestock. Finally, the climate change analysis was used in conjunction with the crop modelling outputs to assess the potential impacts of climate change over a specific area, or for a specific crop, to give more detail on how predicted climate changes translate into location/crop specific impacts. This was developed at a local municipal level and guided by the outcome of the agricultural industry sector screening and climate scenario analysis.

The general climate trend expected for the uMhlathuze LM is a warmer, and slightly wetter climate with more extreme rainfall events. This can lead to a potential increase in sugarcane yield. However, increased exposure to pests such as eldana and chilo. As for chicken farming, an increase in production costs is expected to maintain optimal seasonal temperatures and reduce the risk of heat stress due to an increased investment required in ventilation and cooling). Heat stress on birds will reduce body weight gain, reproduction efficiency and egg quality. Citrus farming will benefit from an increased water availability. However, hot, and moist conditions will benefit a more heat-tolerant disease vector and will lead to an increased exposure to pests.

4. Conclusions and Recommendations

This report provided a description of the current situation and future trends for vulnerability, population change, climate change, exposure to climate hazards, and the impact of climate change on certain resources for uMhlathuze and the Richards Bay PHSHDA in particular.

The greatest climate threat across uMhlathuze and the Richards Bay PHSHDA will be the average annual temperature increase between 1.5-2°C. Apart from this general warming, no drastic climate changes are to be expected (however, no detailed assessment was conducted regarding the impacts of ocean warming on cyclone intensity and frequency). Consequently, the major challenge will be in the compensation for the expected (and ongoing) major population growth. The planning for this population growth should be cognisant of the predicted future climate conditions. However, a brief screening of the latest IDP for the municipality (uMhlathuze 2022) showed that climate change adaptation features only very superficially in this plan.

Socio-economic vulnerability for uMhlathuze is among the 30% least vulnerable in the province, due to the high degree of industrialisation. Physical Vulnerability scores are the highest and relates to the built environment and the connectedness of the settlements in the local municipality. It is a composite indicator that considers road infrastructure, housing types, the maintenance of the infrastructure, densities, and general accessibility. A high physical vulnerability score highlights areas of remoteness and/or areas with structural vulnerabilities. This is related to incongruent development pattern present in the LM (which will be tackled however, in the Integrated Development Plan 2022-2027; uMhlathuze, 2022; see also Figure 29).

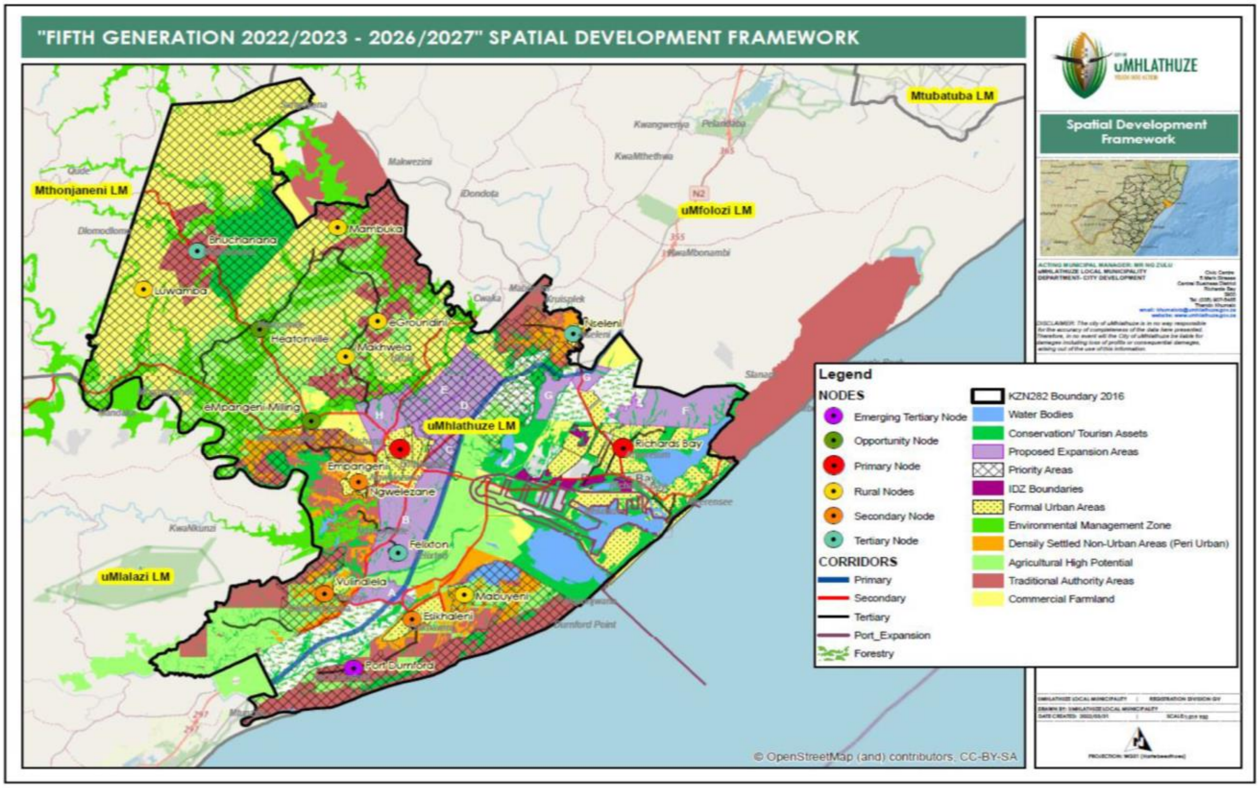


Figure 29: uMhlathuze Spatial Development Framework 2022/2023 – 2026/2027 (Source: uMhlathuze 2022).

However, within the municipality vulnerability varies greatly between settlements. Table 5 provides an overview of the individual settlement vulnerability components and scores for Richards Bay and Mkhoma. Richards Bay is with a total settlement vulnerability score the least vulnerable settlement in the uMhlathuze LM.

Table 5: Settlement vulnerability components and scores for Richards Bay and Mkhoma

Settlement vulnerability components	Richards Bay	Mkhoma
Service Access	2.83	10
Growth Pressure	6.14	4.86
Socio-economic	1.45	7.89
Environmental	1	7.42
Regional connectivity	1	1.81
economic	1	10
Total settlement vulnerability	2.2	**7.0**

Table 5 indicates that almost “perfect” conditions are present in terms of environmental vulnerability, regional connectivity and the economic situation, given the good road and rail network, the port and a balance between preservation of natural environment (here, the uMhlathuze estuary and related swamp forest and wetland ecosystems) and urban development. The economic vulnerability of the population is low, due to the high employment rates. The highest vulnerability factor is however the extreme population growth which puts pressure on the city to keep up with service and infrastructure provision and sustainable spatial development. In contrast, in the Mkhoma area, almost all settlement vulnerability components are of high concern, indicating the dire need to reduce this settlement’s vulnerabilities to external shocks.

A summary of future climate hazards and impacts across the uMhlatuze LM and the Richards Bay PHSHDA area include:

- Average annual temperature will increase between 1.5-2°C by 2050.
- 0 – 20 very hot days (>35°C) today and 11-20 days in 2050.
- Slight increase of heatwave days from currently 2 to 4 days per year.
- An overall very low risk of increase in extreme heat by 2050.
- Average annual rainfall trend unclear with some scenarios predicting an increase of 43 mm per annum, others predict a decrease of 107mm per annum. Both predictions might be of low impact for the area, given the high total amount of baseline annual rainfall between of up to 1600 mm/a.
- In the recent past, there was a slight tendency towards less dry spells. Future climate might bring a slight increase in dry spells, with a moderate risk of droughts.
- Wildfire occurrence on the settlement edges is currently “likely” due to the subtropical climate creating dense and fast vegetation growth in the inland area of Richards Bay, but “rare” in the swampy coastal belt. A “moderate” increase in likelihood of wildfires is predicted in the future for the Mkhoma region, but only a “very low” likelihood of increase for Richards Bay. However, the baseline number of high fire danger days in the region is less than 10 days annually currently and into the future, which is very low in national comparison.
- There is currently a low to medium likelihood of flooding, with a low increase of flood risk in the future, given the very slight increase of 1-2 days of extreme rainfall in 2050.
- Surface water is the main water resource and is not at risk due to the very high rainfall in the region of 1600-2000 mm/a. Water supply vulnerability is however estimated to increase into the future. The future water supply vulnerability is largely driven by failing water and sewage infrastructure and population growth, as well as slight decrease in mean annual precipitation and mean annual runoff, and a slight increase in annual evaporation.
- While this study did not include occurrence and future projections of tropical cyclones, international studies suggest that the frequency and intensity of cyclones will increase, due to higher ocean temperatures.

Therefore, in response to these climate risks and impacts, the following adaptation goals are recommended:

1. To prepare settlements for higher temperatures without increasing carbon emissions: As annual average temperatures rise it will becoming increasingly important to protect population from increasing heat impacts, while avoiding energy-intense adaptation options. This could involve better insulating buildings against heat, orientation settlement layouts and buildings to sun in support of passive heating and cooling, optimising the location of windows for natural ventilation, and planning new townships with consideration of natural air flow and shade effects. Ecosystem based adaptation should particularly be explored in planning and developing urban areas with natural elements that improve micro-climate such as large trees, and parks with water bodies.

2. To ensure water security under a changing climate: Given the water scarcity challenges in the country, developing comprehensive strategies for water resource management is crucial. The uMhlatuze Local Municipality could contribute towards the country's water security and ensure sufficient supply for a growing population and industry by prioritizing water infrastructure maintenance; investing in efficient water supply infrastructure to meet future demand; protecting water sources from pollution by industry and agriculture; promoting water conservation practices by implementing strategies such as public awareness campaigns, leak detection and repairs, and water metering and billing; as well as explore measures to secure alternative water sources such as rainwater (harvesting), groundwater (recharge and extraction) and wastewater (reuse), particularly in the face of a growing demand.

3. To prioritise the health and safety of communities in the face of a changing climate: Climate change hazards such as increase in temperature, wildfires and flooding pose serious risks to public health and safety. Heat-related illnesses such as heatstroke, as well as health challenges associated with smoke pollution, which is a cascading effect of wildfires, are some of the health risks associated with these hazards. Moreover, hot and wet conditions, often lead to the increased spread of water- and vector-borne diseases, while extreme weather events may cause people physical harm. It is therefore necessary to ensure that adequate systems are in place to mitigate (or respond to) the adverse consequences of such impacts. Implementing early warning systems for extreme weather events, ensuring access to climate-sensitive health services (such as heat illness prevention or disease surveillance), and improving emergency response capacity, are some of the measures that the uMhlathuze Local Municipality could look into. Furthermore, public education about the risks of climate change to health and safety is also crucial.

4. To build capacity and raise community awareness: Community awareness raising and capacity building around climate change in settlements should focus on those

communities that are most vulnerable to climate change impacts – for instance, the poor and marginalised, those living within or near a 100-year flood line, those living in areas most prone to losing access to water in times of drought, and those that live in close proximity to the wildland urban interface. The programme could include websites, public information meetings, posters, and message boards, as well as physical sites where practical actions to address climate change and adaptation can be demonstrated. Building capacity of municipal professionals should also be considered. Building capacity and raising awareness within all spheres of government around climate change gets increasingly important as various sectors, and even different spaces, require differentiated adaption responses to climate change.

5. Coastal adaptation: At this stage the coastal zone of the Richards Bay PHSHDA is hardly developed. These are ideal conditions to prevent risks arising from coastal storms, and it is recommended to keep the coastal zone free from future development, especially in the light of a potential increase in cyclone frequency and intensity. However, existing developments and infrastructure need to be "future-proofed", or a planned "retreat" should be considered. Coastal planning needs to include water supply, and the Implementation and maintenance of the water Reconciliation strategy for Richards Bay and Surrounding towns (DWS 2021) should be cognisant of the potential impact coastal storms and cyclones can have on water and sanitation infrastructure.

5. Bibliography

Behsudi, A, 2021. What Is Mitigation vs Adaptation? IMF Finance Dev. Mag. 46–47.

Chen, D., M. Rojas, B.H. Samset, K. Cobb, A. Diongue Niang, P. Edwards, S. Emori, S.H. Faria, E. Hawkins, P. Hope, P. Huybrechts, M. Meinshausen, S.K. Mustafa, G.-K. Plattner, and A.-M. Tréguier, 2021: Framing, Context, and Methods. In Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press. In Press.

Biyela, N.G., 2016. Indigenous wildlife reflected in the road names at eSikhaleni township, South Africa: King Cetshwayo's contribution to conservation. Indilinga – African journal of indigenous knowledge systems, 15 (1), 167-177. Available from: https://journals.co.za/doi/pdf/10.10520/EJC192823

Cole M.J., Bailey R.M., Cullis J.D.S., & New M.G. 2017. Spatial inequality in water access and water use in South Africa. Water Policy, 20 (1): 37-52.

Council for Scientific and Industrial Research (CSIR). 2019. GreenBook Municipal Risk Profile. Available from: https://riskprofiles.greenbook.co.za/

Council for Scientific and Industrial Research (CSIR), 2023. Green Book l Adapting settlements for the future. GreenBook. URL https://greenbook.co.za/

Department of Environment, Forestry & Fisheries (DEFF), 2020. National Coastal Climate Change Vulnerability Assessment: Vulnerability Indices – Technical Report. Pretoria, South Africa. CSIR Report No. CSIR/SPLA/SECO/IR/2020/0068/A.

Department of Water and Sanitation, South Africa, June 2021. Implementation and maintenance of the water reconciliation strategy for Richards Bay and surrounding towns: infrastructure and cost assessment report. Available from: https://www.dws.gov.za/iwrp/RichardsBay/Documents/PDF%20signed%20reports/infrastructure%20and%20cost%20assessment%20report%20for%20the%20implementation%20and%20maintenance%20of%20the%20water%20reconciliation%20strategy%20for%20richards%20bay%20and%20surrounding%20towns.pdf

IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

IPCC, 2021: Annex VII: Glossary [Matthews, J. B. R., J. S. Fuglestvedt, V. Masson-Delmotte, V. Möller, C., Méndez, R. van Diemen, A. Reisinger, S. Semenov (ed.)]. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E.

IPCC-6, Chapter 11, 2021: Seneviratne, S.I., X. Zhang, M. Adnan, W. Badi, C. Dereczynski, A. Di Luca, S. Ghosh, I. Iskandar, J. Kossin, S. Lewis, F. Otto, I. Pinto, M. Satoh, S.M. Vicente-Serrano, M.

Wehner, and B. Zhou, 2021: Weather and Climate Extreme Events in a Changing Climate. In Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1513–1766, doi:10.1017/9781009157896.013. Available from: https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Chapter11.pdf

IPCC, 2022. Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press., Cambridge, UK and New York, NY, USA.

Kubayi, M.M.T. (DHS), 2022. Progress in Developing Integrated and Sustainable Human Settlements, Department of Human Settlements.

KZN (KwaZulu-Natal Province) 2019. District economic profile of King Cetshwayo District 2021. Available at: https://www.kznedtea.gov.za/documents/King%20Cetswayo%20District%20Economic%20Profile%20.pdf

Ministry of Human Settlements (DHS), Republic of South Africa, 2020. Gazette Notice: Declaration of the Priority Human Settlements and Housing Development Areas (PHSHDAs) (No. Gazette Notice No. 526). Department of Human Settlements, Pretoria, South Africa.

Municipal Demarcation Board. 2022. Spatial Knowledge Hub. Available from: https://spatialhub-mdb-sa.opendata.arcgis.com/

National Treasury, 2018. Supplementary Guidance Note for the Built Environment Performance Plan (BEPP) 2019/20– 2021/22: Integrating Climate Response Priorities into the BEPP.

Pieterse, A., 2020. Mainstreaming Climate Change Adaptation into Municipal Planning: Lessons from two South African Cases (PhD Thesis). University of Pretoria.

Pieterse, A., du Toit, J., van Niekerk, W., 2021. Climate change adaptation mainstreaming in the planning instruments of two South African local municipalities. Dev. South. Afr. 38, 493–508. https://doi.org/10.1080/0376835X.2020.1760790

Pieterse, A., Ludick, C., van Niekerk, W., Arnold, K., Chilwane, L., Mateyisi, M., Nangombe, S., Steenkamp, K., John, J., Kotzee, I., Lück-Vogel, M., 2023. GreenBook MetroView: Methodology for eThekwini. Pretoria.

Polokwane Local Municipality (PLM), 2021. City of Polokwane: Draft Integrated Development Plan 2021 - 2026.

Republic of South Africa. (2011), National Climate Change Response White Paper.

Republic of South Africa. (2013), Spatial Planning and Land Use Management Act, 16 of 2013.

Schulze, R. E. et al. 2008. South African Atlas of Climatology and Agrohydrology. Report No. 1489/1/08, Water Research Commission, Pretoria.

uMhlathuze 2017. Ward Base Plan 2017/2018. Ward 30. Available at: https://www.umhlathuze.gov.za/images/departments/IDP/wardbase30.pdf

uMhlathuze 2021. Local Economic Development Strategy Review/ Economic Transformation and Job Creation Roadmap. Available from: https://www.umhlathuze.gov.za/images/x18167-1.pdf

LED STRATEGY
uMhlathuze 2020. Concept plan - Poultry support program for emerging farmers and youth training. Available at: https://www.umhlathuze.gov.za/images/Poultry_Support_Program_Concept_Plan-1.pdf
uMhlathuze 2022. City of uMhlatuze - 5th generation IDP 2022/2027
Vilholth, K.G., Tottrup, C., Stendel, M. & Maherry, A. 2013. Integrated mapping of groundwater drought risk in the Southern African Development Community (SADC) region. Hydrogeology Journal, 21: 863 – 885.

Annexure A: Sector-specific impacts

Climate hazards and climate events can have far-reaching impacts across a range of sectors. The impact of some climate scenarios on selected sectors is summarised in the following sections. The presented impacts are compiled in a generic way, i.e., not specific for the settlement focused on in this report. However, this information has to be seen in conjunction with the actual weight the following sectors have in the uMhlathuze LM. Since a warmer and potentially slightly wetter climate can generally be assumed for the Richards Bay PHSHDA, the respective impacts (such as increased temperature and heat extremes, increase in rainfall and inland flooding) should be given special consideration.

The strongest economic sector in uMhlathuze is manufacturing with 20.58%, with most activities taking place in Richards Bay and Empangeni. The public sector and Finance/Insurance/Real Estate are the second strongest sector in the district (both about 14.6%) followed by wholesale/tourism and transport/communication (both about 12.6%). Agriculture, forestry and fishing contributed 6.9% to the Gross Value Added in 2019 (KZN 2019). Most of the key sectors in uMhlanga therefore rely directly on functioning transport, ICT and energy systems, which are at risk of being impacted by climate change. More indirectly the economy and livelihoods in uMhlanga are also dependent on functioning stormwater, solid waste, sanitation. More broadly, Ecosystem services, such as provision of fresh water, food, medicinal plants, protection from soil erosion, microclimate regulation and flood impact mitigation can be impacted by climate change effects as well. Further, climate, in Africa for example the occurrence of heatwaves impacts human health and cultural activities and heritage sites.

In the following section a generic overview of impacts on these sectors is provided.

Transport and mobility

Within settlements, transport networks comprise of nodes (e.g., buildings and public transport stops and stations) and various connector links (e.g., walkways, roads, bridges, railways, tunnels, and waterways). Apart from being a large asset base in themselves, these networks are indispensable conduits for the movement of people and goods for social, economic, political, health and recreational purposes. Within the context of climate change, therefore, climate resilient transport networks are necessary to ensure unimpeded functioning of society. Vulnerability of transport networks to climate change depends on infrastructure age, its materials, construction practices, design features, and maintenance history. Societal level of risk to infrastructure failure is dependent on individual functions of different parts of the transport network. Therefore, spatial differentiation should be an integral component of adaptation strategies. Disruption to transport networks due to climatic extreme events may lead to social exclusion, trade interruption, and consequently social disorder. It is imperative, therefore, that the design and in-situ upgrading of transport networks and their operations be responsive to threats posed by climate change, especially in high-risk areas. It is equally important to ensure transport networks do not add to landscape vulnerability – for example increasing erosion of steep slopes, landslides or increasing vulnerability of natural habitats to fragmentation and overharvesting.

Increased temperatures and heat extremes	Increase in rainfall, inland flooding, and coastal flooding
• Increased rate of infrastructure deterioration leading to pavement failure including cracking and rutting. • Increased stress on bridges, particularly expansion joints, through thermal expansion and increased movement. • Corrosion of steel reinforcing in concrete structures due to increase in surface salt levels in some locations. • Increased infrastructure maintenance cost for road repair and reconstruction work, causing traffic delays and emergency service response delays. • Increased frequency and intensity of wildfires leading to more road closures. • Increased vehicle accidents, due to low pavement adhesion, leading to higher rates of transport-related fatalities.	• Increased rate of infrastructure deterioration, especially in areas with poor infrastructure maintenance history including potholes, flushing, and stripping. • Temporary and permanent flooding of road, rail, port and airport infrastructure. • Structural integrity of roads, bridges and tunnels could be compromised by higher soil moisture levels. • Potential destruction of bridges and culverts. • Erosion of embankments and road bases leading to undermining of roads or railways. • Increased risk of landslides, slope failures, road washouts and closures. • Undermining of bridge structures (scouring). • Closure of roadways and tunnels leading to traffic delays. • Transportation system disruptions, impacts to traffic signalling and low water crossings. • Increased weather-related accidents.

Information and communication technology

Information and communications technology (ICT), or telecommunications, plays a critical role in society and is central to the operations of every industry and sector, and society relies on it for social and leisure purposes as well as work. Climate change impacts on ICT infrastructure in settlements include the impacts of increased warming and precipitation, extreme weather events, strong winds, and sea-level rise and storm surges. The ICT industry experiences weather-related impacts which are expected to worsen due to ongoing climate variability and climate change. Compared to 'heavy' infrastructure sectors like energy, water or transportation, the ICT sector has smaller infrastructure and shorter lifetimes, reliance on a combined network instead of individual structures, redundancy of service and infrastructure and service providers, and fast-paced technological change and innovation. While technologies in the ICT sector in the future may converge towards wireless technologies and reduced dependence on current infrastructure, this will not negate the need for infrastructure altogether, for example, there will still be a requirement for equipment such as mobile or fixed wireless towers to operate this technology.

Increased temperatures and heat extremes	Increase in rainfall, inland flooding, and coastal flooding
• Increased weathering and deterioration of infrastructure resulting in increased maintenance and repair costs. • Heat stress causing structural damage to infrastructure. • Increased energy demands during heatwaves resulting in power outages which can impact on delivery of telecommunications services. • Increases in temperature and higher frequency, duration, and intensity of heat waves increasing the risk of overheating in data centres, exchanges, and base stations, which can result in increased failure rates of equipment. • Increased mean temperature increasing operating temperature of network equipment which may cause malfunctions if it surpasses design limits. • Decreased precipitation leading to land subsidence and heave, reducing the stability of telecommunications infrastructure above and below ground (foundations and tower structures).	• Increased risk of flooding of low-lying infrastructure, access holes and underground facilities. • Increases in storm frequency or intensity increasing the risk of damage to aboveground transmission infrastructure and impacting on telecommunications service delivery. • Increases in storm frequency leading to more lightning strikes, consequently damaging transmitters and overhead cables, causing power outages. • Increased cost of insurance for infrastructure in areas with repeated incidents of flooding, as well as withdrawal of risk coverage in vulnerable areas by private insurers. • Road closures due to flooding thus inhibiting service and/or restoration efforts. • Rising sea levels and corresponding increases in storm surges, increasing the risk of saline corrosion of coastal telecommunications infrastructure, and leading to erosion or inundation of coastal and underground infrastructure.

Energy

South Africa's energy mix is primarily dominated by the use of fossil fuels to derive grid supplied electricity and imported crude oil and petroleum products. Regarding access to energy within our human settlements, grid-supplied electricity is transmitted from power stations to sub-stations to settlements typically through overhead powerlines. Electricity supply is not equally distributed within the country with many people within informal settlements still not connected to the electricity grid. Many thus rely on the combustion of fuels within or near their homes to meet their cooking, heating, and lighting needs. Electricity infrastructure is exposed to weather and climate and is vulnerable to the effects of climate change. Variations in temperature (hotter and colder days) will increase the demand for energy for both cooling and heating within homes and buildings, as will urban growth. Thus, both the electricity supply and demand of a settlement are likely to be impacted by climate change.

Increased temperatures and heat extremes	Increase in rainfall, inland flooding, and coastal flooding
• Increased heat causing expansion of overhead cables, and cable sag. Sagging below a certain amount result in a reduction in the amount of electricity transmitted. • Increased heat stress on electricity transmission networks (overhead cables). • Increase in heat island effect increasing energy demand for cooling, leading to grid stress. • Increased threat of wildfires causing widespread damage to infrastructure and causing disruptions to service provision.	• Increase in flooding causing damage to electricity transmission and distribution infrastructure, poles, lines and substations. • Increase in frequency and cost of maintenance of concrete structures due to frequent and intense rainfall, flooding, or sea level rise. • Increased repair events increasing stress put on service crews and resulting in delays to power restoration.

Stormwater

A stormwater drainage system collects, conveys and discharges stormwater with the aim to reduce the risk of flooding in settlements and control water quality (traditional pollutants that are commonly associated with municipal and industrial discharges, e.g., nutrients, sediment, and metals). Conventionally rainwater falling onto a hard surface will be collected and drained through surface channels to a collection point or culvert where it will enter a storm water pipe. The pipe will use gravity to discharge the water into a watercourse or a dam. Where a gravity-fed system cannot be used the water will be collected into a storage dam and pumped to the discharge location. Sustainable Urban Drainage Systems (SUDS) seek to minimize the volume of storm water entering the drainage system. It does this in three ways: first, collect and store as much rainwater at source as possible; second, filtrate as much surface water into the ground as possible as close to the source as possible; third, collect storm water at grade in various storage systems (weirs, wetlands, attenuation ponds, etc.).

Increased temperatures, heat extremes, and drought	Increase in rainfall, inland flooding and coastal storms
• Potential risk of undermining the temperature regime of temperature-sensitive stormwater ponds and receiving waters, resulting in a decrease in water quality. • Increased corrosion in stormwater drains due to a	• Increased risk of flooding due to pressure on stormwater systems. • Increased risk of litter entering the stormwater systems. • Increased risk of damage and failure of stormwater systems due to overloading during floods and intense rainfall events.

combination of higher temperatures, increased strengths, longer retention times, and stranding of solids. • Increased shrinking soils increasing the potential for cracking, increased infiltration and exfiltration of water mains and sewers, which in turn exacerbates treatment and groundwater or storm water contamination.	• Failure of stormwater treatment devices during high flow events leading to by-pass and / or flushing of contaminated water. • High wet-weather hydraulic loads and bottle-necks in stormwater and networks due to inflow and sewer infiltration, leading to local inundation and overflows of untreated wastewater. • Increased rainfall causes soil erosion thus damaging underground stormwater systems. • Increased surface and stream erosion causing deposition of sediments in receiving environments. • Stream morphology for undeveloped, developing and fully developed urban areas, may change, hence affecting existing outfall structures and potential stormwater pond locations.

Solid waste

Human settlements generate massive amounts of solid waste that needs to be managed effectively so as not to cause air, water, and soil pollution. As cities grow and need more land, suitable collection and disposal sites can be difficult to acquire and develop. Most households in South Africa (64% in 2015) receive a waste removal service at least once a week, but there are still households that rely on their own or communal rubbish dump sites. Illegal dumping and littering are problems in most municipalities resulting in solid waste often accumulating in waterways and areas otherwise intended for water run-off and flood control. These conditions make municipalities vulnerable to flooding, contamination of water resources, adverse health effects and rehabilitation costs that may overwhelm the resilience of cities.

Increased temperatures and heat extremes	Increase in rainfall, inland flooding, and coastal flooding
• Increased risk of combustion at open waste disposal sites and illegal dumps and increase in explosion risk associated with methane gas. • Increased rate of decay of putrescible waste resulting in increased odour, breeding of flies, and attracting of vermin. • Increased health and safety concern regarding heat stroke to staff collecting waste.	• Increased risk of flooding due to pressure on stormwater and leachate management systems at landfills. • Increased demand for capacity to cope with large volumes of waste generated by flood events. • Increase in soil saturation causing decreased stability of slopes and landfills linings (if clay or soil based) at waste management facilities. • Inundation of waste releasing contaminants to waterways, pathways an low elevation zones.

Increased temperatures and heat extremes	Increase in rainfall, inland flooding, and coastal flooding
• Increased risk of landfill site instability and failure due to changes in consumption patterns with increased waste creation (i.e., glass, plastic and paper cups).	• Potential loss of value and degradation of paper and cardboard for recycling due to increased moisture content. • Increased flooding causing the risk of localised disruption of waste collection rounds. • Flooding in areas with untreated, dumped waste causing the risk of groundwater contamination. • Increased flooding causing the risk of litter entering the storm water systems.

Sanitation

Sanitation and wastewater management poses several operational challenges to governments and settlements. Managing water resources involves contributions from various stakeholders at different points in the value chain. The sanitation value chain comprises eight broadly defined stages, as follows: collection/containment; storage; transport; treatment; distribution; wastewater treatment; and discharge. Re-use of wastewater is becoming more acceptable and feasible because of increasing water shortages, improved purification technology and decreasing treatment costs. A water reuse strategy that is forward thinking over ten to twenty years needs to take these possible changes into account. The direct re-use of treated wastewater can pose a risk to public health and safety and thus must be managed carefully and be subject to water quality management and control. Advanced treatment technologies, sufficient operating capacity and proper monitoring of all processes, and quality of potable water produced is essential.

Increased temperatures and heat extremes Drought and decreased rainfall	Increase in rainfall, inland flooding, and coastal flooding
• Increased heat waves, accompanied by dry weather, can exacerbate already stressed water supply systems leading to competition between sectors for water services; affecting sanitation. • Decrease in water supply for sanitation through decrease in available water to flush sewage systems adequately.	• Increased wet-weather hydraulic loads and bottlenecks in stormwater and sanitary sewer networks due to inflow and sewer infiltration, causing local inundation and overflows of untreated wastewater. • Increased rainfall and heavy rainfall events increasing the washing of faecal matter into water sources due to flooding of wastewater treatment works.

Increased temperatures and heat extremes Drought and decreased rainfall	Increase in rainfall, inland flooding, and coastal flooding
• Declining annual rainfall threatening the viability of water-borne sanitation systems, and the capacity of surface water to dilute, attenuate and remove pollution. • Sewers are structurally vulnerable to drying, hence shrinking soils increase the potential for cracking, increased infiltration and exfiltration, which in turn exacerbates treatment and groundwater or storm water contamination • Increased corrosion in sewers due to a combination of higher temperatures, increased strengths, longer retention times, and stranding of solids.	• Increased risk of flooding resulting in both infrastructure damage and contamination of surface and groundwater supplies. • Increased groundwater levels due to flooding or sea-level rise, putting as risk sewage treatment plants (which are often positioned on low-lying ground as sewerage systems rely on gravity). • Increased vulnerability of sewerage pipe systems due to their size and complexity, and their exposure to multiple flood damage threats from source, through treatment, to delivery. • Increased vulnerability of pit toilets (widely used in rural areas) due to flooding, causing serious environmental contamination. • Increase in groundwater recharge and groundwater levels causing flooding of subsurface infrastructure such as pit toilets or septic tanks. • Sea level rise posing a threat to coastal zones in terms of saline intrusion, and damage to/contamination of water systems and wastewater treatment works from inundation during coastal storms.

Ecosystem services

Urban areas are dependent on natural ecosystems in and around towns to provide communities with services such as safe and plentiful drinking water, increased food security, better health, decreased exposure to natural disasters and extreme weather, and increased recreational opportunities. For these ecosystems to continue to provide these services they need to be in a healthy condition. Unfortunately, many ecosystems have been degraded because of misuse and overuse of soil, water, plant, and animal species. At the same time global climate change is aggravating the vulnerabilities of these ecosystems and therefore diminishing the benefits that ecological infrastructure can provide. It is therefore critical to rehabilitate and maintain ecological infrastructure in the urban environment to help residents adapt to risks posed by future climate change.

Increased temperatures and heat extremes	Drought and decreased rainfall	Increase in rainfall, inland flooding and coastal storm impact
• Increased risks of water shortages increasing demand for irrigation of gardens and agriculture. • Increased evapotranspiration rates with rising temperatures, reducing the water available in reservoirs and water available for reliant ecosystems. • Increase in temperature leading to water loss via evapotranspiration resulting in decreased water quality and loss of wetlands. • Loss or degradation of indigenous species, including threatened species or ecosystems. • Increased threat from invasive species as competition for water increases. • Dieback or death of susceptible plants (e.g. street trees) and animals (e.g. fish). • Increased water temperature leading to increased growth of aquatic weeds which increases breeding of disease vectors and reduces water oxygen levels. • Milder winters and reduced frost increase the duration of the growing season,	• Decreased amounts of rainfall reaching ecosystems as settlements use rainwater harvesting techniques for increased household use. • Increased reliance on irrigation and greater demand for water to maintain public open space and gardens. • Reduced planting and pollination leading to greater risk of erosion and soil loss. • Increasing temperatures together with increased intensity of drought will potentially increase the occurrence of algal blooms in reservoirs and dams which are damaging to ecosystem functioning and water services. • Reduced soil moisture availability increasing moisture stress leading to dieback and death of plants and the loss or degradation of indigenous communities, including threatened species or ecosystems. • Drying up of aquatic systems, perennial systems will become seasonal and seasonal systems will die off and be replaced by terrestrial plants. • Increased spread of drought-adapted alien invasive plant species.	• Increase in intensity of rainfall and flooding leading to increased surface runoff, resulting in increased soil erosion, soil loss and degradation. • Increasingly saturated soils leading to more standing water (ponding) which can result in more insect (pest) activity and their potential to carry diseases. • Increased wave energy and run-up (sea level rise and more storms) causing degradation of natural coastal defence structures.

Increased temperatures and heat extremes	Drought and decreased rainfall	Increase in rainfall, inland flooding and coastal storm impact
increasing the survival rate of insects and diseases.		

Human health

Settlements are faced with a variety of challenges, which may include rapid unplanned urbanization, climate-related pressures such as floods and heat waves, as well as unequal economic growth between different communities. This affects the health and development status within settlements. Climate-health linkages are complex and multi-faceted, and it can confidently be stated that climate change will amplify some of the existing health threats that are already faced by communities. Certain people and communities are especially vulnerable, including children, the elderly, the sick and the poor. Natural disasters (e.g., floods, drought, fires) can have immediate and long-term impacts on health. Poor emergency service delivery immediately after disaster can impact health, as well as damage to services such as water reticulation can have longer-lasting impacts on public health. Natural disasters can also create a conducive environment for the occurrence of mental health problems.

Increased temperatures and heat extremes	Drought and decreased rainfall	Increase in rainfall, inland flooding, and coastal flooding
• More exposure to high temperatures causing increased health risks including heat strokes. • Heat waves increase threat of cardiovascular, kidney, and respiratory disorders. • Increase in fire danger days causing increased loss of life and damage to health infrastructure. • Wildfire smoke significantly reducing air quality, both locally and in areas downwind of fires. Smoke exposure increases respiratory and cardiovascular hospitalizations; emergency department visits; medication dispensations for asthma, bronchitis, chest pain, chronic obstructive pulmonary disease, and respiratory infections; and medical visits for lung illnesses.	• Decreased soil moisture potentially creating more wind-blown dust which has negative impacts on air quality. • Increase in water-washed diseases and diarrhoeal diseases due to inadequate water availability. • Decreased precipitation causing changes in salinity of water, resulting in an increase in algal blooms which can likely lead to increases in food- and waterborne exposures.	• Wetter climate combined with increased temperatures may have negative health impacts as many diarrheal diseases vary seasonally, typically peaking during the rainy season. • Extreme rainfall and higher temperatures increasing the prevalence of fungi and mould indoors, with increased associated health concerns. • Increased flooding increasing the risk of drinking and wastewater treatment facilities being flooded, meaning that diarrhoeal diseases can be transmitted as wastewater

Increased temperatures and heat extremes	Drought and decreased rainfall	Increase in rainfall, inland flooding, and coastal flooding
• Increased emissions in biogenic volatile organic compounds from vegetation causing increases in air pollution. • Increase in evaporative emissions from cars contributing to exposure to, and health impacts from, air pollution. • Increase in distribution of vector-borne diseases in warmer areas. • Increased water temperatures leading to an increase in algal blooms which can likely lead to increases in food- and waterborne exposures. • Increased temperatures combined with fewer clouds (e.g., from increased subsidence that is projected for parts of South Africa) causing increased exposure to UVR which will have negative impacts on health. • Increased temperatures increasing the reaction between certain pollutants and sunlight and heat, resulting in more severe hazardous smog events.	• Increase in stagnant air, decreasing air quality.	systems overflow or drinking water treatment systems are breached. • Increase in natural disasters (e.g. floods) creating a conducive environment for the occurrence of mental health problems.

Culture and heritage

Culture refers to the dynamic totality of distinctive spiritual, material, intellectual, emotional and aesthetic features that characterise a society or social group, including its arts, but also intangible aspects such as values, worldviews, ideas and beliefs, and the expression of these in individual and social behaviour, relationships, organisational and societal forms, and in economic, political, educational and judicial systems. The variance between these groups, known as cultural diversity, is illustrated by the many ways in which the cultures of groups and societies find expression. Within an urban context, culture may manifest itself spatially through heritage sites and resources. These areas are vulnerable to the effects of climate change and require particular management and sensitivity within planning. This heritage may include wildlife and scenic parks, sites of scientific or historic importance, national monuments, historic buildings, works of art, literature and music, oral traditions and museum collections together with their documentation. Due to the sensitive nature of culture and heritage, the physical and cultural value associated with these sites and resources is vulnerable to any aesthetic and functional changes caused by climate change. Potential physical impacts may have indirect social consequences.

Increased temperatures and heat extremes	Drought and decreased rainfall	Increase in rainfall, inland flooding, and coastal flooding
• Increased temperature having significant impacts on the comfort levels of built heritage resources, resulting in the building no longer being fit-for-purpose. • Increased demand for additional heating and cooling resulting in the installation of heating, ventilation and air-conditioning systems with potential negative consequences on the heritage value. • Increased heat stress potentially impacting on the materials and structural integrity of heritage resources. • Migration of several plant species due to changing climate patterns, posing a threat to the conservation of biodiversity hotspots, and potentially altering heritage places. • Increase in veld and forest fires raising the threat of fire to all heritage resources, natural and built, as well as posing health risks to heritage resource dwellers from exposure to smoke and ash pollution.	• Decreased rainfall impacting negatively on ground moisture levels and thus the geological conditions of sensitive heritage resources. Drying out clays, for example, will shrink and potentially undermine founding conditions.	• Increased rainfall in areas with clay soils resulting in swelling which poses a threat to the structural integrity of heritage resources. • Increased floods and changes in precipitation resulting in increasing vulnerability of archaeological evidences buried underground due to changing stratigraphic integrity of the soils. • Increased threat to properties listed as cultural heritage in coastal lowlands due to increased precipitation, sea level and coastal erosion. • Increased threat to materials and structural integrity of heritage resources exposed to higher humidity/ precipitation levels.