CLIMATE RISK AND VULNERABILITY ASSESSMENT REPORT - (FINAL-V1.1)

# Provision of Project Preparation Services to the South African National Biodiversity Institute (SANBI) through the GCF Project Preparation Facility (PPF)

17 March 2025

This report emanates from the project "Scaling up ecosystem-based approaches to managing climate intensified disaster risks in vulnerable regions of South Africa." Commissioned by the South African National Biodiverse Institute (SANBI).

SANBI would like to thank the following institution for contributing towards the project and this report:

**South African Weather Service (SAWS)**

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| Acronym | Definition |
|---|---|
| **ACDI** | African Climate and Development Initiative |
| **ALTCDD** | Longest Period of Consecutive Dry Days |
| **AMS** | Annual Maximum Series |
| **AR4** | (IPCC) Assessment Report Four |
| **AR5** | (IPCC) Assessment Report Five |
| **AR6** | (IPCC) Assessment Report Six |
| **CCAM** | Conformal-Cubic Atmospheric Model |
| **CCKP** | Climate Change Knowledge Portal |
| **CCSM4** | Community Climate System Model |
| **CHPC** | Centre for High Performance Computing |
| **CGCM** | Coupled General Circulation Model |
| **CMIP5** | Coupled Model Intercomparison Project Phase five |
| **CMIP6** | Coupled Model Intercomparison Project Phase Six |
| **CNRM-CM5** | Coupled Model Intercomparison Project Phases Five |
| **CORDEX-CORE** | Coordinated Regional Downscaling Experiment CORE |
| **CRU** | Climatic Research Unit |
| **CRVA** | Climate Risk and Vulnerability Assessment |
| **CSIR** | Council for Scientific and Industrial Research |
| **CSIRO** | Commonwealth Scientific and Industrial Research Organisation |
| **DEM** | Digital Elevation Model |
| **DFFE: EP** | Department of Forestry Fisheries and the Environment Environmental Programme |
| **DFFE** | Department of Forestry Fisheries and the Environment |
| **DM** | District Municipality |
| **DRR** | Disaster Risk Reduction |
| **DWS** | Department of Water and Sanitation |
| **Eco-DRR** | Ecosystem-Based Disaster Risk Reduction |
| **EI** | Ecological Infrastructure |
| **ENSO** | El Niño-Southern Oscillation |
| **FFP** | Full Funding Proposal |
| **FHI** | Flood Hazard Index |
| **FPA** | Fire Protection Association |
| **GCF** | Green Climate Fund |
| **GCI** | Global Change Institute |
| **GCM** | Global Climate Model |
| **GFDL-CM3** | Geophysical Fluid Dynamics Laboratory Coupled Model |
| **GHG** | Green House Gas |
| **GIS** | Geographic Information System |
| **ha** | hectare |
| **IAM** | Integrated Assessment Models |
| **IAP** | Invasive Alien Plant |
| **IFRM** | Integrated Flood Risk Management |
| **IPCC** | International Panel on Climate Change |
| **KZN** | KwaZulu-Natal |
| **$km^2$** | square kilometres |
| **LM** | Local Municipality |
| **LTAS** | Long Term Adaptation Scenarios |
| **masl** | meters above sea level |
| **MCA** | Multi-Criteria Assessment |
| **mm** | millimetre |
| **MPI-ESM-LR** | Max Plank Institute Coupled Earth System Model |
| **MWS** | Mean Wind Speed |
| **NbS** | Nature-based Solutions |

| Acronym | Definition |
|---|---|
| **NCA** | Natural Capital Account |
| **NDMC** | National Disaster Management Centre |
| **NGO** | Non-Governmental Organisation |
| **NorESM1-m** | Norwegian Earth System Model |
| **OFHSM** | Overland Flood Hazard Susceptibility Map |
| **PPF** | Project Preparation Facility |
| **PRCPTOT** | Total Annual Rainfall |
| **QC** | Quaternary Catchment |
| **R95P** | Total Heavy Rainfall |
| **RCP** | Representative Concentration Pathways |
| **RLMA&SI** | Regional L-Moment Algorithm and Scale Invariance |
| **RX1DAY** | Annual Maximum 1-Day Rainfall |
| **SADC** | Southern African Development Community |
| **SANBI** | South African National Biodiversity Institute |
| **SAWS** | South African Weather Service |
| **SCS** | Soil Conservation Service |
| **SPEI** | Standardised Precipitation and Evaporation Index |
| **SPI** | Standardised Precipitation Index |
| **SRES** | Special Report Emission Scenarios |
| **SSPs** | Shared Socioeconomic Pathways |
| **SST** | Sea Surface Temperature |
| **SWSA** | Strategic Water Source Area |
| **TAR** | |
| **TAS** | Mean Air Temperature |
| **TG** | Daily Mean Temperature |
| **TN90P** | Frequency of Very Hot Nights |
| **TNC** | Third National Communication |
| **TS** | Time Series |
| **TX90P** | Frequency of Very Hot/Warm Days |
| **UCT** | University of Cape Town |
| **UNFCCC** | United Nations Framework Convention on Climate Change |
| **WG1** | Working Group 1 |
| **Wits** | University of the Witwatersrand, Johannesburg |
| **WSDI** | Warm Spell Duration Index (Heat Waves) |
| **WWF** | World Wide Fund for Nature |
| **°C** | Degrees Celsius |
| **%** | Percentage |

# 1 Introduction

## 1.1 PROJECT RATIONALE

In South Africa, the increasing frequency and severity of hydrometeorological events – notably high temperature events, floods and droughts - have been recorded in recent decades, which is symptomatic of a changing global climate (Engelbrecht, 2023). Similarly, wildfires have caused significant damage and destruction to among others rangeland and domestic livestock systems as well as forest reserves - even though the records associated with such events are not as extensive as that of floods and droughts. Records of past flooding events in South Africa extend back to 1652 through records from contemporary diaries of the time, where daily records of weather phenomena were kept (Naidoo, 2016). From the middle of the previous century, since 1959, the frequency and severity of flood hazards have been reported to steadily increase (Busayo, et al., 2022). Droughts have a similarly vast historical track record (Ballard, 1986) with major drought periods in the past few decades including 1982–1984, 1991–1992, 1994–1995, 2004–2005, 2008–2009, 2015–2016, and the most recent in 2018–2020 (Mahlalela, et al., 2020; SASSCAL, 2020; Walz, et al., 2020; Unganai & F.N., 1998). Future climate projections and downscaling show that an increasing trend in intensity and magnitude of hydrometeorological hazards including periods of high temperatures, prolonged and more intense drought conditions as well as more intense precipitation (resulting in crop failure, wildfires and floods)s is expected to continue.

Flooding is often considered as significantly devastating natural hazard to manage through disaster risk reduction (DRR) strategies. Integrated flood risk management (IFRM) describes a broader approach, entailing a combination of spatial design and integrated catchment management (especially upstream), and structural as well as non-structural elements, which in combined manner improves resilience to flood disasters. Ecosystem-based approaches and nature-based solutions (NbS) falls within the ambit of ecosystem-based DRR (Eco-DRR) approaches and aim to restore and enhance the natural dynamics of ecosystems to buffer the adverse impacts of climate change, as well as providing many environmental, socioeconomic, and biodiversity benefits for flood risk management solutions (Gajjar, et al., 2021). Some of the latest notable events in South Africa in terms of flooding occurred in April of 2022, when severe storms caused by a cut-off low pressure system located off the coastline of KwaZulu-Natal (KZN), resulted in significant flooding and landslides across the region – even into the interior. Investigations indicated that the cut-off low pressure system ("depression") morphed into a tropical cyclone type system, which is extremely rare considering the latitude of the storm (approximately 30 degrees south of the equator) (Engelbrecht, 2023). Floods further hit South Africa in February-March 2023 due to heavy rainfall as a result of the La Niña weather phenomenon – submerging homes and even entire villages in level areas in the North West Province. Torrential rain damaged and destroyed buildings, bridges and road infrastructure especially in Mpumalanga province, and flash flooding occurred especially in parts of the Eastern Cape Province (FloodList, 2023).

Similarly, drought preparedness and drought mitigation – especially in developing settings worldwide, can be promoted through NbS and ecosystem-based approaches (Solh. & Ginkel, 2014). With drought being one of the major constraints affecting food security and livelihoods, rural communities are often more adversely affected than their urban counterparts (Gajjar, et al., 2021). Coping with drought and water scarcity are critical to address major developmental challenges in dry areas, namely poverty, hunger, environmental degradation and social conflict. Drought is a climatic event that cannot be prevented, but interventions and preparedness to drought can help to: (i) be better prepared to cope with drought; (ii) develop more resilient ecosystems; (iii) improve resilience to recover from drought; and (iv) mitigate the impacts of droughts. Preparedness strategies to drought include for example: (a) geographical shifts of agricultural systems; (b) climate-proofing rainfall-based systems; (c) making irrigated systems more efficient; and (d) expanding the intermediate rainfed-irrigated systems (Gajjar, et al., 2021).

Climate change is also anticipated to impact the likelihood and intensity of wildfires. There are complex feedback loops between climate and biomass build-up, including through $CO_2$ fertilisation effects (Allen et al 2023). This is exacerbated by widescale invasion of exotic and highly flammable tree and shrub species into the natural environment (Brooks et al 2004). Consequently, impacts of wildfire to life, rangeland and livestock and associated livelihoods, wildlife economies, and infrastructure are anticipated to increase (Engelbrecht, 2023). (FloodList, 2023). With the La Niña / El Niño oscillation playing a critical role in the flood-drought cycle, floods are often interspersed with droughts, and therefore, in areas that are both flood and drought prone, it is becoming increasingly important to consider the heightened stressor environment that communities live in, in areas where both hazards occur sequentially. In areas where wet spells are prevalent with significant associated biomass growth associated, followed by dry spells and high heat, wildfires then dominate as a result.

In response, South Africa's National Biodiversity Institute (SANBI) is preparing a full application, with the associated supporting documents, to the Green Climate Fund (GCF) to fund a programme to scale up ecosystem-based approaches to managing climate intensified disaster risks in vulnerable regions of South Africa (the Eco-DRR project). Ecosystem-based approaches are broadly accepted as a cost-effective and sustainable means to promoting resilience in communities vulnerable to climate change intensified drought, flood and wildfire and this project will utilise ecosystem-based approaches to reduce the impacts of climate change to the benefit of 5 481 886 people. This will be achieved through the rehabilitation of vulnerable catchments, the integration of ecosystem-based approaches into settlement planning and disaster risk reduction (DRR), and the creation of an enabling environment that unlocks private sector finance and scales best practices across South Africa.

Some of the interventions that are envisioned for the Eco-DRR project include a range of ecosystem-based approaches coupled with activities related to the enabling environment and knowledge management. More detail regarding the specific activities to be implemented under the Eco-DRR project is presented in the Theory of Change (ToC).

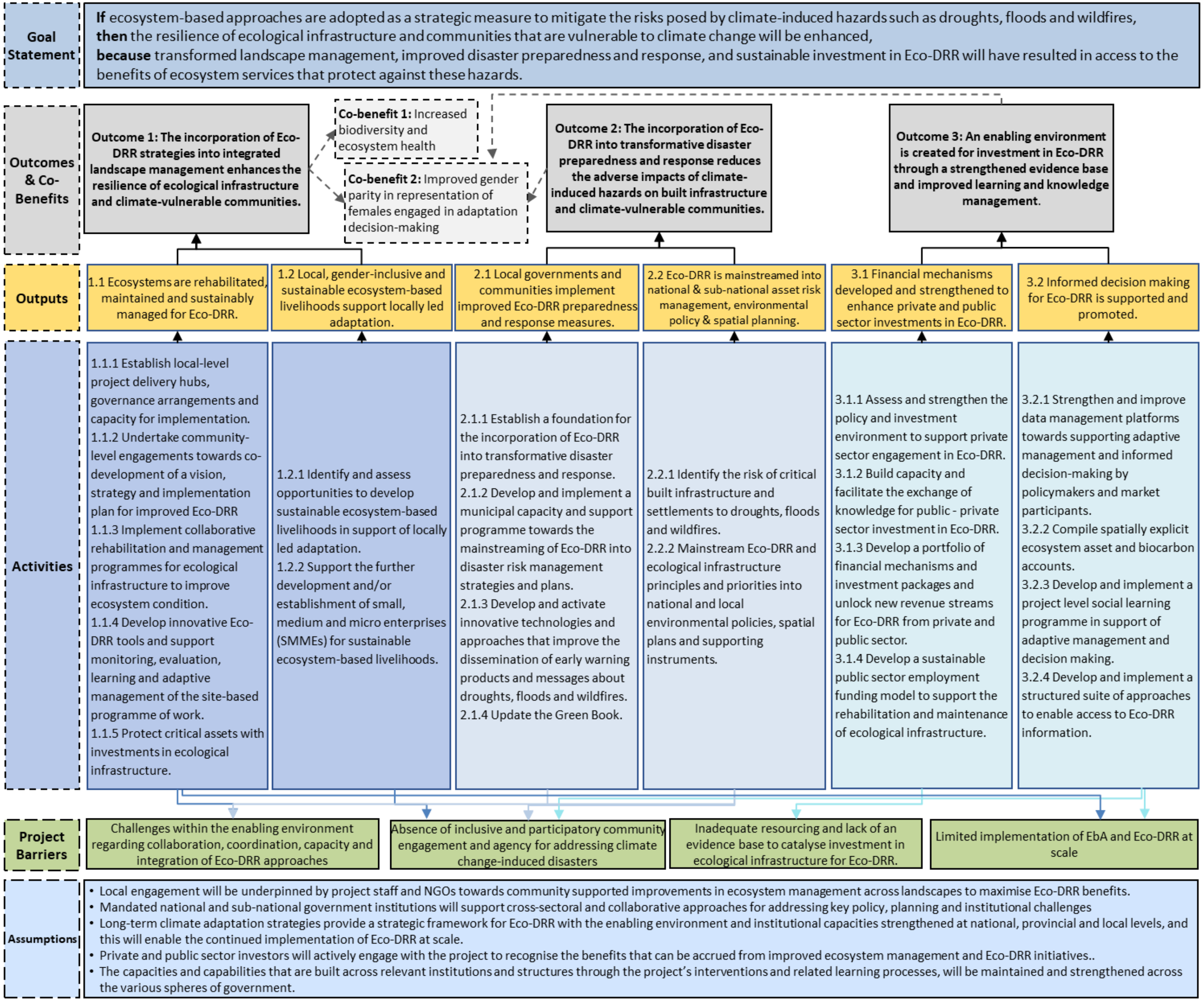



*Figure 1-1: Theory of change for Eco-DRR project*

During concept note development, seven district municipalities (DMs) were selected through a consultative and research driven process by SANBI, NDMC and DFFE. These seven DMs underwent a multicriteria evaluation process to assess their susceptibility to climate hazards coupled with other socio-economic and biophysical information. This helped to identify potential "candidate sites" within the DMs, inside which potential interventions can be implemented - represented by Output 1 in the ToC.

The proposed interventions at each site will be subjected to a feasibility study as well as financial and economic appraisals. The feasibility studies will be accompanied by gender, environmental and social plans applicable to the proposed interventions, and coupled with a monitoring and evaluation logical framework, site-specific risk assessments and detailed project designs. All the outputs as the activities progress, will feed into the drafting, final write-up and submission of the FFP and its Annexes. The GCF FFP and Annexes will undergo iterations after submission, in response to comments from GCF during the review phase.

This report forms part of the key components of Output 2 of the project, focussing on the ***Climate Risk and Vulnerability Assessment*** (CRVA), as part of the -overall process to get to identify the final implementation sites.

The CRVA evolved over more than a year, since the beginning of the project analysis. During this period there was initially a broad overview on three core climate hazards (floods, droughts and wildfires). In the early stages of the assessment, SANBI realised the critical nature of flooding and the severe impacts that it has, as well as the linkages that it has with other hazards and levels of vulnerability and resilience. An in-depth focus was then placed toward assessing flooding as the key hazard for the study. Finally, post the completion of the CRVA and as a consequence of ongoing consultation with effected communities and key stakeholders, the decision was made to again expand the broader focus to include all three hazards: floods, droughts and wildfires.

This means that some components of each of the three hazards in the analysis within this document may be presented to a differing level of detail, with a significantly intensive focus on precipitation and associated floods.

During the CRVA investigations a shortlist of five districts was decided on from the original seven proposed. Post the completion of this document additional climate data (the Wits-GCI - SANBI fact sheets – Annexure B) as well as additional data from local level and stakeholder consultation has become available. This has resulted in changes in the focus areas within Districts, with improved understanding of potential Eco-DRR interventions. This CRVA should be interpreted as foundational information that guides the ultimate site selection and technology interventions. It is essential to acknowledge the context in which this assessment was developed, particularly during the proposal formulation phase, and to recognise any subsequent modifications to the final proposal that occurred following the completion of this analysis. The primary elements concerning climate hazards, social vulnerability, and exposure, remain salient and relevant.

## 1.2 STUDY OBJECTIVES

The objectives of the CRVA that is reported on in this document are to:

- Reflect on the analysis of spatial and non-spatial data, homogenously across South Africa, but specifically the five selected DMs, in support of final implementation site selection that would lead to interventions at specific locations.
- Carry out a CRVA by identifying and analysing the impact of identified climate change intensified hydrometeorological hazards (e.g. extreme rainfall and therefore flooding and drought) on vulnerable and capacity-constrained socio-economic systems, settlements and communities within the five DMs.
- Assess the future change in flood risk and drought based on hydrometeorological hazards and community as well as settlement-level vulnerability, within each of the Districts, by investigating climate change scenarios.

## 1.3 STRUCTURE OF THE REPORT

The structure of this report is as follows:

- Section 1 - provides an introduction to the report including the rationale and objectives;
- Section 2 – outlines the previous work done before the CRVA that contributes to this assessment including selection of the priority DMs, candidate site selection, baseline assessment and review of regional climate change.
- Section 3 - describes the overview of the approach and methods applied in the project.
- Section 4 - presents an overview of the CRVA results on climate change hazards specifically as it relates to flood and drought hazards. This includes results from the hazard, vulnerability and exposure assessment and is presented according to the DMs.
- Section 5 – provides the conclusion and recommendations related to the selected DMs.

# 2 Background to the CRVA

The CRVA, presented in this report pays particular attention to floods, along with droughts and wildfires as important hazards with multiple impacts, especially when the hazards transpire in close succession to each other. The CRVA was guided by an iteration of literature and in-field research activities, expert reviews, stakeholder and expert workshops, and spatial as well as non-spatial data assessments. The CRVA took place in three Phases: 1) selection of the seven priority DMs during concept note development; 2) Output 1 – candidate site selection (5 DMs); and 3) Output 2 – baseline assessment. A summary of each Phase is presented below.

## 2.1 SELECTION OF PRIORITY DMs

In 2016, SANBI was accredited as a direct access entity for the GCF, which was accompanied by access to funding of USD 50 million under which an unlimited number of projects could be included. Following accreditation, SANBI, together with the DFFE: EP and the NDMC, spent eighteen months identifying projects that could be developed into GCF full funding proposals, with the Eco-DRR project being one of these projects.

As part of the GCF FFP application process, a concept note was developed for the Eco-DRR project which was endorsed in 2019 and subsequently revised. A pre-feasibility study was also undertaken during concept development. The study suggested that QCs be the subsequent unit of analysis, and that high-priority QCs be chosen based on vulnerability to climate impacts; plus other vulnerability indicators including land tenure, density of invasive alien plants (IAPs), reliance of communities on ecosystem goods and services; potential for scale-up and replication of existing projects and programmes; and community buy-in (for local ownership).

SANBI followed up the concept note development with a multi-stakeholder consultation and engagement process, examining, together with the NDMC and DFFE, the spatial overlap of climate change hazards on floods, droughts and wildfire hazards with the additional vulnerability factors relevant to the programme. Stakeholders, including experts from leading South African institutions and key departments such as the University of Cape Town, University of Witwatersrand, and the South African Environment Observation Network, arrived at and adopted a final selection rubric. The criteria chosen were:

- *Increase in climate hazards* – areas where climate change and climate variability are expected to increase the frequency and/or intensity of floods, wildfires and droughts;
- *High impacts on the population from disasters emanating from such climate* hazards – records of loss and damage from floods, droughts, and wildfires;
- *Linkages between floods, wildfires, droughts and biodiversity management* – where areas are relatively rich in biodiversity but where there is a need for enhanced management of the ecosystem in the face of increased climate hazards and impacts; with a specific focus on soil heath;

- *Linkages between biodiversity interventions with impacts on local economy and settlements* – areas with potential for improved biodiversity management aimed at reducing vulnerability and enhancing adaptive capacity through restoration of ecosystem services, income-generation opportunities and economic activities related to biodiversity management strategies;
- *Existence of landscape initiatives* related to ecosystem and biodiversity services – areas where prior interventions have taken place and where there is potential to build on, scale-up or replicate the prior interventions to achieve greater impact and broader paradigm shift; and
- *Existence of some local capacity and ongoing community of practice* – areas demonstrated institutional buy-in and ownership, to increase the opportunity for interventions to have sustainable long-term activities associated with it.

Through a consensus-driven approach coupled with a Project Site Selection Workshop in 2021, seven priority DMs were selected within the high-priority at-risk tertiary catchments that also reflected the criteria above. These DMs are as follows (

Figure *2-1*):

1. Waterberg District – in Limpopo Province;
2. Garden Route – in Western Cape Province;
3. Alfred Nzo District – in Eastern Cape Province;
4. Joe Gqabi District – in Eastern Cape Province;
5. Ehlanzeni District – in Mpumalanga Province;
6. Sekhukhune District – in Limpopo Province; and
7. Ngaka Modiri District – in North West Province.

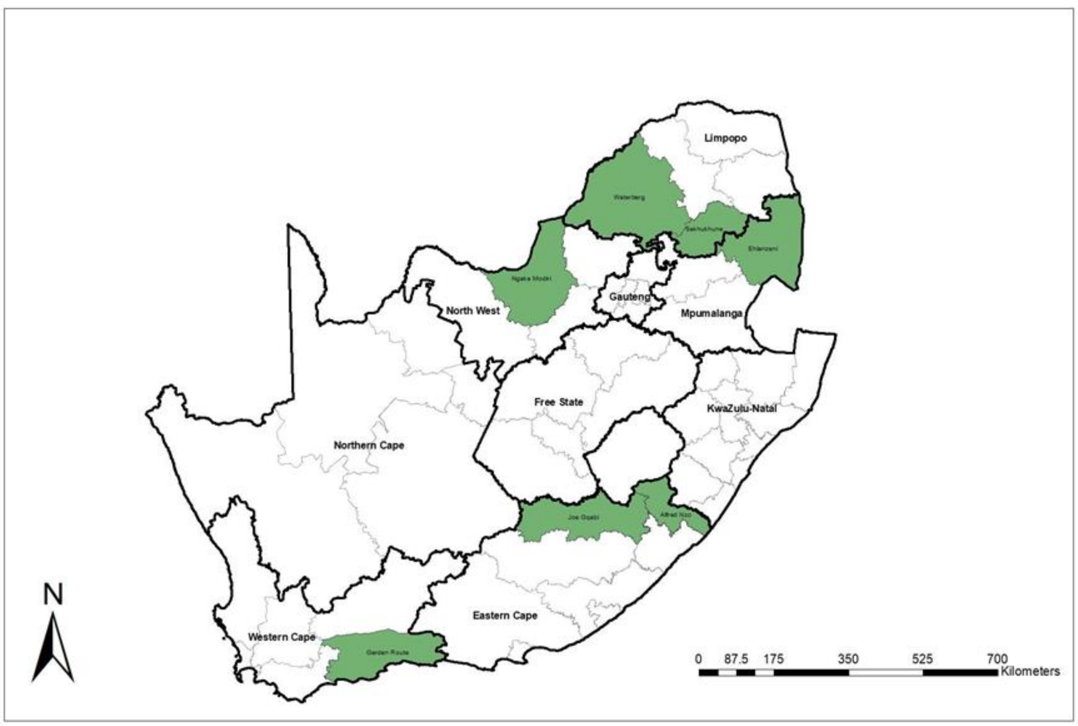



*Figure 2-1: The seven selected District municipalities*

Upon identification of the seven DMs, an analysis of the DMs was done to investigate the climate disaster risk drivers in the DMs. A study into future climate drivers of disaster risks across the seven DMs was undertaken by experts from the University of Cape Town's (UCT) African Climate and Development Initiative (ACDI). The study, drawing on data generated by Silmann et. al. , provided a first order assessment of projected changes in climatic drivers of four climatic hazards – flooding, drought, wildfire and heat stress (Sillmann, et al., 2013a; Sillmann, et al., 2013b).

The study was reported on by New (2021) and indicated that all seven DMs, across the four climatic hazards considered, *will experience increased climate risk which will be statistically significant* at 2.0 °C of warming, and in many cases, at 1.5 °C of warming, making them suitable candidates for climate change adaptation responses and interventions (New, 2021).

The table below (from New, 2021) presents the severity of projected changes in the climate hazards considered, over the rainfall regions[1] within which the seven selected DMs s are located (New, 2021). The numbers in the table are interpreted as follows: A severity of 3, 2, 1 correspond to the projected changes being statistically significant from today's climate 1.5, 2.0 and 2.5-3.0 °C warming, respectively, while a severity of 0 (zero) means that the change is not significant, even at 3.0 °C of warming. Indices representative of different climate hazards that were considered during the analysis include annual maximum 1-day rainfall (RX1DAY), total heavy rainfall (R99P), total annual rainfall (PRCPTOT), longest period of consecutive dry days (ALTCDD), mean air temperature (TAS), frequency of very hot days (TX90P), frequency of very hot nights (TN90P), warm spell duration (heat waves) (WSDI), and mean wind speed (MWS).

*Table 2-1: Average of ranking of metrics for each hazard, via taking the mean of the ranking for each metric, and then the overall average across all hazards*

| Province | DM | Rainfall Region | Flooding | Drought | Fire | Heat | All |
|---|---|---|---|---|---|---|---|
| **Western Cape** | **Garden Route** | South Coast | 0.5 | 3.0 | 3.0 | 3.0 | 2.2 |
| **Limpopo** | **Waterberg** | North East Interior | 3.0 | 2.7 | 2.0 | 3.0 | 2.6 |
| **Eastern Cape** | **Alfred Nzo** | Transkei Coast | 2.0 | 2.0 | 2.3 | 3.0 | 2.1 |
| **Eastern Cape** | **Joe Gqabi** | Central-South Interior and Transkei Coast | 2.5 | 2.7 | 2.5 | 3.0 | 2.6 |
| **Mpumalanga** | **Ehlanzeni** | North East Lowveld | 3.0 | 2.0 | 1.8 | 3.0 | 2.3 |
| **Limpopo** | **Sekhukhune** | East Interior | 3.0 | 2.0 | 1.5 | 3.0 | 2.2 |
| **North West** | **Ngaka Modiri Molema** | North East and Central Interior | 3.0 | 2.7 | 2.0 | 3.0 | 2.6 |

All the DMs will experience statistically significant increases in heat stress risk at 1.5 °C warming, noting the consistent increases in mean temperature and extreme warm temperature metrics across the whole country (Table 2-1). The Ngaka Modiri Molema,

[1] Overall, rainfall is greatest in the east and gradually decreases westward, with some semi-desert areas along the Central-southern Karoo and western edge of the country. For most of the country, rain falls mainly in the summer months with brief afternoon thunderstorms. The exception is the Western Cape where the climate is Mediterranean and it rains more in the wintertime. In the summer rainfall region, in the central and northern parts of the country, rain falls from October to February and is often heavy, with the amount of precipitation increasing from west to east. The Eastern Cape experience both summer and winter rainfall, which may come down in the form of severe downpours. The arid regions in the north-west, has the driest areas being the north-west coast. The interior plateau, the eastern Free State, KwaZulu-Natal, Eastern Cape and Mpumalanga Provinces receive almost all its rain as thunderstorms (convective rains related to high temperatures).

Waterberg, Sekhukhune and Ehlanzeni DMs are projected to have the most significant increases in rainfall-driven flood risk, all of which become statistically different from the present day at 1.5 °C of warming. These DMs also have moderate projected changes in drought risk, which would become significant at 2.0 °C of warming, while the Ngaka Modiri Molema and Waterberg DMs also have significant changes in fire risk at 2.0 °C warming (New, 2021).

*Table 2-2: Severity of projected changes in climate metrics relevant to flooding, drought, fire and heat stress over the rainfall regions within the seven DMs*

| Province | DM | Rainfall Region | Flooding | | Drought | | | Fire | | | | Heat Stress | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Increase in maximum daily rainfall | Increase in total heavy rainfall | Decrease in annual rainfall | Increase in evaporative drying | Increase in dry spell | Higher fuel dryness | Higher dryness and fuel flammability | | Stron-ger wind | [2]Higher Temperatures | | More heat waves |
| | | | RX1DAY | R99P | PRCPTOT | TAS | ALTCDO | PRCPTOT | TAS / TX90P | WSDA | MSW | TX90 | TN90 | WSDI |
| Western Cape | Garden Route | South Coast | 1 | 0 | 3 | 3 | 3 | 3 | 3 | 3 | ++ | 3 | 3 | 3 |
| Limpopo | Water-berg | North East Interior | 3 | 3 | 2 | 3 | 3 | 2 | 3 | 3 | - | 3 | 3 | 3 |
| Eastern Cape | Alfred Nzo | Transkei Coast | 2 | 2 | 1 | 3 | 2 | 1 | 3 | 3 | + | 3 | 3 | 3 |
| Eastern Cape | Joe Gqabi | Central-South Interior and Transkei Coast | 3 | 2 | 2 | 3 | 3 | 2 | 3 | 3 | + | 3 | 3 | 3 |
| Mpum-alanga | Ehlan-zeni | North East Lowveld | 3 | 3 | 1 | 3 | 2 | 1 | 3 | 3 | - | 3 | 3 | 3 |
| Limpopo | Sekhu-khune | East Interior | 3 | 3 | 0 | 3 | 3 | 0 | 3 | 3 | - | 3 | 3 | 3 |
| North West | Ngaka Modiri Molema | North East and Central Interior | 3 | 2.5 | 2 | 3 | 3 | 2 | 3 | 3 | - | 3 | 3 | 3 |

A summary of the results in Table 2-2 shows a pattern of steep increase in TAS, TX90P, TN90P and WSDI over the seven DMs. This on its own does not influence flood intensities - however, parched ground is less likely to absorb water and increases the risk of dangerous flash floods (Katwala, 2022). Therefore, where the trend is towards high intensity drought and dry periods, along with higher intensity precipitation, flooding is expected to be more severe. The study indicated that PRCPTOT shows varied patterns across the country – with the Alfred Nzo, Joe Gqabi, Ehlanzeni, Sekhukhune and Ngaka Modiri Molema DMs showing increased maximum daily rainfall. Heavy rainfall metrics (RX1DAY and R95P) are projected to increase across the north

[2] For windspeed, quantitative information on windspeed at different warming levels was not available, but an assessment from secondary information in (ref needed) was used to assess the magnitude of change in the future (++ = clear increase; + = moderate increase; - = no increase).

and east of the country – especially noting that in areas where future climate projections show that annual rainfall may not decrease much, heavy rainfall events increase. As a statement from the 2021 report of particular importance notes "... *even when total rainfall decreases, heavy rainfall stays the same or increases, indicating that more of the total rainfall falls as heavy rainfall events*" (New, 2021). This significant assertion highlights the importance, especially in the prioritised DMs, that flood hazards are very likely to increase, as a direct result of climate change.

## 2.2 CANDIDATE SITE SELECTION (OUTPUT 1)

Candidate sites, in this report, refer to potential locations for intervention implementation within the DMs that have been prioritised (as per Section 2.1) as potential implementation areas for the Eco-DRR project. The candidate site selection process recognised, to commence with, that all seven DMs have populations and environments that are exposed and vulnerable to climate hazards and the potential impacts of climate change and climate variability. The aim of the candidate site selection process was two-fold – first, to identify which of the seven DMs were most vulnerable – resulting in five DMs being selected - and second, to identify potential locations *within* the then five DMs that are more vulnerable to climate-induced floods, fires and droughts when compared to each other. This two-fold process took into consideration biophysical data (rangeland condition, biodiversity resilience and ecological infrastructure (EI) condition, potential risk of EI loss), socio-economic data (unprotected water sources, fuel for cooking, women- and child-headed households, poverty line), climate data and local stakeholder inputs, as well as expert inputs from DFFE: EP (Figure 2-2). Additionally, finer spatial resolution of the Green Book climate projections[3] were included in the assessment.

Rangeland EI condition is recognised as a critical indicator, as it encompasses rangelands, including grazing pastures vital to the rural livelihoods of the seven selected DMs, as well as woodlands and savanna ecosystems. The condition of these lands serves as an effective proxy for assessing shifts in the potential impacts associated with each identified hazard. Consequently, rangeland EI condition was assigned the highest weighting of 3 in the biophysical prioritisation framework. Change in EI condition, using soil loss as an indicator, was also included, however, assigned a weighting of 2 – a slightly lower weighted value, since at this time, the specific types of soil at each site is not known: soil specifics would be integrated in on-site assessments during project implementation. Potential for EI loss is driven by land transformation, and was assigned a weighting of 1, as it is not a direct indicator of degradation of EI but is important in terms of the threat of loss of EI due to land transformation.

[3] The Green Book is an open-access online planning support tool providing quantitative scientific evidence to support planning and design of climate-resilient, hazard-resistant settlements. The Green Book looks forward to the year 2050 by projecting settlement growth and likely climate change impacts on settlements in South Africa (Le Roux, et al., 2019).

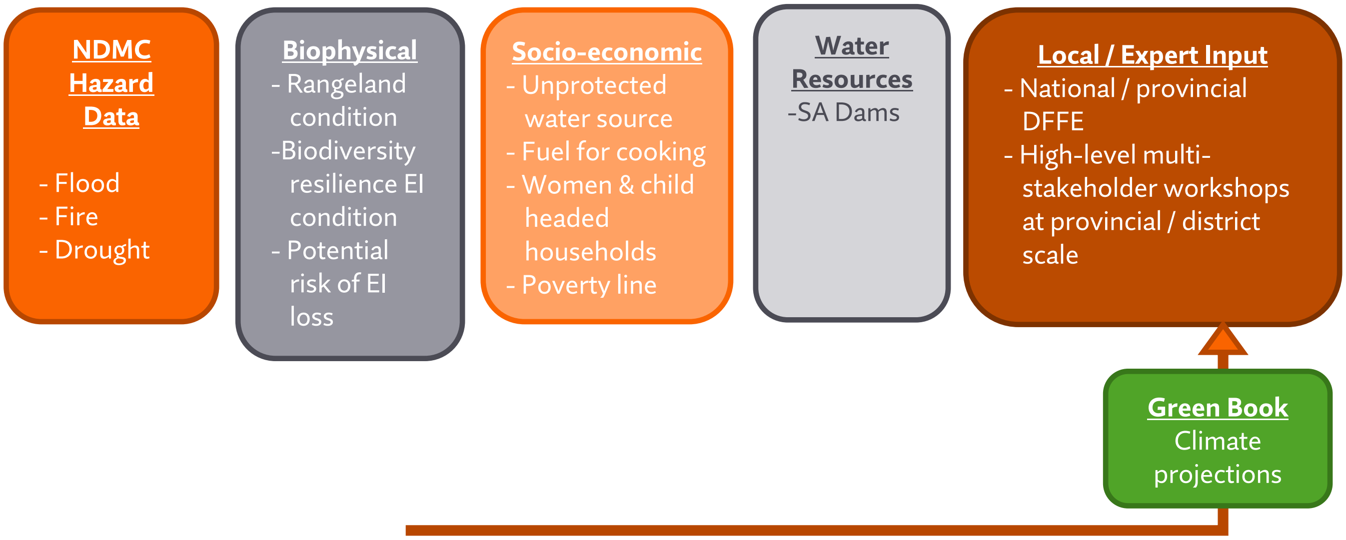



*Figure 2-2: Data used for candidate site selection process*

The data sources indicated in the figure above were analysed through a quantitative multi-criteria assessment (MCA) process using spatial and non-spatial data, and a qualitative process applying non-spatial information and knowledge gained through expert engagement. The result was a prioritisation of the DMs and the QCs within each of the seven DMs, based on relative assessment scores. The outcome of the MCA provided a score indicating the relative level of risk that each DM is subject to.

Of the seven DMs analysed, the Waterberg and Garden Route DMs respectively had the lowest scores (for combined floods, droughts and wildfires) when compared to the other DMs and were thus excluded from further analysis. The assessment further potential locations for intervention implementation within the **remaining five DMs** that had the highest scores when compared to the other locations in their respective DMs (Table 2-3). In some instances, certain locations were removed from the selection due to the absence of settlements or the small size of the location (see crossed-out text in Table 2-3). These two top potential locations for intervention implementation within each of the five DMs were considered for the baseline assessment and CRVA. There were no climate projections from the Green Book for the Ngaka Modiri Molema DM and the analysis of the DM only considered climate hazard data, biophysical data, socio-economic data and local as well as expert inputs from DFFE: EP.

*Table 2-3: Candidate sites within the five DMs*

| Province | DM | LM | Proportion of LM in Potential Location (ha) | Top Two Potential Locations according to quaternary catchments (QCs)[4] |
|---|---|---|---|---|
| **EASTERN CAPE** | **Alfred Nzo** | Umzimvubu | 598.4 | T32G |
| | | Ntabankulu | 24 217.5 | |
| | | Mbizana | 13 660.2 | |
| | | Umzimvubu | 202.6 | T40A |
| | | Mbizana | 12 717.1 | |

[4] When looking at potential locations, the use of QCs were considered within the five DMs due data availability and the hydrological nature of the areas.

| Province | DM | LM | Proportion of LM in Potential Location (ha) | Top Two Potential Locations according to quaternary catchments (QCs)[4] |
|---|---|---|---|---|
| | **Joe Gqabi** | ~~Elundini~~ | ~~291.4~~ | ~~T34H~~ |
| | | Elundini | 23 600.6 | T34A |
| | | Senqu | 478.6 | |
| | | Elundini | 20 144.1 | T35E |
| **MPUMALANGA** | **Ehlanzeni** | Thaba Chweu | 7 880.1 | B60H |
| | | Bushbuckridge | 15 749.5 | X32F |
| **LIMPOPO** | **Sekhukhune** | Ephraim Mogale | 1 010.2 | B51H |
| | | Makhuduthamaga | 70 732.4 | |
| | | Makhuduthamaga | 43 083.3 | B52B |
| | | Fetakgomo Tubatse | 20 220.7 | |
| **NORTH WEST** | **Ngaka Modiri Molema**** | ~~Ratlou~~ | ~~10 756.5~~ | ~~D41C~~ |
| | | Ratlou | 435 119.1 | D41B |
| | | Tswaing | 73 738.4 | |
| | | Mafikeng | 37 040.7 | |
| | | Ditsobotla | 3 357.5 | |
| | | Ramotshere Moiloa | 68 511.4 | A31H |

** More details regarding how the scoring was determined can be found in the Candidate Site Selection Report.*
***The results for Ngaka Modiri Molema DM do not incorporate climate data as this was not available at the time of analysis.*

In Figure 2-3 the location of the top two potential locations identified per the five DMs are shown in yellow .

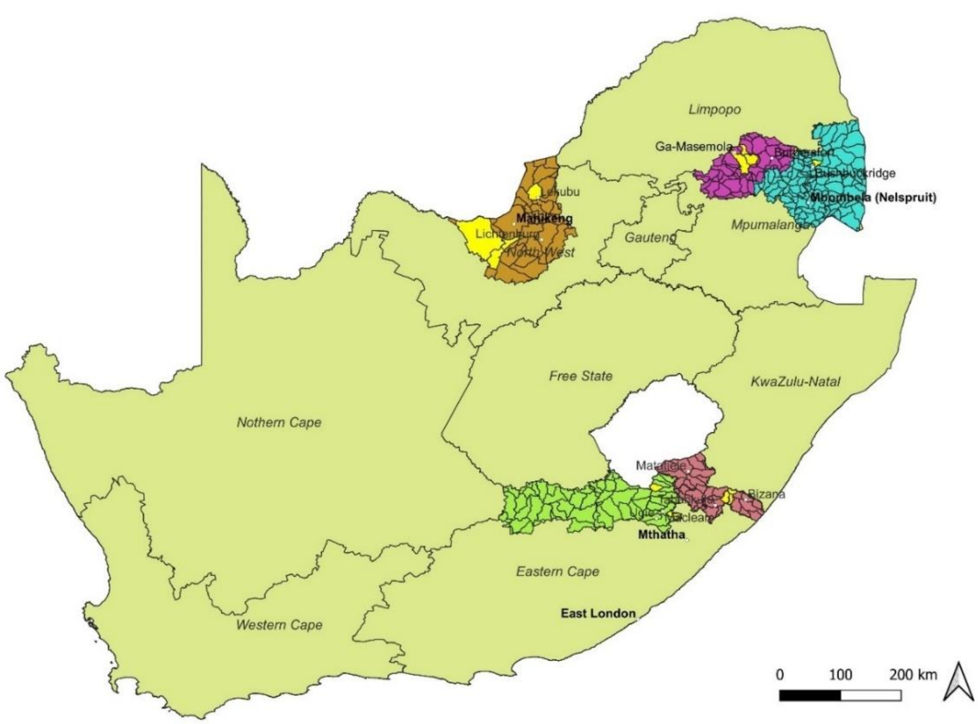



*Figure 2-3: Map showing the potential locations (candidate sites) for intervention implementation within the five DMs*

More details regarding the candidate site selection process can be found in the report titled "**Process and Selection Criteria for Candidate Site Identification and Prioritisation**" (SANBI, 2022) that was developed under this project.

During the site visits and workshops that were held with a range of stakeholders within each of the five DMs (Alfred Nzo, Joe Gqabi, Ehlanzeni, Sekhukhune and Ngaka Modiri Molema), discussions included a focus on floods, droughts (and the inter-relationship between wet and dry periods/events) as well as consideration of the interrelationship of these two hazards with wildfires. The potential for interventions regarding floods and droughts along with associated hazards specific to each DM was interrogated. The stakeholders during the process included provincial and municipal officials, local non-governmental organisations (NGOs) as well as community leaders, along with representatives from DFFE. Through this discourse, the most significant concern across all the DMs was noted as the rapid onset and impacts of flooding, noting that rural communities in particular, across the DMs, are extremely sensitive to the impacts of flood events. Further, due to limited response time and adaptive capacity at a local level towards floods in particular, the rural communities and communities that live in often semi-formalised settled areas but outside of larger towns, are highly vulnerable. With regard to droughts, there was varying perspectives across the DMs, with some – notably those toward the north (Ngaka Modiri Molema, Ehlanzeni and Sekhukhune) reporting a higher vulnerability and perceived higher frequency of droughts, with higher heat intensities in the drought periods, than those toward the south (Alfred Nzo and Joe Gqabi DMs). Nevertheless, even those toward the south still noted droughts as a concern due to the intensity of such events, when it does occur. However, many stakeholders highlighted drought as a district-wide concern across the five DMs, rather than a site specific occurrence.

During the site visits, district-level workshops and engagements with local experts, challenges regarding the status of ecological and built infrastructure alike, in all the five DMs, were noted to further exacerbate these impacts of floods and droughts. Previous climate vulnerability studies undertaken in the period 2016-18 (Let's Respond Toolkit, n.d.) confirm these stakeholder inputs, all indicating that rural communities are highly sensitive to the impacts of flooding and droughts, and thus these hazards should be a priority focus to enable the building of climate resilience in such rural areas.

As stated earlier on in the document, based on area-specific and focus-hazard inputs, insights and requests from the local stakeholder engagements, it was agreed that the Eco-DRR project would focus at its core primarily on ***floods*** as a primary hazard, with ***droughts*** being secondary, and ***fires*** as an associated hazard. Erosion associated with floods, as well as droughts and wildfires lead to degraded landscapes, and the interaction between these hazards often gives rise again to increased flood impacts – thus enacting a circular process of ever-intensifying degradation and vulnerability. This interaction, coupled with further land degradation, has been underlined by the South Africa Government's declaration of a National State of Disaster in February 2023, after flood impacts across various provinces – most of which include the five priority DMs in this study. The floods were all caused by heavy rainfall, and areas affected included the Eastern Cape (where Joe Gqabi and Alfred Nzo DM's are located), Northern Cape, Mpumalanga (Ehlanzeni DM), KwaZulu-Natal, and North West (Ngaka Modiri Malema DM) (FloodList, 2023).

Whereas floods across many areas in the South African landscape are often fast onset events, the slow onset impacts of droughts are well recognised across the country, with wildfires occurring as fast onset events that result from the slow process of biomass accumulation triggered by dry spells and high heat days. Due to the recurring nature of dry spells in the southern

Africa region, and frequent occurrence of high numbers of heat days, national, provincial and local spheres of government have existing programmes focussing on building adaptive capacity to more effectively support communities during these slow-onset events. Likewise, the management of fire regimes in natural landscapes and the presence of, for example, Fire Protection Associations (FPA) and local civil society groups involved in landscape-based fire management programmes, provide capacity to support management and mitigation of the prevalence of fire under ever-warming climates. With regards to flooding, however, there is consistently reported limited capacity to address the rapid onset and ever-increasing variability of precipitation-related hazards. The contrasting nature of flooding, with huge deluges of water appearing and often disappearing within short timespans, versus droughts which come and go at a slow pace, puts the capacity of communities to the test. This testing occurs constantly and without reprieve, no matter what season it is, or which Oscillation pattern - El Niño and La Niña (the two opposite phases of the El Niño-Southern Oscillation (ENSO) cycle) - is present. Rapid onset floods *versus* slow onset droughts, are usually addressed through separate initiatives, hence the decision to focus primarily on floods in the Eco-DRR project, with secondary consideration given to droughts.

The site visits to areas across the five DMs and stakeholder engagements during site visits with local experts, as well as via virtual interviews after the visits, further revealed limited institutional, financial and technical capacity in municipalities as well as communities in all five the DMs. This capacity constraint reflects as an inadequate ability to prepare for, prevent, mitigate, respond to and manage the impacts of floods and droughts alike. Rapid onset of floods and lack of early warning systems for floods and droughts, but especially to flash floods, were mentioned as having significant impacts not only at the time of the event, but thereafter - usually derailing or delaying other development initiatives as a result. Although, in the case of droughts, the situation usually progressively becomes worse over longer periods, and more time is available to communities and institutions to theoretically better prepare for drought-related impacts, the reality is that early warning and preparedness is generally not applied. This lack of early intervention often is due to the communities and institutions having to deal with other and especially rapid onset events, resulting in an inability to attend to the slower-onset nature of droughts. As a result, communities and institutions tend to be almost entirely reactive when responding to floods and drought alike (rather than proactive). Such a responsive approach is not productive and low mitigation, prevention and adaptation outcomes result, with the ultimate consequence being even lower resilience, higher vulnerability, and livelihoods that rely on external assistance and developmental support.

The impacts of droughts, floods and ultimately overall disaster risk levels, are explored in several publications, showing the complexity in understanding and addressing the impacts of climate change and climate variability on these hazards (Liu, et al., 2022; Sofia & Nikolopoulos, 2020).

The impacts of climate change related flood and drought disasters affect food production with subsequent impact on food security and human health and wellbeing – with subsequent stressors on governance and humanitarian actors when supporting communities affected by these hazards and secondary long-term impacts. Flood, drought and wildfire disasters alike have often devastating consequences on food production. Floods inundate settlements, farms, pastures and livestock, which could subsequently reduce crop yields and animal production. Droughts similarly impact food production through reduced yields, poor quality of produce, with lower subsequent market value and nutritional efficacy, or even entire crop failure. Wildfires can have devastating impacts on rangeland quality as well as result in loss of crops and livestock. Floods also destroys physical infrastructure and disrupts socio-economic activities which are linked to agriculture sector and could affect food production – inhibiting the ability of farmers to deliver their goods as well as communities to access markets. This eventually decreases food availability, accessibility, utilization, and stability in the region (Atanga & Tankpa, 2021)

Therefore, the need to undertake flood-, drought- and wildfire related interventions require a much deeper understanding and an integrated approach, than merely considering one or the other hazard on its own. In areas where only one of the hazards dominates, it is feasible to have a singular and focussed approach. However, where these hazards coalesce, a better understanding of how climate change induced ecosystem impacts occur is becoming increasingly important. The integrated approach in areas where multiple hazards dominate is especially necessary in rural and peri-urban or under-serviced communities where sensitivity and vulnerability to the impacts of hazards are high and resilience and capacity is low. Furthermore, the nexus between flood and drought hazards requires integrated approaches, since only integrated approaches to increase resilience against these hydro-extremes can bring the needed systemic changes because of the complexity of their impacts (Aich, 2023). An example of recent efforts include the joint flood and drought programmes of the World Meteorological Organisation and Global Water Partnership. These efforts focus on a combined approach to address both hazards in an integrated manner whilst enabling ecosystem-based approaches and NbS solutions on the ground, for example to protect services and road infrastructure, dwellings, crops and cropping as well as grazing land in differentiated manners against floods, droughts and wildfires. As a result, the resilience of communities and institutions are enhanced to provide a combined approach to the hazards. In this manner, a multiplication effect can be harnessed, where resilience is strengthened to these hazards at the same time, through improved capacity, awareness, and strengthening of community and institutional bonds.

## 2.3 BASELINE ASSESSMENT (OUTPUT 2)

The baseline report includes details of the five DMs and two potential locations for intervention implementation that are relevant to the proposed interventions and used to support the CRVA describe in this report. The report sought to carry out a baseline assessment of the current climate risk by assessing the impact of the identified climate change intensified hydrometeorological hazards (i.e. floods) on vulnerable socio-economic systems within the five DMs.

The World Wide Fund for Nature's (WWF) Risk Filter assessed the 3-day 50-year flood using historical climate data acquired from 1950-1999 (rainfall, max/min temperature etc.) to model baseline streamflow using the ACRU hydrological model (Figure 2-4) (WWF, 2023). Overlaying of the prioritised DMs was done in the below figure, under current conditions, at risk to flooding.

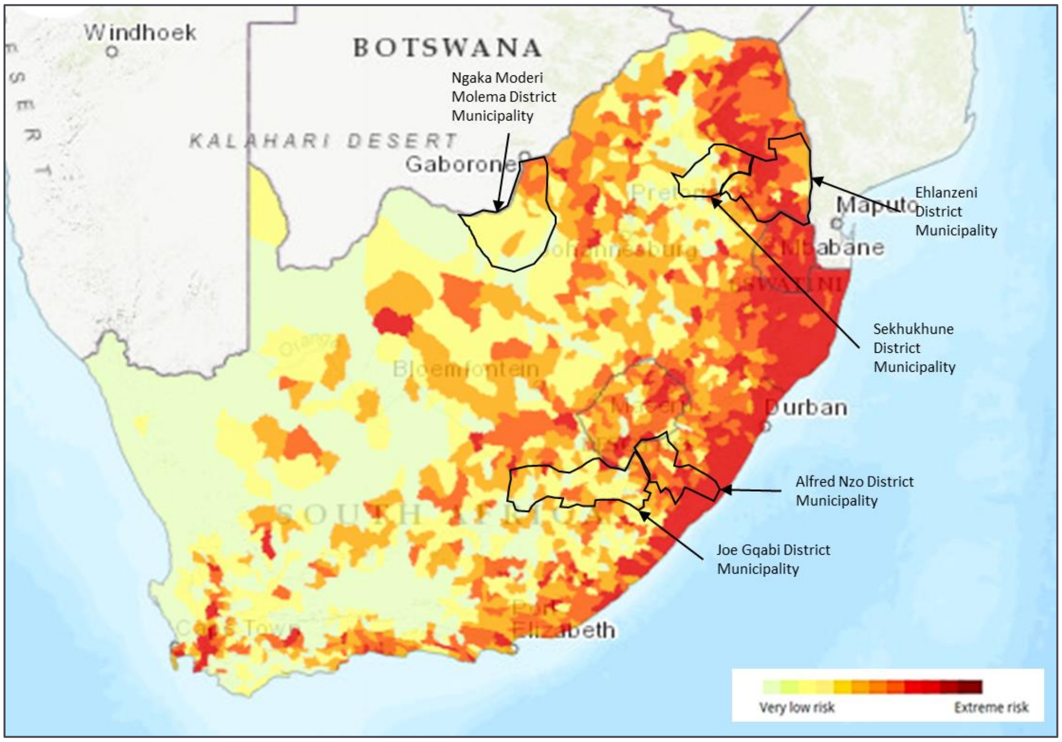



*Figure 2-4: Estimated flood occurrence*

The specific aspects of each site described in the Baseline Report include:

- An overview of climate change risk and vulnerability in South Africa and for each of the five DMs focusing on floods and drawing form a range of different climate change models and scenarios.
- Details of the biophysical characteristics of each priority DM including factors such as topography, soil type, land cover, and the state of EI including catchments, gullies, and IAPs.
- Information derived from the site visits and stakeholder workshops undertaken in each of the priority DMs.
- An evaluation of the vulnerability in each DM based on results of the multi-factor evaluation of vulnerability undertaken as part of the Green Book (CSIR, 2019) which includes social, physical and environmental vulnerabilities.
- Initial recommendations for potential ecosystem-based interventions to address increasing climate related risks in each of the five DMs.

The results from the baseline assessment indicated that there is clear evidence of climate change-induced hazards – specifically floods – and significant levels of underlying vulnerability in each of the five DMs. This substantiates the need for targeted support in these DMs for the co-identification, co-design and co-implementation of Eco-DRR approaches towards preparedness for increasingly severe floods due to climate change.

## 2.4 REGIONAL CLIMATE CHANGE

### 2.4.1 Latest Global Climate Model (GCM) Climate Scenarios, specifically SSPs

Climate scenarios are hypothetical futures based on key driving forces. Scenarios do not predict the future, but rather provide projections of what can happen or pathways to certain outcomes. Climate scenarios help understand the risks of climate change to support policymaking and adaptation plans and activities. Climate projections are always presented for a range of plausible pathways or targets. Climate change does not happen in isolation, but in concert with other processes of environmental, social, technical, economic, and cultural change. Scenario types have therefore emerged that embed climate change in this broader context of change. To capture a range of possible future emissions, energy system modellers have used integrated assessment models (IAMs) that simulate both future energy technologies and emissions. These produce emissions scenarios that are then used to run complex climate models that simulate how the climate might change in the future. Climate models take an enormous amount of computing power to run, and therefore the number of future emission scenarios that can be used tends to be limited. The scenarios are referred to as Representative Concentration Pathways (RCP) and Shared Socioeconomic Pathways (SSPs) and each has their rightful place in climate risk assessments.

This report refers to both RCPs as well as SSPs. While SSP's are considered more "recent" (through IPCC Sixth Assessment Report (AR 6)), RCP's remain significantly valid – especially since the scale of the RCP spatial assessment enables localised and downscaled representations as is available in the Green Book – the details of which are presented later in this report. SSPs, while significantly important, often does not provide the same small-scale insights at local geographical levels that RCP offers. Both RCPs and SSPs are also incomplete by design, in that the **RCPs** generate **climate projections** that are not interpreted as corresponding to specific societal pathways (i.e. does not consider human behavioural and socio-economic development trajectories), while the **SSPs** are alternative **societal** futures with some scaling limitations.

The pathways describe different climate change scenarios, all of which consider the amount of greenhouse gases (GHG) emitted including in years to come. IPCC AR5 applied RCP-based climate modelling and research since 2014. The RCPs – RCP2.6, RCP4.5, RCP6, and RCP8.5 – are labelled after a possible range of radiative forcing values in the year 2100. Higher values mean higher greenhouse gas emissions and therefore higher global surface temperatures and more pronounced effects of climate change. RCP8.5 was intended to be a "very high baseline emission scenario" representing the 90th percentile of no-policy baseline scenarios available at the time. Lower RCP values, on the other hand, are more desirable but would require stringent climate change mitigation efforts to achieve. In IPCC AR6 the original RCP pathways are considered together with SSPs. There are also three new RCPs introduced, namely RCP1.9, RCP3.4 and RCP7. When interpreting the variety of RCP's (circa 2014) and SSP's (most recent and expanded), it is always critical to note that the scenarios are merely potential insights into what the future may hold.

In the case of this report, it is important to recognise that some of the climate extremes associated with higher emission pathways have already been reported in some areas in Southern Africa. Therefore, the debate around which exact RCP and/or SSP to apply is becoming less important than identifying the key risks, impacts and hotspots where critically urgent adaptation is needed.

The latest IPCC AR6 contains climate scenarios for Africa, including South Africa, as shown in Figure 2-5. The expected change in average annual temperature and mean annual precipitation under different global emission scenarios for the whole of South Africa is also presented.

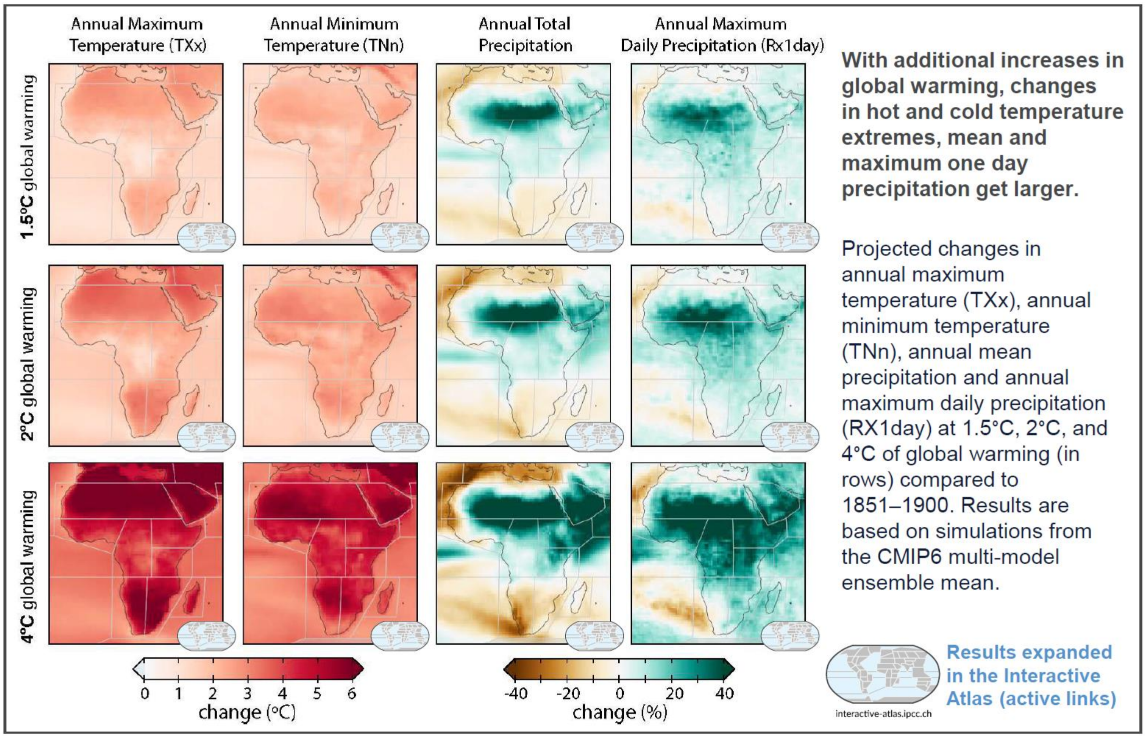



*Figure 2-5*: Summary of the latest IPCC climate scenarios for Africa

*Source: (Intergovernmental Panel on Climate Change , 2021)*

In general, these results indicate an increase in average temperature from around 18.5°C to a median value of between 18.8°C and 23.4°C depending on the resulting global emission scenarios, but with much hotter temperatures expected in the north and inland areas and cooler by the coast. Overall, there is an expected small decrease in precipitation for the country, but with significant spatial variability. The eastern half of the country is expected to see on average no change or a slight increase in precipitation, while the western half of the country, and in particular the southwest, is expected to experience increased drying. It is expected that both the number of very hot days and the maximum daily rainfall will increase across most of the country, which suggests an increased risk of flooding, particularly for the eastern half of South Africa. Consideration of the provinces where the priority DMs are located (Limpopo, North West, Mpumalanga and Eastern Cape) indicates that there is a projected increase in temperature across all these provinces. A majority of models point to a slight decline in average annual rainfall in the priority provinces. As noted earlier in this report, this decline in average annual rainfall, however, does not reflect the severity of the high intensity rainfall that is likely to occur during any single event. Thus, even though the precipitation may well decrease in totality per annum, the extremes in severity of single precipitation events are expected to increase significantly.

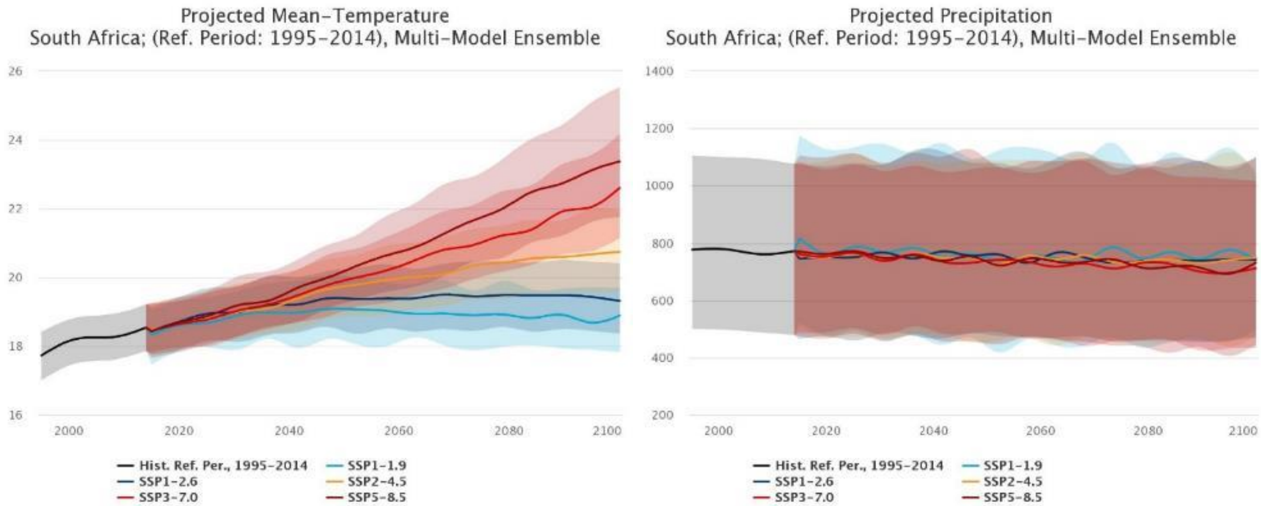



*Figure 2-6: CMIP6 projected changes in mean temperature and mean annual precipitation averaged over South Africa*

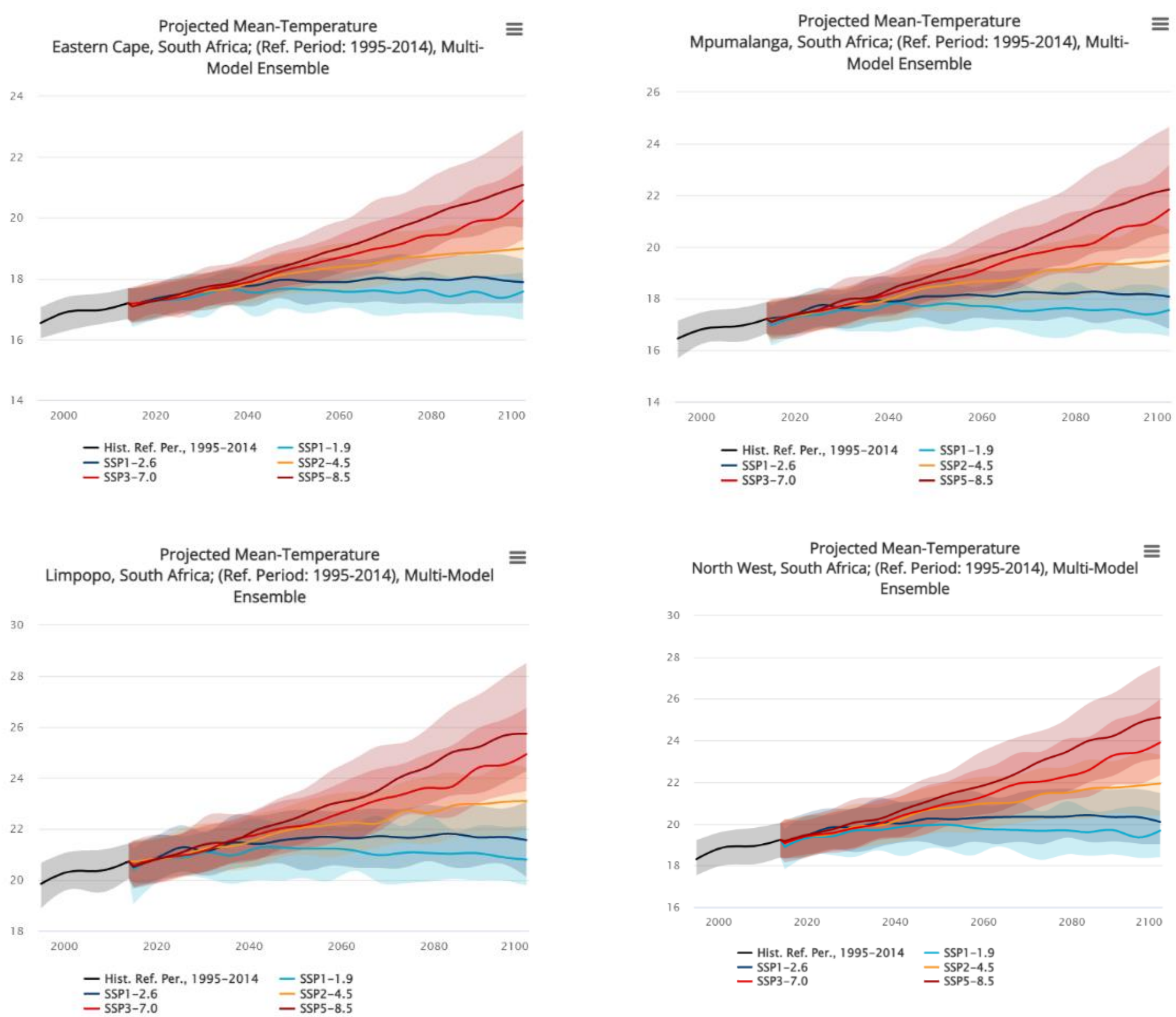



*Figure 2-7: CMIP6 projected changes in mean temperature across priority Provinces in South Africa for the time period 1995-2014 to 2020-2039 (Climate Change Knowledge Portal (CCKP))*

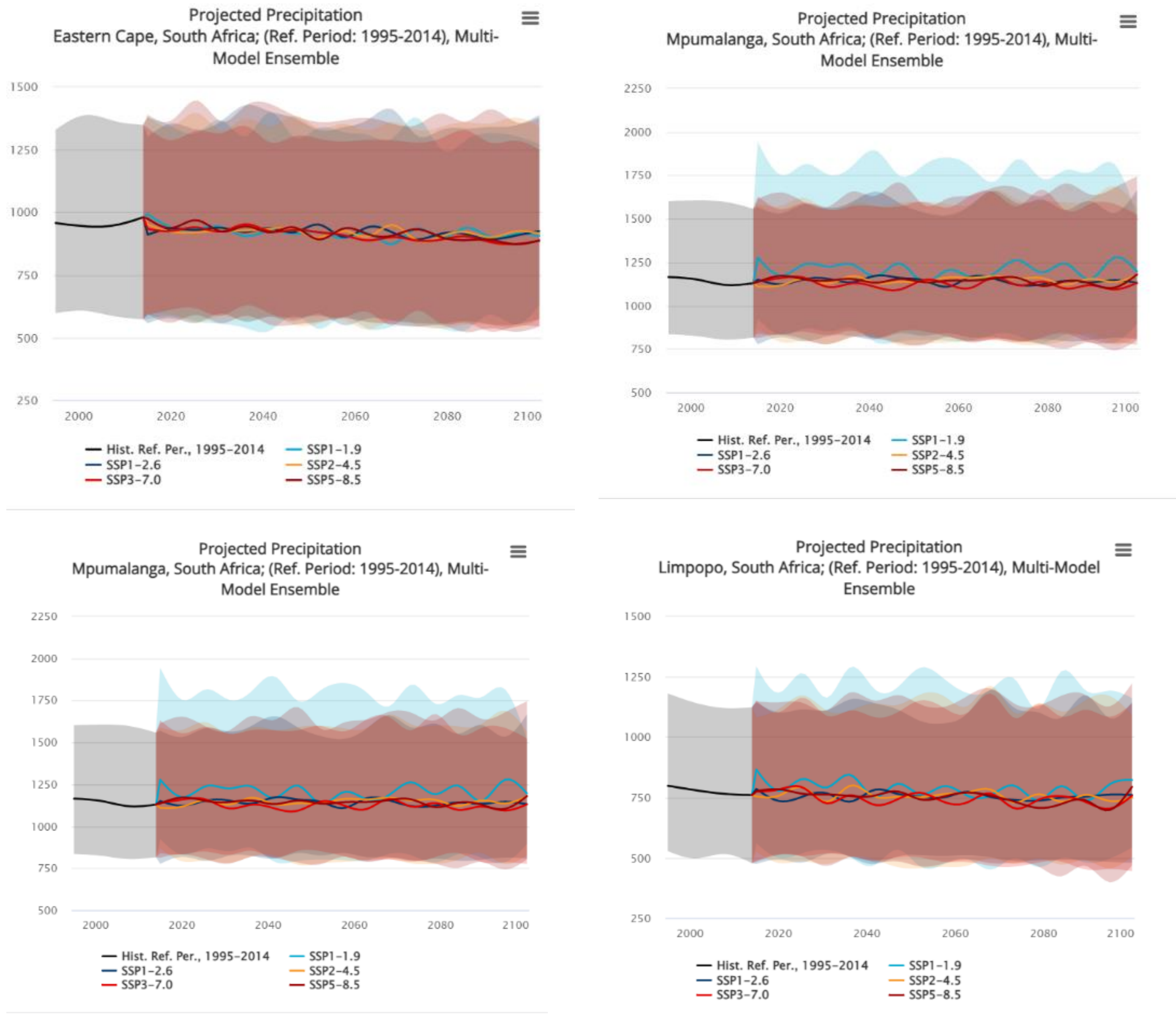



*Figure 2-8: CMIP6 projected changes in mean precipitation across priority Provinces in South Africa for the time period 1995-2014 to 2020-2039 (CCKP)*

## 2.4.2 Downscaled Climate Change Scenarios for South Africa

To date there has been work done on downscaling both the Coupled Model Intercomparison Project Phases Five (CMIP5) and Six (CMIP6) data for South Africa (Engelbrecht, 2023), (Wits-GCA - SANBI, 2024). The facts sheets that were developed are presented in Appendix A. Two notable sets of results are relevant: a) CMIP5; and b) CMIP6.

Between the CMIP5 and CMIP6 reports there are variations in terms of naming convention and projected temperatures, due to differences in Green House Gas (GHG) emission scenarios. Details about these differences are provided in the respective IPCC reports; however, in summary: as a very high-level summary TAR (and IPCC Fourth Assessment Report: Climate Change 2007 (AR4)) describes climate projections based on Special Report Emission Scenarios (SRES), AR5 uses RCPs, while AR6 uses Shared

Socioeconomic Pathways (SSPs). While there is a direct correspondence between SSPs and RCPs, SRES uses different naming convention and temperature ranges. For the purpose of this report, these slight differences fall within the limits associated to climate change predictions uncertainties, and therefore do not impact the results of this assessment or report.

A) CMIP5:

Regional climate models (RCMs) are used to obtain higher resolution climate simulations over limited areas, through the process of downscaling Global Climate Model (GCM) projections. The highest resolution multi-model ensemble of projections obtained to date for Africa is the CORDEX-CORE experiment, in which the simulations have a resolution of about 25 km in the horizontal grid axes. The CORDEX-CORE ensemble consists of the simulations of 3 RCMs that each downscaled 3 GCMs that participated in the second-last global model intercomparison, CMIP5.(CSIR, n.d.). High resolution (8km x 8km) downscaled climate scenarios (the process of which is described in the quoted narrative from Engelbrecht, 2019, below) produced for the CMIP5 RCP4.5 and RCP8.5 climate scenarios (CSIR, n.d.) were reviewed during this project. The RCM applied in the analysis and presented in the Green Book (CSIR, n.d.) is the conformal-cubic atmospheric model (CCAM), a variable-resolution GCM, a global climate model 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). Six GCM simulations of the CMIP5 and Assessment Report Five of the IPCC, obtained for the emission scenarios described by RCP 4.5 (high mitigation / moderate emissions scenario), and RCP 8.5 (low-mitigation/high-emissions scenario) were downscaled. The simulations span the period 1960-2100 (Engelbrecht, et al., 2019).

There is not significant variation between different emission scenarios in the short to medium future (from current up to mid-century). For the hazard assessment component of the Green Book, only RCP 8.5 scenarios were used - the use of which represents a "worst case" scenario and which corresponds to some of the current actual trends that are being observed across Southern Africa, especially regarding severe storm occurrences and associated precipitation and flooding. Climate model downscaling face some challenges especially when observational data is in some local geographies is lacking. The authors of the Green Book have attempted to overcome some of the limitations as follows:

> *...Most current coupled GCMs do not employ flux corrections between atmosphere and ocean, which contributes to the existence of biases in their simulations of present-day sea-surface temperatures (SSTs). An important feature of the downscalings performed for the Green Book is that the model was forced with the bias-corrected SSTs and sea-ice fields of the GCMs. The bias (was) computed by subtracting for each month the Reynolds (1988) SST climatology (for 1961-2000) from the corresponding CGCM climatology. Through this procedure the climatology of the SSTs applied as lower boundary forcing is the same as that of the Reynolds SSTs. However, the intra-annual variability and climate-change signal of the CGCM SSTs are preserved.*
> *A multiple-nudging strategy was (also) followed to obtain the 8 km resolution downscalings. After completion of the 50 km resolution simulations described above, CCAM was integrated in stretched-grid mode over South Africa, at a resolution of 0.08° degrees in latitude and longitude. The high resolution part of the model domain was about 2000 x 2000 km² in size. The higher resolution simulations were nudged within the quasi-uniform global simulations, through the application of a digital filter using a 600 km length scale. The filter was applied at six-hourly intervals and from 900 hPa upwards."* (Engelbrecht, et al., 2019).

The specific GCMs downscaled for the Green Book furthermore include the Australian Community Climate and Earth System Simulator 1-0; the Geophysical Fluid Dynamics Laboratory Coupled Model (GFDL-CM3); the National Centre for Meteorological Research Coupled Global Climate Model, version 5 (CNRM-CM5); the Max Planck Institute Coupled Earth System Model (MPI-ESM-LR); the Norwegian Earth System Model (NorESM1-M) and the Community Climate System Model (CCSM4). These specific GCMs were selected because they are considered to best represent the main climate drivers relevant to the climate of South Africa and consistency with the observed climate (Engelbrecht, et al., 2019).

B) CMIP6:

The IPCC AR6 provided a comprehensive assessment of the latest scientific information on climate change. Summaries of the Working Group I (WG1) assessment of observed trends and projected climate change futures for various regions in the world are provided In the IPCC 'regional fact sheets'. More than 40 GCMs were included in CMIP6, the most extensive multi-model ensemble of projections obtained to date. The GCM spatial resolutions in CMIP6 were relatively low, about 100 km in the horizontal grid axes. The Wits-Global Change Institute (GCI) and SANBI developed fact sheets for South Africa's district municipalities following the IPCC fact sheet style, as mentioned earlier (Appendix A).

The climate model simulations exhibit systematic errors in their representation of present-day climate, and their raw outputs were bias-corrected (the systematic errors were removed) using observations from the Climatic Research Unit. The fact sheets provide visual representations of changes in annual rainfall, temperature, number of very hot days and number of extreme rainfall events. Very hot days are defined as days when the maximum temperature exceeds 35 °C, and extreme rainfall events as the daily rainfall total being equal to or exceeding 20 mm, averaged over an area of 25 x 25 km². Projected changes were developed for the near-future (2021-2040), mid-future (2041-2060) and far-future (2081-2099) periods, relative to the baseline period 1981-2000. Model agreements were assessed and uncertainties in the projections investigated. The outputs consider the area-average rainfall and temperature for each model and each period for each of the district municipalities. The fact sheets provide assessments of observed trends and projected changes for impact-based climate variables. To each of the assessments is assigned a level of confidence statement, following the methodology and processes introduced by the IPCC. The confidence assessment of trends and projections is informed by relevant peer-reviewed research, the degree of model agreement (i.e. of projected changes) and expert knowledge of the weather and climate in each location. The fact sheets focus on the climate variables, and do not take into account significant influences that topography, human settlements and associated microclimatic influences, and EI such as soil health, vegetation cover, water resources availability and quality, AIPs and biomass – all of which influences ultimate levels of risk.

In conclusion: Any study that examines climate risk in future timeframes is beset by uncertainty. The very nature of CRVA is intended to manage the uncertainty ingrained in the climate future hazard expectations. Since the uncertainty result in terms of hazard estimations, from the use of different climate models, different assumptions that go into the construction of the varied climate models, different climate scenarios, evolving generations and typologies of climate scenarios, different timeframes, downscaling (or lack thereof), etc, the hazard itself is exposed to uncertainty. Similarly, levels of vulnerability are also uncertain. To manage uncertainty, best-available observational data as well as local information and knowledge (gained through among others expert insights and local stakeholder engagement) and the best available data, information and scientific analysis is used at the time. In recognition of the Green Book's highly credible approach and robust methods, this study draws on these results, whilst acknowledging any associated limitations and supplementing it accordingly, where appropriate additional information..

### 2.4.3 Climate Change Scenarios for South Africa

A study undertaken by the Department of Water and Sanitation (DWS, 2022), as part of updating the climate change response strategy for water and sanitation in South Africa, did a comparison between different available climate change scenarios for the country. This DWS study included use of the Green Book (CSIR, n.d.) scenarios with CMIP5 and CMIP6 climate scenarios, as well as with downscaled climate scenarios from CORDEX[5]. The resultant wide range of potential climate change impacts are shown in the figures below for the two hydroclimatic zones in South Africa which represent the five prioritised DMs. These results show that the ensemble mean scenario from the Green Book is a reasonable representation of the likely impacts of climate change in each of the two hydroclimatic zones - where temperatures align well, and trends are clear (the top two graphs in Figure 2-9 and Figure 2-10: change in daily mean temperature (TG)).

Precipitation shows a much more variable outlook, which resonates with the challenges emanating from not only future estimates but even current observations, where predictability of rainfall patterns and impacts are becoming increasingly challenging to predict (Bottom graphs in Figure 2-9 and Figure 2-10: change in total precipitation (PRCPTOT)).

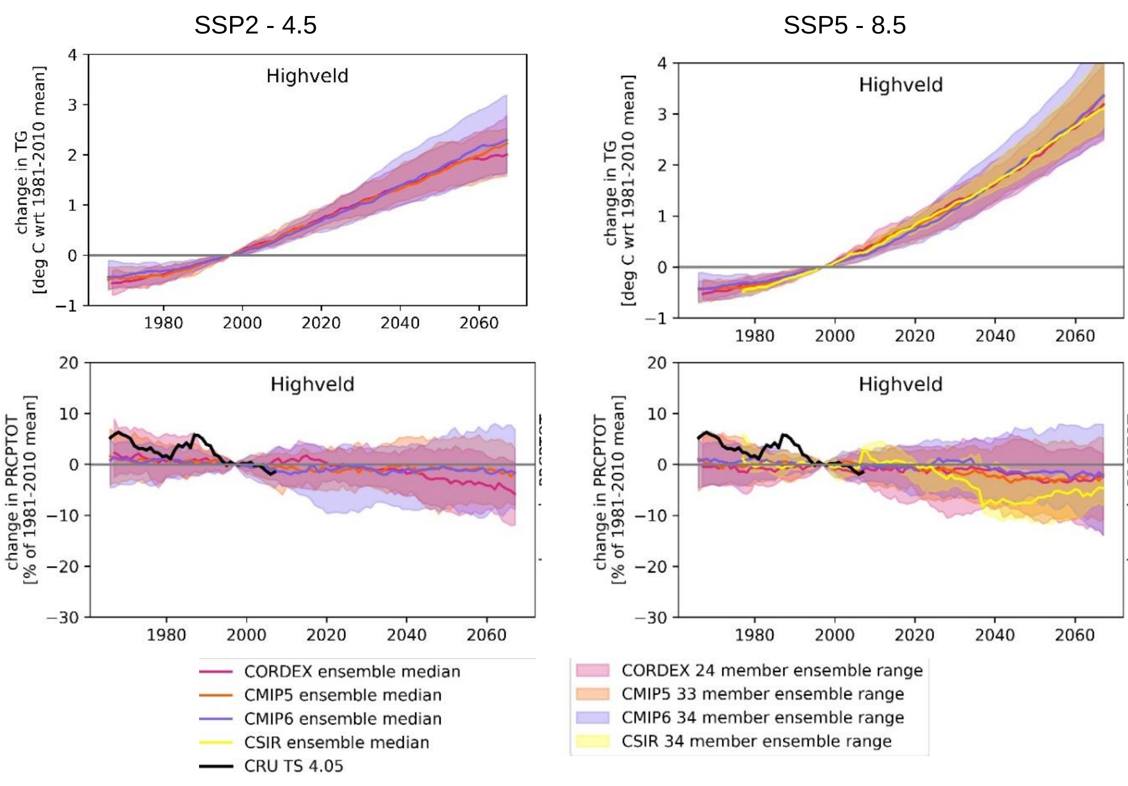



*Figure 2-9: Plume plots comparing multi-generation, multi-model ensemble projections of average annual temperature and mean annual precipitation change under SSP2-4.5 and SSP5-8.5 emission scenario for the Highveld hydro-zone. Shaded areas mark 90 percentile range for individual ensembles, calculated based on 30-year running means*

[5] https://cordex.org/domains/region-5-africa/

Source: (DWS, 2022).

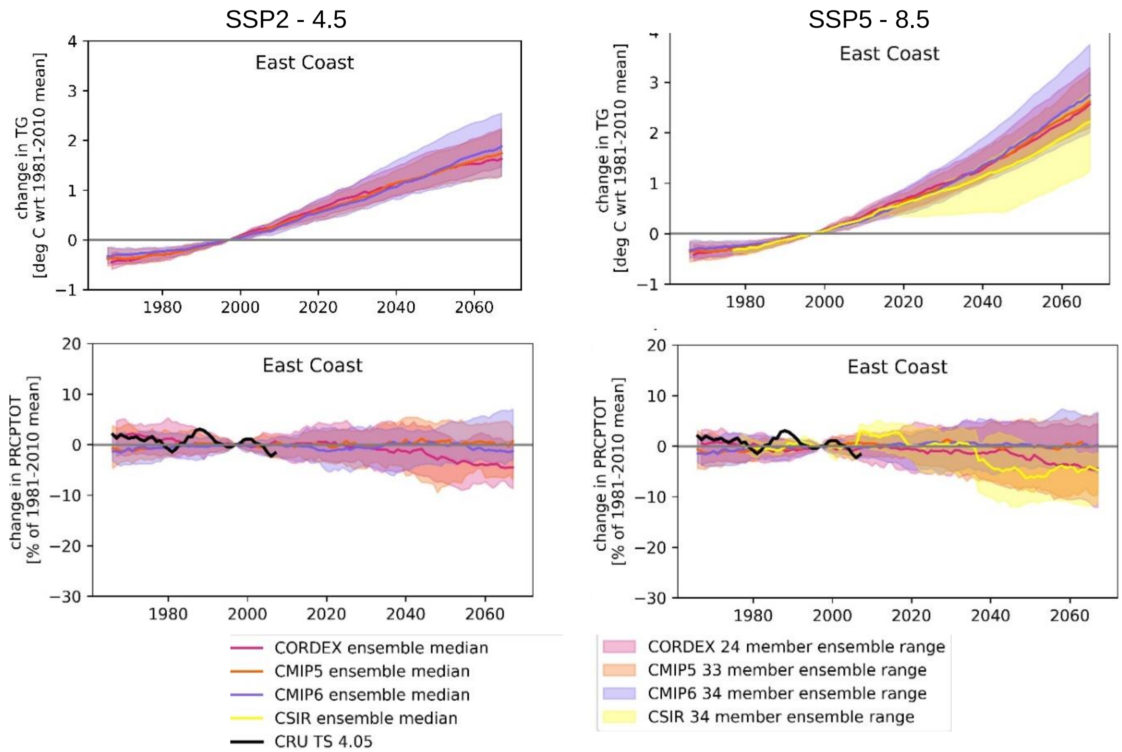



*Figure 2-10: Plume plots comparing multi-generation, multi-model ensemble projections of average annual temperature and mean annual precipitation change under SSP2-4.5 and SSP5-8.5 emission scenario for the East Coast Hydro-zone. Shaded areas mark 90 percentile range for individual ensembles, calculated based on 30-year running means*

*Source: (DWS, 2022).*

## 2.4.4 Anomalies in Extreme Rainfall Under Future Climatic Conditions

The main driver of future flood hazard is a change in rainfall intensity (i.e. the rate of rainfall over a unit of time usually expressed as mm/hour, within a specified geographical area) and rainfall depths (total depth of rainfall over a given period and a given area) during a storm event. Although there are uncertainties and variabilities in rainfall under future climates with different models and different emission scenarios, there is general agreement that rainfall intensities during single events, is expected to increase over most of South Africa (Le Maitre, et al., 2019).

Under future climates, it is likely that the design rainfall depths (i.e. statistically the maximum depth of rainfall that can be expected to occur during a defined period of time, linked to a specific return period and used in design flood hydrology) will increase and that the depths and volumes of storm runoff will similarly increase, leading to increased occurrence of floods. Assessing the anomalies (i.e. degree of change) in extreme rainfall, through a comparison of future rainfall extremes with those under the current rainfall (1971-2000) observations indicates the following:

- In the near future (2021-2050) the extreme daily rainfall depths are expected to increase in many parts of the country, particularly over the Highveld and northern Drakensberg, and in a broad north-south-running belt along the south-eastern and eastern coast (Figure 2-11).

- The western and south-western regions of the country, which are predominantly winter rainfall regions, are likely to experience a decrease in extreme rainfall depths.

The specific details of the 2019 research by Le Maitre et al is available on the Council for Scientific and Industrial Research's (CSIR's) website[6].

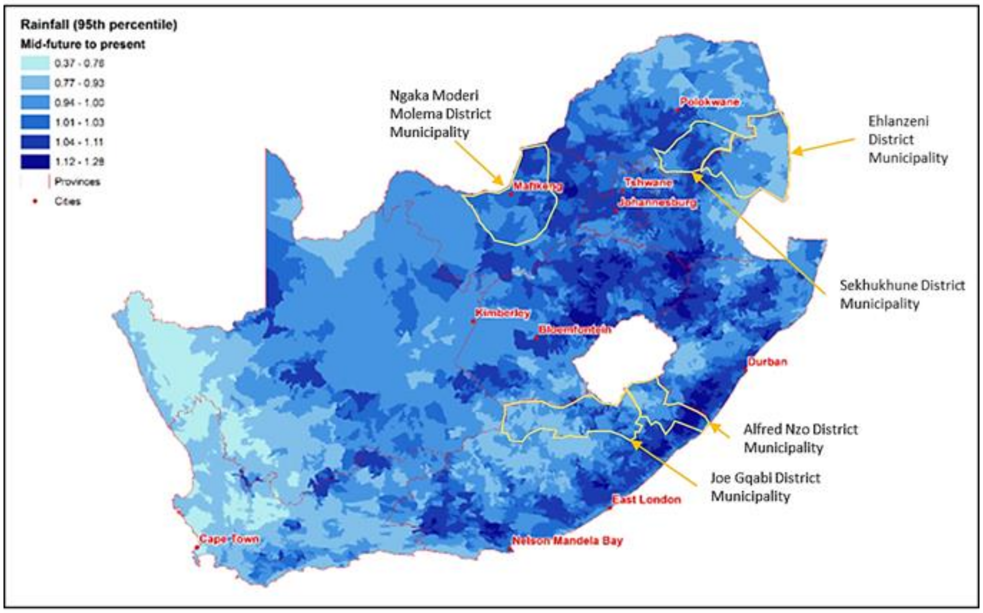



*Figure 2-11 The mean ratio of the near future (2021-2050) and current (1971-2000) extreme daily rainfall (95th percentiles) for each quinary catchment. Values greater than 1.0 indicate an increase in the extreme daily rainfall*

*Source:* (Le Maitre, et al., 2019)

Observed climate indices are already showing a linked alignment to an increase in the frequency and intensity of heavy precipitation, leading to increased flood risk – across South Africa (Ziervogel G, 2022). According to South Africa's Third National Communication (TNC) to the United Nations Framework Convention on Climate Change (UNFCCC), the risk of flooding is likely to increase in the future due to a combination of increasing climate risks as well as other socio-economic pressures resulting from land use change and an increasing number of people living in high-risk areas (Republic of South Africa , 2018).

South Africa's Long Term Adaptation Scenarios (LTAS) flagship research programme (DEA, 2013) found that in all future scenarios considered by LTAS, there is a higher frequency of floods in the future (USAID, 2015). Analysis by the G20 suggests that by mid-century (2050), hundreds of thousands of people nationwide will be exposed to flooding, costing the country at least an estimated 14 billion rand by 2050 (G20, n.d.). Analysis of future flood risk by LTAS show consistent increases across most parts of the country, but particularly the Eastern Cape and Limpopo provinces within which three of the five priority DMs are located. Although, it is noted that there are discrepancies among climate models regarding the locations and magnitude of anomalies in extreme daily rainfall.

[6] (https://pta-gis-2-web1.csir.co.za/portal/sharing/rest/content/items/a9e25e8466de41efb565be83bb8cd8d7/data)

Extreme precipitation events might show different characteristics and commonly larger magnitudes of change when compared to mean precipitation or annual averages. In a future warmer climate, the potential of air to carry moisture goes up as follows: when saturated air is warmed, it can hold more water (relative humidity drops). A warmer atmosphere holds more moisture—about 7 % more per 1°C of warming (Climate Signals, n.d.). Thus, the potential for heavier precipitation and more extreme events goes up, with these more intense events then expected to exacerbate the effects of flooding.

The potential shift in rainfall depths associated with various rainfall event return periods can also be formulated as a change in Future Annual Exceedance Probability[7] - this indicates how much more or less frequent an event might become. A high-level, provincial analysis of this factor indicated that under all pathways, except the SSP1-1.9, the largest 1-day precipitation anomaly will increase. The change in 1:10 year event was projected to increase in all provinces (see Table 2-4) with the Limpopo and Mpumalanga provinces projected to have a 1.5 median change factor. As presented in Table 2-4, the change in 1:100-year event was projected to increase in all provinces by a factor above 1.5 for most pathways. Limpopo and Mpumalanga provinces were projected as having a 2 median change factor for the SSP5-8.5 pathway. Overall, the provinces in which the five prioritised DMs are located clearly present an increased threat of extreme flood events based on projected changes in annual exceedance probability.

*Table 2-4: CMIP6 projected changes in annual exceedance probability of largest 1-day precipitation for the time period 2035-2064 (centre 2050) (CCKP)*

| | Event | 10-yr | | | 100-yr | | |
|---|---|---|---|---|---|---|---|
| | | 10th | median | 90th | 10th | median | 90th |
| **Eastern Cape** | SSP1-1.9 | 0.61 | 1.31 | 1.81 | 0.4 | 1.59 | 2.86 |
| | SSP1-2.6 | 0.64 | 1.15 | 1.99 | 0.42 | 1.32 | 3.23 |
| | SSP2-4.5 | 0.68 | 1.3 | 2.12 | 0.5 | 1.63 | 3.84 |
| | SSP3-7.0 | 0.65 | 1.4 | 2.19 | 0.47 | 1.82 | 3.95 |
| | SSP5-8.5 | 0.65 | 1.28 | 2.25 | 0.47 | 1.61 | 4.09 |
| **Mpumalanga** | SSP1-1.9 | 0.77 | 1.39 | 1.9 | 0.74 | 1.83 | 3.02 |
| | SSP1-2.6 | 0.87 | 1.36 | 2 | 0.82 | 1.68 | 3.18 |
| | SSP2-4.5 | 0.89 | 1.38 | 2.33 | 0.86 | 1.72 | 4.14 |
| | SSP3-7.0 | 0.98 | 1.67 | 2.59 | 1.04 | 2.37 | 4.99 |
| | SSP5-8.5 | 1.09 | 1.65 | 2.7 | 1.19 | 2.39 | 5.09 |
| **Limpopo** | SSP1-1.9 | 0.86 | 1.28 | 1.65 | 0.89 | 1.63 | 2.52 |
| | SSP1-2.6 | 0.81 | 1.22 | 1.74 | 0.73 | 1.4 | 2.75 |
| | SSP2-4.5 | 0.8 | 1.35 | 2.01 | 0.68 | 1.74 | 3.68 |
| | SSP3-7.0 | 0.94 | 1.42 | 2.16 | 0.93 | 1.85 | 4.19 |
| | SSP5-8.5 | 0.86 | 1.52 | 2.4 | 0.8 | 2.04 | 4.79 |
| **North-West** | SSP1-1.9 | 0.63 | 1.15 | 1.59 | 0.55 | 1.31 | 2.19 |
| | SSP1-2.6 | 0.68 | 1.21 | 1.72 | 0.55 | 1.41 | 2.45 |
| | SSP2-4.5 | 0.7 | 1.26 | 1.98 | 0.63 | 1.6 | 3.12 |

[7] A 1:100 year rainfall event may in the future become the 1:50 year rainfall event. Therefore the likelihood of the current 1:100 year rainfall depth will double in future climates. As a result of this, in the first row in Table 2-4, under the median for the 10-year column, the likelihood of getting what is currently pegged as the 1:10 year rainfall depth is 1.31 times greater (31% more likely) under future climates than under the current climate.

| | Event | 10-yr | | | 100-yr | | |
|---|---|---|---|---|---|---|---|
| | SSP3-7.0 | 0.74 | 1.28 | 1.79 | 0.67 | 1.59 | 2.65 |
| | SSP5-8.5 | 0.72 | 1.37 | 1.89 | 0.63 | 1.83 | 2.95 |

The results from the studies detailed under Sections 2.1 to 2.4 presents climate change-induced future hazard extremes where significant flood risk increases are not only likely, but a reality – especially in the five priority DMs. There is no doubt that the future trends, which are already presenting itself in observational data, are due to incur increased damages and loss of infrastructure, livelihood and lives.

### 2.4.5 Drought Hazards within South Africa

Observed climate change is already linked to an increase in the occurrence of multi-year drought events in South Africa, leading to increased flood risk (Ziervogel G, Lennard C, Midgley G, New M, Simpson NP, Trisos CH, et al., 2022).

As described in South Africa's third national communication to the UNFCCC, future climate change projections show a significant increase in the frequency, duration and severity of hydrological droughts events in South Africa during the second half of the 21st century, with the worst affected area being the Western Cape Province (however, there are at-risk areas in all nine provinces) (Republic of South Africa , 2018).

The report also emphasises that in the country's summer rainfall catchments, drought impacts will be experienced even sooner, i.e., from the early 21$^{st}$ century. This increased risk of such meteorological droughts in several catchments appears to be manifesting over a longer time horizon compared to more acute impacts of hydrological droughts, with the winter rainfall regions experiencing impacts in the second half of the century. Summer rainfall regions already starting to feel the impacts of climate change in the form of increased drought tendencies (Republic of South Africa , 2018).

An initial screening tool was used to assess drought risk in South Africa. According to the WRI Aqueduct Water Risk Atlas (Rutger et al., 2019) drought risk is medium in the Eastern Cape, Mpumalanga and Limpopo provinces and medium-high in the North-West provinces (Figure 2-12). Drought risk measures where droughts are likely to occur, the population and assets exposed, and the vulnerability of the population and assets to adverse effects. Higher values indicate higher risk of drought.

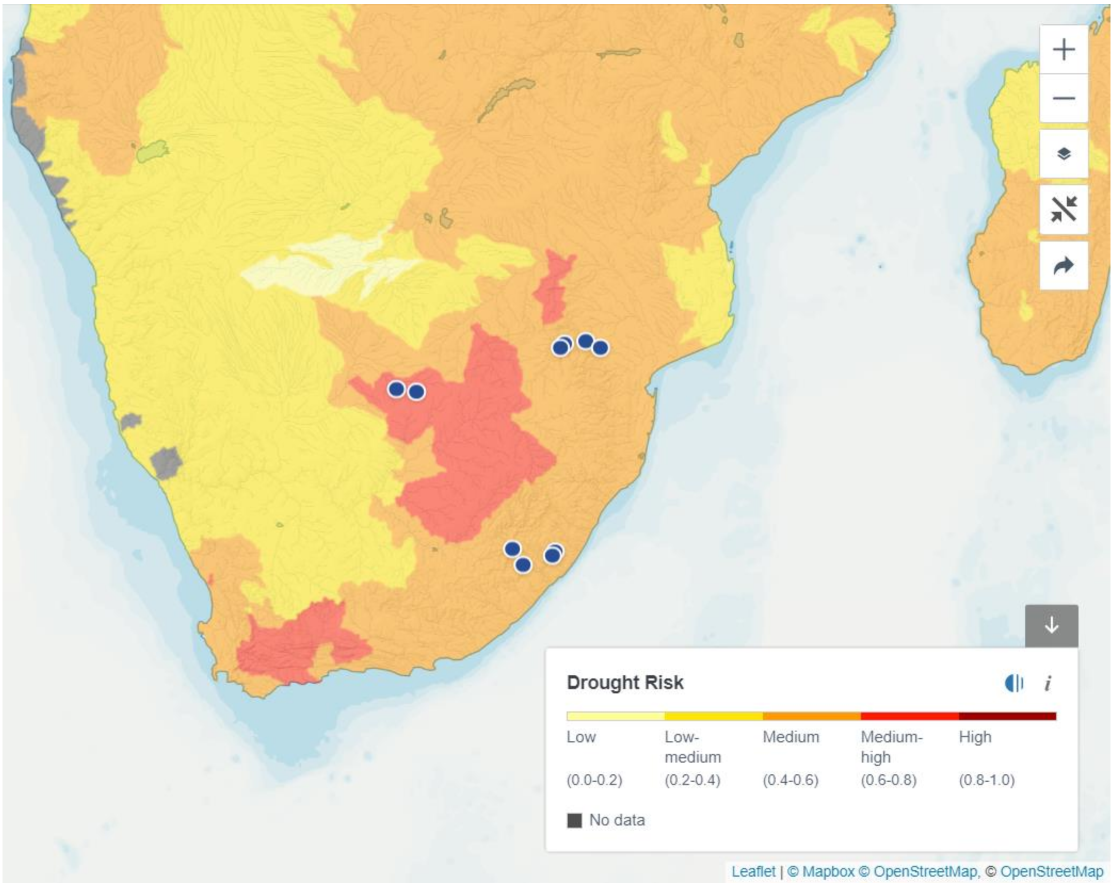



*Figure 2-12: Drought risk for the priority QCs in South Africa (Aqueduct: Water Risk Atlas) (Source: Rutger et al., 2019)*

South Africa's LTAS research project found that in all future scenarios considered by LTAS, there is a higher frequency of droughts in the future (USAID, 2015). Estimates by the G20 posit that droughts in South Africa will cause water demand to increase by up to 24.6% by 2050 – even in a low emissions future (G20, n.d.). This has significant implications for agriculture and for all water users, including agriculture, industry, and domestic users.

South Africa is historically a drought prone country with drought events occurring in cycles at various times historically and often linked to global climate variables. For example, the summer of 2015/16 was associated with the most intense El Niño event ever recorded (Beraki, 2019). In southern Africa, the impacts of the 2015/16 El Niño event were warmer temperatures, critically low dam levels, higher fire risk levels in areas where biomass were sufficient, water restrictions and much reduced crop yields. In 2017, after three successive years of below normal rainfall, dam levels in the Western Cape reached critically low levels. During this same period, the dry conditions and an exceptionally warm autumn contributed to the outbreak of widespread wildfires around Knysna and along the coastal area known as "The Garden Route" (Beraki, 2019). These conditions are representative of the importance of understanding the spatial and temporal scale of droughts to quantify drought risk. It is also shows how most parts of South Africa are already adapted to drought risk.

The signature of climate change on the South African climate extremes with regards to moisture budget was explored in the Green Book. According to data on the Standardised Precipitation Index (SPI) during the last 100 years, the occurrence of extremes in the South African climate barely showed any signature of the climate change signal (Beraki, 2019). The annual variability in moisture budget can therefore generally be explained by natural variability. Addition of evaporation has a marginal impact on the long-term drought tendency, however as measured in terms of the standardised precipitation and evaporation index (SPEI) also shown in Figure 2-13. Over the last couple of decades (both summer and winter rainfall regions) the loss of moisture due to PET has intensified, presumable due to global warming (Beraki, 2019). This indicates that it is important for South Africa to explore options on how to better manage loss of moisture due to evapotranspiration.

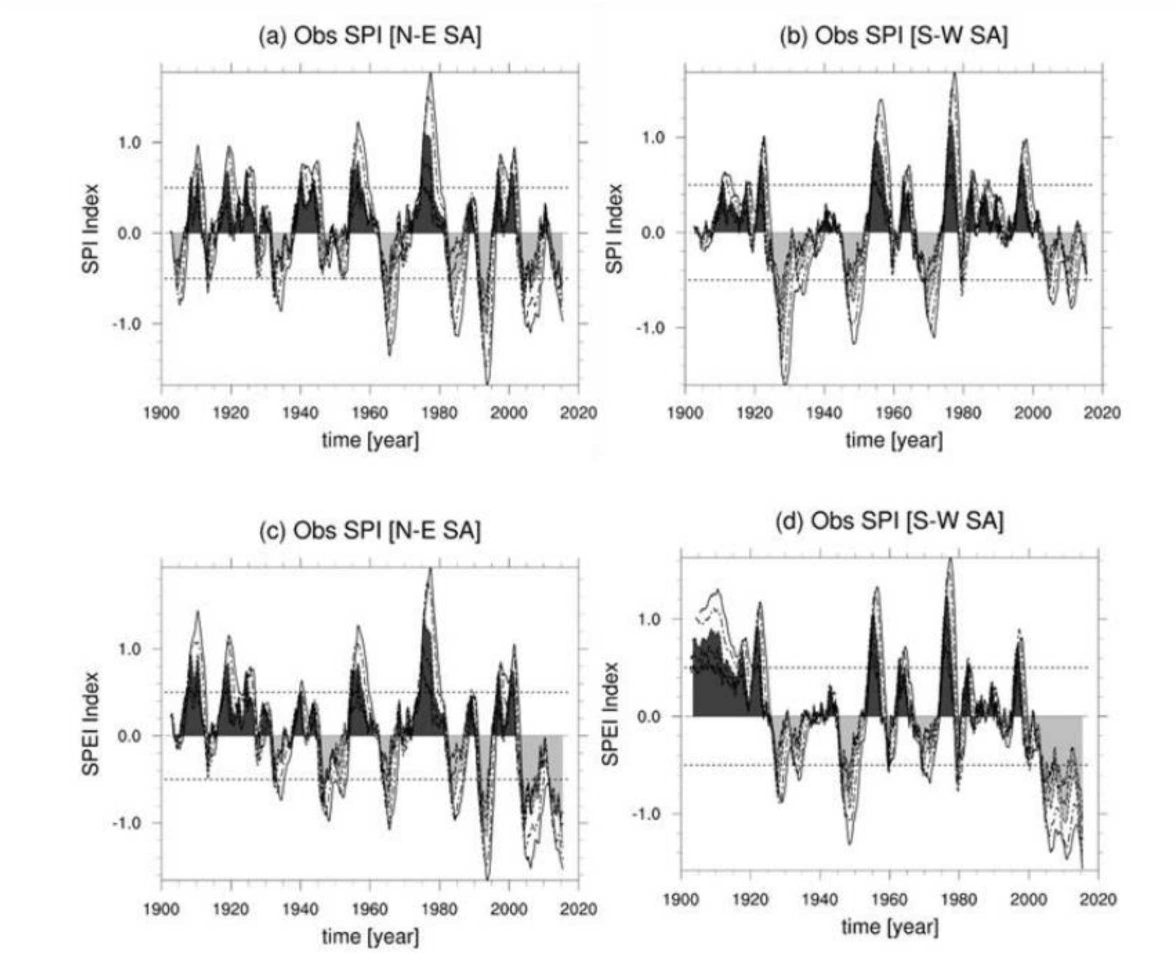



*Figure 2-13: Observed state of drought based on SPI and SPEI for the north-eastern (part of the summer rainfall region (a) and (c)) and south-western (part of winter rainfall region (b) and (d) parts of South Africa (Source (Beraki, 2019)*

# 3 Approach

## 3.1 CLIMATE CHANGE RISK AND VULNERABILITY FRAMEWORK

The CRVA follows the internationally accepted agreed-upon approach which was also integrated in the South African National CRVA Framework (DFFE, 2020). The framework adopts the conceptual risk assessment approach as guided by the IPCC (IPCC, 2014), shown in Figure 3-1.

The conceptual framing presents that: for society to adapt or a situation to be adressed so as to reduce climate risk, interventions should focus on **identifying** the relevant climate hazards and parameters such as precipitation and temperatures, as well as extremes and trends associated with these parameters).

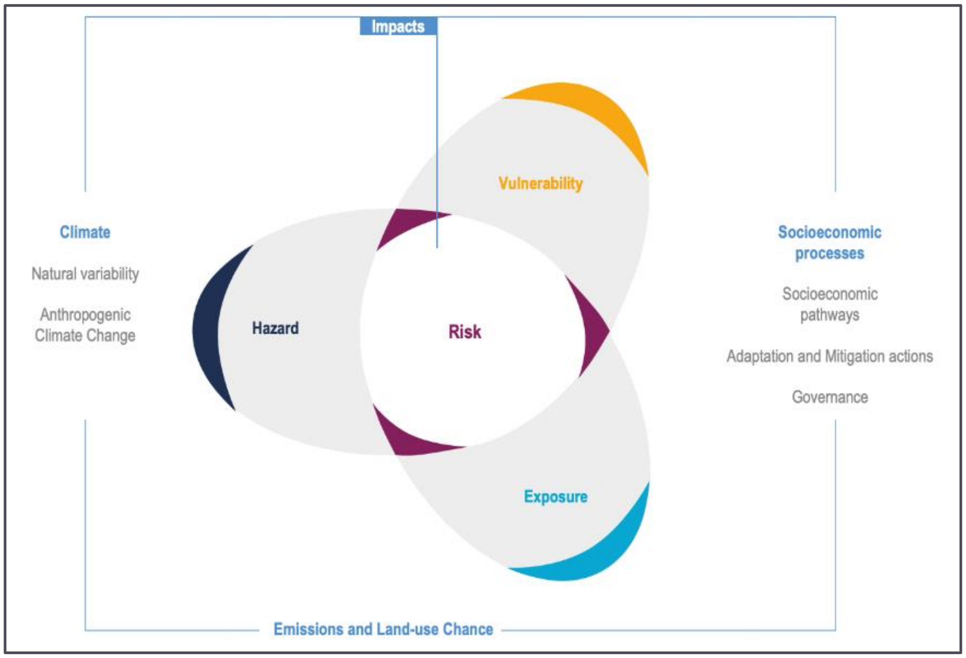



*Figure 3-1: The IPCC conceptual framing of climate risk as a combination of hazards, exposure, and vulnerability*
*Source:* (IPCC, 2014)

Then, the focus moves to reducing the vulnerability to these hazards, at the local level, through reducing sensitivity and/or increasing capacity, and/or reducing exposure to the hazard(s). Reducing exposure to climate hazards are in many cases either difficult or significantly costly. Therefore, it is often more cost-effective, and sustainable in the long-term, to focus on reducing sensitivity and/or increasing capacity. In the case of capacity, and the context of South Africa, the strengthening of adaptive capacity is a particular avenue that is deemed to achieve positive and long-lasting outcomes.

Based on the IPCC and the South Africa CRVA Framework approaches, the propensity or potential for adverse impacts and negative consequences due to climate-related risk are evaluated through a combination of the following climate RISK components: i) HAZARD; ii) EXPOSURE; and iii) VULNERABILITY, where hazard may be reduced or exacerbated by the interaction between levels of exposure and levels of vulnerability. Vulnerability levels are, in turn, influenced (strengthened or reduced) by levels of capacity (also referred to as coping capacity).

The components of risk and the elements that they are made up of are defined below (DFFE, 2020). Each term provide the point of departure for the CRVA Framework:

**Risk:** The potential for consequences (impacts) where something of value is at stake and where the outcome is uncertain, recognising the diversity of values. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk results from the interaction of hazard, exposure and vulnerability**.**

**Hazard:** The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources. The term hazard in CRVA context usually refers to climate-related physical events, or climate and weather phenomena trends or physical impacts thereof.

**Exposure:** The geographical presence or location of settlements, people, their livestock, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or other economic, social, or cultural assets in places and settings that could be adversely affected.

Noting the above three definitions – if a hazardous event occurs in a specific geography, but there is nothing exposed to it (for example if the hazard occurs in an ocean with no affected components in the vicinity) then there is no risk.

**Vulnerability:** The propensity or predisposition to be adversely affected by a hazard, where a hazard and exposure coincide. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of ability to cope and/or adapt.

**Sensitivity:** Factors that directly affect the consequences (level of severity) of a hazard. Sensitivity may include physical attributes or characteristics of a system (e.g. building material of houses, type of soil on agriculture fields), social, economic and cultural attributes (e.g. age structure, income structure).

**Coping capacity:** The ability of people, institutions, organisations, and systems, using available skills, data, knowledge, values, beliefs, resources, and opportunities, to prevent, minimise, address, manage, and overcome or respond to adverse conditions in the short to medium term (e.g. where early warning systems are in place, or where evacuation routes are located, or where Eco-based adaptation is applied to restore and/or rehabilitate landscapes to reduce the magnitude of hazard impact).

**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 (e.g. knowledge of alternative farming methods, changes in crop types to adjust to changing growing seasons, etc.).

**Impact:** Effects on natural and human systems. The IPCC (2014) relate impacts primarily in reference to the effects of extreme weather and climate events and results of climate change on natural and human systems. The reference generally relates to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure which occur as a direct effect of the interaction of climate changes, climate variation, or hazardous climate events. The impacts of climate change on geophysical systems, including floods, droughts, fires, and the like, are a subset of impacts referred to as *physical impacts*.

## 3.2 HAZARD ASSESSMENT

Hydrometeorological hazards that are most prominent across South Africa include long duration dry spells and droughts, and severe storms – especially intense storms and weather associated with tropical cyclones, that result in floods.

### 3.2.1 Flooding

Inland floods are caused by large volumes of water which are generated by rainfall events (Le Maitre, et al., 2019). Anticipated future risks in terms of increased precipitation and flooding include (Republic of South Africa , 2018):

- Large populations exposed to floods in urban and peri-urban areas, particularly in low-income informal settlements;
- Death, injury, and disruption of human security, especially among highly vulnerable groups like children, elderly, and disabled persons;
- Interaction of increasing frequency of intense precipitation and urbanisation, with insurance limits being reached;
- The possible shifting of the burden of risk management from the under-resourced and under-capacitated state to those at risk, spurring even greater inequality;
- Erosion of assets due to infrastructure damage, and abandonment of damaged physical property;
- Overwhelmed, aging, poorly maintained, and inadequate urban drainage infrastructure (also a cause of vulnerability); and
- Limited ability of low-income populations to cope and adapt due to marginalisation, high poverty, and traditionally/culturally defined gender roles.

Flooding can be categorised into either pluvial flooding or fluvial flooding. Pluvial floods are generated by very intense, short duration rainfall events which rapidly saturate or exceed the ability of soils to absorb water (Beven, 1987; Manfreda, et al., 2010) and result in short duration flash floods; or longer, less intense (sequence of) rainfall events which also saturate catchments and result in long duration floods; or groundwater table rise in response to rainfall recharge (Musungu, et al., 2012). Ultimately pluvial or "overland" floods are a consequence of heavy rainfall, that occur outside of a water body (i.e. a stream, river or dam). Pluvial floods are largely associated with flooding in urban areas, which are triggered by the saturation of the urban drainage system, causing water to accumulate in streets. Pluvial floods can also happen due to intense rainfall runoff from hillslope areas when degraded soil and lack of natural vegetation reduce absorbing capacity of soil.

Fluvial floods are caused by an overflow of water in a river or stream due to heavy rainfall and runoff. Fluvial floods occur when the amount of water in a river or drainage line exceeds the river or stream's capacity, as a result of rainfall and runoff in the upstream catchment area, causing the water to overflow and flood the surrounding areas. Fluvial floods are the most common type of flood and can occur in both rural and urban areas. Fluvial floods are especially dangerous as fast-moving water associated with fluvial flooding, is commonly powerful enough to damage buildings, roads, culverts and bridge infrastructure.

Due to the linkage between extreme rainfall to both pluvial and fluvial flooding, changes in extreme precipitation has been a focal point for the hazard analysis undertaken as part of this CRVA. However, in order to contextualise anomalies in rainfall hazards, analysis of broader climate change trends has been undertaken. Thereafter, more focus has been given to anomalies in extreme rainfall across vulnerable DMs in South Africa.

### 3.2.2 Droughts

Droughts are naturally occurring hydrometeorological hazards which can be defined based on their driving mechanisms. Meteorological droughts are caused by extended period of rainfall deficiency – typically range in duration between 3 months to multiple years. A meteorological drought is a conceptual definition based on the deviation from the natural or average conditions over an extended historical period. A good measure of drought trends is the SPEI as it combines both impacts on temperature and precipitation.

This CRVA focused primarily on meteorological droughts, firstly, because this type of drought can be directly linked to hydrometeorological variables that will be intensified by climate change (i.e., increased temperature and reduced rainfall). The second reason is that a meteorological drought that persists due to rainfall deficiency can turn into an agricultural/soil moisture drought (that results in the destruction of plants and crops), which then further propagates into a hydrological drought (that reduces river flows and groundwater table, and ultimately water availability) (Debele, et al., 2019).

According to Malherbe et al (2015), a meteorological drought that persist for 3 – 12 months will typically result in an agricultural drought; and for periods longer than 12 months, hydrological droughts are typically observed, but this does depend on the nature of the water resources and the water resources infrastructure particularly the availability of storage (Malherbe, et al., 2015).

In the context of this study, the level of exposure to drought has been directly related to metrological anomalies, namely SPEI. Possible future changes in the state of drought and flood over South Africa under RCP 8.5 were estimated using the six climatic projections downscaled by the Council for Scientific and Industrial Research (CSIR) in terms of SPI. Daily accumulated monthly mean precipitation values were used to estimate the SPI for multiple scales at a resolution of 50km over South Africa. Similar results were yielded for each scale, therefore the 36 month scale is presented. The annual mean represents the contribution of all the different climate regimes of South Africa. South Africa is already experiencing increased conditions of dryness and is likely heading towards a regional climate system that is associated with more frequently occurring droughts (Figure 3-2). During the period of 2035-2064, a high likelihood of increased conditions of drought are projected to occur within the presence of a drastic increase in maximum temperature and very hot days (Figure 3-2). Despite the uncertainty that exists among model simulations forced with six CMIP5 models, the analysis generally suggests that South Africa's state of drought and its frequency becomes noticeable with a statistical significance at 95% during the period 2044-2064 under RCP 8.5 (Figure 3-3).

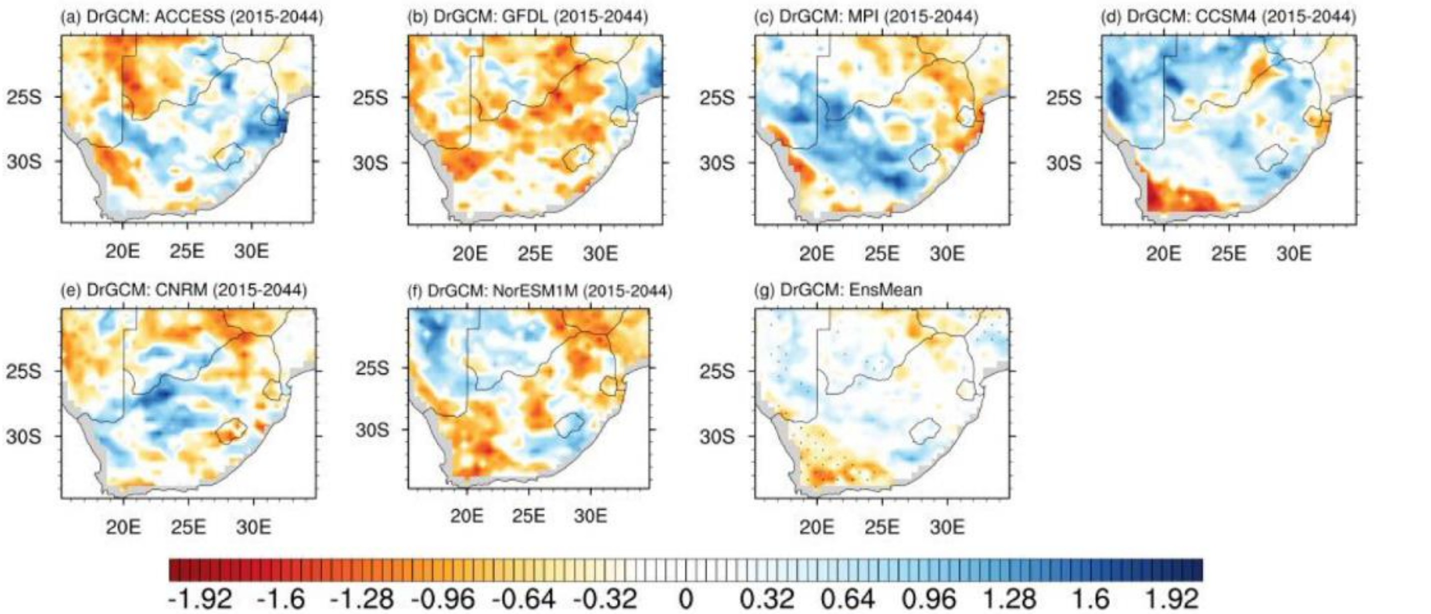



*Figure 3-2: Projected change in the drought (flood) tendencies (i.e. number of cases exceeding near-normal per decade) over South Africa for the period 2015-2044 relative to the 1986-2005 baseline period, under RCP 8.5. Projections are shown for each of the six CCAM downscaling (a-f) and ensemble mean (g). The stipples in figure (g) show significance 95% source: (Beraki, 2019)*

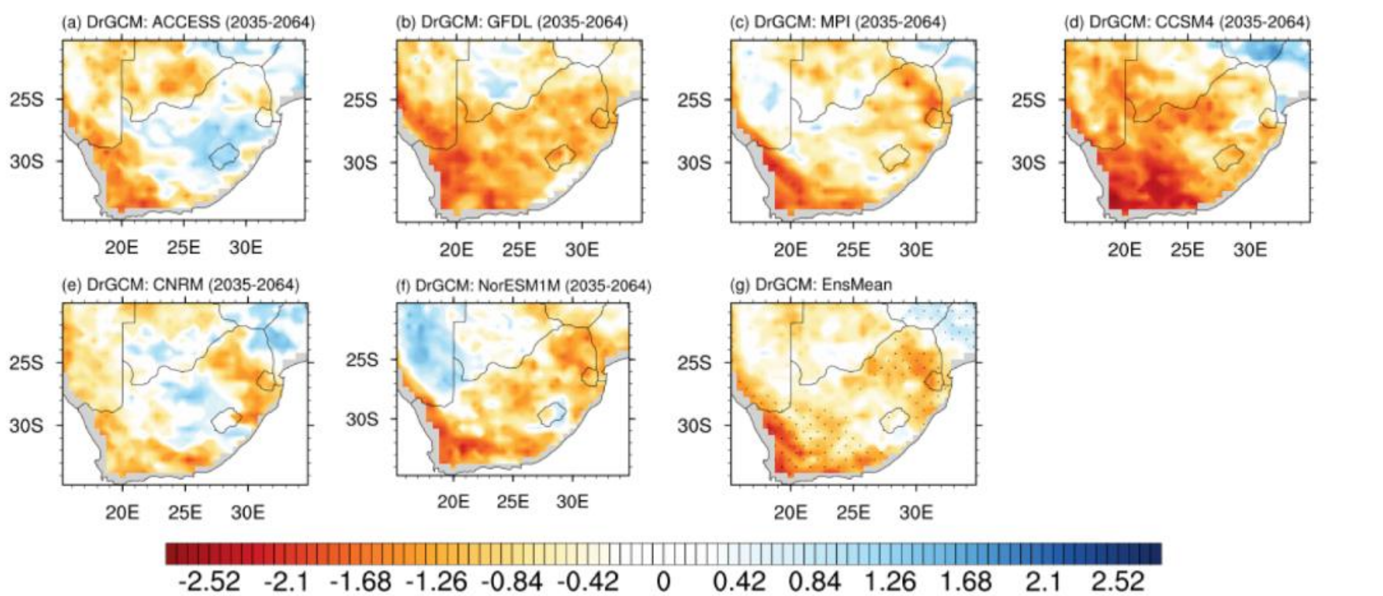



*Figure 3-3: Projected change in the drought (flood) tendencies (i.e. number of cases exceeding near-normal per decade) over South Africa for the period 2035-2064 relative to the 1986-2005 baseline period, under RCP 8.5. Projections are shown for each of the six CCAM downscaling (a-f) and ensemble mean (g). The stipples in figure (g) show significance 95% source: (Beraki, 2019)*

## 3.3 VULNERABILITY ASSESSMENT

In the context of climate change, vulnerability refers to the degree to which a system (e.g., a community, ecosystem, or infrastructure) is likely to experience harm or negative impacts as a result of climate change. Vulnerability is influenced by a variety of factors, including the exposure of the system to climate hazards (e.g., extreme weather events and changes in precipitation patterns), the sensitivity of the system to those hazards (e.g., how much damage will be caused by a given degree of temperature increase), and the adaptive capacity of the system to respond to those hazards (e.g., the ability to implement mitigation measures, manage resources, and respond to emergencies).

Some examples of vulnerable systems in the context of climate change include communities that rely heavily on agriculture for their livelihoods, and ecosystems that are sensitive to changes in temperature or precipitation patterns. Vulnerability can also be exacerbated by factors such as poverty, social inequality, and lack of access to resources, which can limit a community's ability to adapt to changing climate conditions.

Determining vulnerability involves assessing the degree to which a system (e.g., a community, ecosystem, or infrastructure) is likely to be affected by climate change and the extent to which it can cope with or adapt to those impacts. Here are some key steps in determining vulnerability:

Vulnerability is framed within the realities of the specific context and location (Davis-Reddy & Vincent, 2017). Therefore, for vulnerability to exist and be quantified, the capacity of the population to absorb, respond and recover from the impacts must be taken into consideration (Munyai, et al., 2019) The unique characteristics that make up each type of flood, drought and fire hazards and the wide range of ways in which they manifest, makes quantifying vulnerability to different flood hazards very context specific. Context is multifaceted and includes the geographic setting and characteristics of a hazard, as well as pre-existing social, economic, and political conditions (Rufat, et al., 2015). These geographical and temporally varying characteristics are key to deconstructing vulnerability because they describe/explain or amplify the degree to which human or environmental systems are sensitive and unable to adapt or cope with the adverse effects of a particular hazard.

Countries in the Southern African Development Community (SADC) region are vulnerable to climate change impacts due to several factors, such as their geographical location, low incomes, low technological and institutional capacity to adapt to rapid changes (including a greater reliance on rain-fed agricultural sectors) and practices that make communities climate-sensitive (Davis-Reddy and Vincent, 2017).

The impacts of climate change are already being experienced across South Africa, and the country will face multiple challenges in relation to climate change in the coming decade. The significant climate impacts being felt are caused by an increase in temperature and increased variability in rainfall, and due to South Africa warming at twice the global rate of temperature increase. The most vulnerable settlements in South Africa to climate-intensified hazards are those in locations that are already close to temperature and water availability thresholds or where rainfall intensity is already increasing. In South Africa, vulnerability due to the location of a settlement is predominantly accompanied by low economic growth, high levels of unemployment, persistent poverty, and inequality (Republic of South Africa, 2021).

In order to identify municipalities that are most vulnerable, the local municipalities (LMs) within which the two potential locations for intervention implementation in the five DMs are located in were assessed. These LMs were ranked according to their vulnerability relative to all other LMs in the country. This was done using four indicators of vulnerability (based on CSIR Green Book), namely:

- ***Socio-economic vulnerability***. The socio-economic indicator shows the vulnerability of households living in the municipality with regards to the household's age composition, education and health status, access to basic services, and safety and security.
- ***Economic vulnerability***. The economic vulnerability of the municipality to external shocks is based on the economic diversity, size of the economy, labour force, gross domestic product growth rate and the income inequality present in the municipality.
- ***Physical vulnerability***. The physical vulnerability addresses the physical fabric and connectedness of the settlements in the municipality. The more remote and/or structurally vulnerable, the higher the physical vulnerability score.
- ***Environmental vulnerability***. The environmental vulnerability represents the conflict between preserving the natural environment and accommodating the growth pressures associated with population growth, urbanisation, and economic development. The indicator measures air quality, environmental governance, and the competition between the ecology and urban encroachment.

The Green Book data, having been presented at LM level, was assessed – specifically for the LM's within each of the two potential locations of the five DMs - to determine the areas that had the highest vulnerability levels. The administrative boundaries of LM and the hydrological boundaries of the potential locations, in particular QCs, do not necessarily align. Therefore, the vulnerability assessment in this report does not consider the QCs but rather LMs within the DMs.

Further to the above, a multi-dimensional vulnerability assessment of six indicators undertaken by Le Roux et al. (2019) was reviewed for each LM located within the priority DMs. The indicators included low access to services, high socio-economic vulnerabilities, poor regional connectivity, environmental pressure, and high economic pressures. From this analysis, a high vulnerability score (i.e. closer to 10) indicated a scenario where an undesirable state of susceptibility is present. This assessment focused particularly on traditional settlements[8], as these areas of settlement are typically the most vulnerable.

## 3.4 EXPOSURE ASSESSMENT

Exposure refers to the level of vulnerability or susceptibility of people, property, and infrastructure to the impacts of flooding or droughts. Exposure can be influenced by various factors, such as, the location and topography of the area, the type and quality of infrastructure, and the socioeconomic status of the people who live in the area.

In areas with high exposure to flooding and droughts, the risks of damage to property, loss of life and livelihoods and displacement of people are high. The level of exposure to flooding and droughts may be amplified due to climate change. With regards to flooding, increased rainfall intensities or increased frequency of flooding events will result in increased exposure. Changes in rainfall patterns and changes in long-term average rainfall depths will increase exposure to droughts.

[8] According to the StatsSA Household Survey (2015) households were classes as formal, informal or traditional dwellings. These dwellings would have been built in traditional way or used traditional materials.

It is projected that the growing number of South African cities and towns will be exposed to the impacts of climate change-induced hazards such as floods and droughts. This is both a result of exposure to the projected increase in frequency, depth and intensity of hydrometeorological hazards and the poor land use, such as, growing informal settlements in floodplains and urban periphery which can be associated with accommodating a growing urbanising population facing significant development challenges (Republic of South Africa, 2021).

In order to quantify the level of exposure with respect to flooding, both fluvial and pluvial flooding should be considered. As mentioned previously, pluvial or "overland" floods are a consequence of heavy rainfall, that occur outside of a water body (i.e. a stream, river or dam), resulting in flooding in the immediate vicinity of rainfall event(s). Pluvial floods are predominantly associated with flooding in urban areas; however, pluvial floods can also happen due to intense rainfall runoff from hillslope areas when degraded soil and lack of natural vegetation reduce absorbing capacity of soil.

Fluvial floods are caused by an overflow of water from a river or stream, when the amount of water in a river or drainage line exceeds the river or stream's capacity, as a result of rainfall and runoff in the upstream catchment area, causing the water to overflow and flood the surrounding areas. Fluvial floods are the most common type of flood and can occur in both rural and urban areas. Fluvial floods are especially dangerous as fast-moving water associated with fluvial flooding, is commonly powerful enough to damage buildings, roads, and bridge infrastructure.

### 3.4.1 Flooding Exposure

Exposure to flood hazards has been quantified based on available data, as described below, and has ultimately been represented in a flood hazard susceptibility map. The methodology used in the development of this map is aligned to that used in the Green Book, for the development of a national flood hazard index (FHI). This initially included the creation of a geospatial database of selected factors that directly impact upon rainfall and runoff and therefore flooding. These factors, and their associated descriptions, are presented in Table 3-1. Each of these conditioning factors were used in bivariate statistical analysis, within a geographic information system (GIS) environment, to produce a flood hazard susceptibility map, which is representative of exposure to flooding across the study areas.

*Table 3-1: Flood conditioning factors*

| Conditioning factor | Influence on overland flooding |
|---|---|
| **Rainfall** | Rainfall is one of the main contributing factors to overland flooding (Wu et al., 2016). The characteristics of rainfall vary widely according to dominant atmospheric rain-forming mechanisms (convective, frontal, or cyclonic precipitation) as well as topographic conditions (orographic precipitation). This variability causes considerable temporal and spatial differences during rainfall events (Nachappa et al, 2020). High-intensity rainfall can cause flooding within a short period of time, while low-intensity rainfall, distributed within the catchment, occurring for an extended period of time can also cause flooding. |
| **Soil Type** | Soil type influences the susceptibility to flooding of areas of interest in a catchment since different types of soils have varying levels of permeability (Rahmati et al., 2015). Highly permeable soil types have high infiltration and vertical percolation rates and, therefore, are less susceptible to surface runoff and flooding. |
| **Elevation Variability** | The elevation variability of a catchment is an essential factor in flood susceptibility analysis because points of interest at different elevations in a particular catchment can have dissimilar meso-climate characteristics, soil conditions and vegetation distribution. (Rahmati et al, 2015; Arabameri et al., 2020). |

| Conditioning factor | Influence on overland flooding |
|---|---|
| | When considering fluvial flooding, the relationship between flooding and elevation is reciprocal in nature – that is, the higher the elevation of a point of interest, the lower the chance of wide-spread fluvial flooding. However, since the focus of this assessment is overland flooding, the relationship between flooding and elevation can be directly proportional – especially when gully formation or natural drainage pathways at high elevations concentrates the flow of runoff from extreme rainfall events. |
| **Slope** | The slope of an area of interest in a catchment is crucial in determining flood susceptibility as the slope regulates the vertical percolation of rainfall, as well as the surface runoff generation and velocity (Nachappa et al., 2020; Rahmati et al., 2015; Tehrany et al., 2015). |
| **Landscape curvature** | The divergent and convergent nature of runoff in a catchment is dominated by the curvature of the landscape and the upslope contributing area – consequently affecting susceptibility to flooding. Information on landscape curvature can be interpreted as follows: (i) negative curvature values exhibit a concave landscape, where runoff convergence (flooding) is prominent; (ii) zero curvature represents a flat landscape; and (iii) a positive curvature value depicts a convex landscape, where runoff divergence usually occurs (Rahmati et al., 2015; Islam et al., 2020). |

Soil type is one of the dominating factors used to characterise flood responsiveness in catchments. Soil data is grouped/categorised according to its responsiveness to rainfall – taking into account the infiltration rate, percolation rate and soil depth. Soils with a higher runoff potential are associated with a higher flood hazard, as with these soils a higher portion of rainfall is converted to runoff or stormflow. In order to account for soil types across the respective project areas, GIS shapefiles, extracted from the soil conservation services (SCS) soil classifications database, was used. Elevation variability and slope also have a significant impact on rainfall and runoff and therefore flood susceptibility. Steep areas generally result in higher ratios of rainfall to runoff and slope regulates the surface runoff velocity and the vertical percolation of rainfall and therefore the susceptibility to flooding. In order to characterise a catchment according to its topography, digital elevation models (DEMs) were used to classify the various proportions of the catchment falling into predefined slope thresholds.

To identify areas of increased exposure to overland flooding hazards, within each of the priority DMs, an overland flood hazard susceptibility map (OFHSM) was compiled. This was done by extracting the weights of the spatial relationship between the FHI and each conditioning factor. The FHI itself is based on a combination of information on the climate, the observed floods and the characteristics of catchments that make them more or less likely to produce a flood. A process diagram of the methodology used to determine exposure to overland flooding is provided in Figure 3-4. Through this analysis, two potential locations)[9] for intervention implementation were identified within each of the priority DMs. This allowed for a more focused analysis with regards to identifying flooding hazards across the project areas.

[9] When looking at potential locations, the use of QCs were considered within the five DMs due data availability and the hydrological nature of the areas.

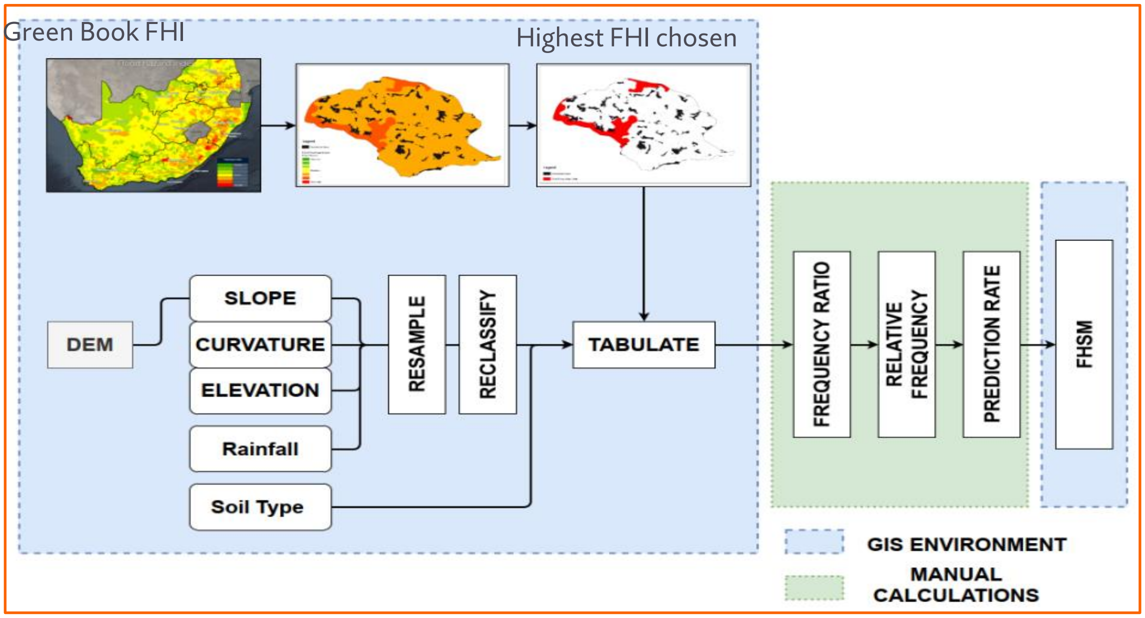



*Figure 3-4: Workflow for developing an overland flood hazard susceptibility map (OFHSM)*

Fluvial floods are caused by an overflow of water from a river or stream, when the amount of water in the said river or stream exceeds its capacity, generally as a result of rainfall and runoff in the upstream catchment area. This results in flooding in the areas surrounding the stream or river (into the adjacent floodplains). According to the NDMC, approximately 10% of the country's population is at risk of flooding. A common issue in South Africa is that many people, particularly associated with informal settlements, are located within areas that are at risk to fluvial flooding.

Identification of areas exposed to fluvial flooding generally involves analysing various factors. These include the analysis of topographical and hydrological characteristics of the contributing catchment area (climate, land use, soils), and undertaking hydraulic analysis (using detailed hydraulic model) of the area of concern. This provides information on the behaviour of flood waters in a particular area of concern (including providing information on flooding extents, depths and flow velocities). These models generally require detailed site specific information and require significant input from a suitably qualified hydrologist or engineer. It is anticipated, due to the level of detail and input required, that this analysis will be undertaken during the feasibility phase of the study. In addition to this, more detailed flood and hydraulic analysis will be undertaken during the design and analysis of effectiveness of proposed interventions.

Due to the level of input required to determine exposure to fluvial flooding, this CRVA study is limited to a high-level assessment. This included the identification of settlements and communities that are located in close proximity to main rivers, located within the two potential locations in the priority DMs. It is acknowledged that associating settlements that are located in close proximity to rivers as being exposed to flooding is a very broad assumption, however, this level of assessment will allow the consulting team to identify whether communities in one particular location are more exposed than another (across a particular DM). The assumptions made during this phase of the study will be firmed up on during the following phase of the project.

### 3.4.2 Drought Exposure

Drought exposure refers to the population, their livelihoods and assets (including land and ecosystem-based assets) affected within a given geographical area in which drought event(s) may occur. Exposure to drought is largely dependent on the sensitivity of a region, community or system to the impacts of drought. As such drought exposure is a concept that is related to socio-economic impact, which recognises the relationship between a lack of water (or goods and services supported by water) and the level of human demand on those goods, services and supply of water (Carrão, et al., 2017). Drought in itself have potentially different characteristics based on whether it is lack of precipitation with widescale land and vegetation degradation, a lack of surface water resources for meeting supply and demand in areas away from the point of storage, river flows being impacted and affecting local communities or commercial agriculture, ground water resources being impacted, or a range of other characteristics. The exposure relates to exactly what the purpose of the water resource serves in the affected area. Therefore, each geographical location where drought may affect the area or people living there or depending on water from such affected area would have a different narrative as to the nature, level/severity and type of exposure that is relevant.

Areas with naturally low rainfall, high evaporation rates, or long dry seasons are typically more exposed to drought. In addition to this, areas with limited water sources or high dependence on unreliable water supplies or difficult-to reach water sources such as deep aquifers, are also more exposed to the impacts of drought. Regions with high water demands, and where water infrastructure management challenges are present (such as where large dams are not operationally efficient), or where inefficient water management practices hold sway, are more exposed to water scarcity and are therefore more exposed to drought impacts. Drought exposure is a complex issue, and to determine the level of exposure of a particular region requires a substantial amount of site-specific information: from environmental and natural geographical perspectives, as well as developmental (infrastructure), governance, operational, community and livelihood perspectives.

In the five DMs where this assignment focuses on, much of the drought exposure relate to an ability to produce local crops and rear livestock. For communities in these rural and peri-urban or underserviced areas, commercial agriculture is not a significant component of their livelihood stack – rather, subsistence agriculture is a key focus, as well as local potable water supply either through surface water sources, or from ground water aquifers. This means that in the study areas of the five DMs, the drought exposure elements would, to a large extent, focus on vegetative health, limitation of alien invasive species (linked to infiltration rates and ecosystem health), wetland productivity, water absorption and aquifer recharge rates, and storage of water for small-scale irrigation and livestock purposes.

To assess the exposure in the five DM areas to drought, based on the above discussion, the WWF Water Risk Filter (WWF, 2023) was used, with the particular risk category used being the *Water Scarcity index*. According to the WWF water scarcity analysis methodology, water scarcity refers to the physical abundance or lack of freshwater resources, which can significantly impact water supply. Waster scarcity was calculated as a function of the volume of water use/demand relative to the volume of water available in a given area.

The Water Risk Filter risk category water scarcity is a comprehensive and robust metric as it integrates a total of 7 best available and peer-reviewed datasets covering different aspects of scarcity. The water scarcity was based on the following:

- ***Aridity Index*** – This index classified regions according to their climate zones, with humid areas being associated with a low index value and arid areas receiving a high index value. The Global Aridity Index (Trabucco, 2019) was based on global climate data for the period 1970-2000, related to evapotranspiration processes and rainfall deficit for potential vegetative growth.

- ***Water Depletion*** - Water depletion measures the ratio of surface and ground water consumptive use to available renewable water. This indicator was based on model outputs from WaterGAP3 to compute average annual and monthly values, for the period 1971-2000, and to map seasonal depletion and dry-year depletion.

- ***Baseline Water Stress*** - The World Resources Institute's Baseline water stress measures the ratio of total surface and groundwater withdrawals to available renewable water. This indicator is based on model outputs from PCR-GLOBWB 2 to compute average monthly values, for the period 1960-2014, then to produce regression values for the year 2014 (baseline). Note that, although this indicator is called "water stress", it does not explicitly take into account environmental flow requirements, water quality, or access to water.

- ***Blue Water Scarcity*** - Surface and ground water (i.e. water in freshwater reservoirs, rivers and aquifers) scarcity measures the ratio of the "blue water footprint" to the total "blue water availability". This indicator is based on the global standard for water footprint assessment to compute average monthly values (10-year average for the period 1996-2005).

- ***Available Water Remaining*** - Available Water Remaining measures the available water remaining in a given river basin relative to the world average, after human and aquatic ecosystem demands have been met. This indicator is based on the Water Use in Life Cycle Assessment to quantify the potential of water deprivation to either humans or ecosystems (for the year 2010) and serves in calculating the impact score of water consumption in Life Cycle Assessments or to calculate a water scarcity footprint.

- ***Drought Frequency Probability*** - The drought frequency and probability Water Risk Filter indicator is based on the SPEI, as described previously. More specifically, SPEI was used to determine the relative frequency probability of hydrological drought events of moderate magnitude occurring in any given year (i.e. ratio of the number of months when index is below or equal to events of moderate magnitude (SPEI <= -1) to the total number of possible outcomes, considering the last 10 years (August 2011 – July 2021) as reference period.

- ***Projected Change in Drought Occurrence*** - This indicator is based on a multi-model simulation that applies both global climate and hydrological models from the Inter-Sectoral Impact Model Intercomparison Project. The 2.5$^{th}$ percentile of soil moisture is calculated for pre-industrial conditions (1661-1860), and defined as the drought threshold. Then years are counted in which soil moisture falls below this threshold for at least seven consecutive months, and it is estimated the probability that an event of at least this magnitude occurs in a given year. Results are expressed in terms of percentage change in probability between preindustrial and the time that the average global temperature reach 2°C warming (around the year 2050, based on RCPs 2.6 and 6.0).

# 4 Hazard, Vulnerability and Exposure Assessment per DM

## 4.1 ALFRED NZO DM

The Alfred Nzo DM stretches from the Drakensberg Mountains, bordering Lesotho to the north, to the OR Thambo DM in the south and Sisonke DM in the east. It is the smallest DM in the Eastern Cape and is considered one of the poorest. The DM is characterised by high levels of poverty (Beraki, 2019). It contains five LMs, namely: Matatiele, Ntabankulu, Umzimvubu, Winnie Madikizela-Mandela (previously Mbizana. Economic opportunities in the region include the potential for tourism and forestry, however, a challenge has been the provision of infrastructure to settlements in hilly areas and including the provision of basic services.

According to the 2011 census, there were just over 800 000 people living in the DM covering an area of just under 11,000 km² (StatsSA, 2015). Households in the DM were then, and are expected to still be predominantly headed by women. In addition, about 80% of the population was below 35 years of age at the time of the Census being conducted. The DM has very low levels of access to piped water and sanitation, and the use of electricity for lighting remains very low (Alfred Nzo DM, 2018). Agriculture was at the time of the 2011 Census the largest land use in the DM, with more than half of households being involved in agricultural activities (StatsSA, 2015) - this situation is not expected to have changed much since then, although intensified rural housing sprawl and migration of households towards centralised towns were clearly visible across the DM when site visits were conducted. Although most agricultural activities are subsistence there are several commercial farms situated toward the northeast of the DM, around Cedarville town. Crop farming consists of mainly dryland farming, with some irrigated crops, and livestock herding includes goat, sheep, beef and dairy farming (Alfred Nzo DM, 2019).

### 4.1.1 Overview of Alfred Nzo DM

The top two potential locations identified in the Alfred Nzo DM, as per QCs, are T32G (in purple) and T40A (yellow) (Figure 4-1). Hydrologically, catchment T32G is located within the Mzimvubu/Umbashe primary catchment and the Mzimvubu secondary catchment. The main river located within this QC is the Mzintlala River, which is a tributary of the Mzimvubu River. This system is a headwater system, which means that there are no rivers contributing streamflow from surrounding catchments. Catchment T40A is also located within the Mzimvubu/Mbhashe primary catchment. The main river draining from QC T40A is the Goxe River, which is a tributary of the Mtamvuna River, which is also a headwater system.

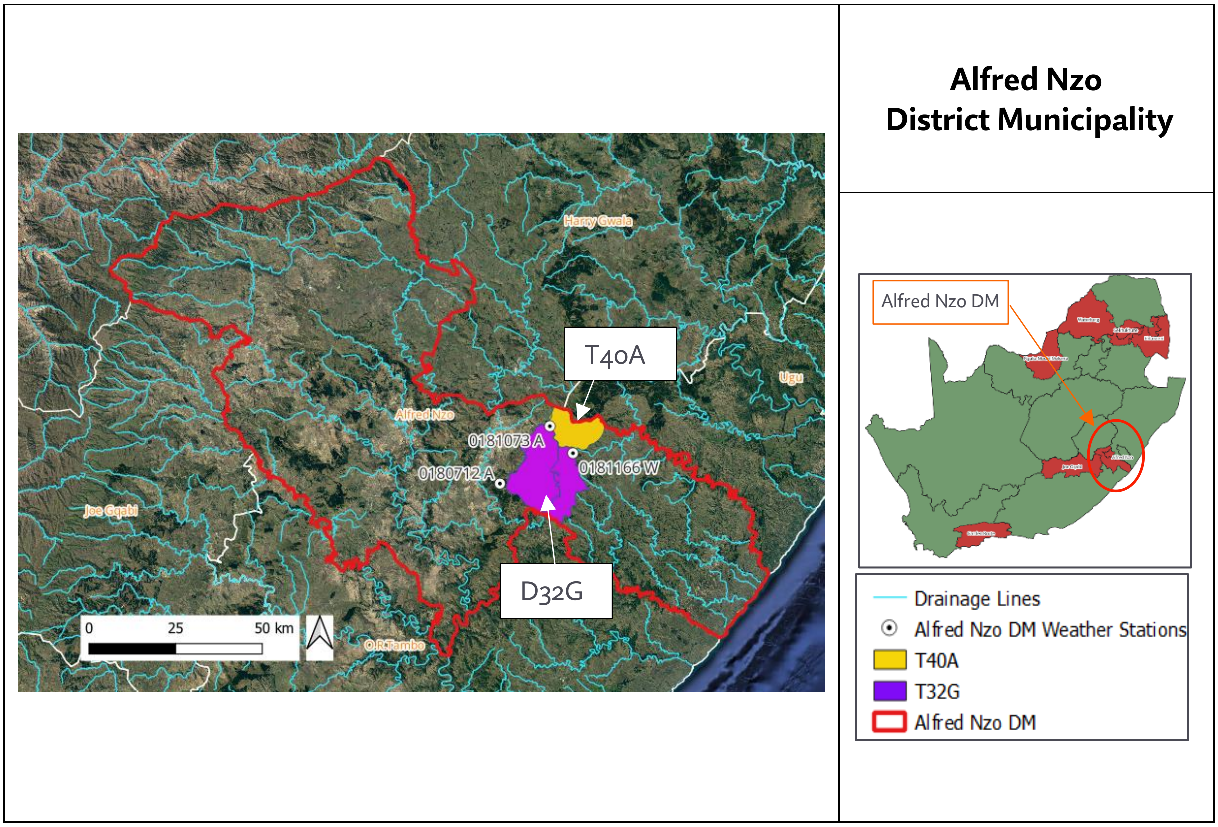
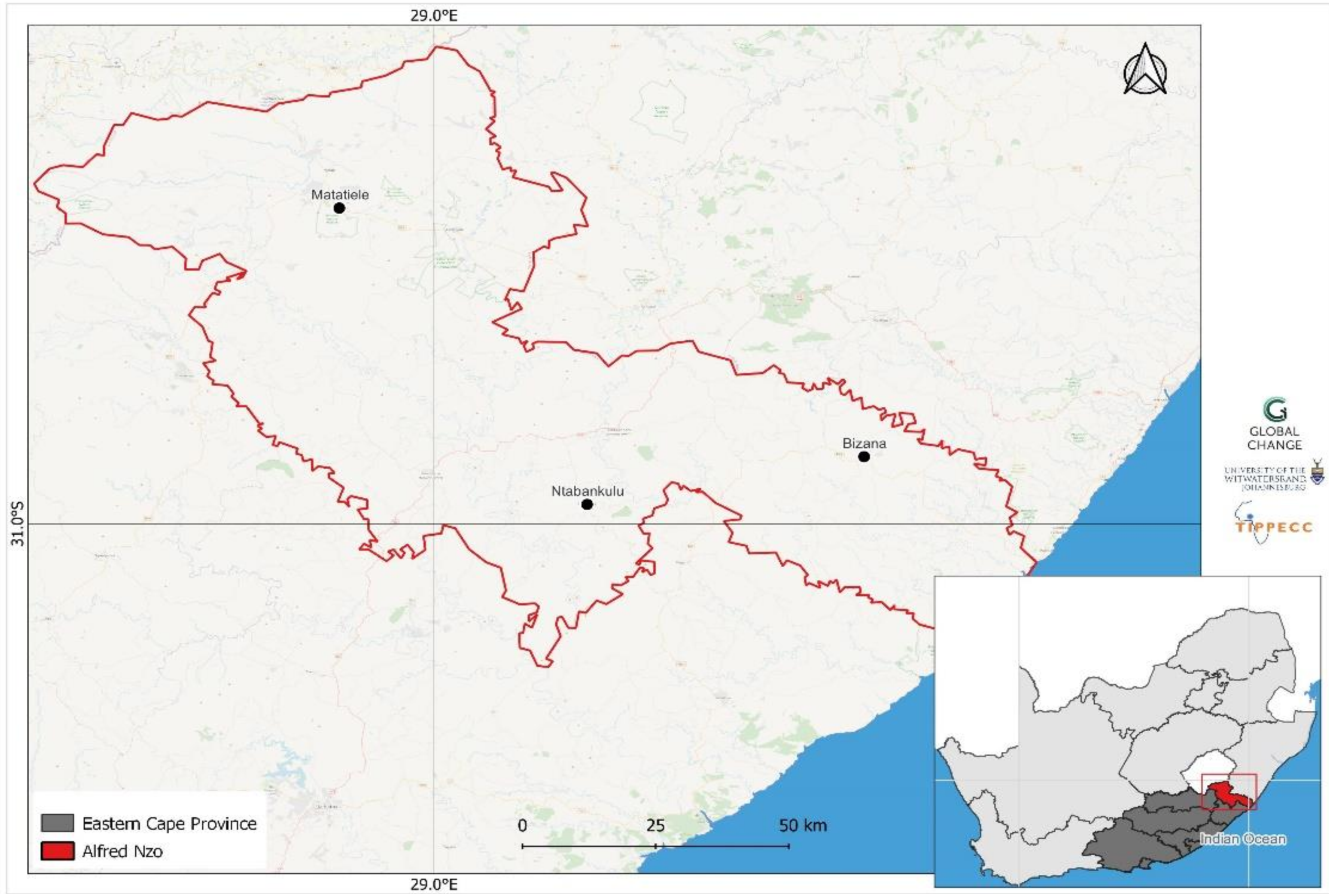



*Figure 4-1: Alfred Nzo DM and Priority QCs*

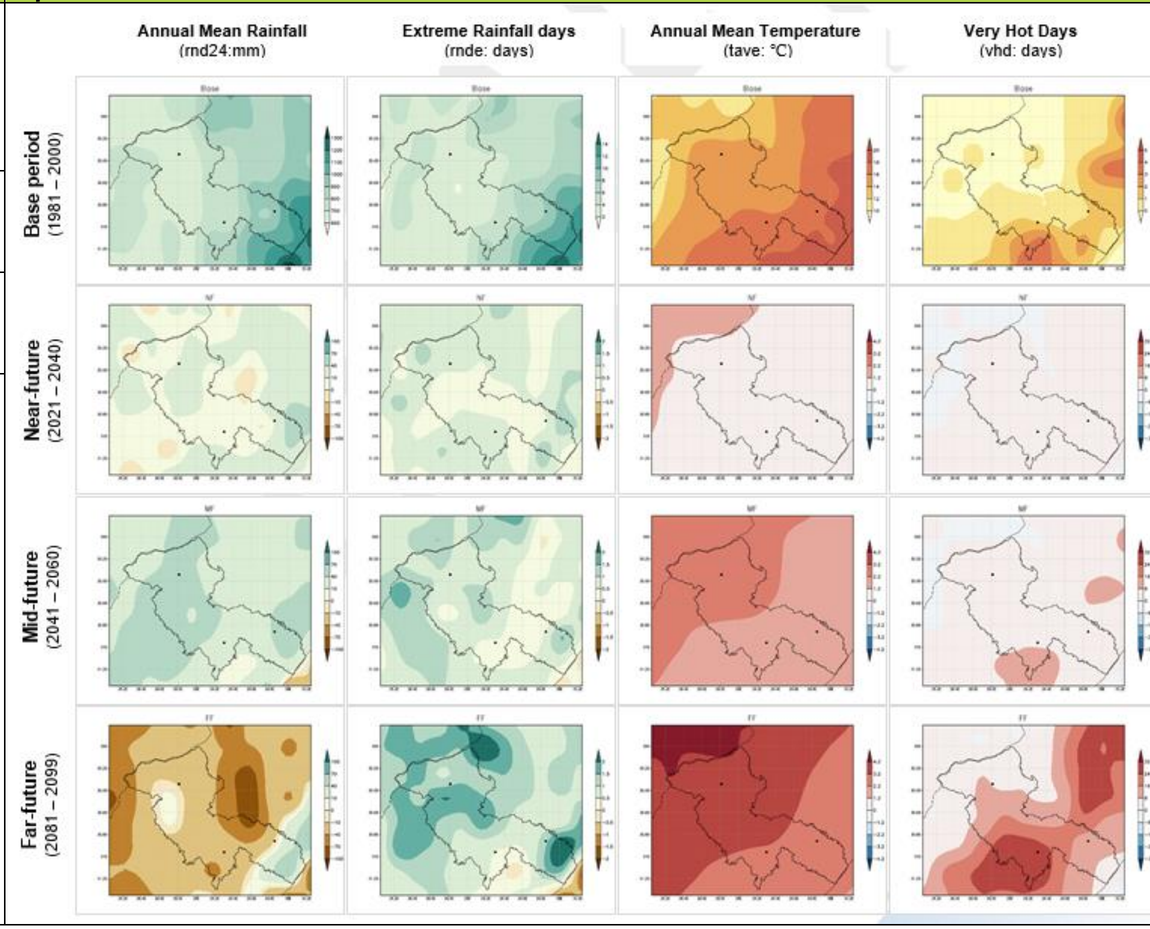
A summary of the observed climate conditions in Alfred Nzo DM (GCI & SANBI, 2024) is presented in the table below.

*Table 4-1: Location and summary of observed climate conditions for Alfred Nzo DM*

| Parameter | Observed conditions | Locality |
|---|---|---|
| Mean annual rainfall | There is an observed general increase in annual mean precipitation (low confidence), with values ranging from 600 mm in the northern interior to more than 1100 mm in the coastal regions. |  |
| Extreme rainfall days | Observed increases in the frequency of extreme rainfall events, with the annual number of extreme rainfall days ranging from 2 in the northern interior to over 12 along the coastal strip, at medium confidence. | |
| Mean annual temperature | Observed increases in annual mean temperature and warm extremes (*virtually certain), with* mean temperature ranging from about 14 °C over the northern interior to more than 20 °C over the coastal strip. | |
| Very hot days | Very hot days range between 1 over the north to about 5 days over the southwestern interior regions. | |

A summary of the projected climate changes and spatial anomalies in Alfred Nzo DM (GCI & SANBI, 2024) is presented in the table below.

*Table 4-2: Projected climate changes and spatial anomalies in Alfred Nzo DM*

| Parameter | Projected conditions | Spatial anomalies |
|---|---|---|
| Mean annual rainfall | Projected decrease in annual mean precipitation *(low confidence in the near- and mid-future, high confidence in the far-future)*. |  |
| Extreme rainfall days | Projected increase in the frequency of heavy precipitation events *(low confidence)*. | |
| Mean annual temperature | Projected increase in annual mean temperature *(virtually certain)*. | |
| Very hot days | Projected increase in warm extremes *(virtually certain)*. | |

### 4.1.2 Flood Hazard Assessment for Alfred Nzo DM

**Flooding History**

The Alfred Nzo DM often experiences heavy rainfall during the summer months, which commonly leads to flooding in low-lying areas. A number of significant historical flood events in the Alfred Nzo DM include:

- **February 2023 Floods**: Above-average rainfall as a result of the La Niña weather phenomenon led to flooding in Provinces and DMs across South Africa - including the Alfred Nzo DM. Roads, stormwater drainages and bridges were severely damaged (Green Times, 2023; SABC News, 2023).
- **April 2019 Floods:** Heavy rainfall in April 2019 caused flooding in several towns and villages in the district, including Bizana, Flagstaff, Lusikisiki, and Mount Ayliff. Homes and infrastructure were damaged or destroyed, and many people were displaced. The flooding was caused by heavy rains that fell over a period of several days, which caused fluvial flooding and inundation in communities located near drainage lines. In response to the flooding, the South African government declared a state of disaster in the affected areas, and emergency relief efforts were initiated to provide food, shelter, and medical assistance to those affected (News24, 2019; Fisher & Lindeque, 2019).
- **March 2017 Floods:** In March 2017, several days of heavy rainfall led to flooding in the district, resulting in the deaths of several people and significant damage to infrastructure and homes. As a result of the flooding, the government declared a state of disaster in the affected areas in order to facilitate rapid responses to the hardest hit areas. The towns and villages most affected by the flooding were Mount Ayliff, Ntabankulu, and Mbizana villages (Kubheka, 2017).
- **December 2014 Floods:** Similar to the 2019 and 2017 floods, a state of disaster was declared during the December 2014 floods. The flooding caused extensive damage to homes, businesses, and public infrastructure, including roads, bridges, and schools. Many residents were left stranded as their homes were flooded, and hundreds of families were displaced. The towns and villages most affected by the flooding were Mount Ayliff, Ntabankulu, and Mbizana.
- **January 2011 Floods:** Heavy rainfall in January 2011 caused significant flooding in several towns and villages in the district, including Mount Ayliff and Mzintlava. The flooding caused damage to homes, businesses, and public infrastructure, including roads, bridges, and schools. Many residents were left stranded as their homes were flooded, and several families were displaced. During these floods, a state of disaster was also declared (South African Government, 2011).
- **January 2000 Floods:** The Alfred Nzo District Municipality experienced severe flooding in January 2000, which resulted in the deaths of several people and caused extensive damage to infrastructure and homes. The towns and villages most affected by the flooding were Mount Ayliff, Tabankulu and Lusikisiki.

Further to the above, flooding was recognised as a significant hazard in the DM by participants during the district-level workshop. The impact of flooding was felt on communities' dwellings as well as farmers' crops and livestock in the affected areas. Roads and bridges were also severely damaged during flooding periods and often resulted in villages being cut-off from services and surrounding towns. According to workshop participants, flooding was most prevalent during heavy rains and hailstorms in the region and was also exacerbated by deforestation, overgrazing, illegal sand mining, soil erosion due to steep slopes and terrain (especially the presence of large dongas i.e. dry gullies formed by the eroding action of running water). It was also noted that some houses have been built along drainage and flood lines, further increasing communities' risk to flooding. The wetlands in the area were noted as degraded by many of the attendees. The participants were in agreement with the two potential locations identified for intervention implementation in the district (T32G and T40A) as well as being in alignment with DM and LM plans.

In addition, the site visit in the Alfred Nzo DM revealed the presence of IAPs, specifically wattle that was present in significant amounts (Figure 4-2). IAPs that are easily dislodged during heavy rains or floods (e.g. wattles and sesbania) tend to block watercourses, exacerbating the flood event or diverts flood water to other more vulnerable areas. There is also encroachment of "ouhout" bushes (*Leucosidea sericeas).* The flowers and young shoots are browsed by cattle and goats in spring. However, it forms dense thickets on overgrazed, eroded or otherwise disturbed areas, and can therefore become a problem plant on farmland. Poor and inefficient rangeland management practices, coupled with climate change impacts on the drought-fire cycle exacerbates alien plant invasion and bush encroachment alike, and secondarily decrease undergrowth, resulting in increased runoff, erosion and subsequent flooding challenges downstream.

*Figure 4-2: Examples of wattle invasive growth (photo on the left and on the top left-hand side of the photo on the right) and removal (right-hand side on the photo on the right) in Alfred Nzo DM*

*Figure 4-3: IAP clearing in Alfred Nzo DM: current activities (photo on the left) and historical clearance (photo on the right)*

The site visits also highlighted current as well as historical IAP clearing activities (Figure 4-3), showcasing strong intent and commitment within the DM to address IAP issues. At the same time, it was established that there is opportunity to build on previous work, and expand and upscale existing strategies whilst learning from the previous experiences.

During the site visit, there was also clear evidence of erosion during heavy rains which threatens households as well as roads and bridges (see figures below). Significant erosion challenges were visible, especially where infrastructure development was poorly implemented. An example is where the size of culverts are too small for the volume of runoff that is being experienced, and erosion subsequently occurs on both sides of a road where this is prevalent. In other instances, floods/floodplains exceed the span of bridges, and surrounding road infrastructure is eroded away. In yet other examples, pipe installations and road construction does not accommodate the level of flood and extent of downpours, resulting in landslides cliff-road failures, downstream flooding and siltation, etc. In some locations, entire settlements were close to sliding down hillsides due to erosion and subsequent flooding. It was also noted during the site visit that pollution (i.e. nappies) are blocking culverts, which exacerbates flooding across much of the DM.

*Figure 4-4: Examples of erosion and run-off threatening households in Alfred Nzo DM*

*Figure 4-5: Example of erosion and flood extent threatening a bridge in Alfred Nzo DM*

Wetland degradation was also seen during the site visits due to pollution, encroachment of villages and poor agricultural practices, although this is related more to poor spatial planning and lack of local enforcement.

**Rainfall Analysis**

***Historical Rainfall Analysis***

There are several rainfall stations located within the Alfred Nzo DM. Three rainfall stations in the vicinity of QCs T40A and T32G were selected to determine whether any trends in changes in extreme rainfall could be identified, based on an analysis of historical rainfall data. Each of the selected rainfall stations are presented in Figure 4-1. At each rainfall station, the Annual Maximum Series (AMS) was extracted, based on information provided by the Southern African Weather Services (SAWS). The AMS refers to the maximum depth of rainfall, over a 24-hour period, that has been measured during a hydrological year. AMS data is generally used in design flood hydrology to estimate design rainfall depths, which in turn are used in the estimation of flood peaks associated with a return period. Based on the connection between AMS rainfall data and design rainfall depths and therefore flood estimation, changes in the AMS can be linked to changes in flood hydrology.

Figure 4-6, Figure 4-8 Figure 4-10 present the AMS for the selected rainfall stations, located within the Alfred Nzo DM, and in proximity to QC's T40A and T32G. In each of the graphs, a trendline was fitted to the historic data. In each case an upward trend is evident in the AMS data. Further analysis was also undertaken to determine whether the increasing trend in AMS, for each respective rainfall station analysed in the vicinity of the Alfred Nzo DM (as shown in Figure 4-1), showed increasing trends in the design rainfall (i.e. statistically the maximum depth of rainfall that can be expected to occur during a specific period of time and associated with a return period). This analysis was undertaken by estimating the design rainfall depths associated with a 10-year and 50-year return periods, over a 24-hour period. Initially the analysis was based on the first 30 years of observed AMS data. Thereafter, the design rainfall depths were re-estimated based on incrementally adding a year onto the record period used for the estimation of the design rainfall depths. This was repeated until the entire record period was considered. Design rainfall estimates were based on the Gumbel distribution. The results of this analysis are provided in Figure 4-7, Figure 4-9 and Figure 4-11. The sudden increases in return period rainfall depths, presented in these graphs, are as a result of an extreme rainfall event (or AMS value) that would have occurred in that particular year. The extreme rainfall event changes the statistics associated with return periods and rainfall depths. At each rainfall station, trends of the AMS and design rainfall depths showed a very obvious increasing trend. This analysis clearly demonstrates changes in the hazard associated with extreme rainfall, which would result in more severe floods in the vicinities of QC's T40A and T32G.

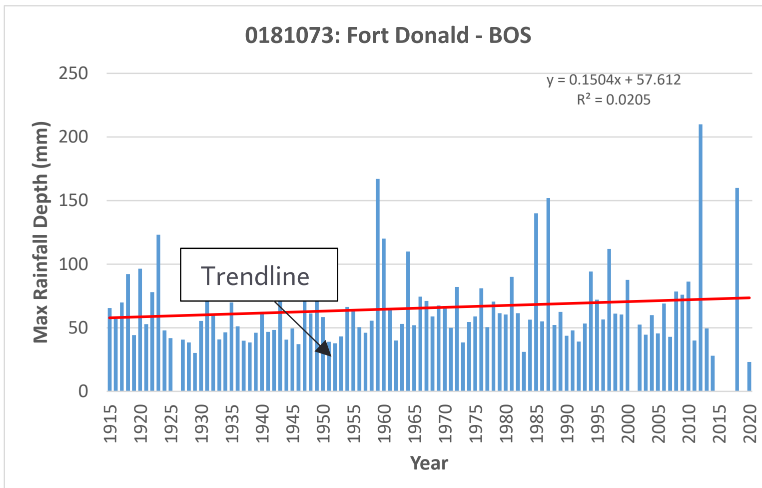



*Figure 4-6: Annual Maximum Series Rainfall Data - Station 0181073 W (1914 – 2020)*

*Data sourced from SAWS.*

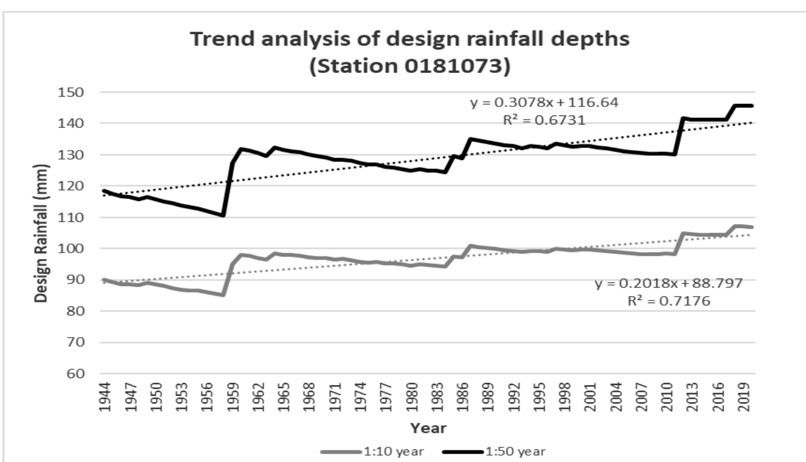



*Figure 4-7: Analysis of 1:10 and 1:50 year design rainfall depth trends for weather station 0181073*

*Data sourced from SAWS.*

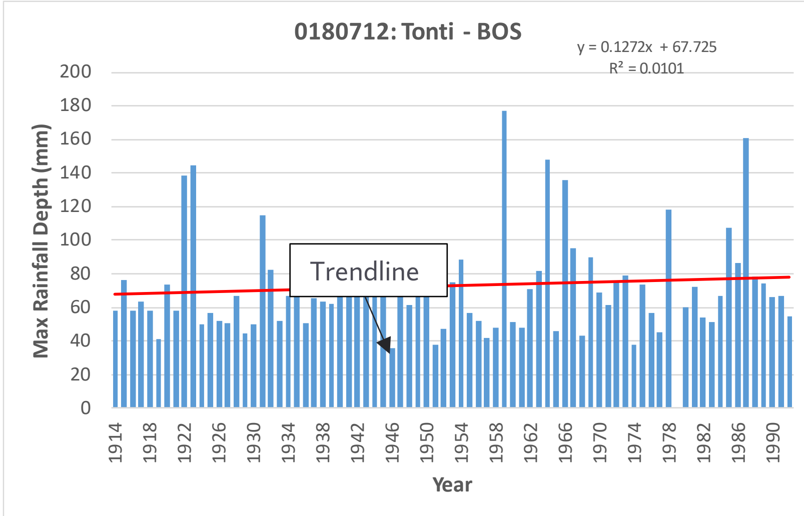



*Figure 4-8: Annual Maximum Series Rainfall Data - Station 0180712 W (1914 – 1992)*

*Data sourced from SAWS.*

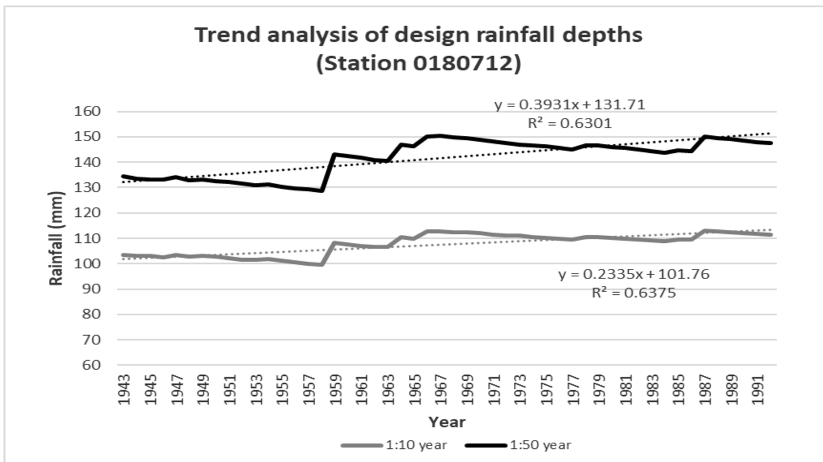



*Figure 4-9: Analysis of 1:10 and 1:50 year design rainfall depth trends for weather station 0180712*

*Data sourced from SAWS.*

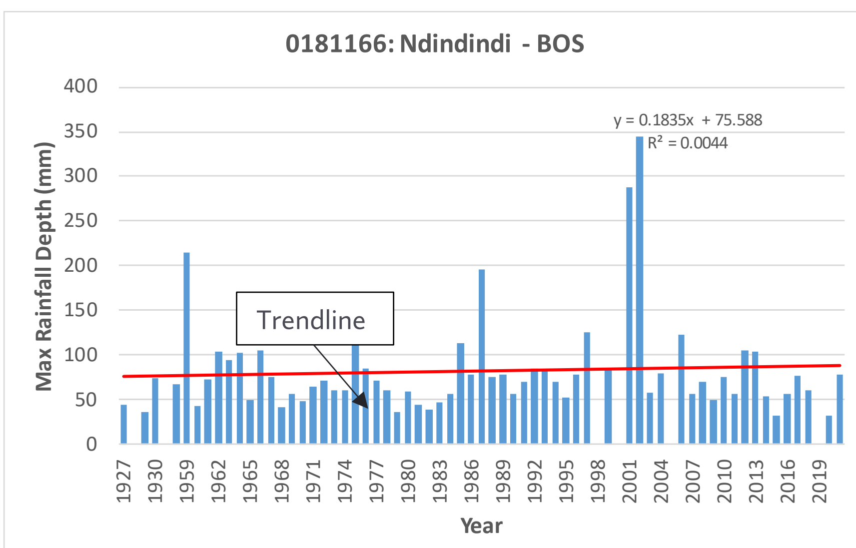



*Figure 4-10: Annual Maximum Series Rainfall Data - Station 0181166 W (1927 – 2021)*

*Data sourced from SAWS.*

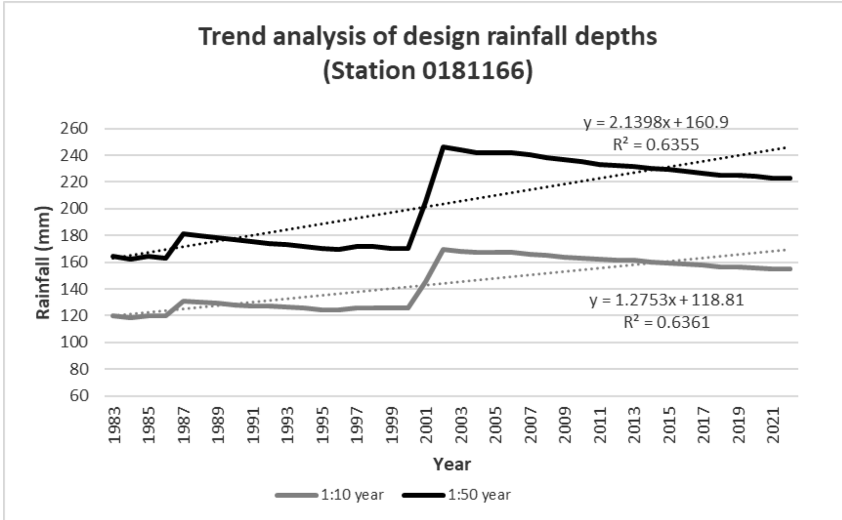



*Figure 4-11: Analysis of 1:10 and 1:50 year design rainfall depth trends for weather station 0181166*

*Data sourced from SAWS.*

**Projected Changes in Extreme Precipitation and Consequently Flood Hazard**

As indicated previously, the estimation of design floods for ungauged catchments is generally the product of a combination of design (extreme) rainfall and catchment characteristics (which impacts on the conversion of rainfall to stormflow). Due to the complexities of accounting for the variability in catchment characteristics across the study areas (catchment area, slope, land cover characteristics, soil characteristics etc.), the assessment has focused on changes in precipitation and in extreme precipitation trends to identify changes in flood hazards.

For this analysis, anomalies of extreme precipitation were sourced from the Climate Change Knowledge Portal (CCKP). To determine anomalies in extreme rainfall, comparisons between baseline (historic) rainfall data and forecasted rainfall data was undertaken. The extreme precipitation anomalies extracted from the CCKP are based on SSP5-8.5, and centralised over the 2050 period, using the 50$^{th}$ and 90$^{th}$ percentiles of multi-model ensembles. Both the 50$^{th}$ and 90$^{th}$ percentiles were used to illustrate the range of possible anomalies using different SSPs (therefore illustrating uncertainty). Anomalies based on the changes in magnitude of the 1:100-year return period rainfall depths. A map of the anomalies, across the Alfred Nzo DM is presented in Figure 4-12, which indicates a range of change from 2mm (50$^{th}$ percentile) and 52mm (90$^{th}$ percentile) at the South-eastern portion of the DM to 8mm (50$^{th}$ percentile) and 53mm (90$^{th}$ percentile) in the northern portion of the DM. QCs T40A and T32G show an increase of between 2mm and 6mm for the 1:100-year design rainfall using the 50$^{th}$ percentile model ensembles, and between 52mm and 56mm using the 90$^{th}$ percentile model ensembles.

| | |
|---|---|
| | **Alfred Nzo DM**<br>***Extreme Rainfall Anomalies*** |

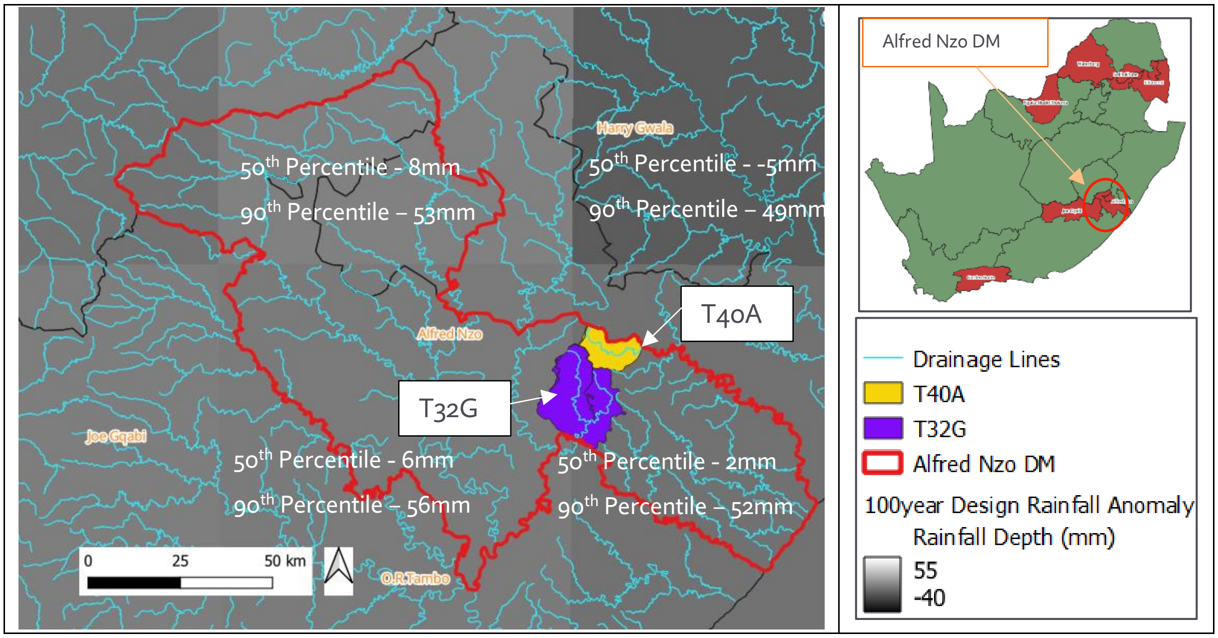



*Figure 4-12: Alfred Nzo DM extreme rainfall anomalies based on the CCKP SSP5-8.5 for 2050*

To contextualise the increase in extreme rainfall across the Alfred Nzo DM, design rainfall at the centroid of each priority QC was extracted using the RLMA&SI approach developed by Smithers and Schulze (2002). The resultant design rainfall for the T40A and T32G QCs are presented in Table 4-3. Based on these estimates of design rainfall compared to the anomalies of extreme rainfall related to the 100-year return period rainfall event (indicated in yellow in the table below), an increase in extreme rainfall of between 3% and 29% is projected for QC T40A and T32G, based on the 50th and 90th percentiles of model ensembles.

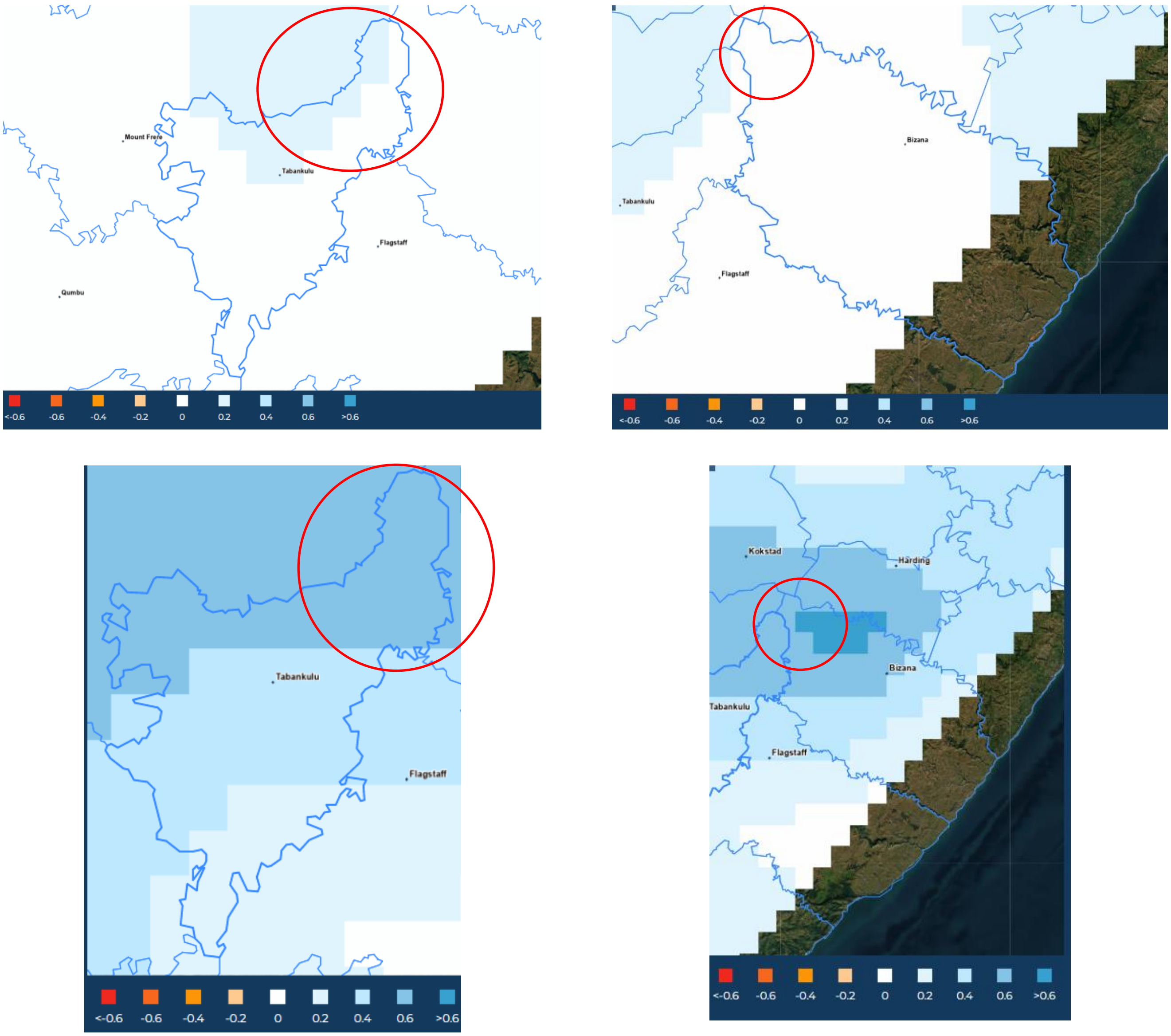
*Table 4-3: Alfred Nzo DM Design Rainfall Estimates*

| | Design Rainfall Depths (mm) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1:2 year | 1:5 year | 1:10 year | 1:20 year | 1:50 year | 1:100 year | 1:200 year |
| T40A | 72 | 99 | 119 | 141 | 171 | 197 | 225 |
| T32G | 69 | 95 | 114 | 134 | 163 | 188 | 215 |

### 4.1.3 Drought Hazard Assessment for Alfred Nzo DM

Drought has been known to impact the DM, with the recent drought in 2016 being the result of dry spells and extreme hot conditions associated with the strong 2015/16 El Niño event and preceding drier than normal years, especially over the central parts of the country. This impacted dam levels and harvests of 2015/2016 (South African Government, 2016; Let's Respond Toolkit, n.d.). It should also be noted that participants during the district workshops highlighted the issue of drought in the DM due to the presence of IAPs.

As presented in Section 3, drought hazard analysis is based on anomalies in the SPEI index, which is a proxy indicator for drought and importantly changes in drought hazards due to climate change. The current drought hazard for the two potential locations for intervention implementation within Alfred Nzo DM indicates that T32G has reduced drought tendency per 10 years in the north-west of the catchment (Figure 4-13). An assessment of the change in drought hazard indicates that both T32G and T40A are projected to have a decrease in drought tendencies per 10 years by 2050[10] (Figure 4-13).




Ntabankulu LM (T32G) Mbizana LM (T40A)

*Figure 4-13: SPEI drought tendencies for 2014 to 2044 for Alfred Nzo DM (Source: Engelbrecht et al., 2019)*

### 4.1.4 Vulnerability Assessment for Alfred Nzo DM

Assessment of the LMs in the Alfred Nzo DM versus the other LMs in the country indicated that these LMs in Alfred Nzo DM are some of the most vulnerable from a socio-economic and physical perspective. The three LMs in the table below all rank below

[10] The change in drought hazard map presents the projected change in the drought (flood) tendencies (i.e. number of cases exceeding near-normal per decade) over South Africa for the period 1995-2024 relative to 1986-2005 baseline period under low mitigation scenario (RCP 8.5). Projections are shown for each of the six CCAM downscaling and an ensemble mean. A negative value is indicative of an increase in drought tendencies per 10 years (more frequent than baseline).

190 out of 213 regarding socio-economic vulnerability while the Umzimvubu and Mbizana LMs also rank low for physical vulnerability.

*Table 4-4: Multi-dimensional vulnerability (ranking out of 213) for LMs in Alfred Nzo DM.*

*Source:* (Le Roux, et al., 2019)

| DM | LM | Socio-Economic | Economic | Physical | Environmental |
|---|---|---|---|---|---|
| Alfred Nzo | Umzimvubu | 192 | 70 | 182 | 172 |
| | Ntabankulu | 213 | 23 | 118 | 88 |
| | Mbizana | 203 | 32 | 212 | 137 |

As presented in Figure 4-14, the Umzimvubu and Mbizana LMs are identified as most vulnerable within the Alfred Nzo DM.


*Figure 4-14: Vulnerability of LMs within the Alfred Nzo DM, with focus on traditional settlements*

*Source:* (Le Roux, et al., 2019)

According to the Green Book (Le Roux, et al., 2019), the projected growth pressure for Alfred Nzo DM indicates that the Mbizana LM has the highest growth scenario across the periods 2030 and 2050 (Table 4-5).

*Table 4-5: Growth scenarios for local municipalities in Alfred Nzo DM.*

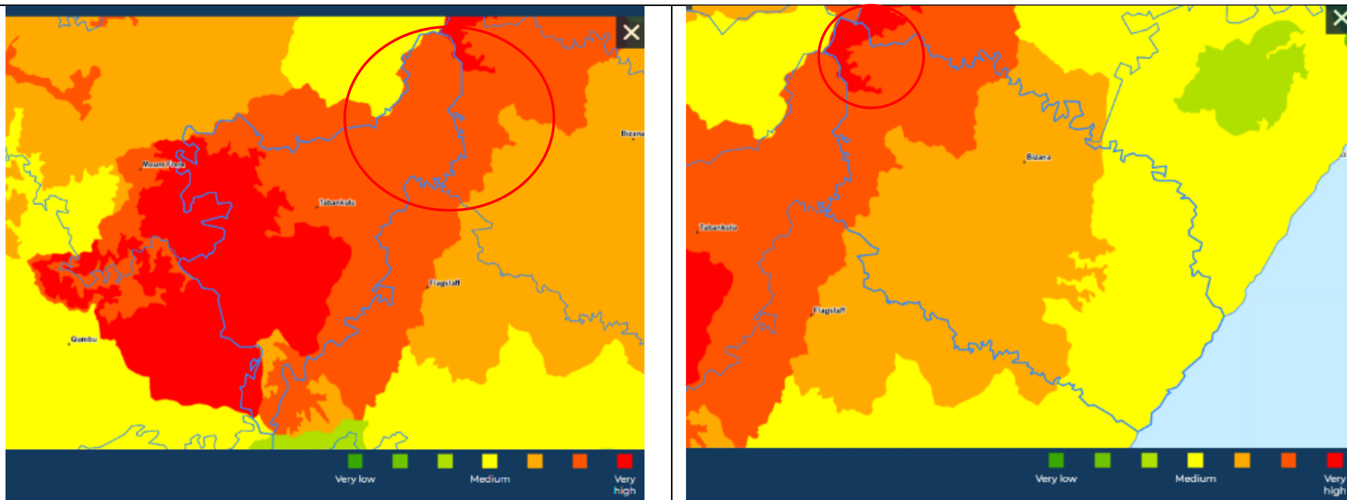
*Source:* (Le Roux, et al., 2019)

| DM | LM | Growth scenario | 2011 | 2030 | 2050 |
|---|---|---|---|---|---|
| **Alfred Nzo** | Umzimvubu | Medium | 191,722 | 211,253 | 204,294 |
| | | High | 191,722 | 221,535 | 224,941 |
| | Ntabankulu | Medium | 123,638 | 138,990 | 138,512 |
| | | High | 123,638 | 145,741 | 152,481 |
| | **Mbizana** | **Medium** | **281,265** | **414,964** | **555,478** |
| | | **High** | **281,265** | **435,134** | **611,564** |

### 4.1.5 Exposure Assessment for Alfred Nzo DM

The resultant level of flooding exposure associated with the Alfred Nzo DM, is presented in Figure 4-15. The Alfred Nzo DM is associated with a high to very high FHI across the areas in which the two potential locations for intervention implementation are located.

***Alfred Nzo DM Flood Exposure***




Ntabankulu LM (T32G) | Mbizana LM (T40A)

*Figure 4-15: Current relative flood hazard index for Alfred Nzo DM*

*Source: (Engelbrecht et al., 2019)*

**Exposure to Pluvial Flooding**

Based on the OFHSM results, and in particular QC T32G, a relatively large area around Mbizana region is highlighted as being exposed to pluvial flooding (Figure 4-16). The area most vulnerable to flooding in the T40A catchment is located in the upper catchment areas, as presented in Figure 4-17, and is most likely as a result of the steep topography and shallow soils in this area.

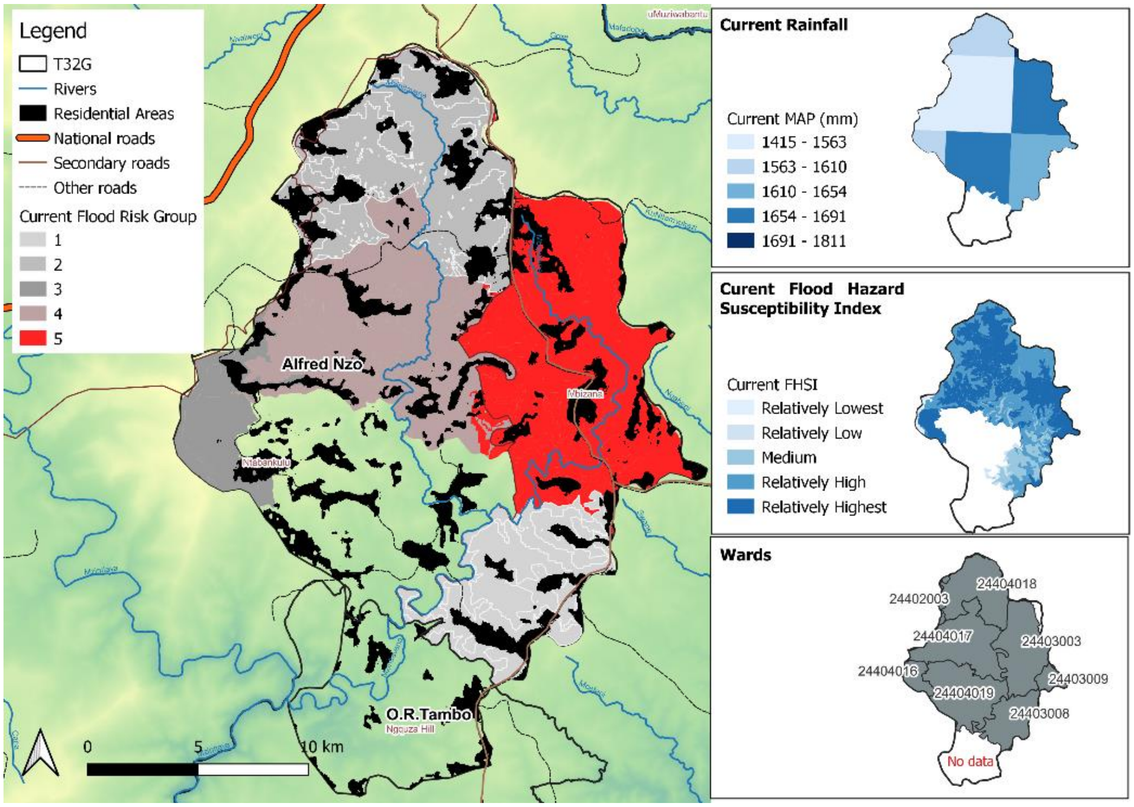



*Figure 4-16: Current relative flood risk groups based on current rainfall for T32G in Alfred Nzo DM*

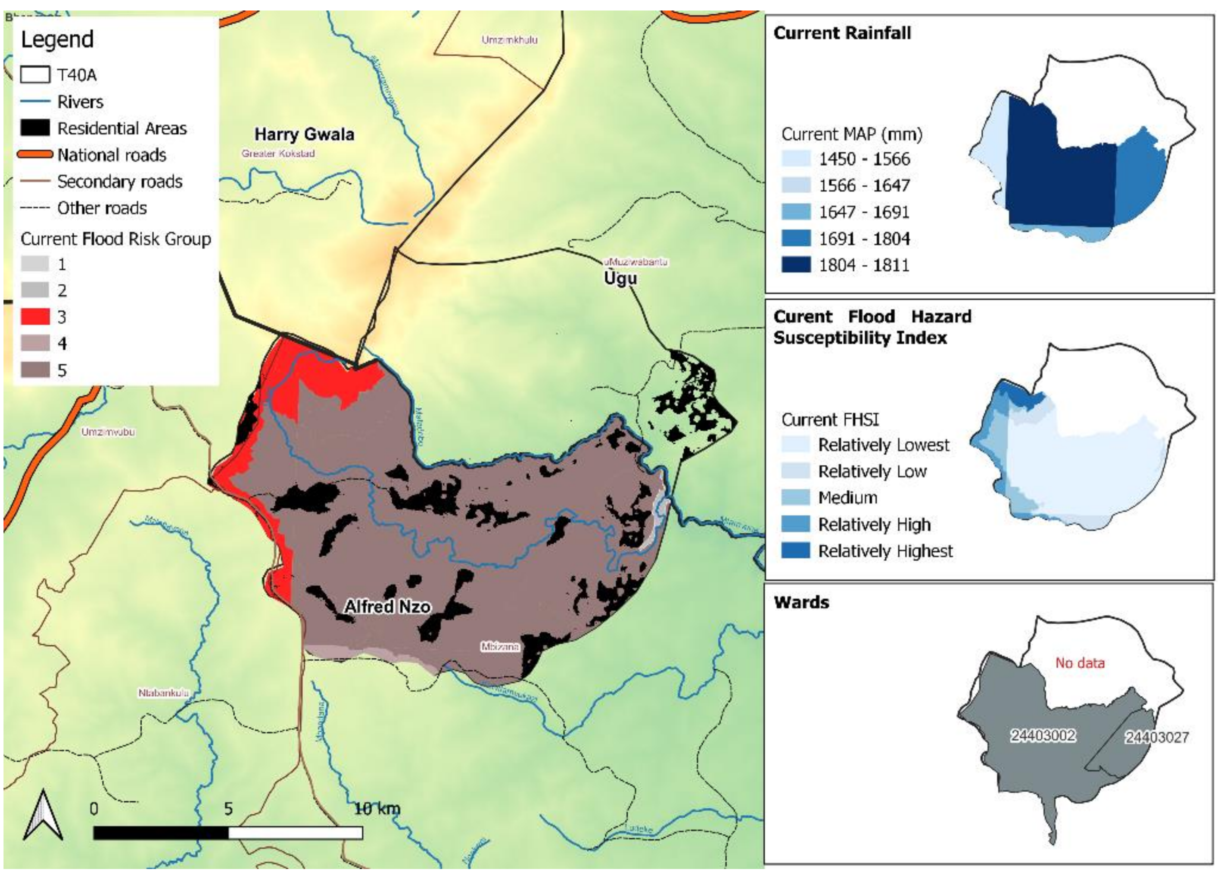



*Figure 4-17: Current relative flood risk groups based on current rainfall for T40A in Alfred Nzo DM*

### Exposure to Fluvial Flooding

QC T40A and T32G are associated with steep and undulating topography. The majority of settlements within these QCs are located towards the crests of hills, and are therefore not located in close proximity to main drainage lines that would be the source of fluvial flooding. However, two areas of concern were identified across the two priority QCs, as presented in Figure 4-18. Both of these areas are located towards the centre of the QCs and should be investigated in more detail during the feasibility phase of the study.

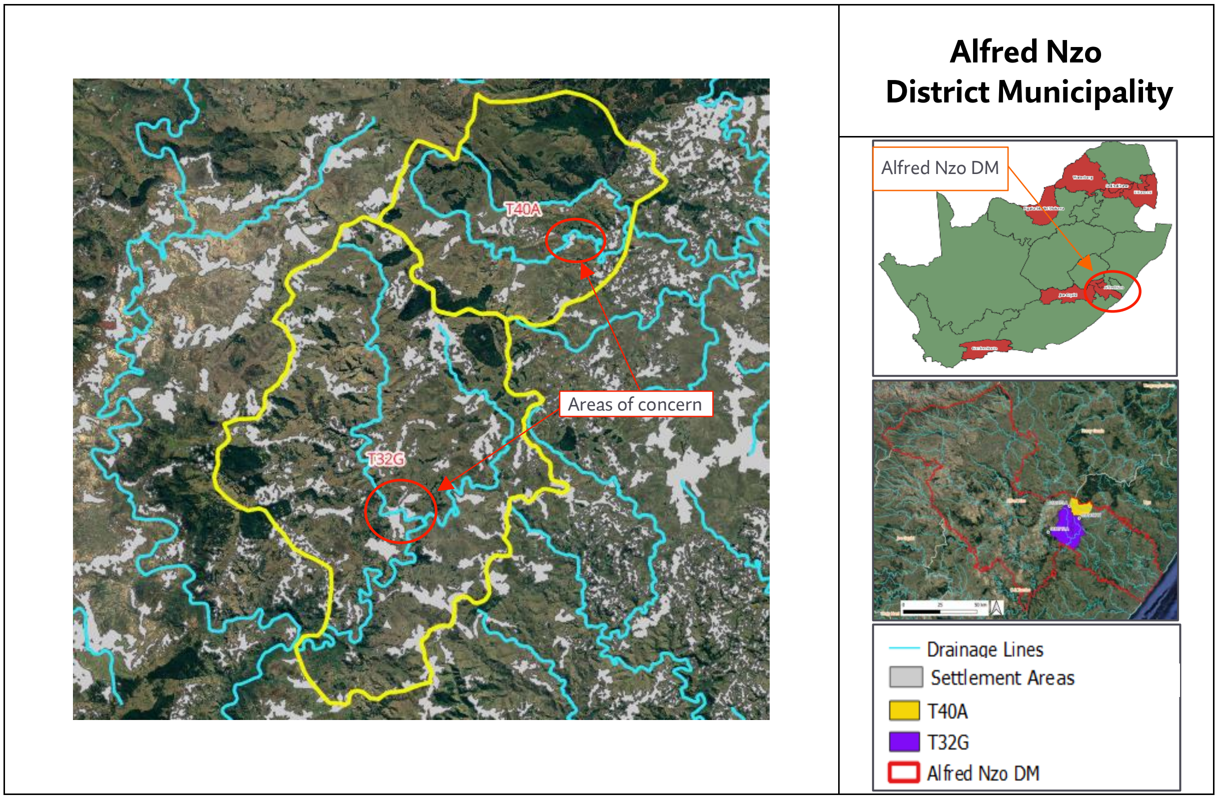



*Figure 4-18: Distribution of settlements in relation to main drainage lines across priority catchments in the Alfred Nzo DM*

**Exposure to Drought**

According to the WWF Water Risk Filter, and specifically the water scarcity index (proxy for exposure to drought), as described in Section 3.4.2, the Alfred Nzo region has a low to moderate level of exposure to drought. This is illustrated in Figure 4-19, which also shows that the Alfred Nzo DM is the least exposed DM when being compared to the other priority DMs.

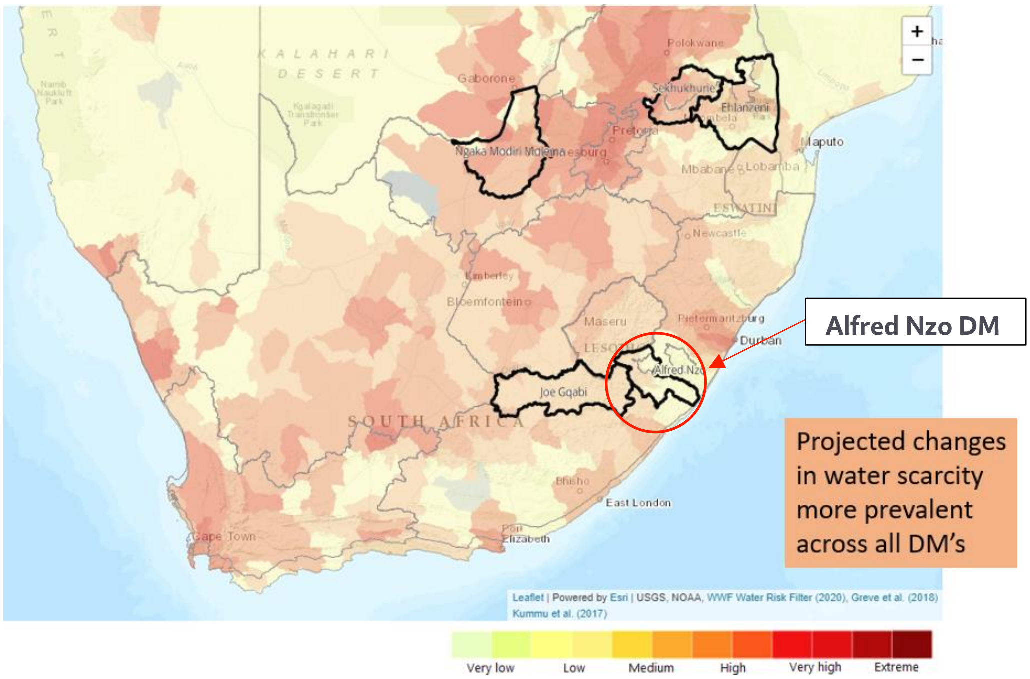



*Figure 4-19: WWF Water Risk Filter - Water Scarcity Index, Proxy for Drought Exposure (Alfred Nzo District Municipality)*

## 4.2 JOE GQABI DM

The Joe Gqabi DM borders the Free State Province and Lesotho to the north, Alfred Nzo DM is to the east and Chris Hani and OR Thambo DMs are to the south. The southern Drakensberg Mountains form a watershed that separates the eastern and western parts of the DM. The DM falls within the Umzimvubu and Orange River Basins and is largely rural in nature with a few smaller urban nodes. The Joe Gqabi DM contains three LMs: Elundini, Walter Sisulu and Senqu.

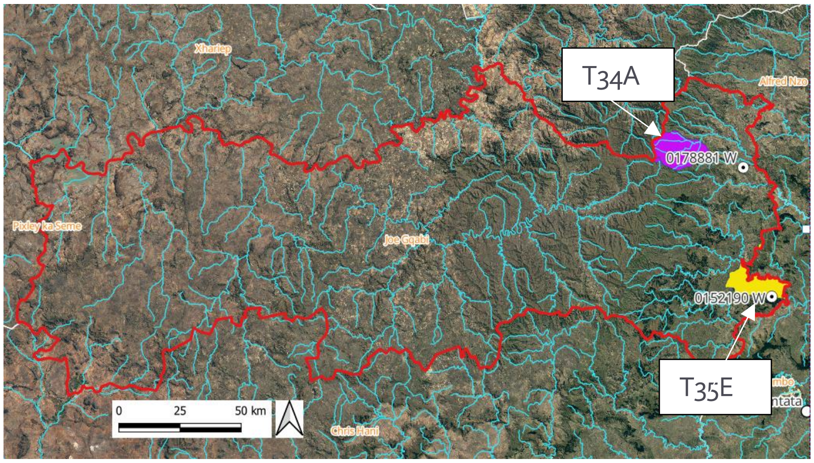
According to the 2011 Census there were just under 350,000 individuals living in the DM at the time, in an area of 25,663 km$^2$ (StatsSA, 2015). About 50% of the population was at the time below 35 years of age. The average income for households in the DM was approximately R15 000 per annum, indicating that most of the population lived below the poverty line – the situation is not expected to have changed much since then. The Elundini LM has the highest percentage of people within this DM living in poverty - at almost 70% (Joe Gqabi DM, 2019) across the LMs within the DM. The economy of the DM has a high reliance on subsistence agriculture, with the main subsistence being the production of sheep, cattle, goats, maize and vegetables (Joe Gqabi DM, 2015). The agricultural sector plays an important role for employment, with at the time of the Census almost 43% of households being involved in agricultural activities (StatsSA, 2015).

### 4.2.1 Overview of Joe Gqabi DM

The top two potential locations identified for Joe Gqabi DM are located to the east of the DM (as shown in the Figure 4-20 below). T34A occurs at 30°38'8.45"S 28°13'14.01"E at an elevation range of between 2925 and 1425 masl. The T34A QC is located entirely within Joe Gqabi DM. The catchment is on the edge of the Great Escarpment within the Mzimvubu/Umbashe primary catchment (T) and the Mzimvubu secondary catchment (T3).

The main rivers within QC T34A (indicated in purple in the map below) are the Thina, Vuvu and Khohlong rivers. As the catchment is a headwater system and there are no rivers contributing streamflow into the QC from surrounding catchments.

Catchment T35E (indicated in yellow on the map below) occurs at an elevation range of 1769 to 872 masl, and the main rivers located within the QC are the Tsitsa and Ghukhunqa Rivers. The catchment is located within Joe Gqabi DM (33%) and OR Thambo DM (67%). The catchment has contributing streamflow from QCs T35A, T35B, T35C and T35D.




**Joe Gqabi District Municipality**

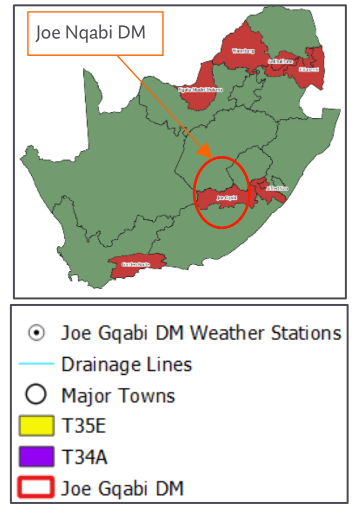
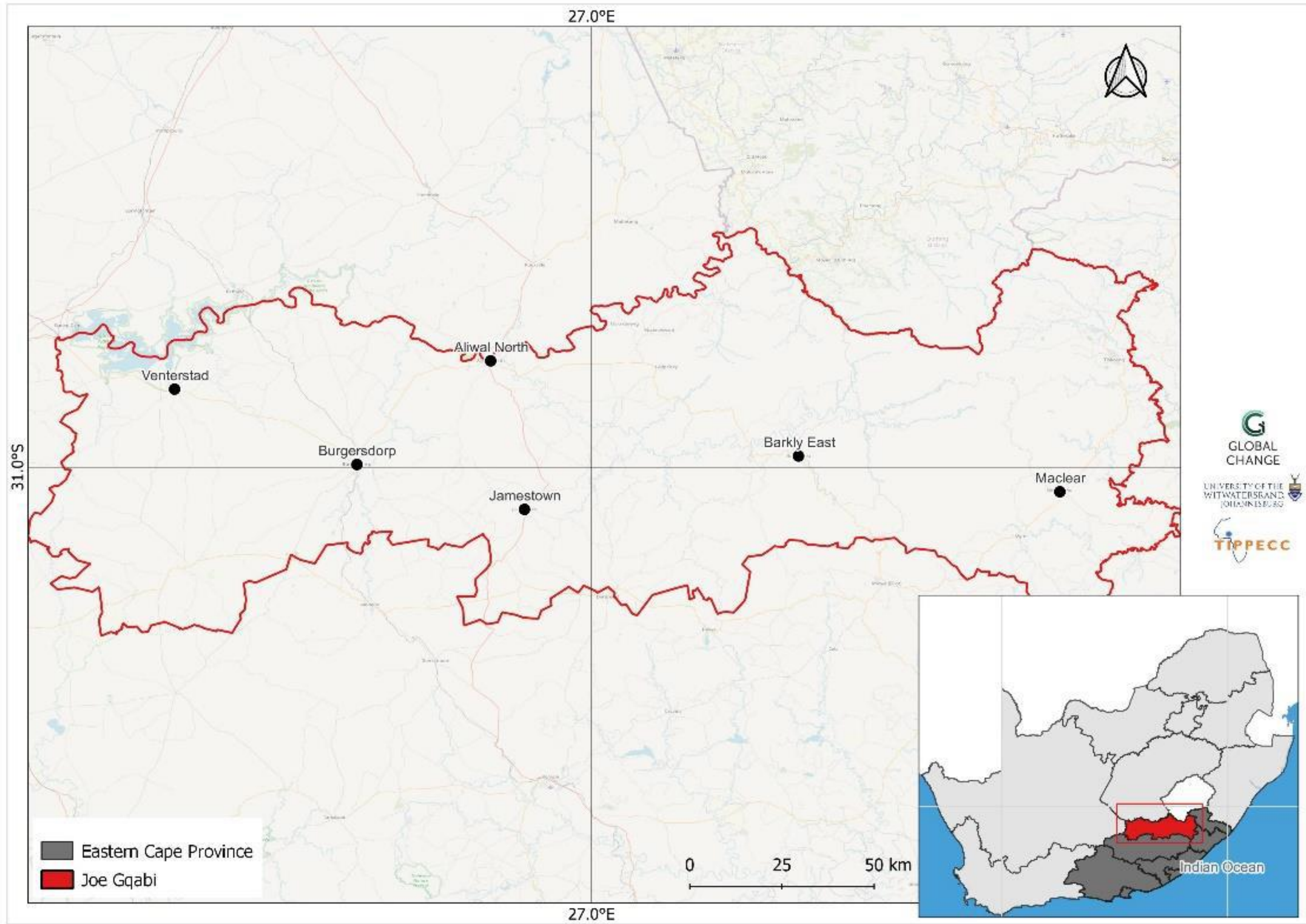



*Figure 4-20: Joe Gqabi DM and Priority QCs*

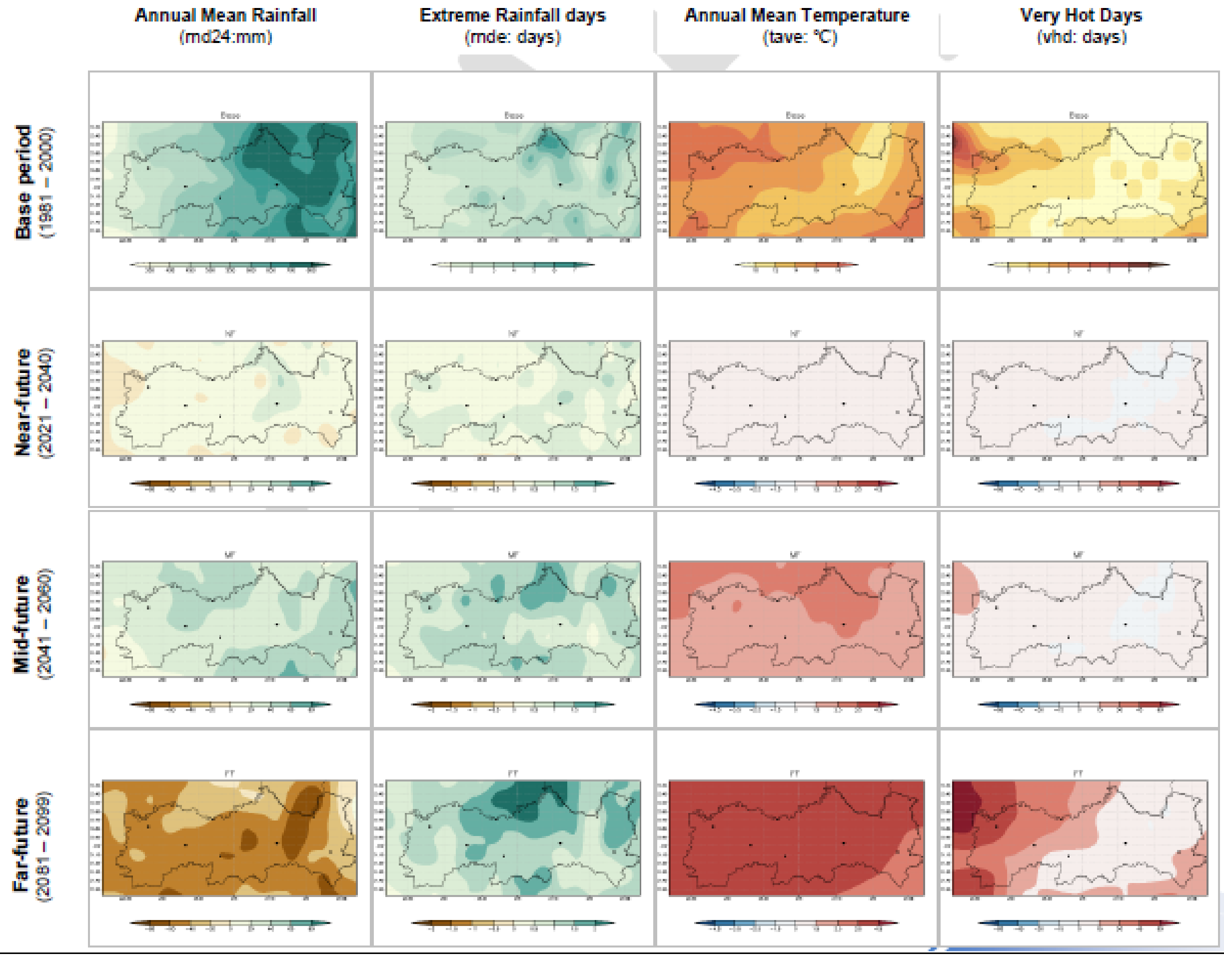
A summary of the observed climate conditions in Joe Gqabi DM (GCI & SANBI, 2024) is presented in the table below.

*Table 4-6: Location and summary of observed climate conditions for Joe Gqabi DM*

| Parameter | Observed conditions | Locality |
|---|---|---|
| Mean annual rainfall | Annual mean precipitation ranges from about 400 mm in the west to more than 800 mm over the eastern mountains. Observed general increase in annual mean precipitation (low confidence). |  |
| Extreme rainfall days | Observed number of heavy precipitation days range from about 1 in the west to about 7 over the eastern mountains. Observed increase in the frequency of heavy precipitation events (low confidence). | |
| Mean annual temperature | Annual mean temperature ranges from about 10 °C over the eastern mountains to about 18 °C in the west. Observed increase in annual mean temperature and warm extremes (virtually certain). | |
| Very hot days | Annual mean number of very-hot days range from less than 1 over the eastern mountains to about 5 in the west. | |

A summary of the projected climate changes and spatial anomalies in Joe Gqabi DM (GCI & SANBI, 2024) is presented in the table below.

*Table 4-7: Projected climate changes and spatial anomalies in Joe Gqabi DM*

| Parameter | Projected conditions | Spatial anomalies |
|---|---|---|
| Mean annual rainfall | Projected increase in annual mean precipitation in near- and mid-future (low confidence); projected decrease in the far-future (medium confidence). |   |
| Extreme rainfall days | Projected increase in the frequency of heavy precipitation events (high confidence). | |
| Mean annual temperature | Projected increase in annual mean temperature (virtually certain). | |
| Very hot days | Projected increase in warm extremes (virtually certain). | |

### 4.2.2 Flood Hazard Assessment for Joe Gqabi DM

**Flooding History**

The Joe Gqabi DM has experienced several significant floods in the past. Some of these include:

- **2018 Floods:** In early Feb 2018 roads and bridges were washed away by floods in Elundini and Senqu LMs (Let's Respond Toolkit, n.d.).
- **2011 Floods:** In December 2011, heavy rains caused flooding in the Barkly East and Elliot areas of the municipality. The floods caused damage to roads, bridges, and other infrastructure, and several people were displaced.
- **2001 Floods**: In January 2001, heavy rains caused flooding in the Sterkspruit and Lady Grey areas of the municipality. The floods caused damage to houses, roads and bridges, and several people were left homeless.
- **1988 Floods:** In February 1988, heavy rainfall led to severe flooding in the town of Maclear in the municipality. The floods caused damage to buildings, roads, and other infrastructure.
- **1974 Floods:** In February 1974, heavy rains caused flooding again in the Elliot and Barkly East areas, once again resulting in damage to roads, bridges, and other infrastructure. Several people were left homeless, and the floods disrupted the local economy.
- **1968 Floods:** In March 1968, heavy rainfall led to severe flooding in the Elliot and Barkly East areas of the municipality. The floods caused extensive damage to property and infrastructure, and several people lost their lives.

Based on historical anecdotes of flooding in the Joe Gqabi DM, the areas commonly affected include the Barkley East and Elliot areas of the DM. Furthermore, drought has also been reported in the DM with droughts occurring in 2016.

During the district-level workshop, it was emphasised that flood events were common within the Joe Gqabi DM with mention being made of past floods. The impact of flood was most felt on roads, cropping land, grazing land, crops and livestock, as sited by participants in the workshop. Poor settlement planning in the area has also led to houses and schools being built on wetlands which worsens soil erosion during high rainfall events. There was also an IAP problem in the two LMs of Elundini and Senqu, with specific reference to Slangbos (*Seriphium*).

Similar to observations in the stakeholder workshop in Joe Gqabi DM, floods were identified as a critical issue during the site visit with T40A having a high flood risk and T32G a medium flood risk. This was exacerbated by the presence of IAPs, soil erosion, habitat destruction (especially wetlands), poor land management, bush encroachment, overgrazing, wetland degradation and poor governance. In particular, local impoundments such as the Mt Fletcher Dam (Figure below) were silting up significantly reducing storage capacity and thereby increasing the flood risk to the downstream communities.

*Figure 4-21: A dam in Joe Gqabi DM that has reduced capacity due to siltation*

Erosion was identified during site visits and threatened households and livelihoods (figure below). As noted during the site visit, the DM experienced both fluvial and pluvial flooding both of which had impacts on households and livelihoods.

*Figure 4-22: Example of erosion threatening households in Joe Gqabi DM*

*Figure 4-23: Presence of IAPs along a river in Joe Gqabi DM*

In the photo above that was taken during the site visit, IAPs is evident along rivers and streams in the DM – this is indicative of the manner in which the IAP issue challenge present itself in the DM, with presence of IAPs in upstream areas having a definitive impact downstream due to seeds being carried into valleys where IAPs then proliferate.

It was also very clear during the site visit that, where road culverts have been constructed in the DM, there are resultant dongas that have impacts on safety, households and livelihoods (Figure 4-24).

Other problems that were identified during the site visit included poor rangeland management and grazing strategies which contributed to environmental degradation and erosion. In addition, planning is not implemented effectively at the local level, especially with regards to settlement planning and development along flood lines and wetlands which impacts communities during floods.

*Figure 4-24: Donga erosion below road culverts*

## Rainfall Analysis

### *Historical Rainfall Analysis*

There are a numerous of rainfall stations located within the Joe Gqabi DM. Two rainfall stations in the vicinity of priority QC T35E and QC T34A were selected to determine whether trends in changes in extreme rainfall could be identified, based on an analysis of historical rainfall data. The AMS was extracted at each rainfall station for the period during which observed data was available. As mentioned previously, in this analysis the AMS refers to the maximum depth of rainfall, over a 24-hour period, that has been measured during a hydrological year (i.e. from September to August). AMS data is used in design flood hydrology to estimate design rainfall depths, which in turn are used in the estimation of flood peaks associated with a return period. Based on the connection between AMS rainfall data and design rainfall depths and therefore flood estimation, changes in the AMS can be linked to changes in flood hydrology.

Figure 4-25 and Figure 4-27 present the AMS for the selected rainfall stations, located within the Joe Gqabi DM, and in proximity to QCs T34A and T35E. As described previously, in each of the graphs a trendline was fitted to the historic AMS data to determine whether any trends in the AMS could be identified. In each case an upward trend is evident in the AMS, although it is noted that the upward trend in station 0178881 is subtle. As indicated previously, an analysis of increasing trends in the design rainfall depths associated with the 1:10- and 1:50-year return periods was also undertaken. The analysis of trends in the AMS and design rainfall depths allows for a full picture of the changing hazard associated with extreme rainfall to be obtained. The results of the 1:10- and 1:50-year design rainfall trend analysis (based on the Gumbel distribution and an incremental inclusion of AMS data from 30 years until the full record is analysed), is presented in Figure 4-26 and Figure 4-28. Although the AMS trend analysis is subtle, the trend of increasing design rainfall depths (Figure 4-26) is far more obvious. Both the analysis of the AMS data and the design rainfall depths for station 0152190 W clearly show an increasing trend of extreme rainfall. Based on this analysis, there is a clear indication of an increasing flooding hazard in the Joe Gqabi DM and in the vicinity of QC's T35E and T34A.

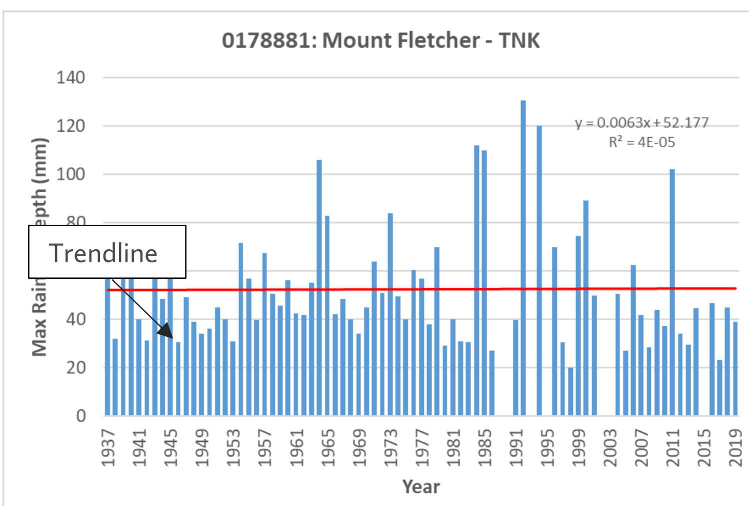



*Figure 4-25 : Annual Maximum Series Rainfall Data - Station 0178881 W (1937 – 2020)*

*Data sourced from SAWS.*

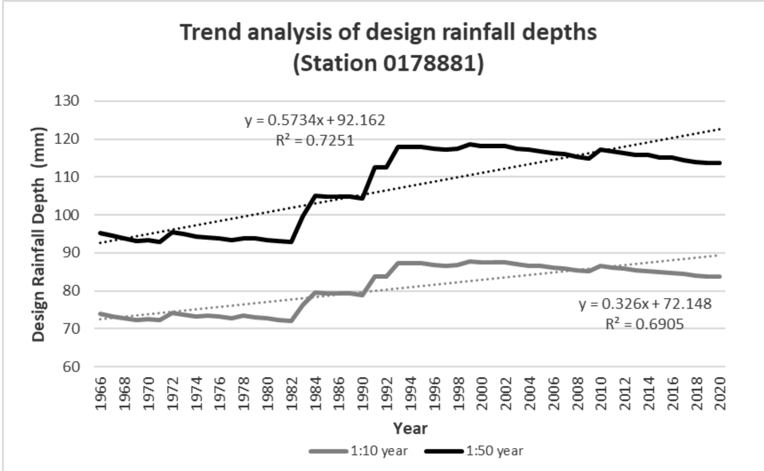



*Figure 4-26: Analysis of 1:10 and 1:50 year design rainfall depth trends for weather station 0178881*
*Data sourced from SAWS.*

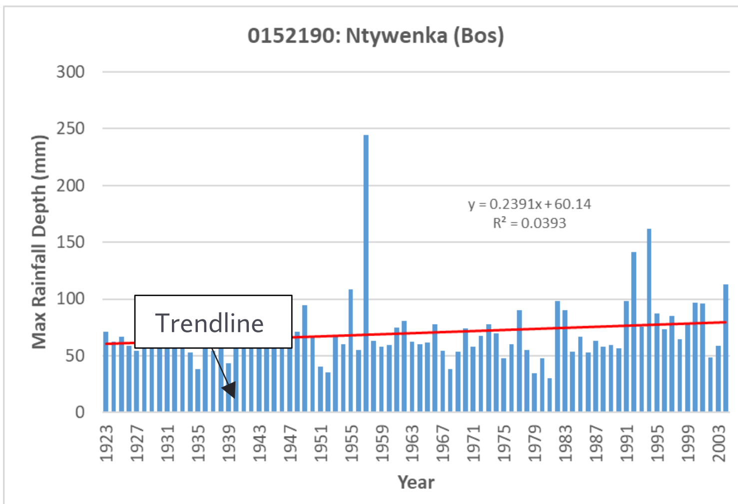



*Figure 4-27: Annual Maximum Series Rainfall Data - Station 0152190 W (1922 – 2004)*
*Data sourced from SAWS.*

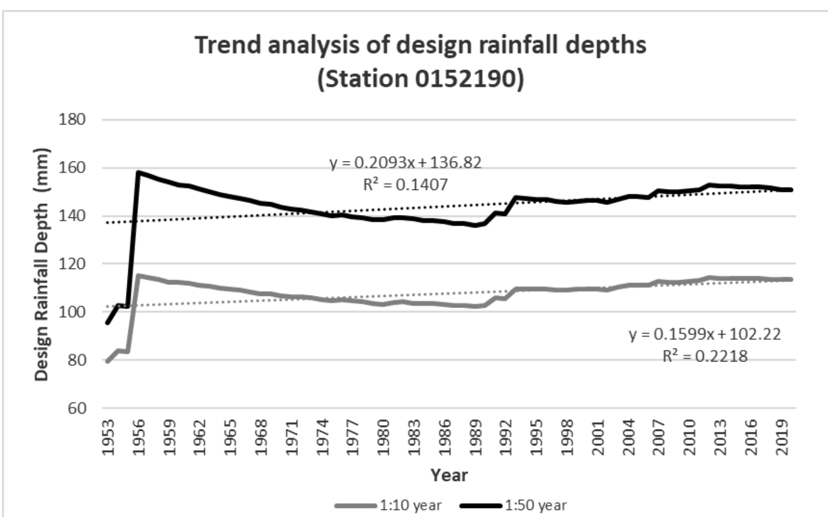



*Figure 4-28: Analysis of 1:10 and 1:50 year design rainfall depth trends for weather station 0152190 W*
*Data sourced from SAWS.*

**Projected Changes in Extreme Precipitation and Consequently Flood Hazard**

As indicated earlier, the estimation of design floods for ungauged catchments is generally the product of a combination of design (extreme) rainfall and catchment characteristics (which impacts on the conversion of rainfall to stormflow). Due to the complexities of accounting for the variability in catchment characteristics across the study areas (catchment area, catchment slope, land-cover characteristics, soil characteristics etc.), the assessment has focused on changes in precipitation and in extreme precipitation trends to identify changes in flood hazard levels and impacts.

For this analysis, anomalies of extreme precipitation were sourced from the CCKP, as noted earlier. To determine anomalies in extreme rainfall, comparisons between baseline (historic) rainfall data and forecasted rainfall data was undertaken. The extreme precipitation anomalies extracted from the CCKP are based on SSP5-8.5, and centralised over the 2050 period, using the $50^{th}$ and $90^{th}$ percentiles of multi-model ensembles. Both the $50^{th}$ and $90^{th}$ percentiles were used to illustrate the range of possible anomalies using different models (therefore illustrating uncertainty). Anomalies are based on the changes in magnitude of the 1:100-year return period rainfall depths. A map of the anomalies, across the Joe Gqabi DM is presented in Figure 4-29, which indicates a range of change from 13mm ($50^{th}$ percentile) and 40mm ($90^{th}$ percentile) at the central area of the DM to 3mm ($50^{th}$ percentile) and 45mm ($90^{th}$ percentile) in the eastern portion of the DM. QCs T35E and T34A show an increase of approximately 7mm for the 1:100-year design rainfall using the $50^{th}$ percentile model ensembles, and an increase of approximately 45mm using the $90^{th}$ percentile model ensembles.

| | |
|---|---|
| | **Joe Gqabi DM**<br>***Extreme Rainfall Anomalies*** |

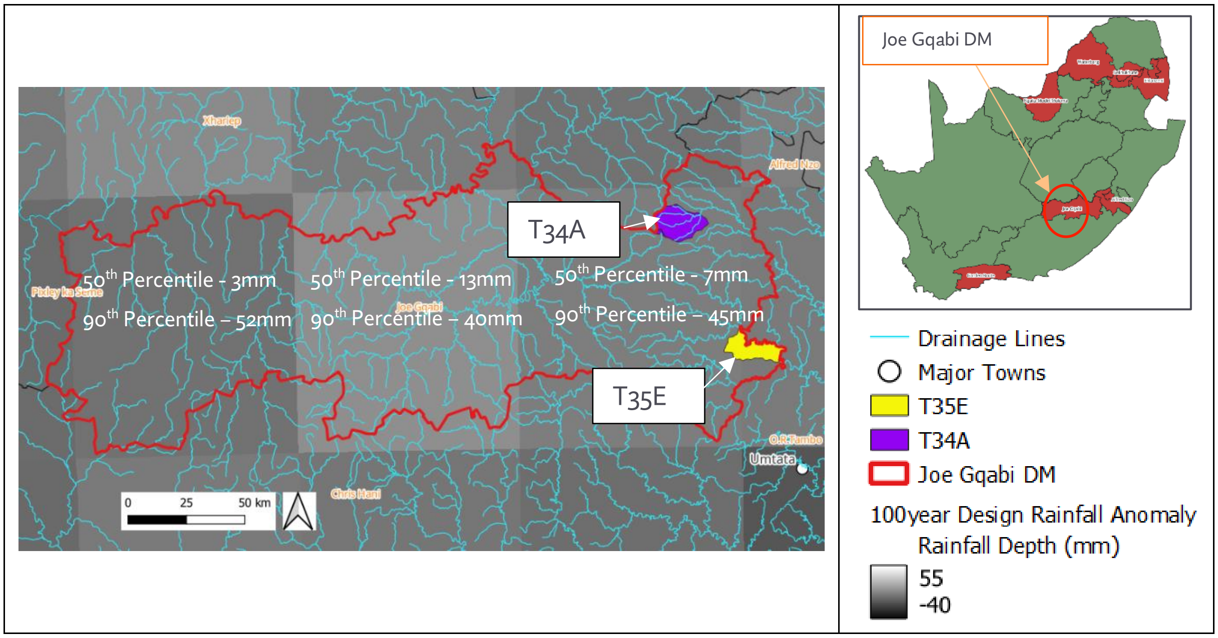



*Figure 4-29: Joe Gqabi DM Extreme Rainfall Anomalies*

To contextualise the increase in extreme rainfall across the Joe Gqabi DM, design rainfall at the centroid of each priority QC was extracted using the RLMA&SI approach developed by Smithers and Schulze (2002). The resultant design rainfall for the T35E and T34A QCs are presented in Table 4-8. Based on these estimates of design rainfall compared to the anomalies of extreme rainfall related to the 100-year return period rainfall event (in yellow in the table below)-, an increase in extreme rainfall of approximately 3.5% and 4.5% is projected for QC T35E and T34A respectively, based on the 50th percentile ensemble models, and between 23 and 30% using the 90th percentile ensemble models.

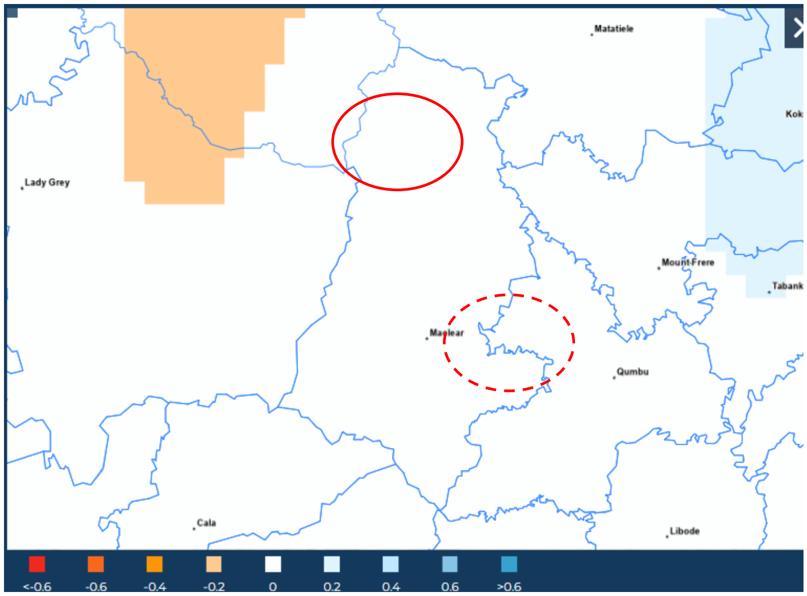
*Table 4-8: Joe Gqabi DM Design Rainfall Estimates*

| | Design Rainfall Depths (mm) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1:2 year | 1:5 year | 1:10 year | 1:20 year | 1:50 year | 1:100 year | 1:200 year |
| T34A | 59 | 79 | 94 | 110 | 132 | 149 | 168 |
| T35E | 73 | 100 | 120 | 142 | 173 | 199 | 227 |

### 4.2.3 Drought Hazard Assessment for Joe Gqabi DM

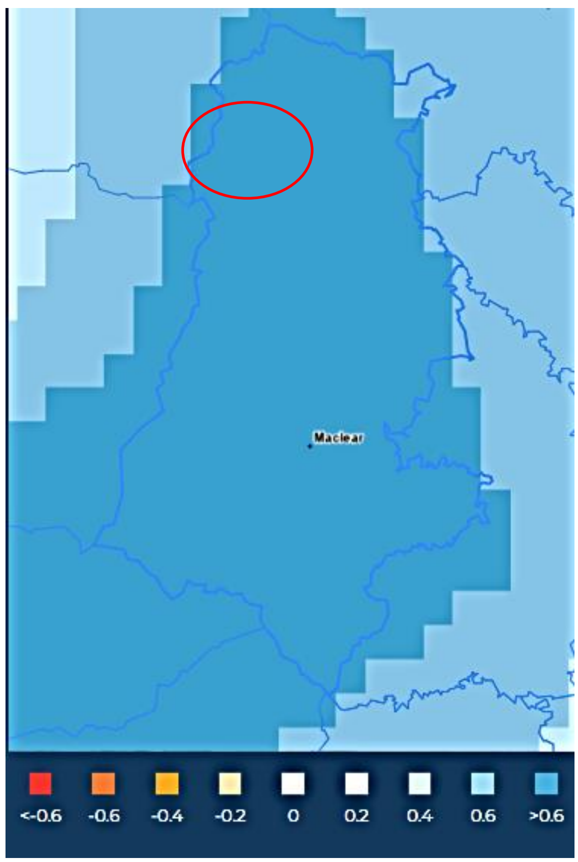
The DM has a history of drought with the recent drought between 2015 and 2017 impacting dam levels and agricultural activities – both commercial and small-scale (South African Government, 2016; Let's Respond Toolkit, n.d.). The Let's Respond Toolkit noted that this drought resulted in higher occurrences of veldfires, and farmers were battling to adapt to this. Participants during the district workshop also highlighted this drought and its impact on agri-processing business in the DM as well as water supply.

An assessment of **current drought hazard** for Joe Gqabi DM indicates that (Figure 4-30) the priority QCs are not considered at risk of drought. An assessment of **change in drought hazard** for Joe Gqabi DM indicates that projections for 2050 (Figure 4-31) suggest that both priority QCs are predicted to get have a reduced drought tendency per 10 years.




Elundini LM (T34A: red circle and T35E: dotted red circle)

*Figure 4-30: SPEI drought tendencies over 1995-2024 for Joe Gqabi DM (Source: Engelbrecht et al., 2019)*




Elundini LM (T34A: red circle and T35E: dotted red circle)

*Figure 4-31: Drought tendencies for 2015 to 2044 for Joe Gqabi M (Source: Engelbrecht et al., 2019)*

### 4.2.4 Vulnerability Assessment for Joe Gqabi DM

The LMs in Joe Gqabi DM show very high vulnerability for socio-economic and environmental vulnerability with both LMs ranking below 170 out of 213 LMs.

*Table 4-9: Multi-dimensional vulnerability (ranking out of 213) for LMs in Joe Gqabi DM*

*Source:* (Le Roux, et al., 2019)

| DM | LM | Socio-Economic | Economic | Physical | Environmental |
|---|---|---|---|---|---|
| Joe Gqabi | Elundini | 194 | 51 | 135 | 206 |
| | Senqu | 172 | 127 | 167 | 190 |

Both the Elundini and Senqu LMs show high vulnerability, with the Elundini LM scoring relatively lowly for environmental vulnerability (see Figure 4-32).

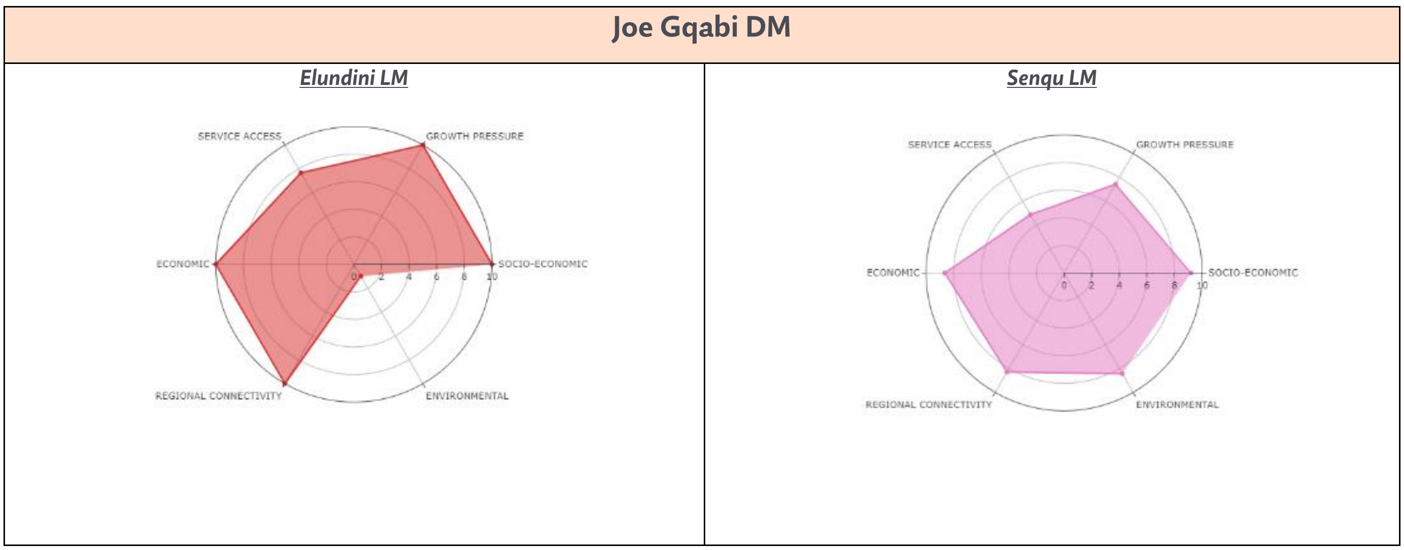



*Figure 4-32: Vulnerability of LMs within the Joe Gqabi DM, with focus on traditional settlements*

*Source:* (Le Roux, et al., 2019)

According to the Green Book (Le Roux, et al., 2019), the projected growth pressure for the Joe Gqabi DM indicates that the Senqu LM has the highest growth scenario (Table 4-10).

*Table 4-10: Growth scenarios for local municipalities in Joe Gqabi DM.*

*Source:* (Le Roux, et al., 2019)

| DM | LM | Growth scenario | 2011 | 2030 | 2050 |
|---|---|---|---|---|---|
| **Joe Gqabi** | Elundini | Medium | 136,729 | 169,430 | 187,969 |
| | | High | 136,729 | 167,790 | 187,796 |
| | **Senqu** | **Medium** | **134,003** | **162,756** | **175,629** |
| | | **High** | **134,003** | **161,200** | **175,558** |
| | | **High** | **77,451** | **118,345** | **165,590** |

### 4.2.5 Exposure Assessment for Joe Gqabi DM

The resultant level of flooding exposure, associated with the Joe Gqabi DM, is presented in Figure 4-33. The Joe Gqabi DM is associated with a medium to high FHI across the areas in which the T34A and T35E QCs are located.

***Joe Gqabi DM Flood Exposure***

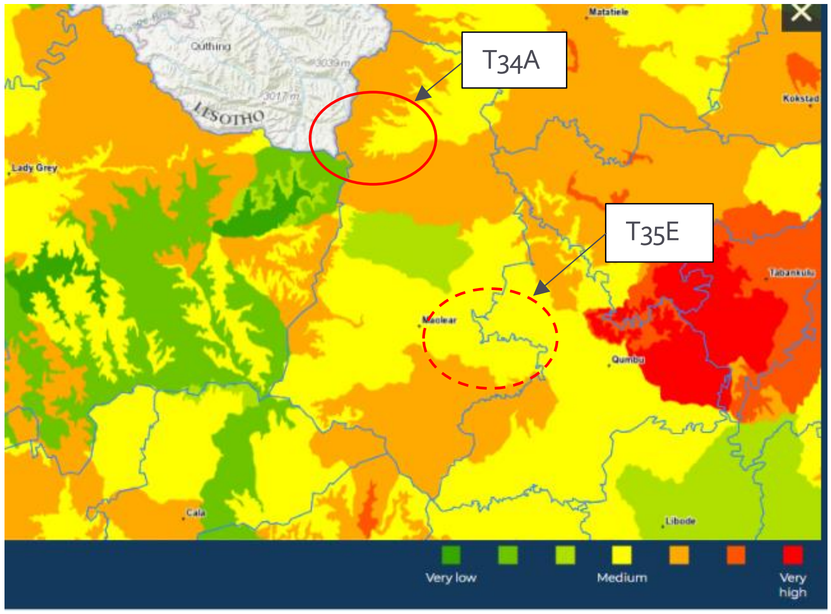



*Figure 4-33: Current flood hazard index for Joe Gqabi DM*

*Source: (Engelbrecht et al., 2019)*

**Exposure to Pluvial Flooding**

Based on the FHSI analysis results, and in particular those for QC T34A, as presented in Figure 4-34, the area of particular exposure is located towards the lower lying areas of the QC and overlaps with areas of urban settlement. The area most vulnerable to pluvial flooding in the T35E catchment is located in the South-western areas of the catchment, as presented in Figure 4-35. This area, identified as having increased exposure to flooding, also coincides with the location of a number of settlements. This signifies that people within QC T35E and T34A are particularly susceptible to flooding.

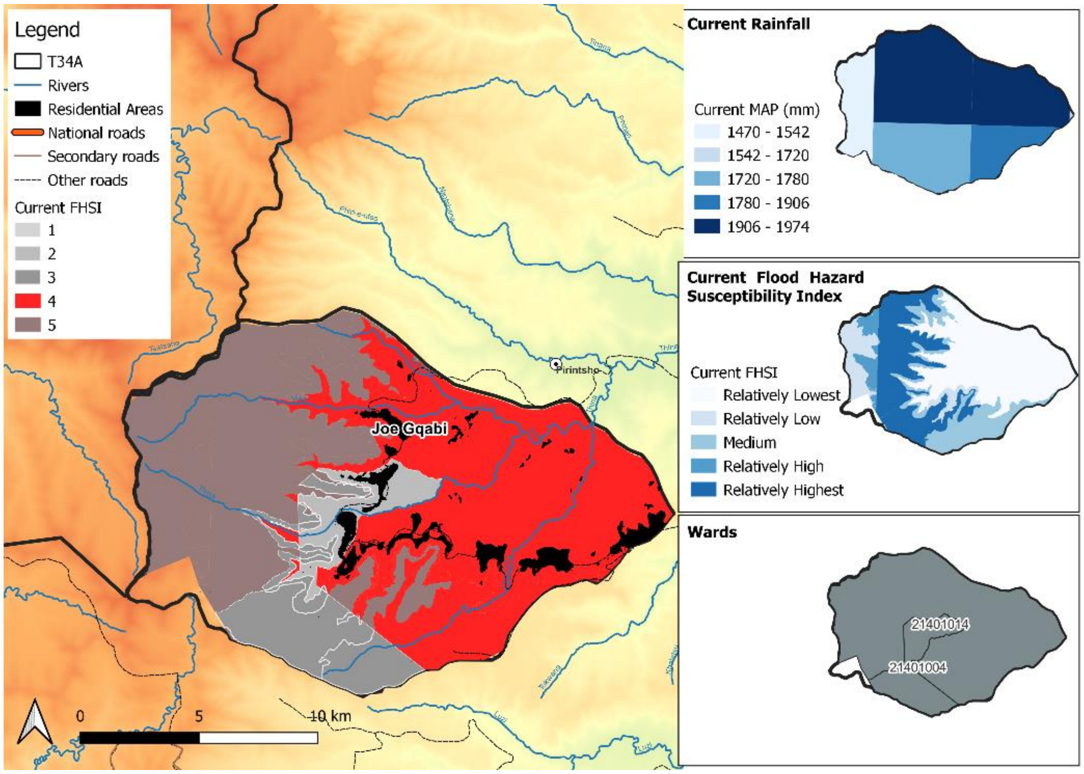



*Figure 4-34: Current relative flood risk groups based on current rainfall for T34A in Joe Gqabi DM*

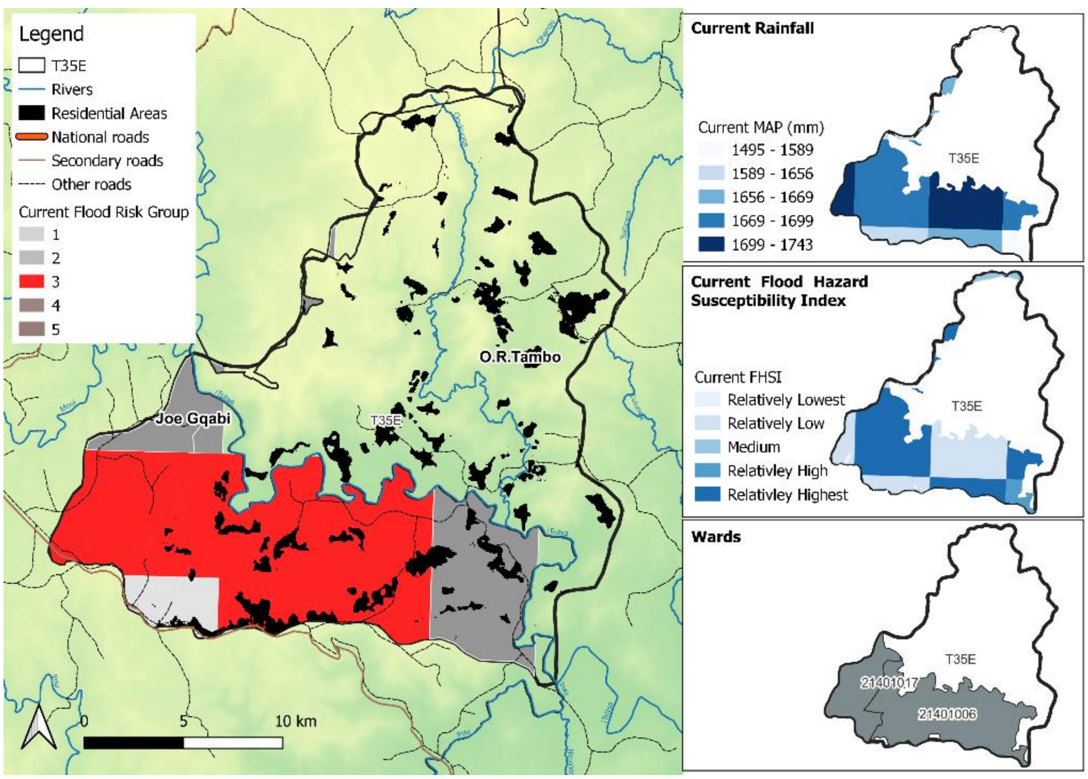



*Figure 4-35: Current relative flood risk groups based on current rainfall for T35E in Joe Gqabi DM*

### Exposure to Fluvial Flooding

Similar to that of the Alfred Nzo DM, the Joe Gqabi DM is also characterised by steep and undulating topography. The location of settlement areas in both QC T34A and T35E is less extensive than that noted in the Alfred Nzo DM, which is a neighbouring

DM. As with the Alfred Nzo DM, the majority of settlements appear to be located away from drainage lines. However, two areas in the T34A QC and one in the T35E QC were identified as potentially exposed to fluvial flooding, and should be investigated further during the feasibility phase of this project. The locations of these areas are presented in Figure 4-36.

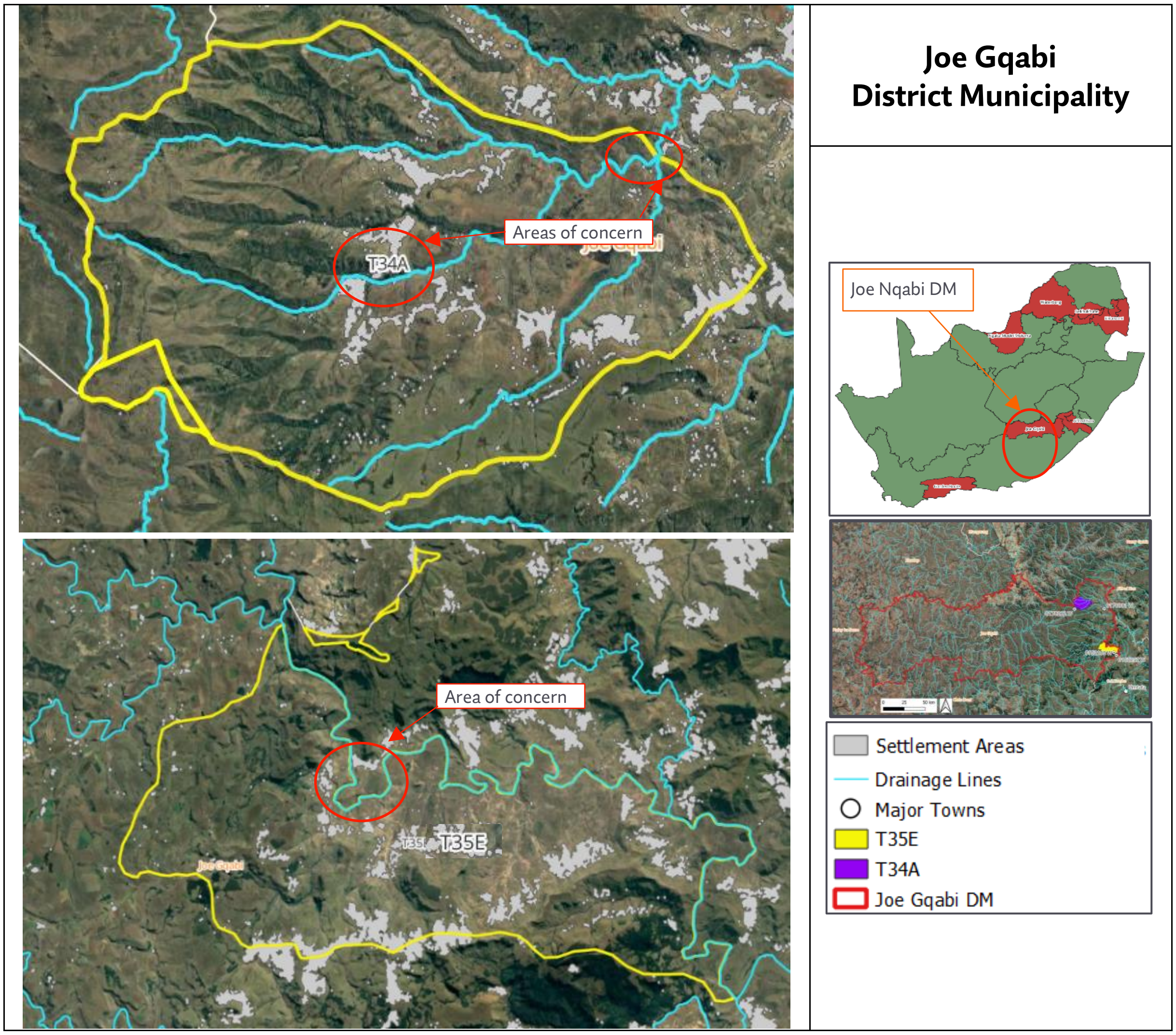



*Figure 4-36: Distribution of settlements in relation to main drainage lines across priority catchments in the Joe Gqabi DM*

### Exposure to Drought

According to the WWF Water Risk Filter water scarcity index (proxy for exposure to drought), as described in Section 3.4.2, the Joe Gqabi DM has moderate level of exposure to drought. This is illustrated in Figure 4-37, which also shows that the DM has a higher level of exposure than that of the Alfred Nzo DM, located to the immediate east of the Joe Gqabi DM.

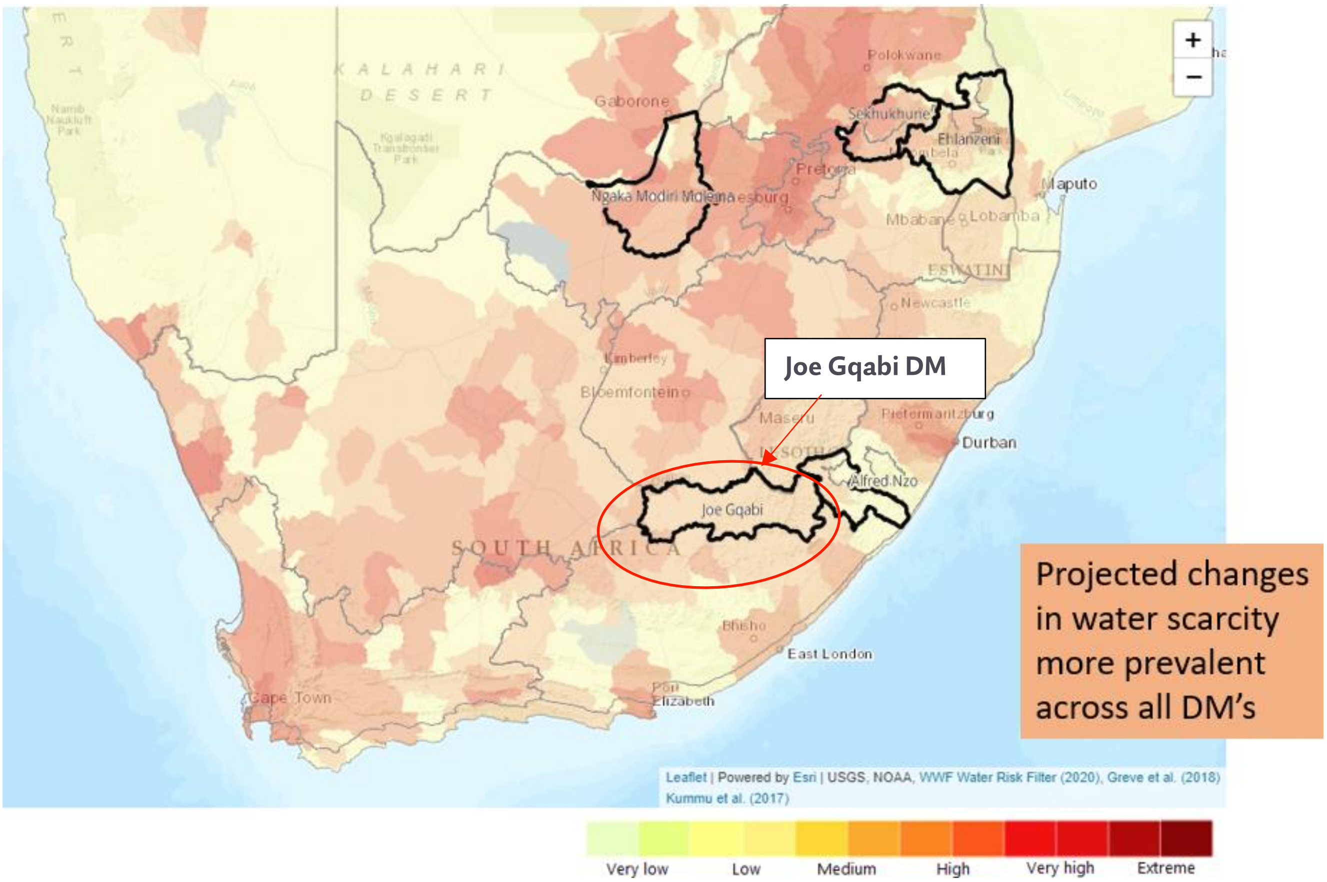



*Figure 4-37: WWF Water Risk Filter - Water Scarcity Index, Proxy for Drought Exposure (Joe Gqabi District Municipality)*

## 4.3 EHLANZENI DM

The Ehlanzeni DM is located in the north-eastern part of the Mpumalanga Province and is bordered by Mozambique and Eswatini. The DM contains four LMs: Thaba Chweu, City of Mbombela, Nkomazi and Bushbuckridge. The Ehlanzeni DM falls within the Komati and Olifants River Basins. This is an important watershed area, which, because of high rainfall, is a source of a number of perennial rivers as well as containing important wetlands (Partridge, et al., 2010).

Mpumalanga has substantial coal mining activity and an active mining sector. It produces close to 90% of South Africa's coal and is home to three of the biggest coal power stations in Southern Africa. In addition to mining, other major sectors in the province include forestry and agriculture. The province also has a large fruit and vegetable market.

According to the 2011 census, there were just under 1,7 million individuals living in the DM at the time, which was at that time the highest in the province – and expected to still remain the highest currently. The DM covers an area of 28,896 km² and therefore has a population density of 61 people per km². The DM has Mbombela as the capital city, and main contributor to the DMs overall economy. The district had a 66% unemployment rate, and low levels of education. Further to this, just under 30% of households were involved in agricultural activities and subsistence farming, having high levels of dependence on social support systems. A high percentage (just under 33.5%) of the population sourced water from sources other than piped water schemes, at the time that the Census was conducted. Projects have been implemented during the past decade that addressed some of the backlog, however there is still to date a very high percentage water usage from non-piped water sources.

### 4.3.1 Overview of Ehlanzeni DM

The top two potential locations identified in the Ehlanzeni DM, are located to the north of the DM, as presented in the Figure 4-38 below, and includes QCs B60H (in teal colour) and X32F (in yellow colour). Catchment B60H is located predominantly within Sekhukhune DM, however, a small portion of the QC overlaps with the Ehlanzeni DM, as highlighted in the Figure 4-38 below. This catchment contributes flows to the Olifants River Basin (Primary Basin B), and it is located downstream of the QCs B60E, B60F and B60G. The main river within the catchment is Ohrigstad river, which joins the Blyde River at the outlet of B60H and then joins the Olifants River. Catchment X32F is located entirely within Ehlanzeni DM. This catchment is located within the Komati River Basin (Primary Basin X) and drains to the Mutlumuvi, which is a tributary of the Sand River.

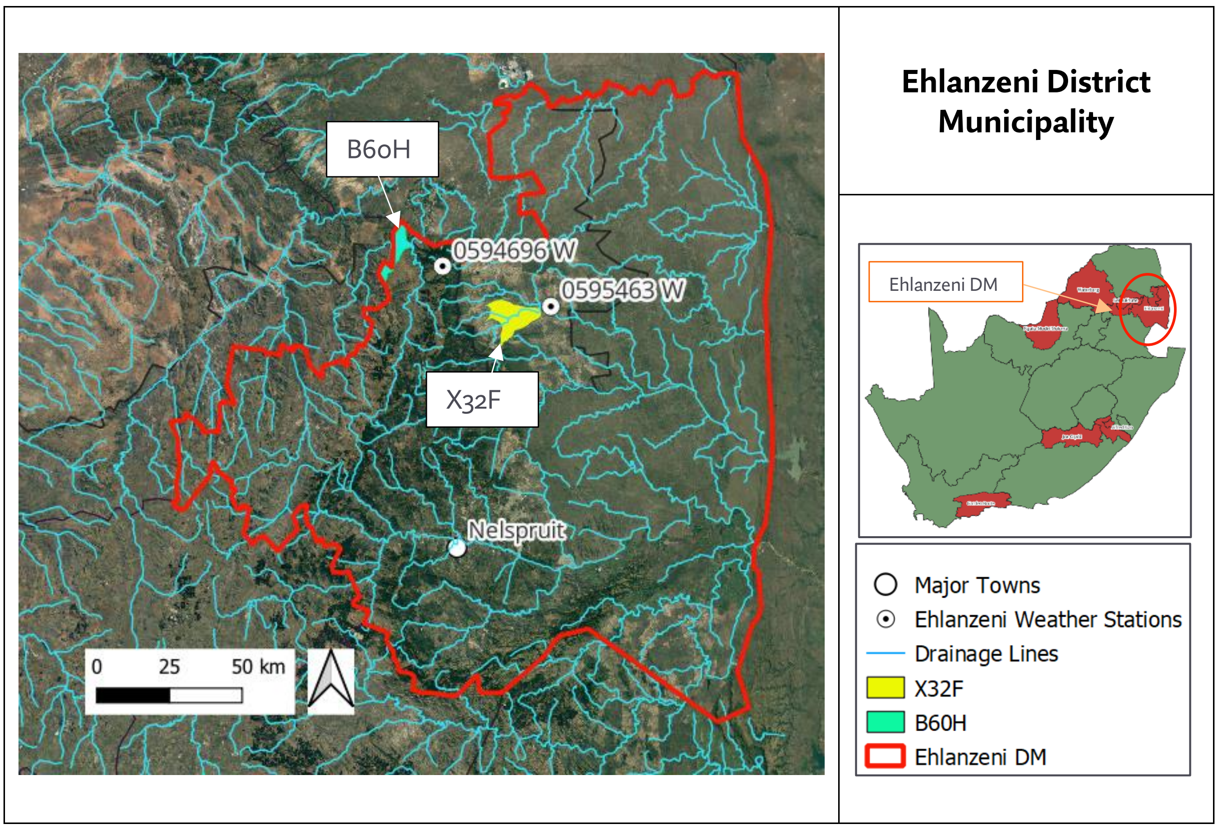
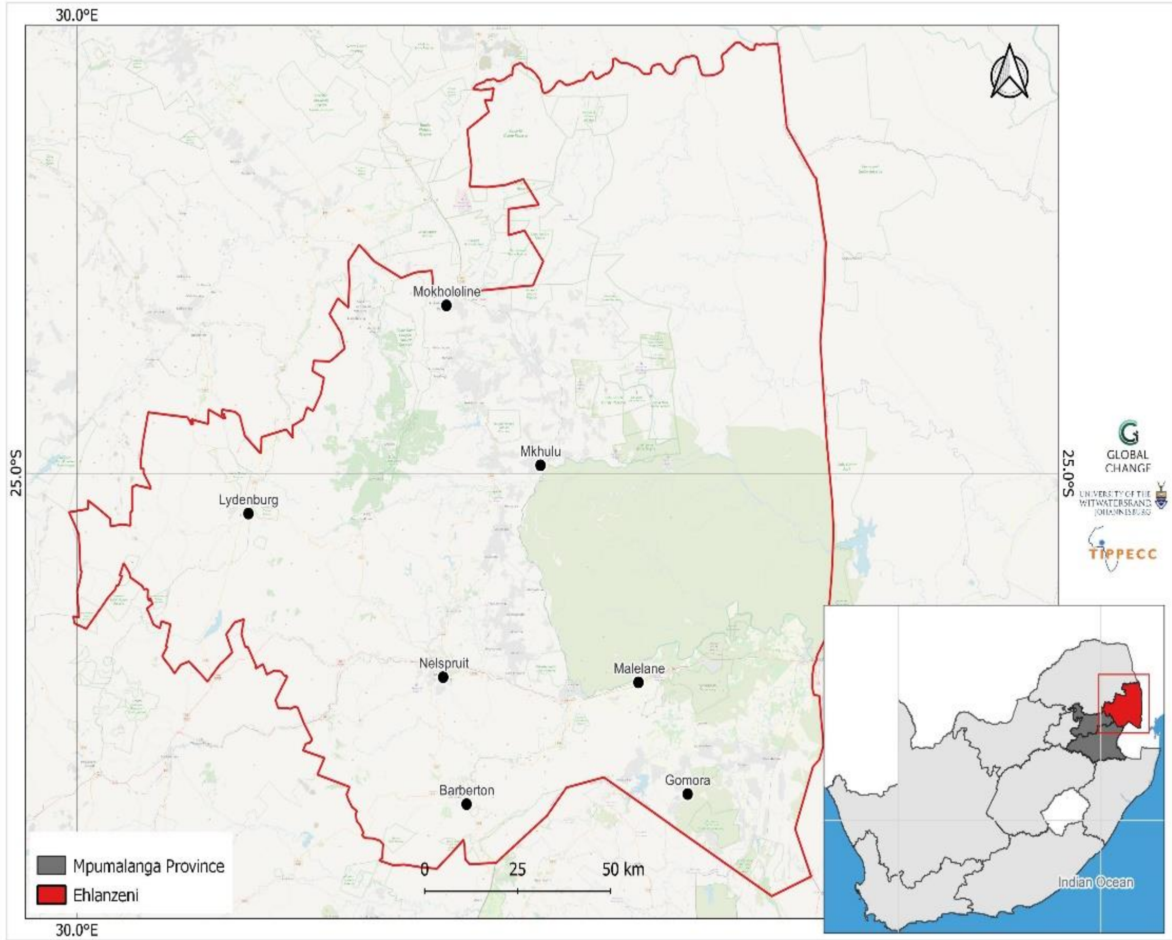



*Figure 4-38: Ehlanzeni DM and Priority QCs*

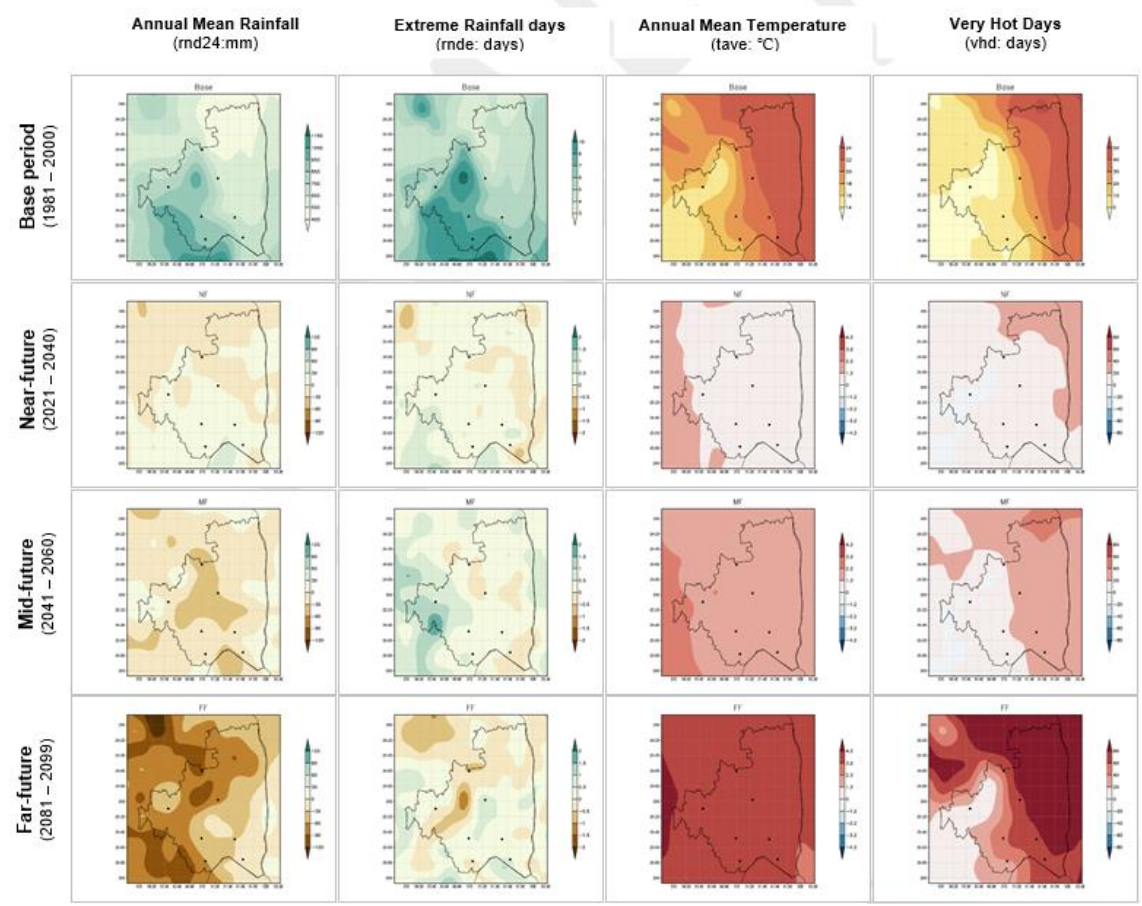
A summary of the observed climate conditions in Ehlanzeni DM (GCI & SANBI, 2024) is presented in the table below.

*Table 4-11: Location and summary of observed climate conditions for Ehlanzeni DM*

| Parameter | Observed conditions | Locality |
|---|---|---|
| Mean annual rainfall | An observed decrease in annual mean precipitation (*medium confidence*) with annual mean precipitation ranging from 450 mm over the northern Lowveld to more than 1 000 mm over the southwestern Highveld. |  |
| Extreme rainfall days | An observed decrease in the frequency of extreme rainfall events is recorded (low confidence), with the average annual number of heavy precipitation days ranging from 3 in the northern Lowveld to 10 in the southwestern Highveld. | |
| Mean annual temperature | Observed increases in annual mean temperature and warm extremes are noted (high confidence), with annual mean temperatures ranging from 14°C in the southwestern Highveld to 24°C in the eastern Lowveld. | |
| Very hot days | The average annual number of very hot days ranges from less than 1 over the southwestern Highveld to more than 40 over the eastern Lowveld. | |

A summary of the projected climate changes and spatial anomalies in Ehlanzeni DM (GCI & SANBI, 2024) is presented in the table below.

*Table 4-12: Projected climate changes and spatial anomalies in Ehlanzeni DM*

| Parameter | Projected conditions | Spatial anomalies |
|---|---|---|
| Mean annual rainfall | A projected decrease in precipitation is expected, with modest increases over the southern Lowveld and southwestern Highveld in the near future (medium confidence). In the far future, a general and substantial decrease in annual precipitation is projected (high confidence). |  |
| Extreme rainfall days | A general increase in extreme precipitation events is projected for the near future (medium confidence), with an expected rise in heavy precipitation events in the south in the far future (medium confidence). | |
| Mean annual temperature | Temperatures and warm extremes are virtually certain to increase, while cold extremes decrease, in the near, mid, and far future. | |
| Very hot days | Projected increase in warm extremes (*virtually certain)* | |

### 4.3.2 Flood Hazard Assessment for Ehlanzeni DM

**Flooding History**

The Ehlanzeni DM is a region that has been grappling with the devastating impacts of climate change, particularly when it comes to flooding. The region is home to many low-lying areas, which are particularly impacted by flood hazards. Over the past decade, the frequency and intensity of flooding events in the region in which the DM is situated, have increased, causing significant damage to homes, infrastructure, and agricultural land. The floods have also resulted in loss of life, with people drowning or being injured in the raging waters. The cause of these floods is largely attributed to the effects of climate change, with increased rainfall intensities, causing the rivers and streams in the region to swell and overtop their banks. The impacts of flooding in the DM have been significant. Many communities have been left without access to basic services such as electricity and clean water, and homes have been destroyed. The agricultural sector has also been hit hard, with crops being washed away and livestock being lost.

Some of the most notable floods in recent times include:

- **The 2023 floods:** Heavy rains in the area in February 2023 caused significant damage in the Bushbuckridge LM. Roads and houses were damaged as well as bridges being submerged resulting in some villages being completely cut-off from surrounding areas. In addition, roads and railways, drainage systems and water resource infrastructure were also damaged impacting communities' ability to access basic services (SABC News, 2023; SABC News, 2023).
- **The 2018 floods**: The 2018 floods resulted in several fatalities and caused significant damage to infrastructure, homes, and crops in the district. Reports indicate that, again, many residents were forced to evacuate their homes, and that transportation infrastructure such as roads and bridges was severely impacted by the rising water levels. In addition to the damage to infrastructure, the floods had a significant impact on the local economy, with crops and other agricultural lands being particularly hard-hit (Mabuza, 2018; South African Weather Services, 2018).
- **The 2012 floods**: The 2012 floods caused significant damage to crops and property in the region. The floods impacted a wide area, including low-lying areas and agricultural lands, and caused widespread disruption to daily life. Based on the information available, the extent of the damage caused by the 2012 floods included a significant impact on the local economy, with crops and other agricultural lands being particularly hard-hit. In addition to the damage to crops, infrastructure such as roads and bridges was also impacted on (South African Government, 2012; IOL, 2012).
- **The 2000 floods**: The exact extent of the damage caused by the 2000 floods is not widely reported. However, it is known that the floods caused significant damage to infrastructure and homes in the area. Reports indicate that roads, bridges, and other transportation infrastructure were severely impacted, and many residents were forced to evacuate their homes. It is likely that the floodwaters also caused damage to crops and other agricultural lands, which would have had a significant impact on the local economy (ReliefWeb, 2000; Matlou, 2000).

During the district-level workshop, flood was reported as a high priority hazard, particularly within the Bushbuckridge LM. Localised flooding was common within the LM due to sand mining; deforestation; overgrazing; unplanned settlements; limited or ineffective land use planning and associated poor services delivery; limited waste and road infrastructure; and poor drainage resulting in excessive soil erosion. Workshop participants also highlighted the impact of floods on dwellings, roads and crops (amongst others).

The site visit in Ehlanzeni reaffirmed what was observed during the DM workshop in that flooding is a major risk, particularly in QC X32F. Localised flooding has occurred in the Casteel area and stakeholders emphasised the issue of tropical cyclones moving overland from the Indian ocean, and the dangers that intense rainfall and high wind strengths associated with these cyclones pose to the communities homesteads and livelihoods, and to bulk infrastructure. Recent tropical cyclones that moved overland from southern Mozambique across South Africa, has been reported to impact this area and high levels of intense rainfall associated with these events have been reported by residents and stakeholders.

Furthermore, the site visit showed the presence of IAPs in X32F. Stakeholders during the site visit also emphasised the importance of a number of upstream wetlands in the area that are in various states and require introduction of improved management regimes as well as interventions to rehabilitate them. Additionally, erosion was high in many areas visited during the site visit coupled with poor bank stabilisation. Culverts and bridges were also linked to erosion and poor bank stabilisation. Other challenges observed during the sight visit included poor waste management practices, with nappies being discarded and blocking culverts and bridges (see figure below)

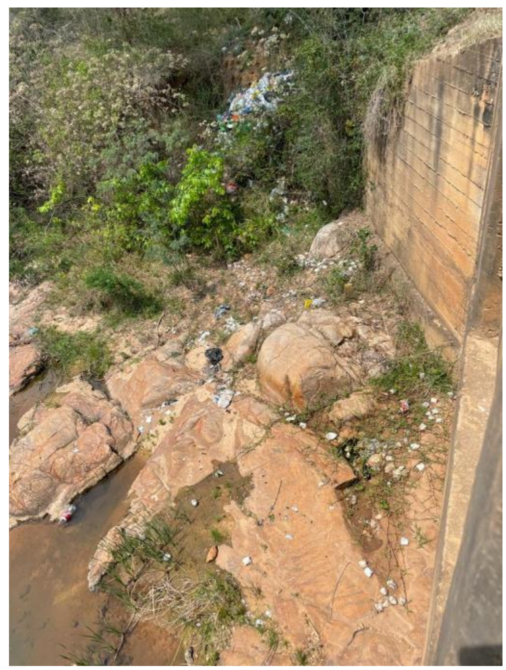


*Figure 4-39: Small-scale built infrastructure in the Bushbuckridge area can be undermined by flooding Presence of waste in culverts in Ehlanzeni DM*

### Rainfall Analysis

#### *Historical Rainfall Analysis*

Two rainfall stations in the vicinity of QC X32F and QC B60H were selected to determine whether trends or anomalies in extreme rainfall could be identified, based on an analysis of observed historical rainfall data. As described previously, at each rainfall station the AMS data was extracted for the years of reliable observed data. In this analysis the AMS refers to the maximum depth of rainfall, over a 24-hour period, that has been measured during a hydrological year.

As mentioned previously, AMS data is used in design flood hydrology to estimate design rainfall depths, which in turn is used in the estimation of flood peaks associated with a return period. More specifically, design rainfall is determined based on statistical analysis of the AMS, which involves analysing the frequency and intensity of historic extreme rainfall events to estimate the expected frequency and intensity of future rainfall events. Based on the connection between AMS rainfall data and design rainfall depths and therefore flood estimation, changes in the AMS and design rainfall depths can be linked to changes in flood hydrology.

Figure 4-40 and Figure 4-42 present a graphical representation of the AMS for the selected rainfall stations, located within the Ehlanzeni DM, and in proximity to QCs B60H and X32F. The locations of the selected rainfall stations are presented in the Figure 4-38. In each of the graphs, a trendline was fitted to the historic data to determine whether there is an increasing trend in the AMS. Further to this, as indicated previously, an analysis of trends in the design rainfall depths associated with the 1:10- and 1:50-year return periods was also undertaken. The analysis of trends in the AMS and design rainfall depths allows for a full picture of the changing hazard associated with extreme rainfall to be obtained, based on observed historical data. The results of the 1:10- and 1:50-year design rainfall trend analysis (based on the Gumbel distribution and an incremental inclusion of AMS data from 30 years until the full record is analysed), is presented in Figure 4-41 and Figure 4-43. Based on this analysis, it was noted that both the AMS and design rainfall trend analysis for station 059463 (representative of QC X32F) is subtle, although still increasing. Both the analysis of the AMS data and the design rainfall depths for station 0594696 W more clearly shows an increasing trend of extreme rainfall. Based on this analysis, there is an indication of an increasing flooding hazard in the Ehlanzeni DM and in the vicinity of QC's X32F and B60H, however, the increasing hazard is more obvious for QC B60H.

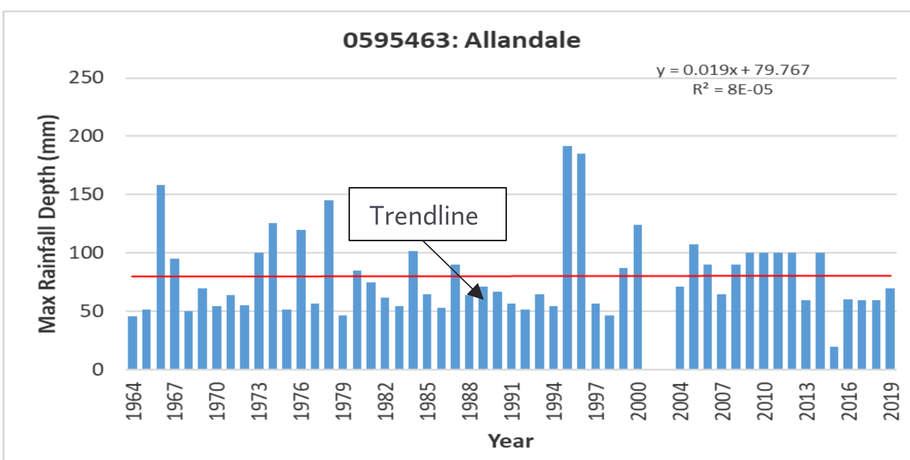



*Figure 4-40: Annual Maximum Series Rainfall Data - Station 0595463 W (1964 – 2019)*

*Data sourced from SAWS.*

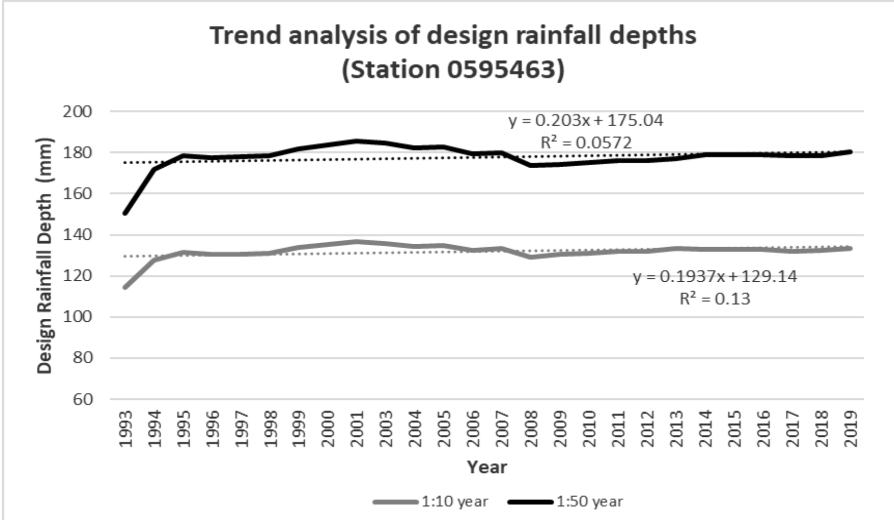



*Figure 4-41: Analysis of 1:10 and 1:50 year design rainfall depth trends for weather station 0595463 W*

*Data sourced from SAWS.*

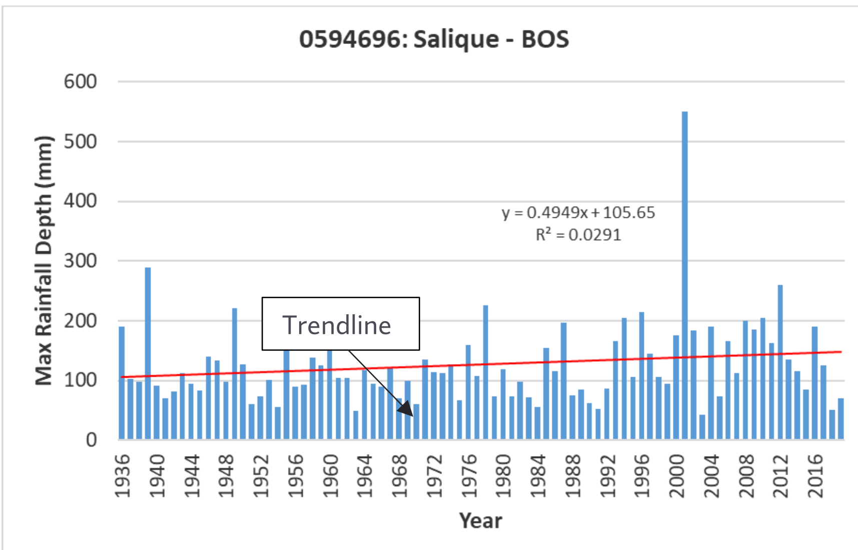



*Figure 4-42: Annual Maximum Series Rainfall Data - Station 0594696 W (1936 – 2019)*

*Data sourced from SAWS.*

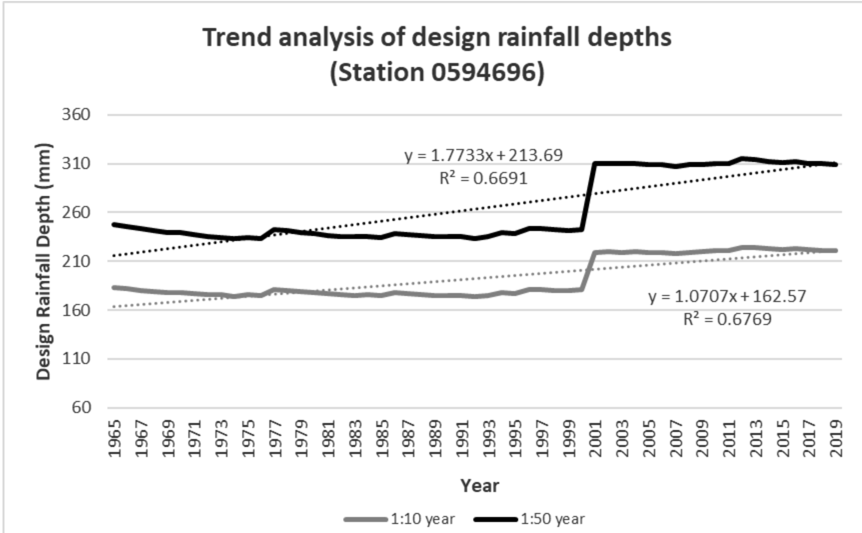



*Figure 4-43: Analysis of 1:10 and 1:50 year design rainfall depth trends for weather station 0594696 W*

*Data sourced from SAWS.*

**Projected Changes in Extreme Precipitation and Consequently Flood Hazard**

As indicated previously, the estimation of design floods for ungauged catchments is generally the product of a combination of design (i.e. extreme) rainfall and catchment characteristics (which dictates the conversion of rainfall to runoff). Due to the complexities of accounting for the variability in catchment characteristics across the study areas (catchment area, catchment slope, land-cover characteristics, soil characteristics etc.), this assessment has focused on changes in precipitation, and in particular, changes in extreme precipitation trends, to identify changes in flood hazards. For this analysis, anomalies of extreme precipitation were sourced from the World Banks' Climate Change Knowledge Portal (CCKP) (World Bank, 2021). Climate projection data presented on the CCKP is derived from CMIP6. Modelled climate data for CCKP is presented at a 1.0° latitude by 1.0° longitude grid.

As presented in the CCKP, to determine anomalies in extreme rainfall, comparisons between baseline (historic) rainfall data and forecasted rainfall data is required. In line with this, the source of historic data, from which the anomalies of extreme rainfall have been calculated, is the Climatic Research Unit CRU () gridded Time Series (TS), which is noted to be one of the most widely used observational climate dataset sources. Data in CRU is presented on a 0.5° latitude by 0.5° longitude grid. The CRU gridded dataset is derived from observational data and provides quality-controlled rainfall values from weather stations in the respective analysis regions.

For this analysis, anomalies of extreme precipitation were sourced from the CCKP, as noted earlier. To determine anomalies in extreme rainfall, comparisons between baseline (historic) rainfall data and forecasted rainfall data were undertaken. The extreme precipitation anomalies extracted from the CCKP are based on SSP5-8.5, and centralised over the 2050 period, using the 50$^{th}$ and 90$^{th}$ percentiles of multi-model ensembles. Both the 50$^{th}$ and 90$^{th}$ percentiles were used to illustrate the range of possible anomalies using different models (therefore illustrating uncertainty). Anomalies are based on the changes in magnitude of the 1:100-year return period rainfall depths. A map of the anomalies, across the Ehlanzeni DM is presented in Figure 4-44, which indicates a range of change from 11mm (50$^{th}$ percentile) and 45mm (90$^{th}$ percentile) at the central area of the DM to 12mm

($50^{th}$ percentile) and 56mm ($90^{th}$ percentile) in the northern portion of the DM. QCs B60H (n orange in the figure below) and X32F (in yellow in the figure below) show an increase of approximately 11mm for the 1:100-year design rainfall using the $50^{th}$ percentile model ensembles, and an increase of approximately 45mm using the $90^{th}$ percentile model ensembles.

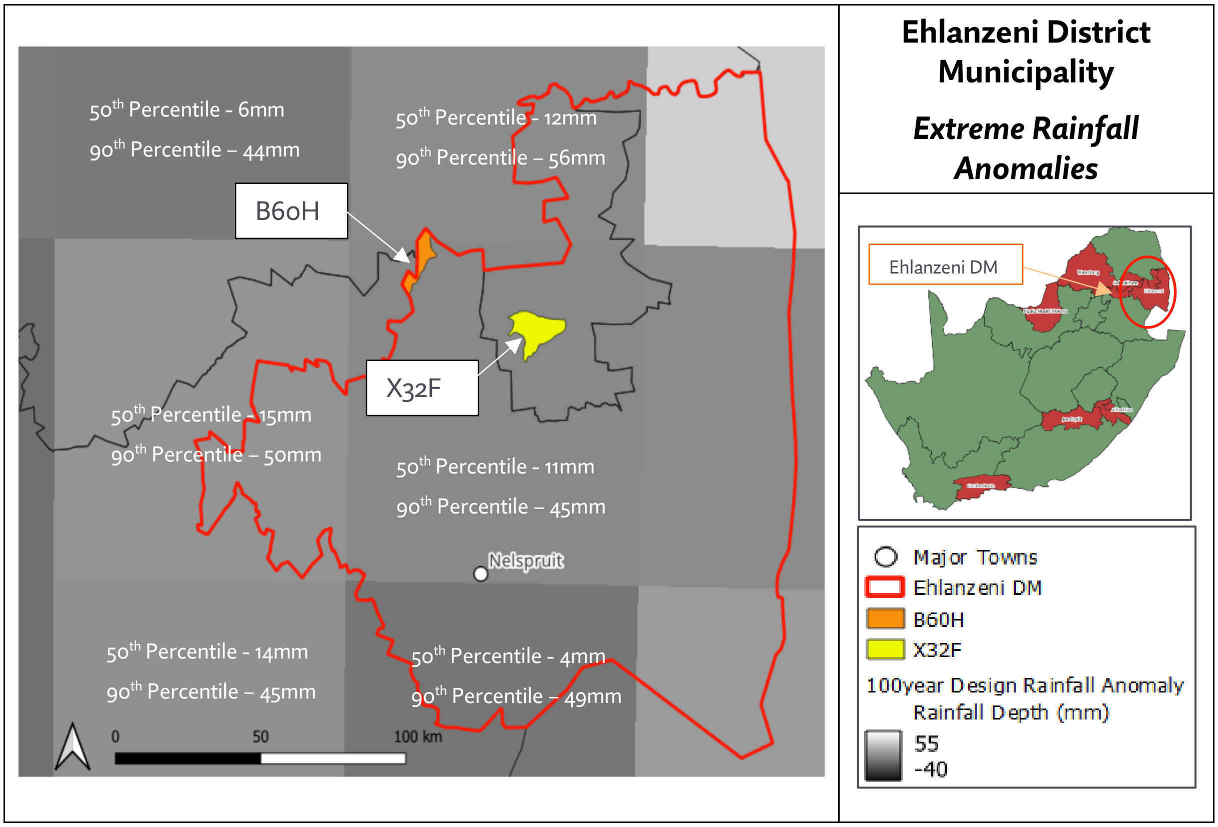


*Figure 4-44: Ehlanzeni DM Extreme Rainfall Anomalies*

In order to contextualise the increase in extreme rainfall across the Ehlanzeni DM, design rainfall at the centroid of each priority QC was extracted using the Regional L-Moment Algorithm and Scale Invariance (RLMA&SI) approach developed by Smithers and Schulze in 2002 (Smithers & Schulze, 2002).The RLMA&SI procedures developed by Smithers and Schulze (2002) enable the estimation of design rainfall in South Africa at any 1' x 1' latitude and longitude grid and for durations ranging from 5 minutes to 7 days and for return periods ranging from 2 to 200 years. The resultant design rainfall for the B60H and X32F QCs are presented in Table 4-13. Based on these estimates of design rainfall compared to the anomalies of extreme rainfall related to the 100-year return period rainfall event (indicated in yellow), an increase in extreme rainfall of approximately 6% and 5% is projected for QC B60H and X32F respectively, based on the $50^{th}$ percentile ensemble models, and approximately 27% and 21% using the $90^{th}$ percentile ensemble models.

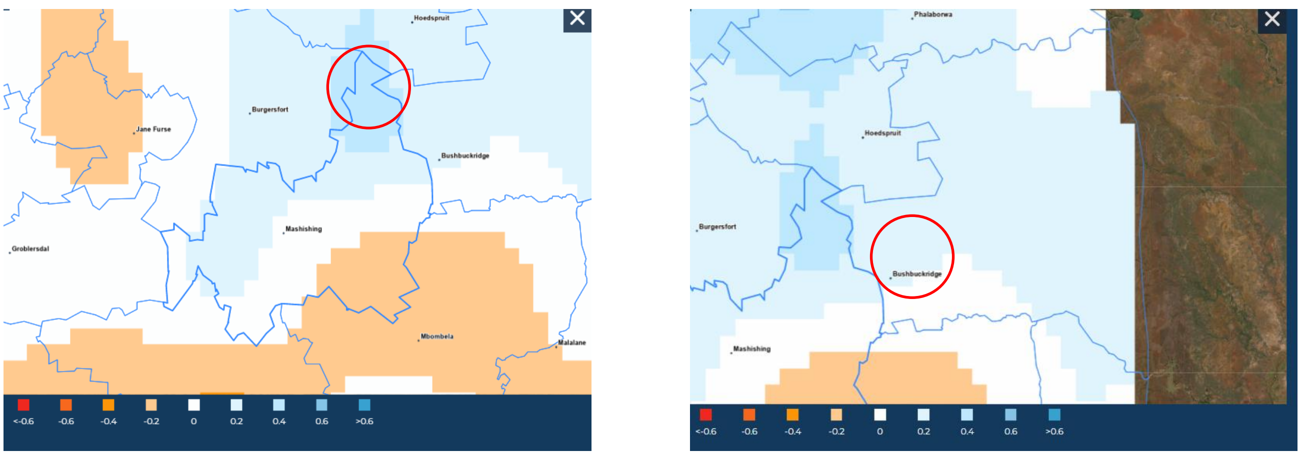
*Table 4-13: Ehlanzeni Design Rainfall Estimates*

| | Design Rainfall Depths (mm) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1:2 year | 1:5 year | 1:10 year | 1:20 year | 1:50 year | 1:100 year | 1:200 year |
| B60H | 64 | 88 | 105 | 122 | 146 | 166 | 186 |
| X32F | 73 | 101 | 122 | 146 | 179 | 208 | 240 |

### 4.3.3 Drought Hazard Assessment for Ehlanzeni DM

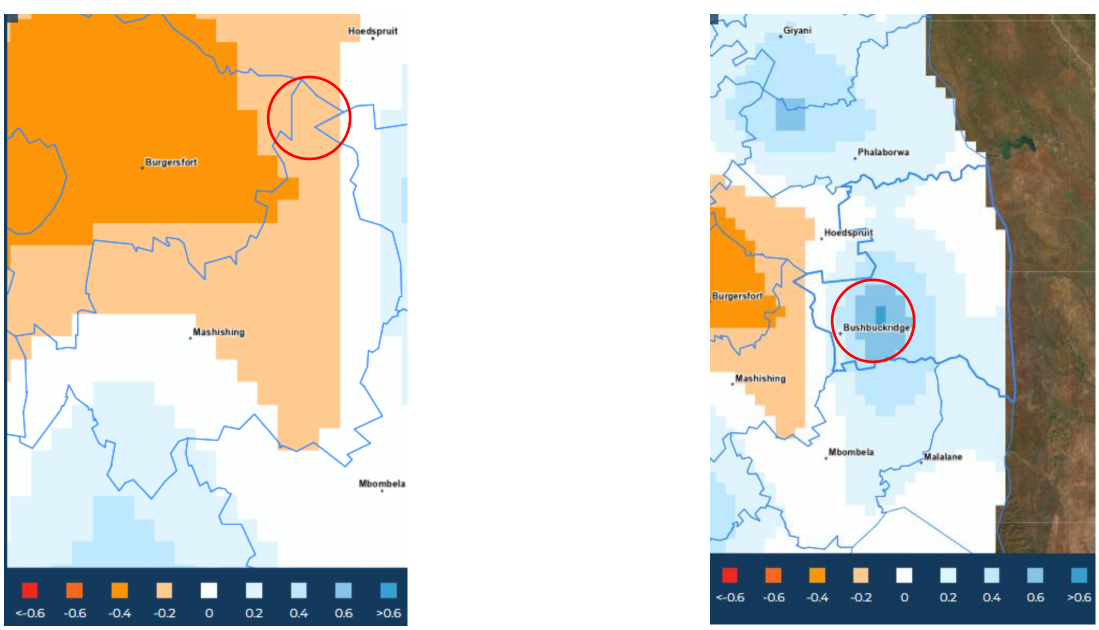
The Mpumalanga province, within which the Ehlanzeni DM is located in, has reported several droughts over the years with the most recent being in 2019 when the Mpumalanga provincial government's executive council declared a provincial drought disaster (Lowvelder, 2019). The Let's Respond Toolkit highlighted the plight of subsistence and commercial farmers during the 2016 drought (Let's Respond Toolkit, n.d.). Furthermore, participants during the district workshop emphasised the impact of past droughts on household water supply, crop and livestock production and most importantly food security.

An assessment of **current drought hazard** for Ehlanzeni DM indicates that (Figure 4-45) the priority QCs are within reduced drought tendency per 10 years therefore are not considered at risk for drought. An assessment of **change in drought hazard** for the Ehlanzeni DM indicates that projections for 2050 (Figure 4-46) suggest that B60H will have an increase in drought tendencies per 10 years but that X32F will have a reduced drought tendency per 10 years.




Thaba Chweu LM (B60H) Bushbuckridge LM (X32F)

*Figure 4-45: SPEI drought tendencies over 1995-2024 for Ehlanzeni DM (Source: Engelbrecht et al., 2019)*




Thaba Chweu LM (B60H) Bushbuckridge LM (X32F)

*Figure 4-46: Drought tendencies for 2015 to 2044 for Ehlanzeni DM (Source: Engelbrecht et al., 2019)*

### 4.3.4 Vulnerability Assessment for Ehlanzeni DM

Bushbuckridge LM has one of the highest economic vulnerabilities in the country indicating income inequality and low economic diversity. There is also high physical vulnerability reflecting the limited connectivity and remote location of the LM. Future projections indicate that the towns in the LM have a reducing growth pressure. The Thaba Chweu LM has a high environmental vulnerability indicating that there is increasing conflict between a growing population on the natural environment.

*Table 4-14: Multi-dimensional vulnerability (ranking out of 213) for LMs in Ehlanzeni DM*

*Source:* (Le Roux, et al., 2019)

| DM | LM | Socio-Economic | Economic | Physical | Environmental |
|---|---|---|---|---|---|
| Ehlanzeni | Thaba Chweu | 51 | 104 | 139 | 191 |
| | Bushbuckridge | 158 | 204 | 210 | 116 |

In the Ehlanzeni DM, Bushbuckridge appears most vulnerable (see Figure 4-47).

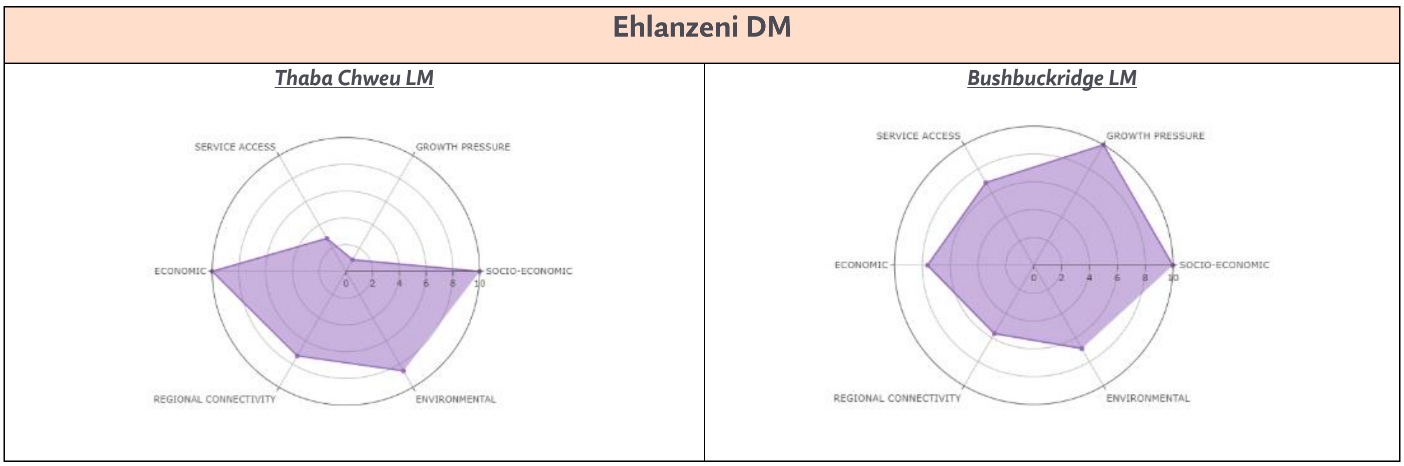



*Figure 4-47: Vulnerability of LMs within the Ehlanzeni DM, with focus on traditional settlements*

*Source:* (Le Roux, et al., 2019)

According to the Green Book (Le Roux, et al., 2019), the projected growth pressure for the Ehlanzeni DM indicates that the Thaba Chweu LM has the highest growth scenario over the periods of 2030 and 2050 (Table 4-15).

*Table 4-15: Growth scenarios for local municipalities in Ehlanzeni DM.*

*Source:* (Le Roux, et al., 2019)

| DM | LM | Growth scenario | 2011 | 2030 | 2050 |
|---|---|---|---|---|---|
| **Ehlanzeni** | **Thaba Chweu** | **Medium** | **98,385** | **118,249** | **130,810** |
| | | **High** | **98 385** | **122,195** | **140,947** |
| | | **High** | **392,991** | **486,036** | **550,612** |
| | Bushbuckridge | Medium | 539,028 | 529,300 | 458,878 |
| | | High | 539,028 | 546,904 | 494,251 |

### 4.3.5 Exposure Assessment for Ehlanzeni DM

The resultant level of flooding exposure, associated with the Ehlanzeni DM is presented in Figure 4-48. The Ehlanzeni DM is associated with a medium to high FHI. It is also noted that QC B60H is associated with a higher FHI than X32F.

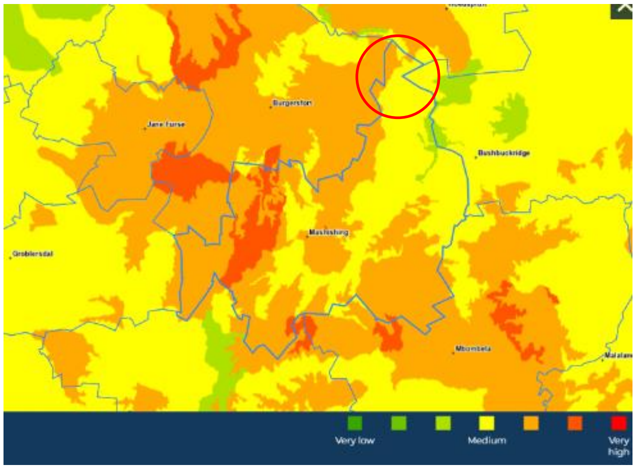
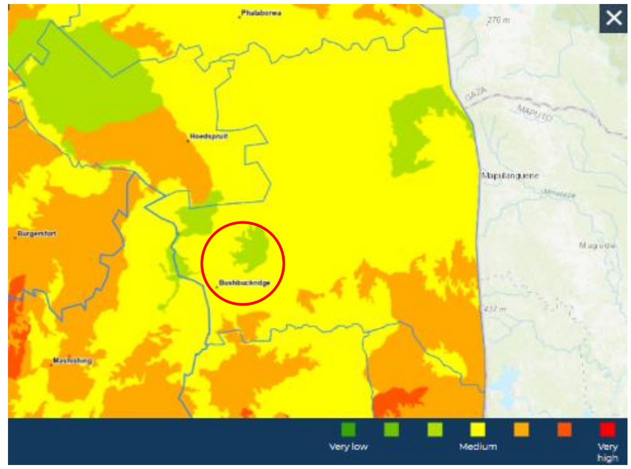
| ***Ehlanzeni DM Flood Exposure*** | |
|---|---|
|   Thaba Chweu LM (B60H) |   Bushbuckridge LM (X32F) |

*Figure 4-48: Current flood hazard index for Ehlanzeni DM*

*Source: (Engelbrecht et al., 2019)*

**Exposure to Pluvial Flooding**

Based on the FHSI analysis results, and in particular those for QC X32F, as presented in Figure 4-49, the area of particular exposure is located along the western portion of the QC, particularly in the area of Bushbuck Ridge. As presented in this figure, this particular area is associated with extensive settlement areas. Therefore, the identified increase in flooding exposure due to topographical and soils characteristics is associated with extensive settlement, indicating people in this area are likely to be particularly susceptible to flooding.

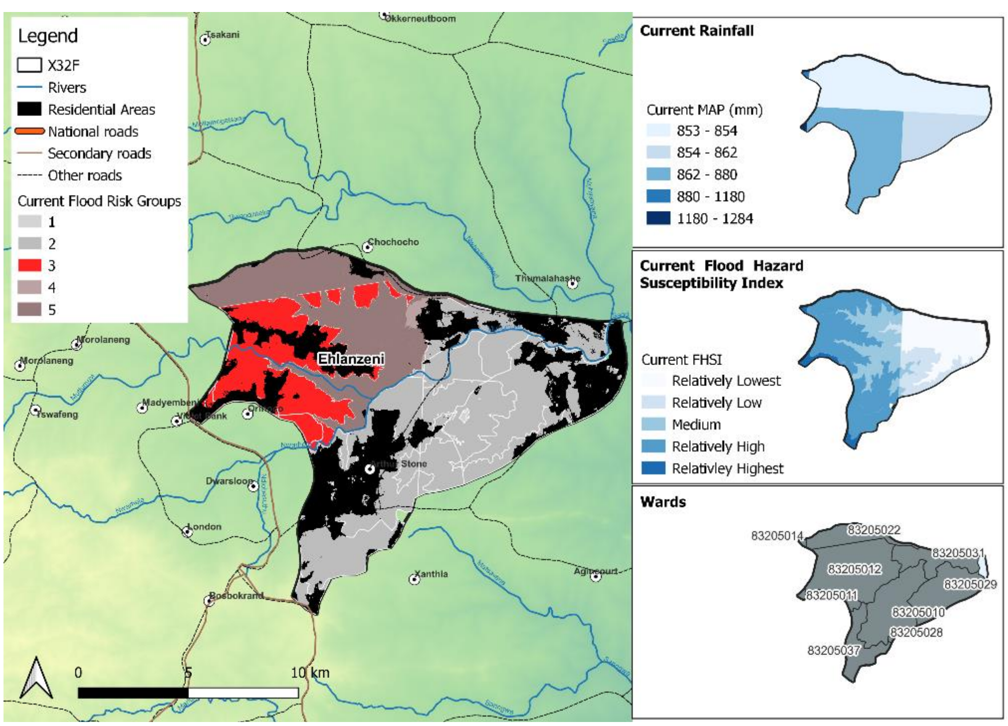



*Figure 4-49: Current relative flood risk groups based on current rainfall for X32F within Ehlanzeni DM*

### Exposure to Fluvial Flooding

As presented in Figure 4-50, QC B60H appears to have very limited human settlement located within the catchment area. This area is therefore associated with a low level of exposure to fluvial flooding. However, QC X32F has extensive settlements located within the catchment. Large portions of these settlements are located adjacent to drainage lines, and are therefore associated with being exposed to fluvial flooding. During the feasibility phase of the study, particular attention should be given to fluvial flooding in QC X32F, particularly in the areas highlighted in Figure 4-50.

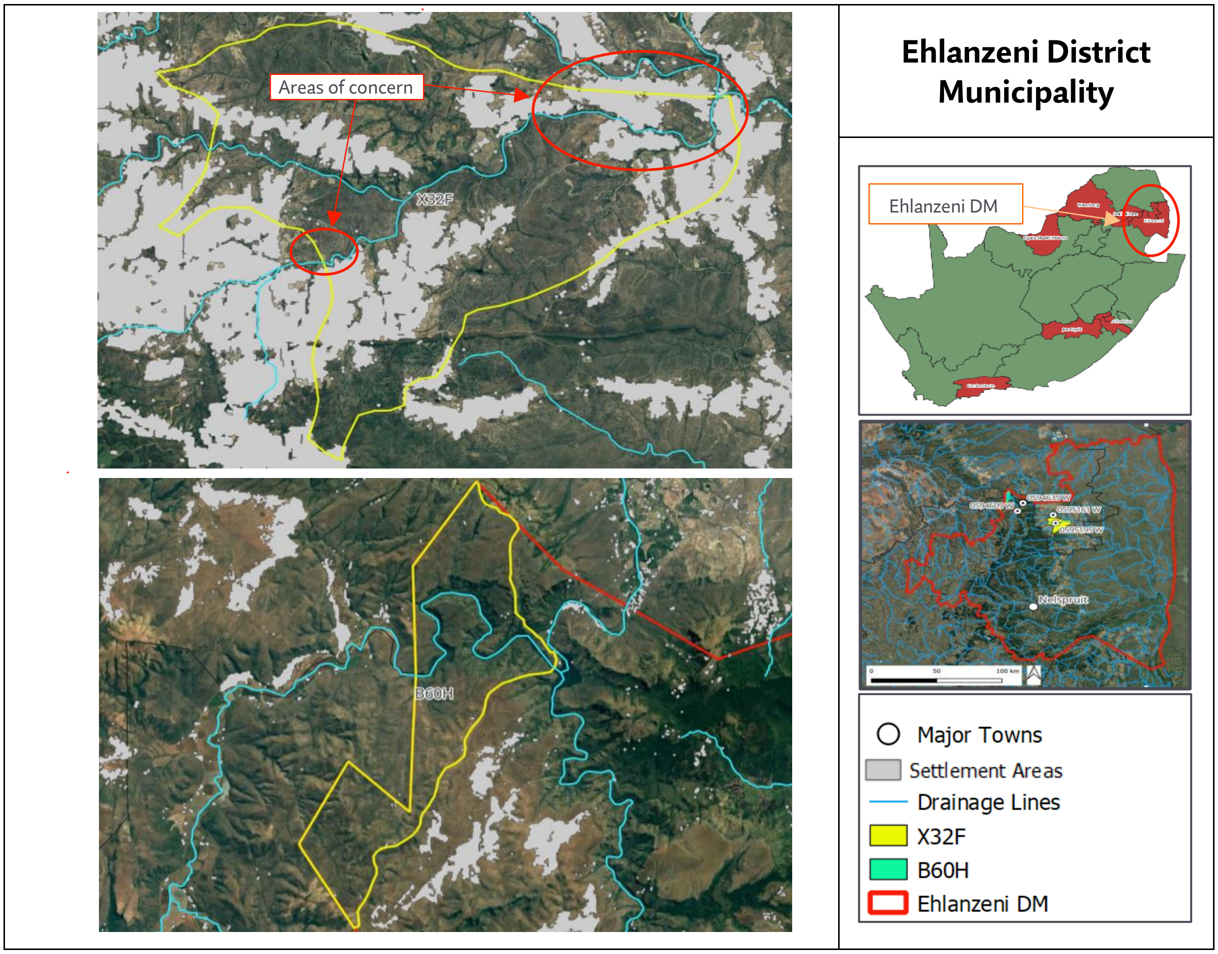



*Figure 4-50: Distribution of settlements in relation to main drainage lines across priority catchments in the Ehlanzeni DM*

### Exposure to Drought

According to the WWF Water Risk Filter water scarcity index (proxy for exposure to drought), as described in Section 3.4.2, the Ehlanzeni region has areas of both moderate and low levels of exposure to drought. This is illustrated in Figure 4-51, which also shows that the Ehlanzeni DM has a lower level of exposure than the Sekhukhune DM, located to the immediate west of Ehlanzeni DM.

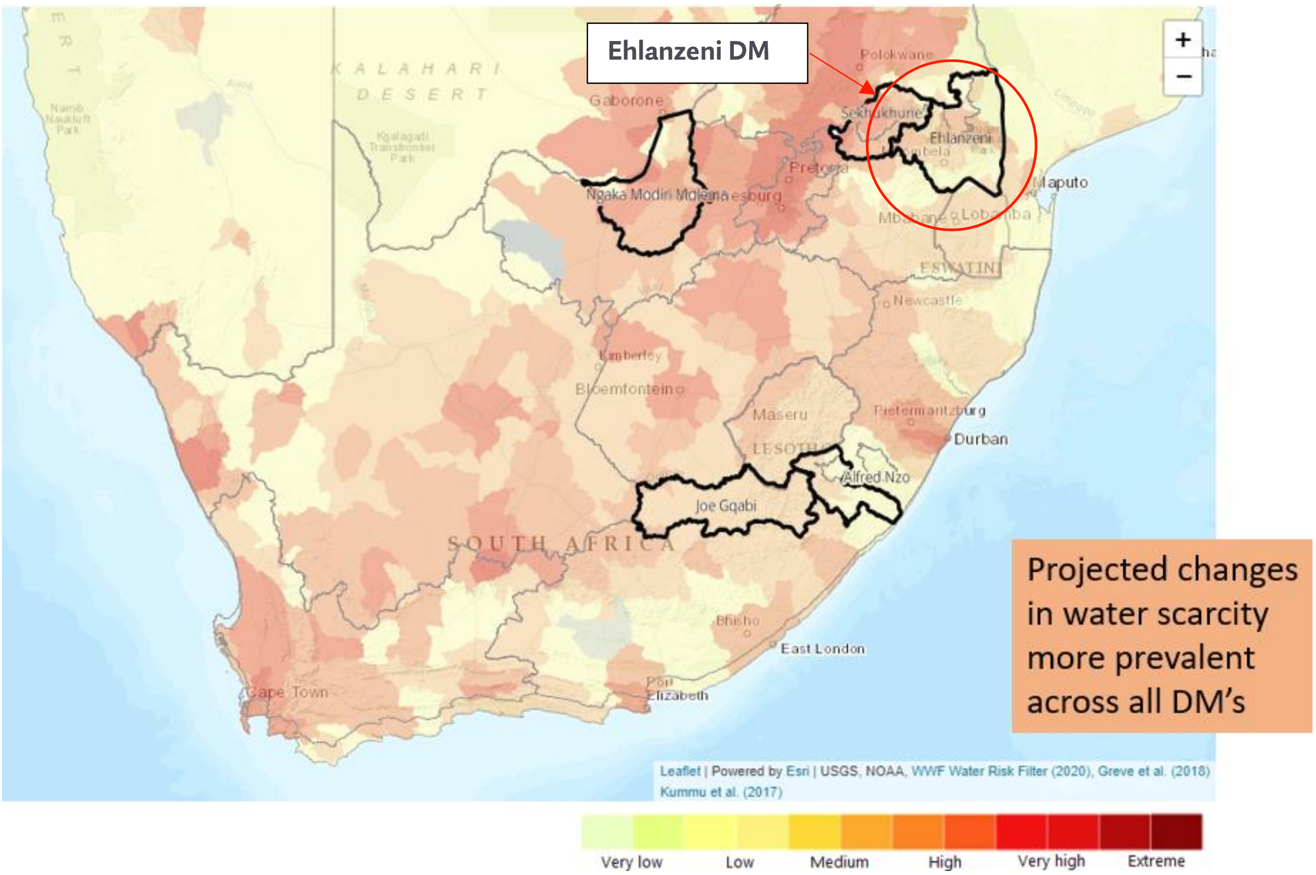



*Figure 4-51: WWF Water Risk Filter - Water Scarcity Index, Proxy for Drought Exposure (Ehlanzeni District Municipality)*

## 4.4 SEKHUKHUNE DM

The Sekhukhune DM is located in the Limpopo Province, in the south-eastern part bordering on the Capricorn and Mopani DMs in the north, Waterberg in the west, Nkangala in the south and Ehlanzeni DM in the east. The main sectors of the Sekhukhune DM that contribute to the growth of economy in the district are agriculture, mining and community services. Mining is the biggest contributor to the economy of the district (Sekhukhune, 2022). This has influenced the population growth rate, particularly in areas within the Fetakgomo Tubatse LM. The rural nature of the district provides less job opportunities therefore males migrate to the big cities in search for work.

The Sekhukhune DM has four LMs: Elias Motsoaledi, Ephraim Mogale, Makhuduthamaga and Fetakgomo Tubatse. New mining developments are concentrated in Fetakgomo Tubatse LM, while other parts of the district have little potential for increased income levels, and thus expected to remain suffering high levels of poverty (Sekhukhune DM, 2022).

According to the 2011 Census (StatsSA, 2015) there were at the time just under 1,1 million individuals living in Sekhukhune DM, which covers an area of 13 528 km$^2$. Thus, the population density is approximately 80 people per km$^2$. There was a 79% unemployment rate in 2011 with only 36% of this group having been recorded as having received high school education at any given time. Of the district's households, just over 33% of households were involved in agricultural Activities. Informal dwellings made up just over 7% of the dwelling types with an average of slightly more than four people per household. A high percentage (approximately 45%) of the population sourced water from other sources outside of piped water schemes (StatsSA, 2015).

### 4.4.1 Overview of Sekhukhune DM

The top two potential locations identified in the Sekhukhune DM include QC's B51H and B52B, located towards the centre of the DM (Figure 4-52). The DM has significant undulating plains, with the Klein Drakensberg Mountains covering the north-eastern and eastern side of the Municipality. The main river located within the catchment is the Lepellane River, which is a tributary of the Olifants River and ultimately drains to the Limpopo River. The B51H catchment (indicated in green) is at the headwaters of the system, and therefore has no other catchments draining into it. The main river located within the QC B52B (indicated in orange) is the Ngwaritsi River, which is also a tributary of the Olifants River and ultimately drains into the Limpopo River System.

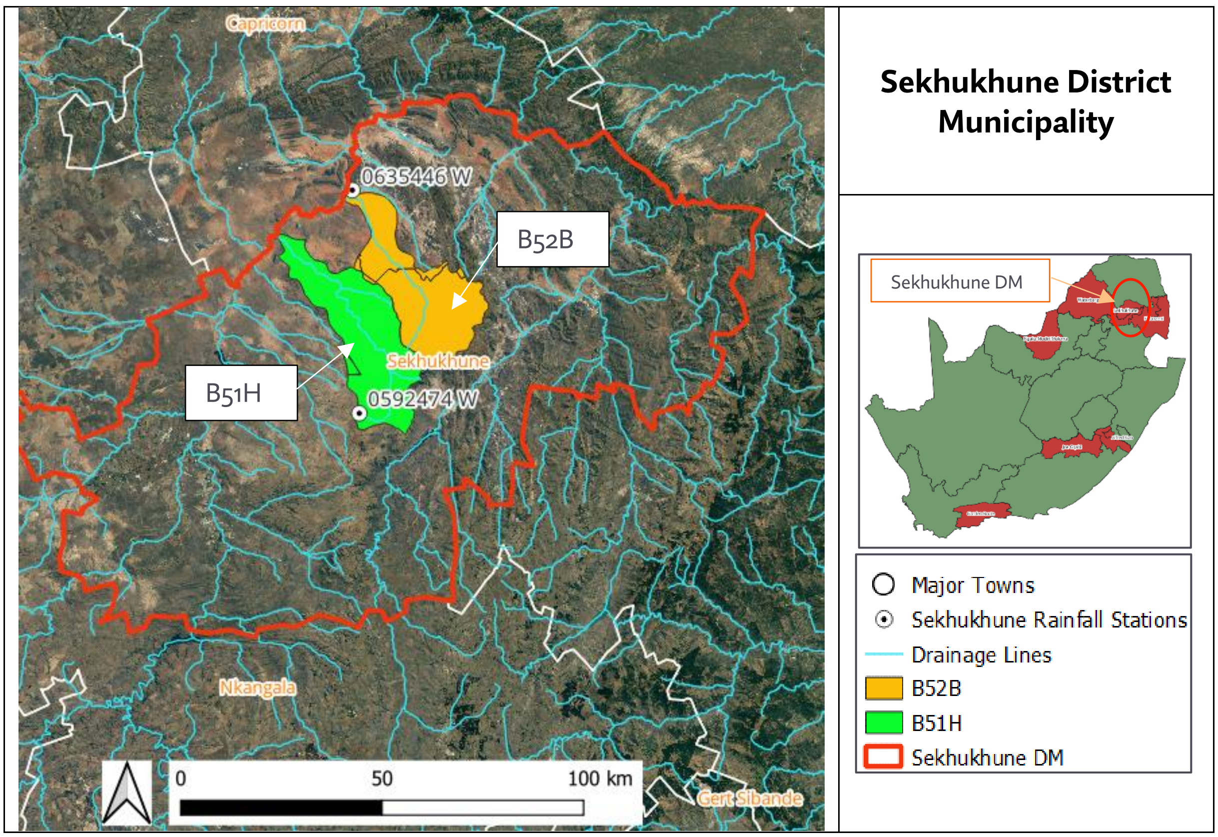
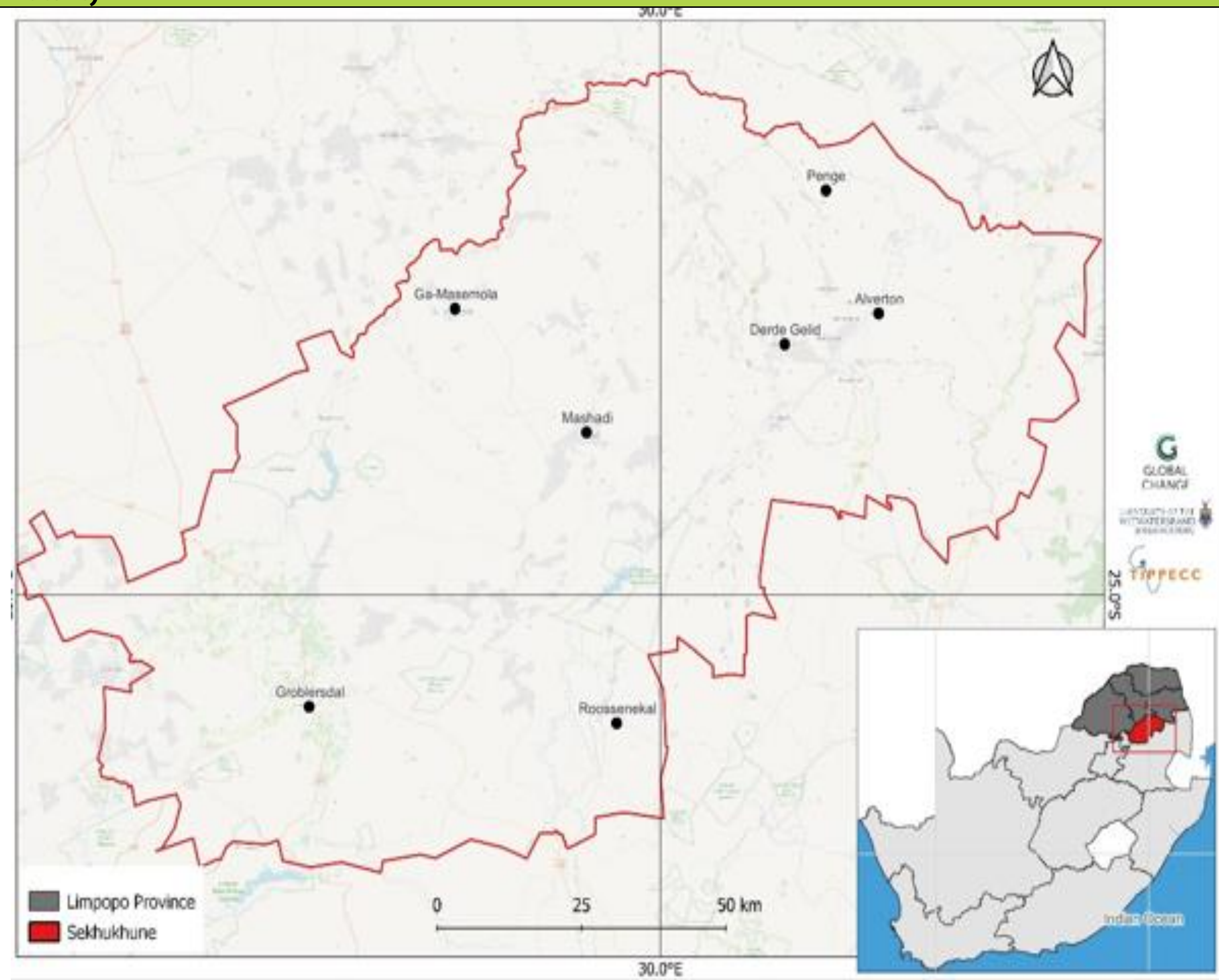



*Figure 4-52: Sekhukhune DM and Priority QCs*

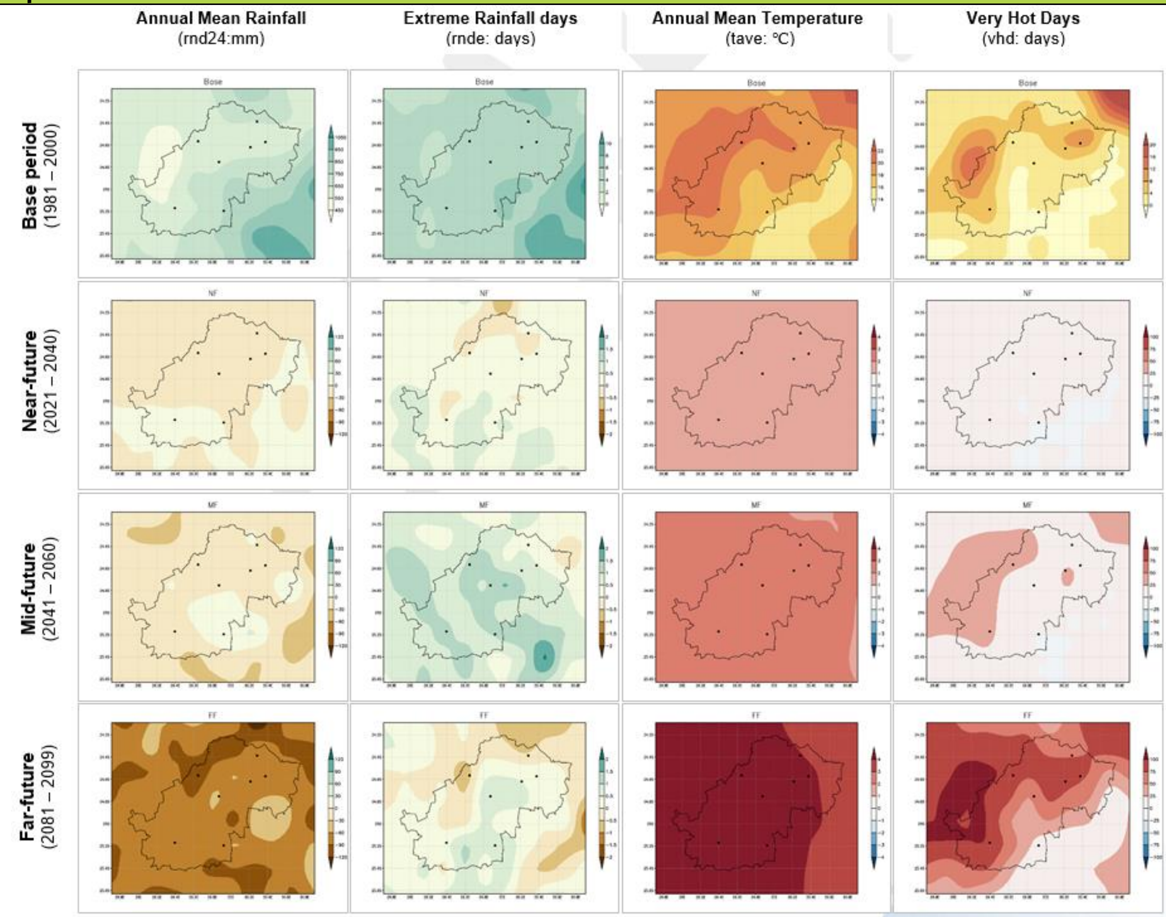
A summary of the observed climate conditions in Sekhukhune DM (GCI & SANBI, 2024) is presented in the table below.

*Table 4-16: Location and summary of observed climate conditions for Sekhukhune DM*

| Parameter | Observed conditions | Locality |
|---|---|---|
| Mean annual rainfall | A decrease in annual mean precipitation has been observed (medium confidence), with levels ranging from 450 mm in the northwest to approximately 750 mm in the southeast near the escarpment. |  |
| Extreme rainfall days | An increase in the frequency of heavy precipitation events has been observed (medium confidence), with the annual average ranging from 2 to 4 events across the district and reaching up to 6 days in the far southeast. | |
| Mean annual temperature | Increases in annual mean temperature and warm extremes have been observed with virtual certainty, with mean temperatures ranging from about 14°C in the southeastern highlands to 22°C in the northwest. | |
| Very hot days | The annual mean number of very-hot days ranges from 2 days over the highlands in the southeast to more than 12 days in the northwest. | |

A summary of the projected climate changes and spatial anomalies in Sekhukhune DM (GCI & SANBI, 2024) is presented in the table below.

*Table 4-17: Projected climate changes and spatial anomalies in Sekhukhune DM*

| Parameter | Projected conditions | Spatial anomalies |
|---|---|---|
| Mean annual rainfall | Precipitation is projected to decline in the near future, with also significant decreases anticipated in the mid-and far future (high confidence). |   |
| Extreme rainfall days | Heavy precipitation events, primarily thunderstorms, are projected to increase in the near future (medium confidence), with further increases expected in the mid- and far future (medium confidence). | |
| Mean annual temperature | Temperature and warm extremes are projected to increase (virtually certain), with cold extremes decreasing (high confidence) in the near future. In the mid and far future, temperature and warm extremes will continue to rise (virtually certain). | |
| Very hot days | Projected increase in warm temperature extremes (virtually certain). | |

### 4.4.2 Flood Hazard Assessment for Sekhukhune DM

**Flooding History**

The Sekhukhune DM has a history of severe flooding. Due to the district being characterized by rugged terrain, it is particularly vulnerable to flash floods and fluvial flooding.

One of the most devastating floods in the history of the Sekhukhune DM occurred in 2014. This flood resulted in significant damaged to infrastructure, including roads, bridges, and buildings, and swept away homes and impacted significantly on livelihoods of local communities. During these floods, at least 14 people lost their lives and thousands were displaced. The flooding also affected the water supply, with many areas experiencing water shortages for extended periods.

In January and February 2021, the Sekhukhune DM experienced another significant flood. The flooding affected several areas within the municipality, including the towns of Burgersfort, Steelpoort, and Groblersdal. The extent of the flooding was significant, with roads and bridges being washed away and many communities being cut off from basic services such as electricity and water. The South African government declared the Sekhukhune District a disaster area in order to enable swift emergency relief efforts to assist those affected by the flooding (Makhafola, 2021; Davies, 2021).

During the district-level workshop, the impact of floods was highlighted by participants, specifically the impact on dwellings, roads, bridges, crops and cropping land. Access to services such as healthcare was also raised at the workshop with such services often being difficult to access during floods. Participants also noted that flood events were exacerbated by overgrazing and illegal sand mining in the area which often resulted in open dongas. The geographical slope of the region was also cited as a key contributor to soil erosion during flooding.

The site visit confirmed the occurrence of flood in the two priority QCs (B51H and B52B) with the flood risk being medium to high. Much of the areas visited were densely populated and peri-urban in nature. Due to poor settlement planning at a DM and LM level, regular flooding often negatively impacted communities. In some instances, communities were located close to flood plains, within known floodlines, and within wetlands. This indicate that local spatial planning does not always confirm to accepted standards or norms. Furthermore, due to the nature of the steep topography, very localised flash-flooding is known to occur which threaten homes, livelihoods and lives.

The site visits also highlighted the presence of IAPs in the QCs and was linked to bush encroachment. Further, in some contexts, wetland degradation was also linked to poor rangeland management and the management of livestock.

Due to extensive erosion during rains, gullies and dongas were evident in the QCs during the site visit (Figures below). which present a risk to communities' livelihoods and households / property. Dongas were also linked to culverts and bridges.

*Figure 4-53 Examples of dongas and erosion in Sekhukhune DM*

*Figure 4-54: High levels of erosion near households in Sekhukhune DM*

## Rainfall Analysis

### *Historical Rainfall Analysis*

Two rainfall stations in the proximity of the priority QCs B52B and B51H were selected for analysis to determine whether any trends in changes in extreme rainfall could be identified, based on an analysis of historical rainfall data in the region. As mentioned previously, the AMS was extracted for the period in which observed and reliable data was available. The AMS refers to maximum depth of rainfall, over a 24-hour period, that has been measured during a hydrological year. As mentioned previously, based on the connection AMS data can be linked to changes in extreme rainfall and therefore regional flood hydrology.

Figure 4-55 and Figure 4-57 present the AMS for the selected rainfall stations, located within the Sekhukhune DM, and in proximity to QC's B52B and B51H. The locations of these rainfall stations are presented in Figure 4-52. Due to limited data availability, information presented for station 0635446 is based on patched data, as sourced from the daily rainfall extraction utility (Lynch, 2003). In each of the graphs, a trendline was fitted to the historic data to determine whether there is an increasing trend in the AMS. Further to this, as indicated previously, an analysis of trends in the design rainfall depths associated with the 1:10- and 1:50-year return periods was also undertaken. The analysis of trends in the AMS and design rainfall depths allows for a full picture of the changing hazard associated with extreme rainfall to be realised, based on observed historical rainfall data. The results of the 1:10- and 1:50-year design rainfall trend analysis (based on the Gumbel distribution and an incremental inclusion of AMS data from 30 years until the full record is analysed), is presented in Figure 4-56 and Figure 4-58. Based on this analysis, it was noted that a subtle increase in both the AMS and design rainfall is evident for station 0635446 (representative of QC B52B) is subtle, although still increasing. Both the analysis of the AMS data and the design rainfall depths for station 0592474 W more clearly shows an increasing trend of extreme rainfall. Based on this analysis, there is an indication of an increasing flooding hazard in the Sekhukhune DM and in the vicinity of QC's B52B and B51H, however, the increasing hazard is more obvious for QC B51H.

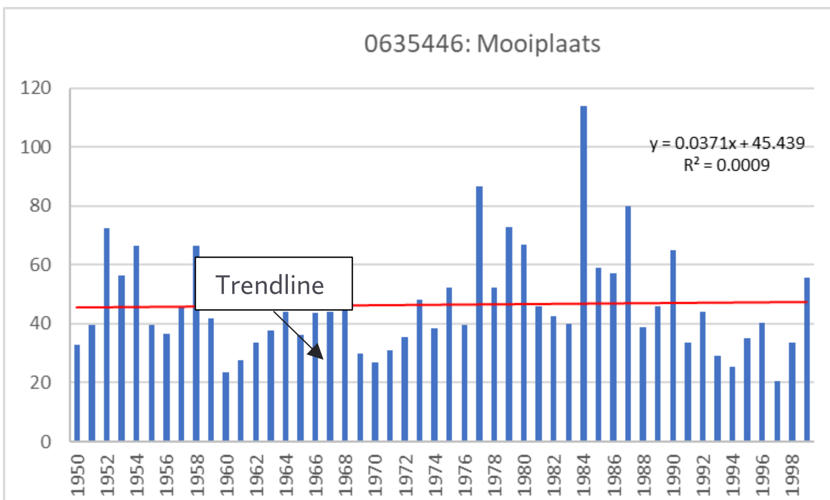



*Figure 4-55: Annual Maximum Series Rainfall Data - Station 0635446 W (1950 – 1999)*

*Data sourced from Daily Rainfall Extraction Utility.*

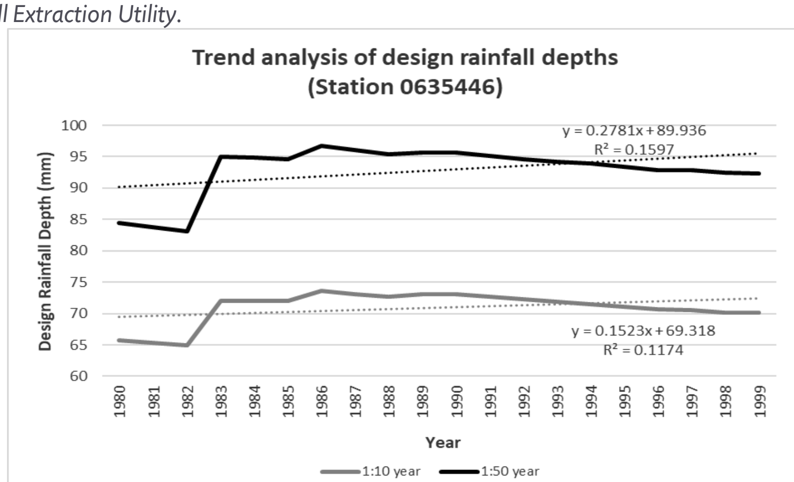



*Figure 4-56: Analysis of 1:10 and 1:50 year design rainfall depth trends for weather station 0635446 W*

*Data sourced from SAWS.*

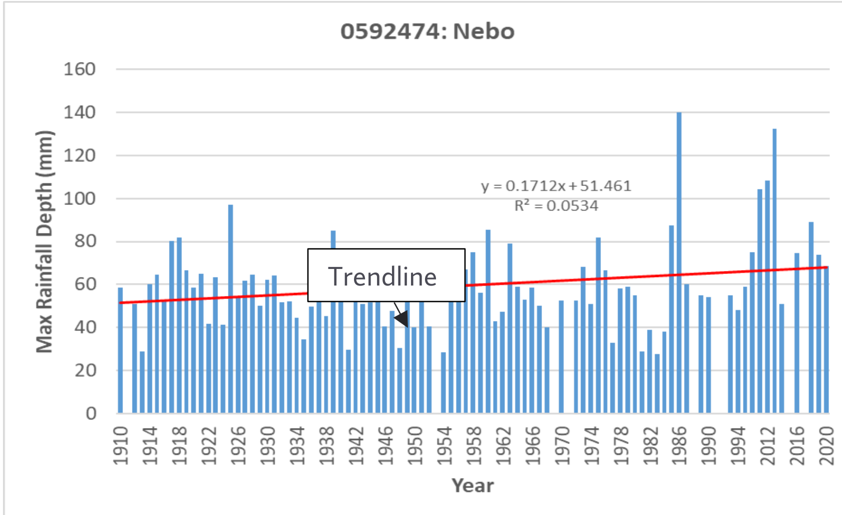



*Figure 4-57: Annual Maximum Series Rainfall Data - Station 0592474 W (1910 – 1998)*

*Data sourced from SAWS.*

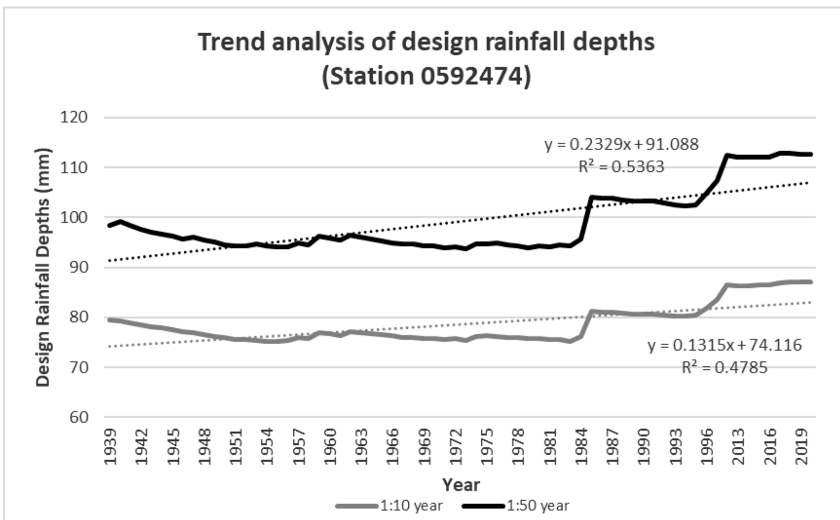



*Figure 4-58: Analysis of 1:10 and 1:50 year design rainfall depth trends for weather station 0592474 W*

**Projected Changes in Extreme Precipitation and Consequently Flood Hazard**

As indicated previously, the estimation of design floods for ungauged catchments is generally the product of a combination of design (extreme) rainfall and catchment characteristics. For this analysis, anomalies of extreme precipitation were sourced from the CCKP, as noted earlier. As indicated previously, the climate projection data presented on the CCKP is derived from the CMIP6. To determine anomalies in extreme rainfall, comparisons between baseline (historic) rainfall data and forecasted rainfall data was undertaken. The extreme precipitation anomalies extracted from the CCKP are based on SSP5-8.5, and centralised over the 2050 period, using the 50$^{th}$ and 90$^{th}$ percentiles of multi-model ensembles. Both the 50$^{th}$ and 90$^{th}$ percentiles were used to illustrate the range of possible anomalies using different models (therefore illustrating uncertainty). Anomalies are based on the changes in magnitude of the 1:100-year return period rainfall depths. A map of the anomalies, across the Sekhukhune DM is presented in Figure 4-59, which indicates a range of change from 15mm (50$^{th}$ percentile) and 50mm (90$^{th}$ percentile) at the central area of the DM to 6mm (50$^{th}$ percentile) and 44mm (90$^{th}$ percentile) in the northern portion of the DM. QCs B52B and B51H show an increase of approximately 15mm for the 1:100-year design rainfall using the 50$^{th}$ percentile model ensembles, and an increase of approximately 50mm using the 90$^{th}$ percentile model ensembles.

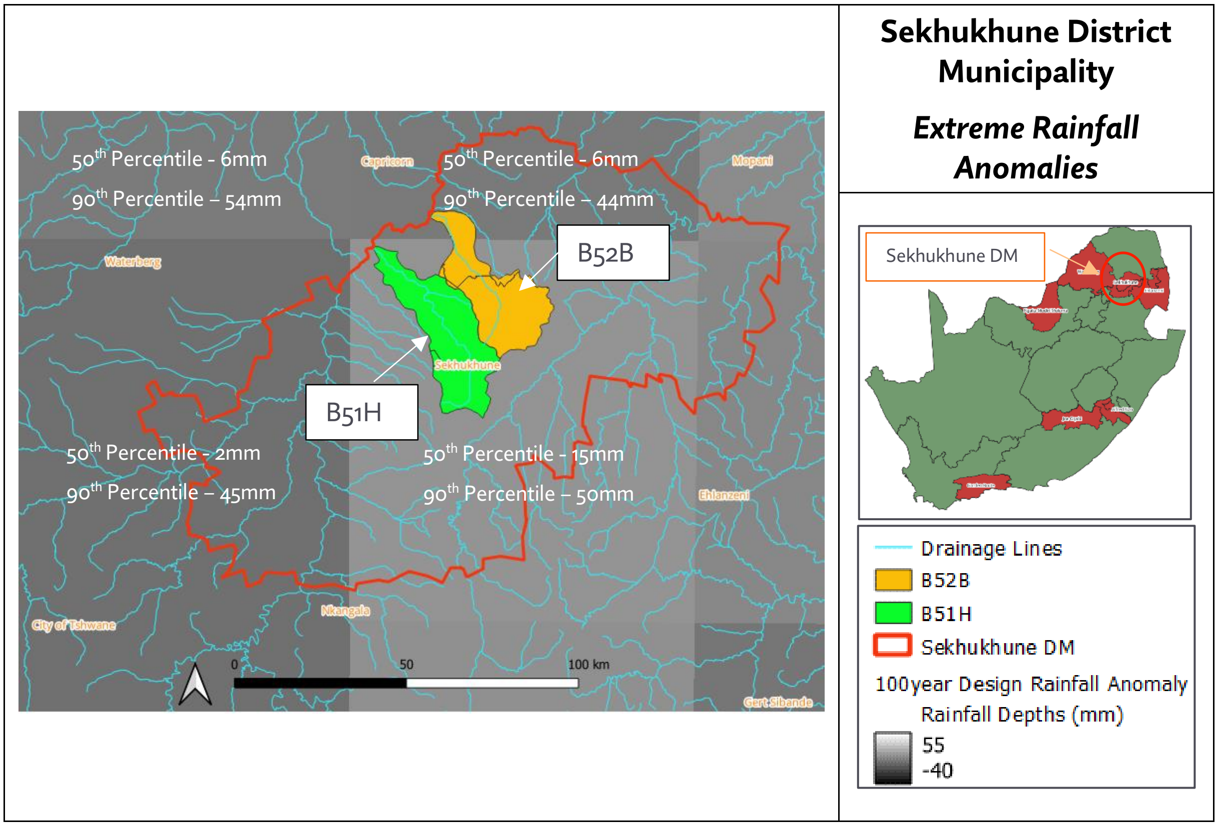



*Figure 4-59: Sekhukhune DM Extreme Rainfall Anomalies*

To contextualise the increase in extreme rainfall across the Sekhukhune DM, Design Rainfall at the centroid of each priority QC was extracted using the RLMA&SI approach developed by Smithers and Schulze (2002). The resultant design rainfall for the B51H and B52B QCs are presented in the Table 4-18 below. Based on these estimates of design rainfall compared to the anomalies of extreme rainfall related to the 100-year return period rainfall event (indicated in yellow), an increase in extreme rainfall of approximately 10% and 11% is projected for QC B52B and B51H respectively, based on the 50$^{th}$ percentile ensemble models, and approximately 38% and 33% using the 90$^{th}$ percentile ensemble models.

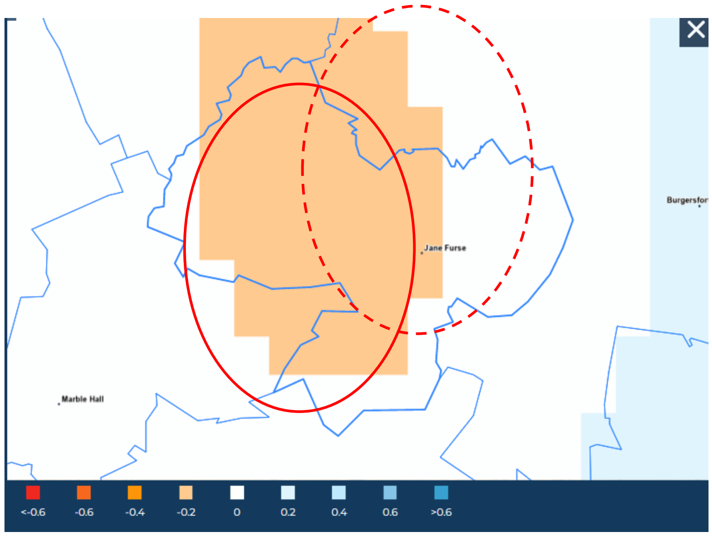
*Table 4-18: Sekhukhune Design Rainfall Estimates*

| | Design Rainfall Depths (mm) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1:2 year | 1:5 year | 1:10 year | 1:20 year | 1:50 year | 1:100 year | 1:200 year |
| B52B | 51 | 70 | 83 | 97 | 117 | 132 | 149 |
| B51H | 58 | 79 | 95 | 110 | 132 | 150 | 168 |

### 4.4.3 Drought Hazard Assessment for Sekhukhune DM

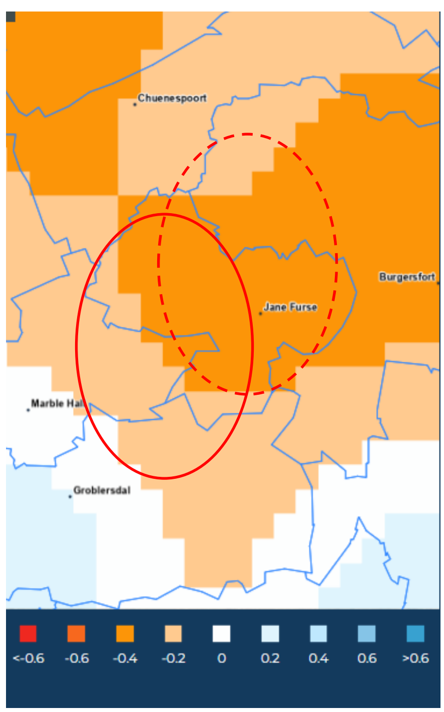
The Sekhukhune DM is recognised as drought prone with water shortages and poor rainfall distribution being cited as one of the constraints hindering the socio-economic growth. The district has experienced droughts in 1926, 1930, 1932, 1962, 1975, 1986, 1992, 2006, 2012 with the most recent being in 2019 (Mpandeli, et al., 2015; Motene, 2021; Mopanya, 2019). The 2019 drought was due to the area receiving less rainfall over the past four years with dams being close to empty (Mopanya, 2019). Participants at the district workshop highlighted the erratic rainfall patterns in the area which has contributed to past droughts with household farmers finding it difficult to produce reasonable yields of staple food crops. Furthermore, workshop participants noted that drought has compromised the quality and quantity of forage species for their livestock and farmers often experience livestock losses particularly during winter.

An assessment of **current drought hazard** for the priority QCs within Sekhukhune DM indicates that (Figure 4-60) both catchments are within a drought tendency per 10 years. An assessment of **change in drought hazard** for the priority QCs within Sekhukhune DM indicates that (Figure 4-61) both catchments will increase drought tendency per 10 years.




Makhuduthamaga LM (B51H: red circle and B52B: dotted red circle)

*Figure 4-60: SPEI drought tendencies over 1995-2024 for Sekhukhune DM (Source: Engelbrecht et al., 2019)*




Makhuduthamaga LM (B51H: red circle and B52B: dotted red circle)

*Figure 4-61: Drought tendencies for 2015 to 2044 for Sekhukhune DM (Source: Engelbrecht et al., 2019)*

### 4.4.4 Vulnerability Assessment for Sekhukhune DM

The Makhuduthamaga LM has high socio-economic, economic and physical with environmental vulnerability being slightly lower. Fetakgomo Tubatse LM also shows high economic, physical and environmental vulnerability.

*Table 4-19: Multi-dimensional vulnerability (ranking out of 213) for LMs in Sekhukhune DM.*

*Source:* (Le Roux, et al., 2019)

| DM | LM | Socio-Economic | Economic | Physical | Environmental |
|---|---|---|---|---|---|
| Sekhukhune | Ephraim Mogale | 130 | 151 | 22 | 70 |
| | Makhuduthamaga | 149 | 161 | 147 | 104 |
| | Fetakgomo Tubatse | 121 | 210 | 211 | 205 |

In the Sekhukhune DM, the Makhuduthamaga LM seems most vulnerable, particularly due to the high scores associated with economic, socio-economic, regional connectivity and growth pressure scores (see Figure 4-62).

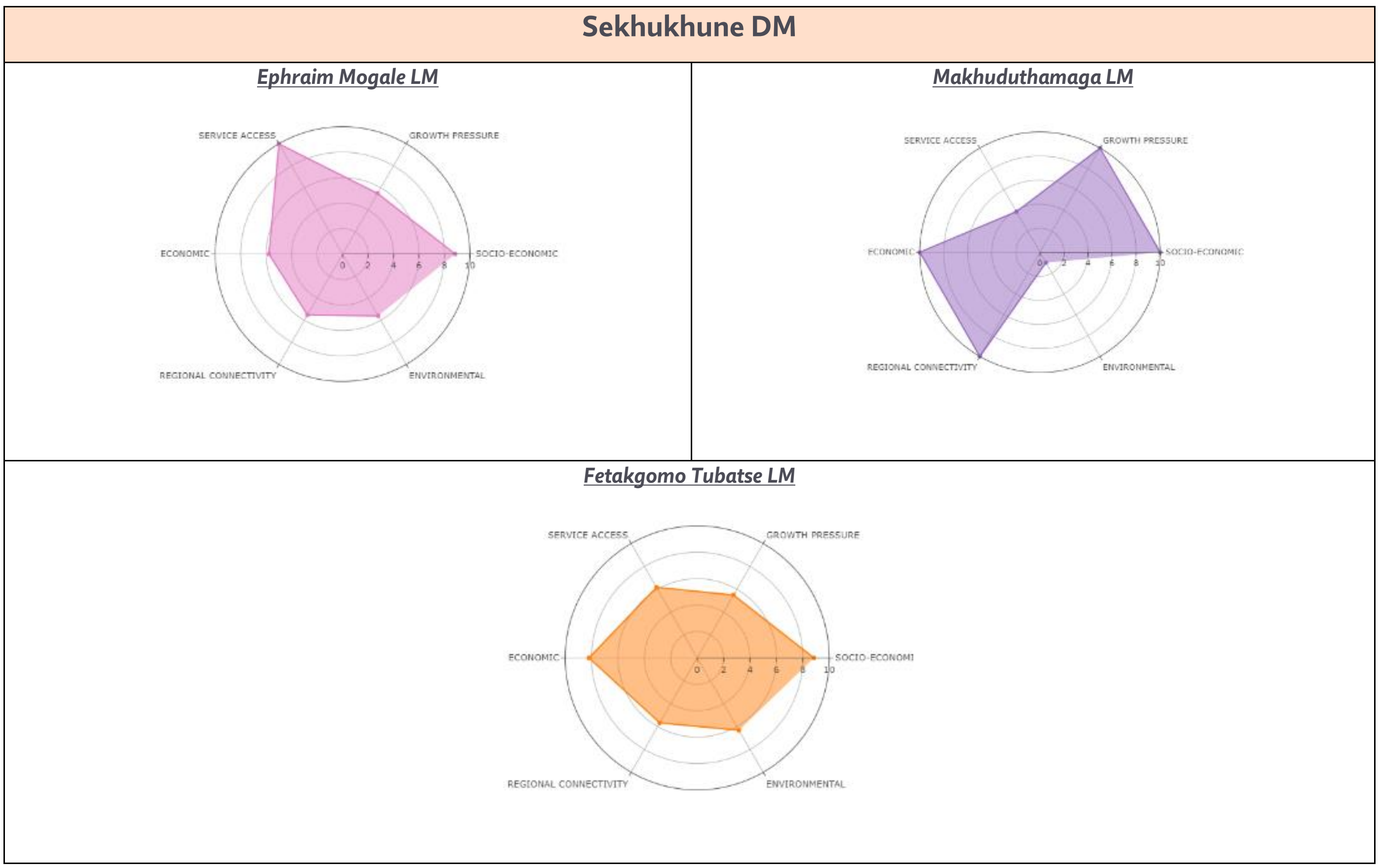



*Figure 4-62: Vulnerability of LMs within the Sekhukhune DM, with focus on traditional settlements*

*Source:* (Le Roux, et al., 2019)

According to the Green Book (Le Roux, et al., 2019)< the projected growth pressure for the Sekhukhune DM indicates that the Fetakgama Tubatse LM has the highest growth scenario in 2030 and 2050 (Table 4-20).

*Table 4-20: Growth scenarios for local municipalities in Sekhukhune DM.*

*Source:* ***(Le Roux, et al., 2019)***

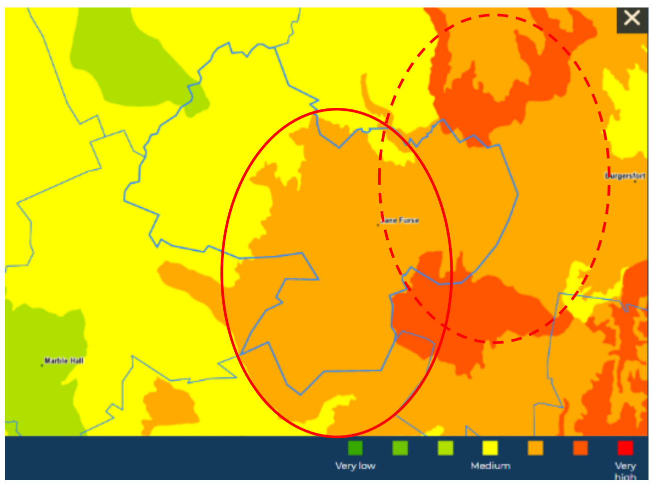
| DM | LM | Growth scenario | 2011 | 2030 | 2050 |
|---|---|---|---|---|---|
| **Sekhukhune** | Ephraim Mogale | Medium | 23,558 | 138,854 | 135,185 |
| | | High | 123,558 | 142,441 | 145,429 |

| DM | LM | Growth scenario | 2011 | 2030 | 2050 |
|---|---|---|---|---|---|
| | Makhuduhamaya | Medium | 274,689 | 291,103 | 262,716 |
| | | High | 274,689 | 298,626 | 282,831 |
| | **Fetakgomo Tubatse** | **Medium** | **428,648** | **615,008** | **754,542** |
| | | **High** | **428,648** | **630,925** | **810,936** |

## 4.4.5 Exposure Assessment for Sekhukhune DM

The resultant level of flooding exposure, associated with the Sekhukhune DM, is presented in Figure 4-63. The flood hazard analysis in the vicinity of priority QCs D41B and A31H, within **Sekhukhune DM**, indicates that the FHI ranges from medium to very high. The higher FHI is associated with QC B52B, both towards the north and south of the QC.

***Sekhukhune DM Flood Exposure***




Makhuduthamaga LM (B51H: red circle and B52B: dotted red circle)

*Figure 4-63: Current flood hazard index for Sekhukhune DM* (Source: Engelbrecht et al., 2019)

*Source: (Engelbrecht et al., 2019)*

### Exposure to Pluvial Flooding

Based on the FHSI analysis results, and in particular those for QC B51H, as presented in Figure 4-64, the area of particular exposure is located in the central part of QC, particularly in the area of Maleetse. As presented in this figure, this area is associated with extensive settlement. Therefore, people living within this area are likely to be particularly susceptible to flooding. Based on the FHSI analysis results for QC B52B, as presented in Figure 4-65, the area of exposure is also located in the central part of QC, particularly in the area of Mashite. As presented in this figure, this area is associated with a high degree of settlement. Therefore, people living within this area are likely to be particularly susceptible to flooding.

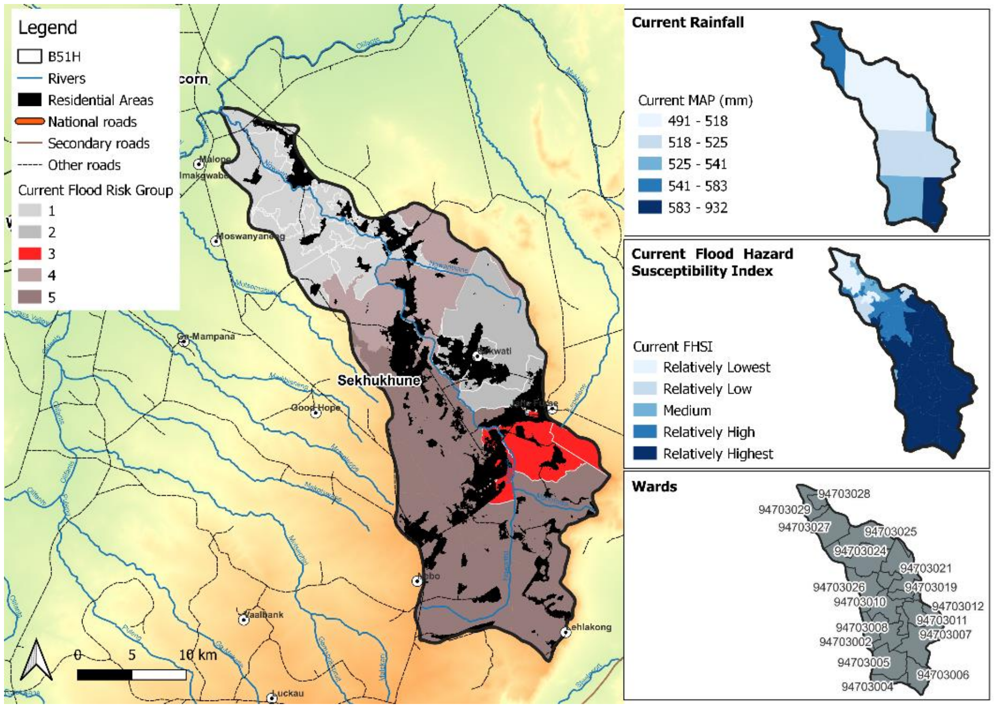



*Figure 4-64: Current relative flood risk groups based on current rainfall for B51H within Sekhukhune DM*

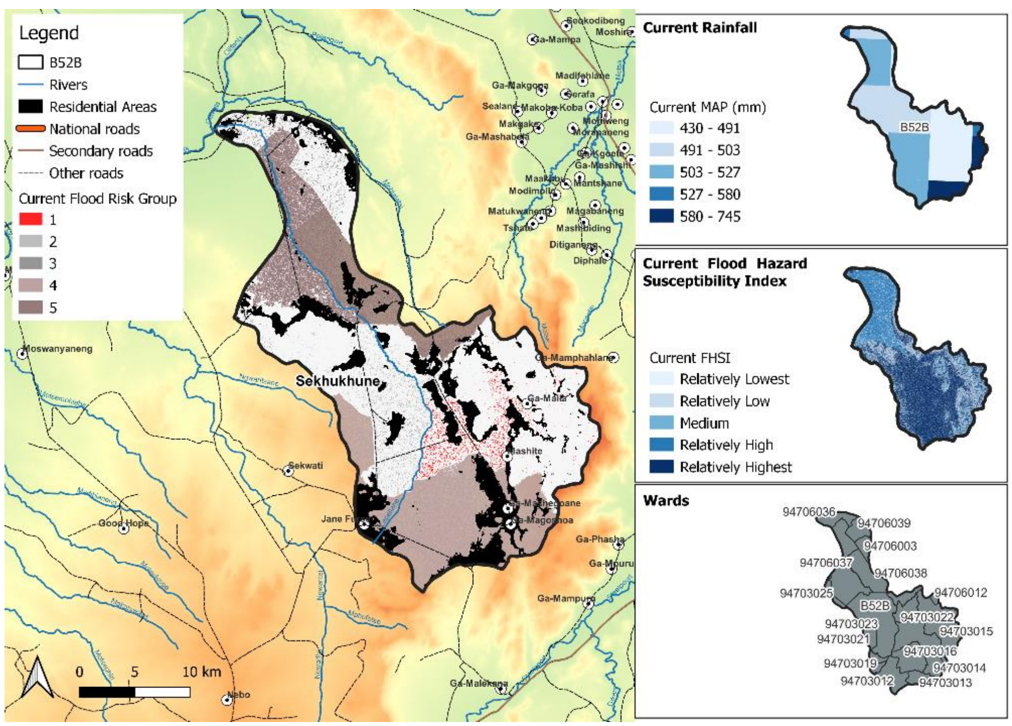



*Figure 4-65: Current relative flood risk groups based on current rainfall for B52B within Sekhukhune DM*

### Exposure to Fluvial Flooding

In the Sekhukhune DM, QC B51H is associated with a higher degree of exposure to fluvial flooding, due the extent of settlement areas located in close proximity to a river, as presented in Figure 4-66. The main area of concern in QC B52B is at the outlet of the catchment.

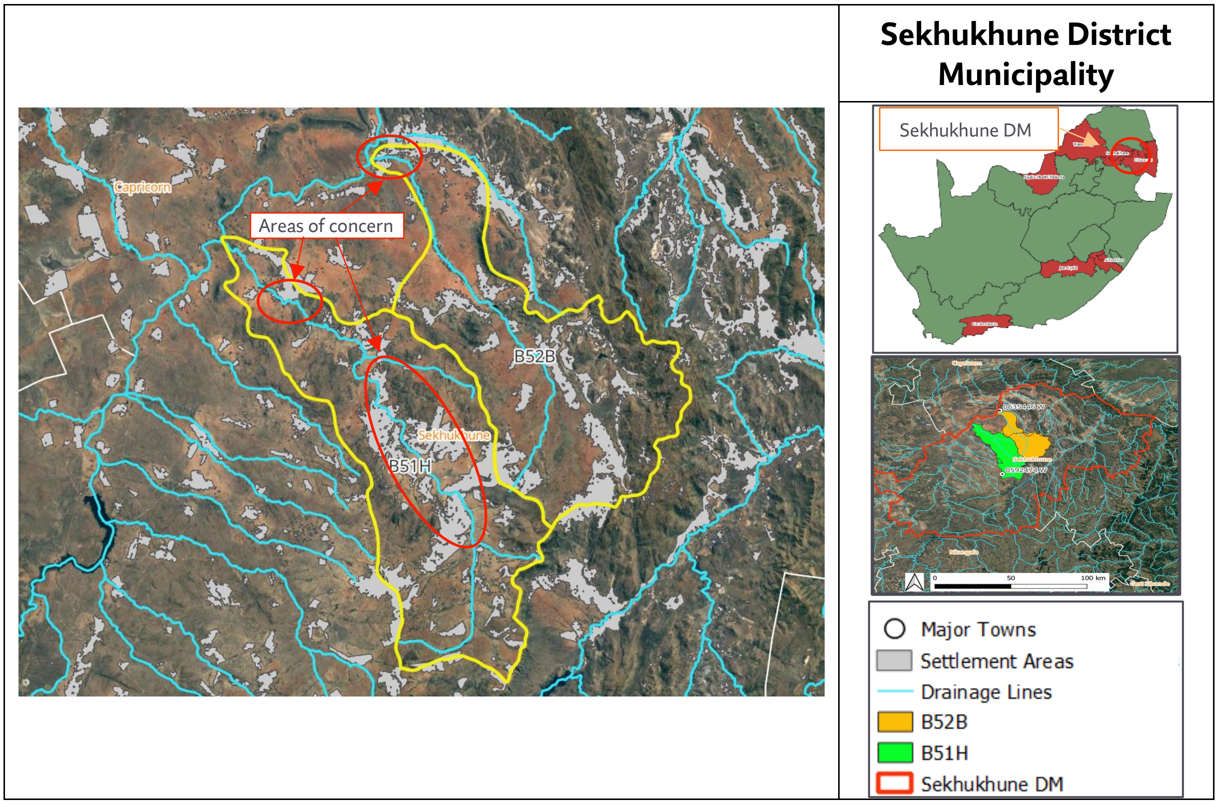



*Figure 4-66: Distribution of settlements in relation to main drainage lines across priority catchments in the Sekhukhune DM*

### Exposure to Drought

According to the WWF Water Risk Filter water scarcity index (proxy for exposure to drought), as described in Section 3.4.2, the Sekhukhune region has areas of moderate and high levels of exposure to drought. This is illustrated in Figure 4-67, which also shows that the Sekhukhune DM has one of the highest levels of exposure to drought across the selected priority DMs.

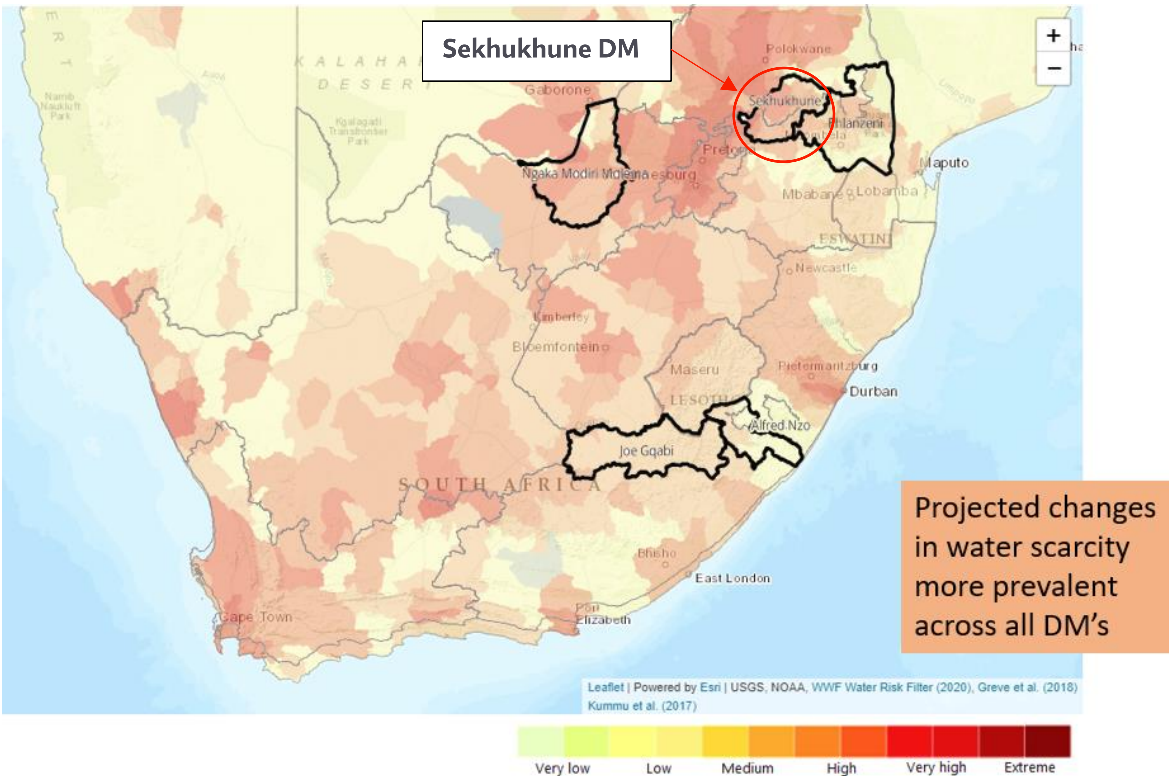



*Figure 4-67: WWF Water Risk Filter - Water Scarcity Index, Proxy for Drought Exposure (Sekhukhune District* Municipality)

## 4.5 NGAKA MODIRI MOLEMA DM

The Ngaka Modiri Molema DM is located in the North West Province and border with Botswana. The province is known for its rich natural resources, wildlife and mining and agricultural sectors. The capital of the province, Mahikeng, occurs within the DM. The DM comprises of five LMs: Mahikeng, Ratlou, Ramotshere Moiloa, Ditsobotla and Tswaing.

The province is dominated by a flat savanna and grassland landscape, with hills and ridges such as the Magaliesberg and Pilanesberg ridges dividing the landscape and the Kalahari Desert occurring in the west of the province.

According to the 2011 census there were just under 1 million individuals living in the DM at the time, accounting for one fifth of the population of the North West Province (StatsSA, 2015). The DM covers 28,144 km², resulting in a population density of 32 people per km². There was a 70% unemployment rate and low levels of education (Ngaka Modiri Molema DM, 2021).

### 4.5.1 Overview of Ngaka Modiri Molema DM

The top two potential locations identified in the Ngaka Modiri Molema DM are located to the north of the DM close to the border with Botswana (see Figure 4-68). Catchment D41B occurs within the Orange River Basin (Primary Basin D) and A31H occurs within the Limpopo River Basin (Primary Basin A) and both are headwater catchments. The main river in the catchment D41B is the Setlagole River, which is a tributary of the Molopo River, which forms the border between South Africa and Botswana. The main river within catchment A31H is the Sandspruit River, which is a tributary of the Marico River.

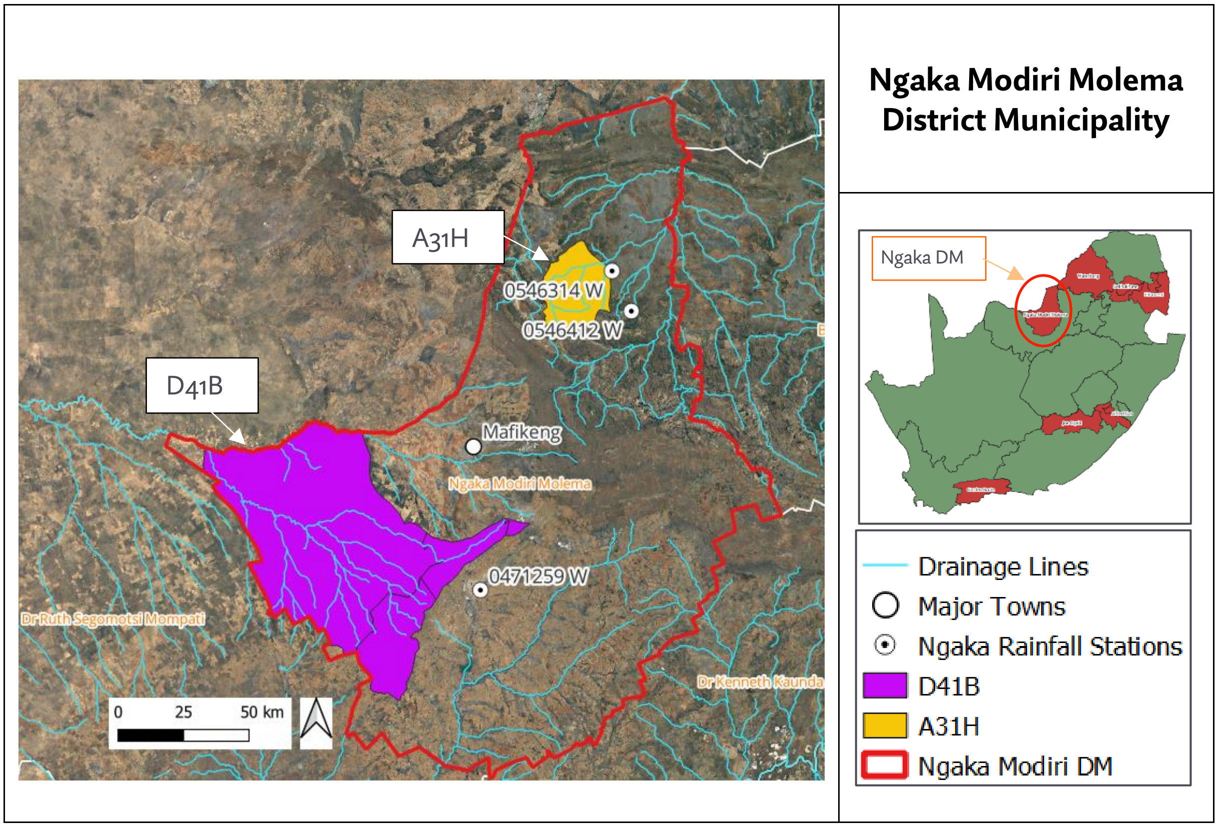
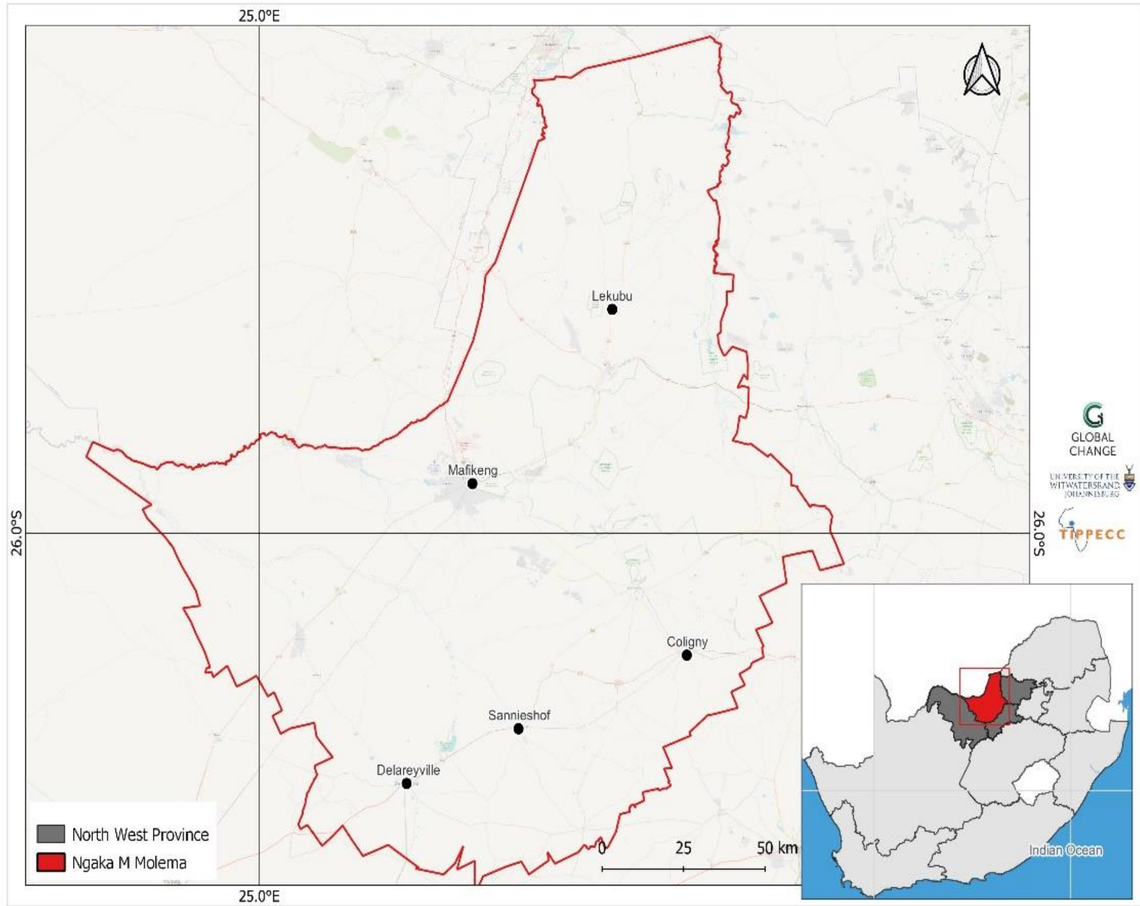



*Figure 4-68: Ngaka Modiri Molema DM and Priority QCs*

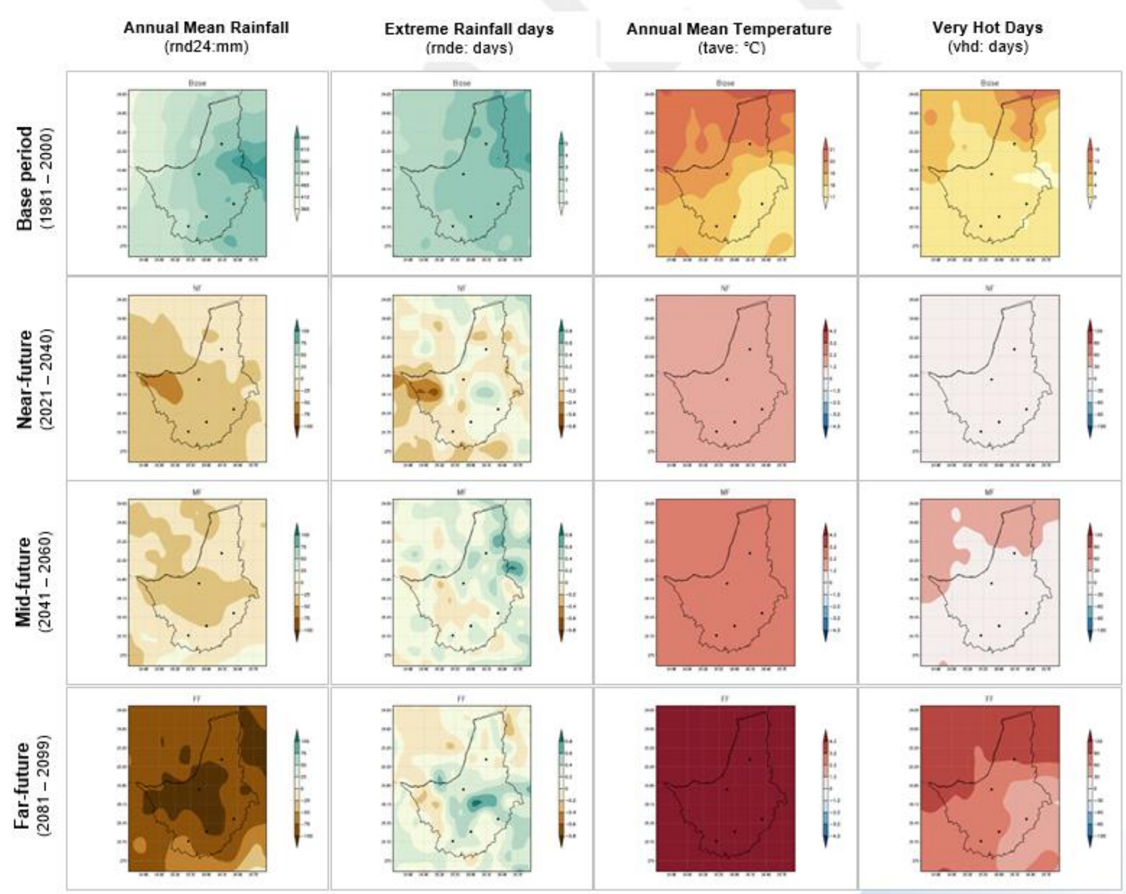
A summary of the observed climate conditions in Ngaka Modiri Molema DM (GCI & SANBI, 2024) is presented in the table below.

*Table 4-21: Location and summary of observed climate conditions for Ngaka Modiri Molema DM*

| **Parameter** | **Observed conditions** | **Locality** |
|---|---|---|
| Mean annual rainfall | An observed decrease in annual mean precipitation has been recorded, though with low confidence. Precipitation levels range from 360 mm in the west to 660 mm in the east. |  |
| Extreme rainfall days | An observed increase in the frequency of heavy rainfall events has been recorded (low confidence), with the annual number of extreme rainfall days ranging from 2 in the northern interior to more than 12 along the coastal strip. | |
| Mean annual temperature | Annual mean temperature and warm extremes have shown virtually certain increases, with mean temperatures ranging from approximately 14°C in the northern interior to exceeding 20°C along the coastal strip. | |
| Very hot days | Very hot days range between 1 over the north to about five days over the southwestern interior regions. | |

A summary of the projected climate changes and spatial anomalies in Ngaka Modiri Molema DM (GCI & SANBI, 2024) is presented in the table below.

*Table 4-22: Projected climate changes and spatial anomalies in Ngaka Modiri Molema DM*

| Parameter | Projected conditions | Spatial anomalies |
|---|---|---|
| Mean annual rainfall | Mean annual precipitation is likely to decrease in the near future, with substantial declines projected for the mid- to far future (high confidence). |  |
| Extreme rainfall days | Heavy precipitation events are projected to increase in the near future (low confidence), with a likely increase expected in the mid and far future. | |
| Mean annual temperature | A projected increase in temperature and warm extremes (virtually certain) and a decrease in cold extremes (virtually certain) are expected in the near future, with a continued increase in temperature (virtually certain) in the mid- and far future. | |
| Very hot days | Projected increase in warm extremes (*virtually certain*). | |

### 4.5.2 Flood Hazard Assessment for Ngaka Modiri Molema DM

**Flooding History**

The Ngaka Modiri Molema DM has experienced several significant historical flooding events. In 2014, heavy rains caused flooding in several areas of the district, including Mahikeng, Lehurutshe, and Delareyville (SABC News, 2014; Coleman, 2014). The flooding was severe enough to cause damage to infrastructure, homes, and crops, and resulted in the displacement of several people from their homes. According to media reports at the time, the flooding was particularly bad in the city of Mahikeng, where some residents had to be rescued by emergency services after their homes were submerged in water (News24, 2014; OFM, 2014). The flooding also caused damage to roads and bridges, making it difficult for emergency services to reach affected areas. While there is no comprehensive data available on the extent of the flooding in the Ngaka Modiri Molema DM in 2014, local stakeholders report that the flooding had a significant impact on local communities and highlighted the need for improved disaster management and preparedness measures.

In 2017, the district experienced another round of flooding, which was even more severe than the 2014 floods. The flooding was caused by heavy rainfall and overflowing rivers, and it resulted in widespread damage to infrastructure, homes, and businesses. Several people lost their lives in the floods, and many more were displaced. During this flood, Itsoseng was particularly badly affected.

In response to the 2017 floods, the government of South Africa declared the district a disaster area and provided relief and support to affected communities. The government also committed to implementing measures to mitigate the impact of future flooding in the area, such as improving drainage systems and building flood-resistant infrastructure.

The district-level workshop confirmed that flooding is consistent throughout the DM with much of the area being low-lying, and typified by flat surfaces. During flood events, the area experiences excessive soil erosion and poorly developed road infrastructure often collapses. Homes, schools, hospitals and shops also become inaccessible to communities during floods. Additionally, houses become flooded, and personal assets are destroyed. Poor settlement planning has resulted in some communities settling on pans, thus increasing their vulnerability to environmental hazards such as floods.

During the site visit, the issue of flooding was emphasised with a focus on localised and sporadic flooding. Communities in the areas were more spread out and ranged from rural to peri-urban in nature. Due to the presence of a dense network of pans in the priority QC D41B, communities often experienced flooding of their households (see figures below). In particular, flooding in Kraaipan was known to be very destructive and impacted accessibility of communities due to damage to roads and bridges. Stakeholders that were engaged with during the site visit indicated that communities are increasingly impacted by these flooding events and the impacts that these have had on property and livestock. There were also concerns regarding water security and supply challenges with most being dependent on groundwater supply, due to the area being typically arid.

*Figure 4-69: Flooding of households in Deelpan, Ngaka Modiri Molema DM*

*Figure 4-70: Bridge washed away in Kraaipan during flooding, Ngaka Modiri Molema DM*

Additionally, small-scale erosion was observed during the site visit (see figures below) and this was typically associated with roads and culverts. In certain areas of the DM, the communities expressed their concerned about the dangers of flash flooding, particularly their children that have to walk home each day. Furthermore, poor rangeland management practices linked to livestock also contributed to erosion and environmental degradation in these areas of Ratlou LM.

*Figure 4-71: Donga development alongside roads in Ratlou LM that experience flash flooding during extreme rain events*

Overall, the Ngaka Modiri Molema DM has a history of flooding and flood reduction interventions would be well placed to reduce the impact of future floods and protect the lives and livelihoods of those living in the area.

**Rainfall Analysis**

***Historical Rainfall Analysis***

There are a number of rainfall stations located within the Ngaka Modiri Molema DM. Three rainfall stations in the proximity of D41B and A31H were selected to determine whether any trends in changes in extreme rainfall could be identified, based on an analysis of historical rainfall data. At each rainfall station, the AMS was extracted for the period during which observed and reliable data can be obtained. In this analysis the AMS refers to the maximum depth of rainfall, over a 24-hour period, that has been measured during a hydrological year. As mentioned previously, AMS data is generally used in design flood hydrology to estimate design rainfall depths, which in turn are used in the estimation of flood peaks associated with a return period. More specifically, design rainfall is determined based on statistical analysis of the AMS, which involves analysing the frequency and intensity of historic extreme rainfall events to estimate the expected frequency and intensity of future rainfall events. Based on the connection between AMS rainfall data and design rainfall depths and therefore flood estimation, changes in the AMS can be linked to changes in flood hydrology.

Figure 4-72, Figure 4-74 and Figure 4-76 present the AMS for the selected rainfall stations, located within the Ngaka Modiri Molema DM, and in proximity to QC's D41B and A31H. The locations of these rainfall stations are presented in Figure 4-68. In each of the graphs, a trendline was fitted to the historic data to determine whether there is an increasing trend in the AMS. Further to this, as indicated previously, an analysis of trends in the design rainfall depths associated with the 1:10- and 1:50-year return periods was also undertaken. The analysis of trends in the AMS and design rainfall depths allows for a full picture of the changing hazard associated with extreme rainfall to be realised, based on observed historical rainfall data. The results of the

1:10- and 1:50-year design rainfall trend analysis (based on the Gumbel distribution and an incremental inclusion of AMS data from 30 years until the full record is analysed), is presented in Figure 4-73, Figure 4-75 and Figure 4-77. Based on this analysis, it was noted that a decrease in both the AMS and design rainfall is evident for station 0417259 (representative of QC D41B). However, both the analysis of the AMS data and the design rainfall depths for stations 0546314 W and 0546412 W clearly show an increasing trend of extreme rainfall. Based on this analysis, it appears that QC A31H is more susceptible to an increasing flood hazard than QC D41B.

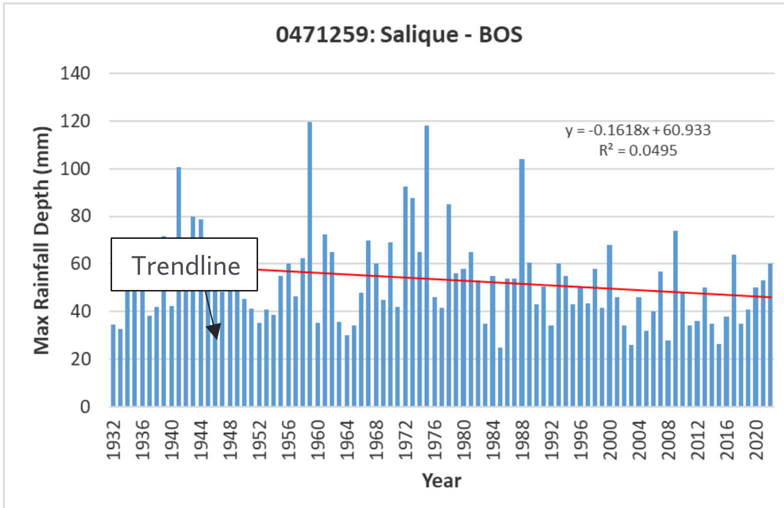



*Figure 4-72: Annual Maximum Series Rainfall Data - Station 0471259 W (1931 – 2023)*

*Data sourced from SAWS.*

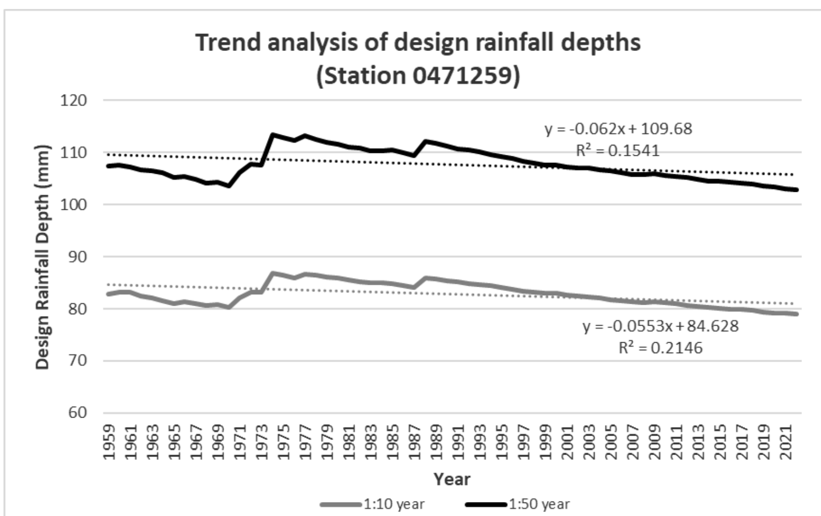



*Figure 4-73: Analysis of 1:10 and 1:50 year design rainfall depth trends for weather station 0471259 W*

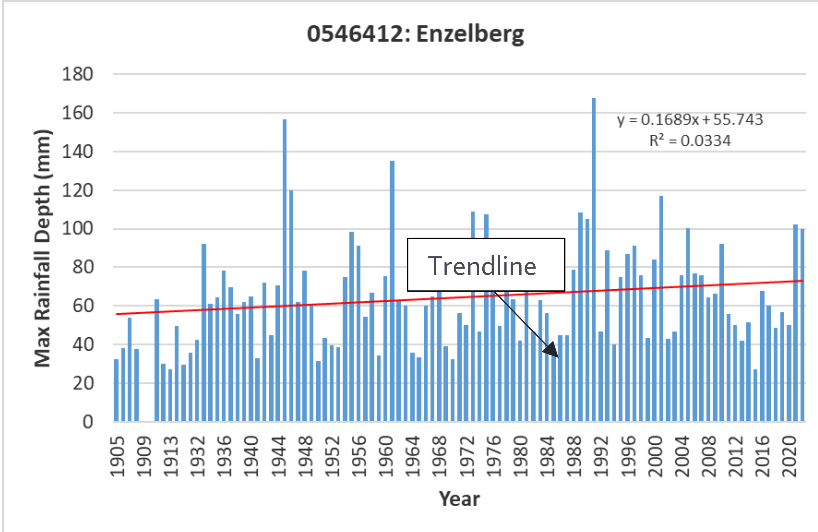



*Figure 4-74: Annual Maximum Series Rainfall Data - Station 0546412 W (1905 – 2023)*

*Data sourced from SAWS.*

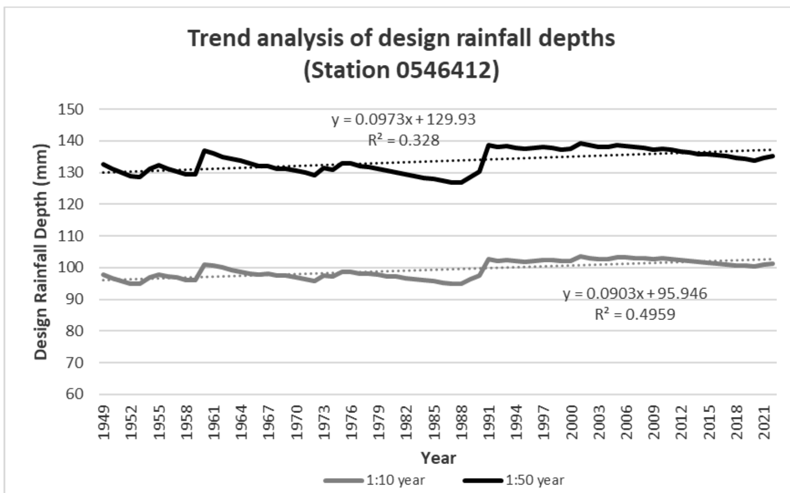



*Figure 4-75: Analysis of 1:10 and 1:50 year design rainfall depth trends for weather station 0546412 W*

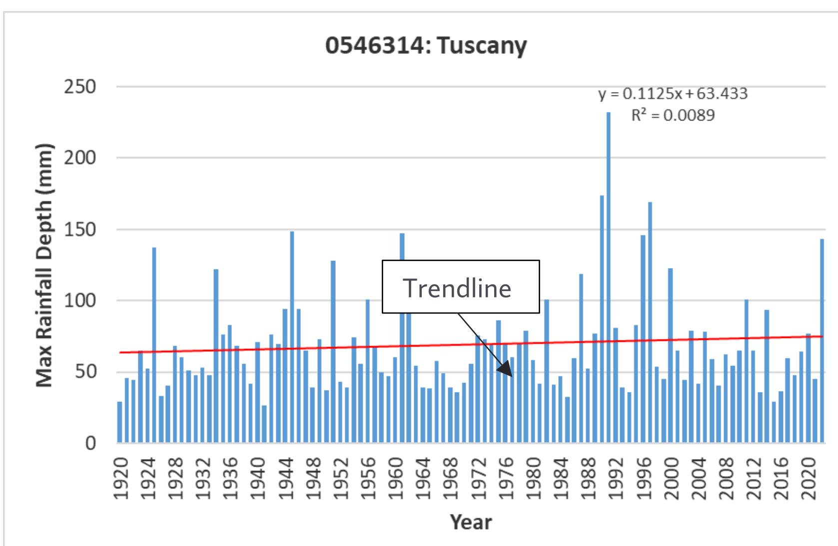



*Figure 4-76: Annual Maximum Series Rainfall Data - Station 0546314 W (1920 – 2023)*

*Data sourced from SAWS.*

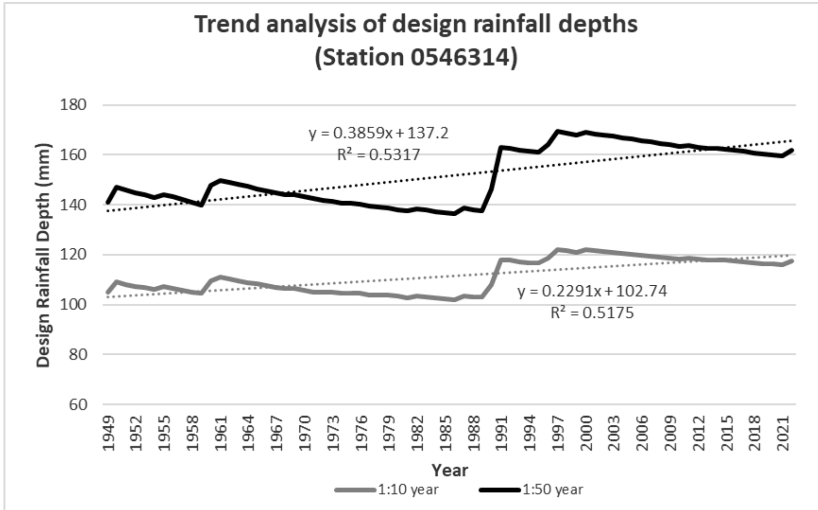



*Figure 4-77: Analysis of 1:10 and 1:50 year design rainfall depth trends for weather station 0546314 W*

*Data sourced from SAWS.*

**Projected Changes in Extreme Precipitation and Consequently Flood Hazard**

As indicated previously, the estimation of design floods for ungauged catchments is generally the product of a combination of design (extreme) rainfall and catchment characteristics. Due to the complexities of accounting for the variability in catchment characteristics across the study areas, the assessment has focused on changes in extreme precipitation trends to identify changes in flood hazard.

For this analysis, anomalies of extreme precipitation were sourced from the CCKP, as noted earlier. In order to determine anomalies in extreme rainfall, comparisons between baseline (historic) rainfall data and forecasted rainfall data was undertaken. The extreme precipitation anomalies extracted from the CCKP are based on SSP5-8.5, and centralised over the 2050 period, using the 50$^{th}$ and 90$^{th}$ percentiles of multi-model ensembles. Both the 50$^{th}$ and 90$^{th}$ percentiles were used to illustrate the range of possible anomalies using different models (therefore illustrating uncertainty). Anomalies are based on the changes in magnitude of the 1:100-year return period rainfall depths. A map of the anomalies, across the Ngaka Modiri Molema DM is presented in Figure 4-78, which indicates a range of change from 4mm (50$^{th}$ percentile) and 52mm (90$^{th}$ percentile) at the central and western areas of the DM to 2mm (50$^{th}$ percentile) and 54mm (90$^{th}$ percentile) in the northern portion of the DM. QC B41B shows an increase of approximately 4mm for the 1:100-year design rainfall using the 50$^{th}$ percentile model ensembles, and an increase of approximately 51mm using the 90$^{th}$ percentile model ensembles. Similarly, QC A31H shows an increase of approximately 2mm for the 1:100-year design rainfall using the 50$^{th}$ percentile model ensembles, and an increase of approximately 54mm using the 90$^{th}$ percentile model ensembles.

| | |
|---|---|
| | **Ngaka Modiri Molema DM**<br>***Extreme Rainfall Anomalies*** |

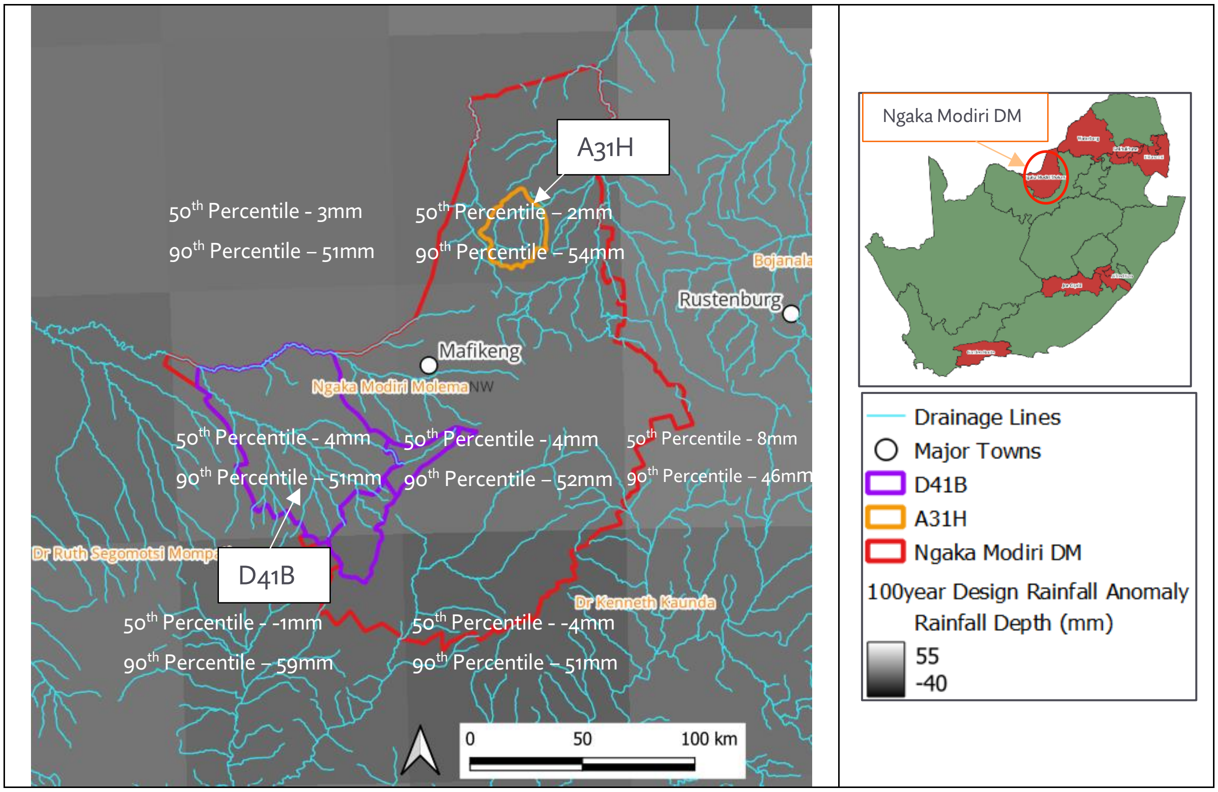



*Figure 4-78: Ngaka Modiri Molema DM Extreme Rainfall Anomalies*

In order to contextualise the increase in extreme rainfall across the Ngaka Modiri Molema DM, Design Rainfall at the centroid of each priority QC was extracted using the RLMA&SI approach developed by Smithers and Schulze (2002). The resultant design rainfall for the D41B and A31H QCs are presented in Table 4-23. Based on these estimates of design rainfall compared to the anomalies of extreme rainfall related to the 100-year return period rainfall event, an increase in extreme rainfall of approximately 2% and 3% is projected for QC D41B and A31H respectively, based on the 50th percentile ensemble models, and approximately 36% and 32% using the 90th percentile ensemble models.

*Table 4-23: Ngaka Modiri DM Design Rainfall Estimates*

| | Design Rainfall Depths (mm) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1:2 year | 1:5 year | 1:10 year | 1:20 year | 1:50 year | 1:100 year | 1:200 year |
| D41B | 59 | 80 | 95 | 109 | 128 | 143 | 158 |
| A31H | 66 | 90 | 107 | 125 | 150 | 170 | 191 |

It should be noted that across all DMs and priority QCs, an increase in rainfall is often amplified in the resultant increase in flow rates emanating from a catchment. Therefore, the magnitude of the 1:100 year could potentially be significantly worse than the percentage increases in rainfall identified in this study.

### 4.5.3 Drought Hazard Assessment for Ngaka Modiri Molema DM

The Ngaka Modiri Molema DM has a history of drought with recent droughts being reported between 2013 and 2015 and in 2018. In 2015, the North West province was recognised as drought-stricken with water trucks being deployed across the DM to support household water supply (South African Government , 2015; Mashaba, 2015). In 2018, high temperatures and low rainfall contributed to prevailing drought conditions and provincial government, together with the Department of Water and Sanitation, urged residents to improve water use efficiency and reduce water consumption (South African Government , 2018). During the district workshops, participants highlighted the impact of droughts on livestock as well as water supply with communities that rely on water from streams being particularly challenged during droughts.

Due to absence of data from the Green Book for the Ngaka Modiri Molema DM, a drought hazard assessment, similar to that applied to the other priority DMs assessed, was not possible. The information sourced in order to determine the drought hazard associated with the Ngaka Modiri Molema DM was from the World Banks CCKP, which is based on CMIP6. This index was based on the anomalies of SPEI across the project area, comparing SPEI for the base period of 1995 – 2014 to the forecasted period of 2040 -2059, using the 50$^{th}$ percentile ensemble models. The results indicated a drying trend across the DM, with areas to the west of the DM showing higher anomalies in the drought hazard index when compared to the areas of the eastern portion of the DM. The SPEI associated with QC D41B equated to approximately -0.79 whereas the anomalies associated with QC A31H equated to -0.66.

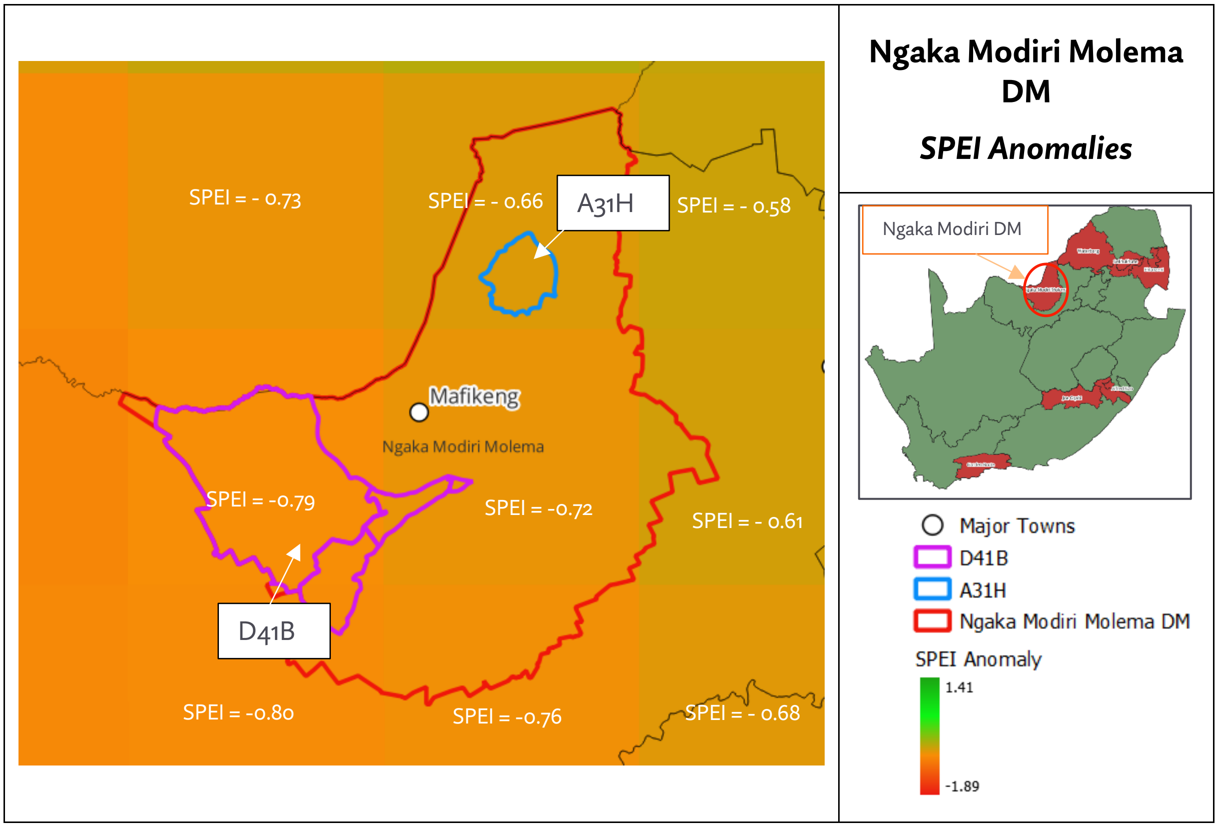



*Figure 4-79: Ngaka Modiri Molema DM SPEI Anomalies*

### 4.5.4 Vulnerability Assessment for Ngaka Modiri Molema DM

The Tswaing LM has high vulnerability from a socio-economic, economic and physical perspective. Ratlou LM also shows high socio-economic and economic vulnerability.

*Table 4-24: Multi-dimensional vulnerability (ranking out of 213) for LMs in Ngaka Modiri Molema DM*

*Source:* (Le Roux, et al., 2019)

| DM | LM | Socio-Economic | Economic | Physical | Environmental |
|---|---|---|---|---|---|
| Ngaka Modiri Molema | Ratlou | 176 | 177 | 124 | 26 |
| | Tswaing | 151 | 142 | 179 | 48 |
| | Mafikeng | 94 | 186 | 94 | 108 |
| | Ditsobotla | 120 | 92 | 148 | 101 |

In the graphs presented in Figure 4-80, for the Ngaka Modiri Molema LMs, the Ditsobotla and Mafikeng LMs appear to be most vulnerable, however, the Tswaing LM also showed a particularly high vulnerability score.

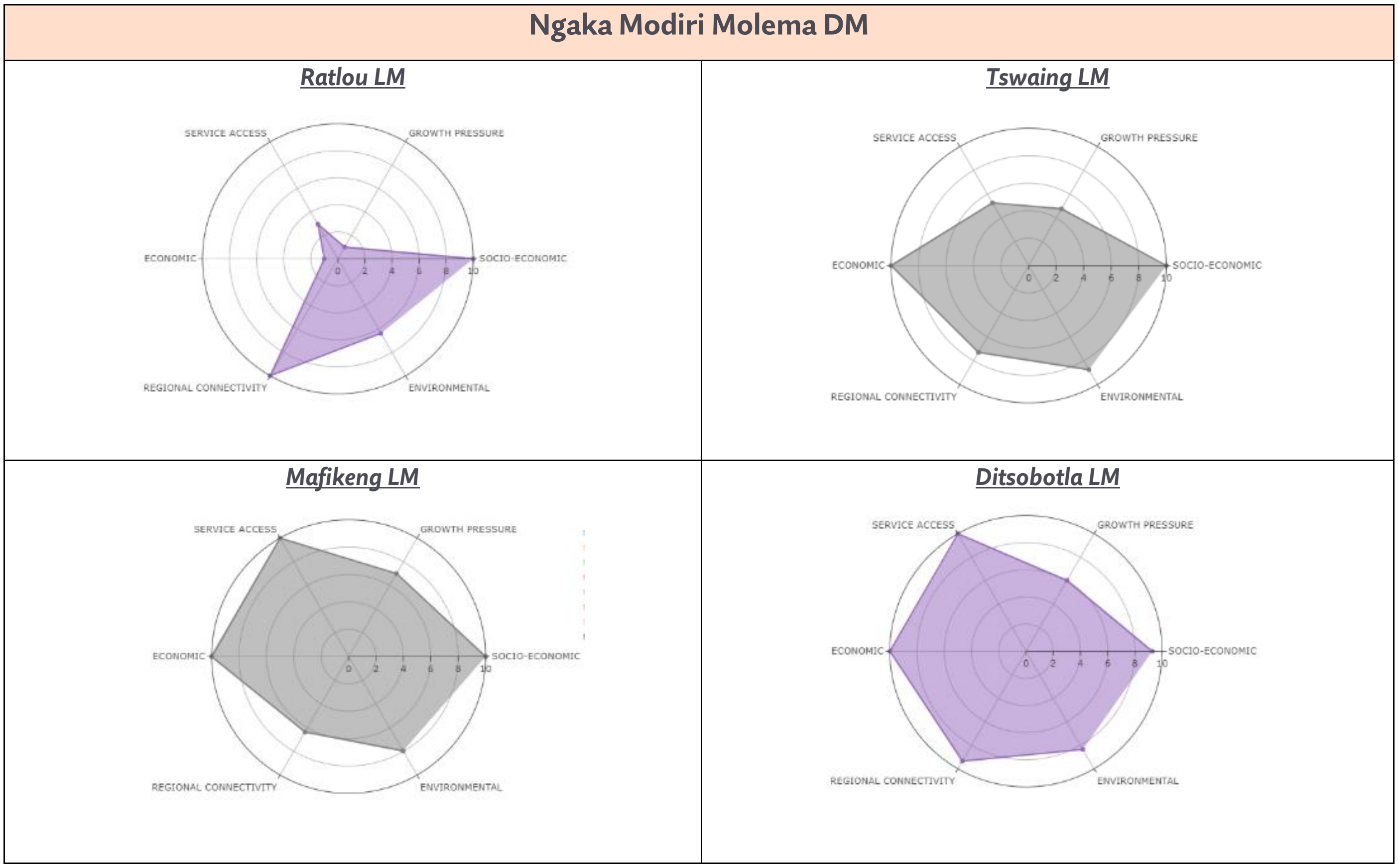



*Figure 4-80: Vulnerability of LMs within the Ngaka Modiri Molema DM, with focus on traditional settlements*

*Source:* ((Le Roux, et al., 2019)

According to the Green Book (Le Roux, et al., 2019), the projected growth pressure for the Ngaka Modiri Molema DM indicates that the Mafikeng LM has high projected growth pressure (Table 4-25).

*Table 4-25: Growth scenarios for local municipalities in Ngaka Modiri Molema DM.*

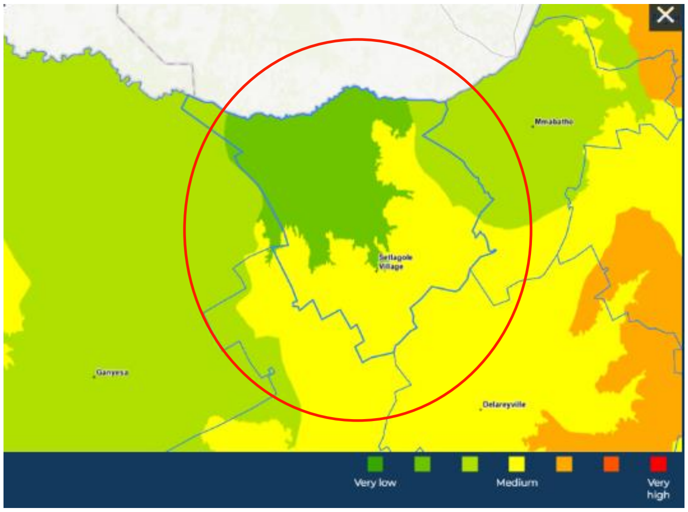
*Source:* ***(Le Roux, et al., 2019)***

| DM | LM | Growth scenario | 2011 | 2030 | 2050 |
|---|---|---|---|---|---|
| **Ngaka Modiri Molema** | Ratlou | Medium | *107,315* | *124,173* | *118,788* |
| | | High | *107,315* | *114,983* | *106,550* |
| | Tswaing | Medium | 124,093 | 171,891 | 199,238 |
| | | High | 124,093 | 159,089 | 178,848 |
| | **Mafikeng** | **Medium** | **291,362** | **414,996** | **490,891** |
| | | **High** | **291,362** | **384,271** | **440,442** |
| | Ditsobotla | Medium | 168,852 | 248,776 | 306,188 |
| | | High | 168,852 | 230,338 | 274,952 |

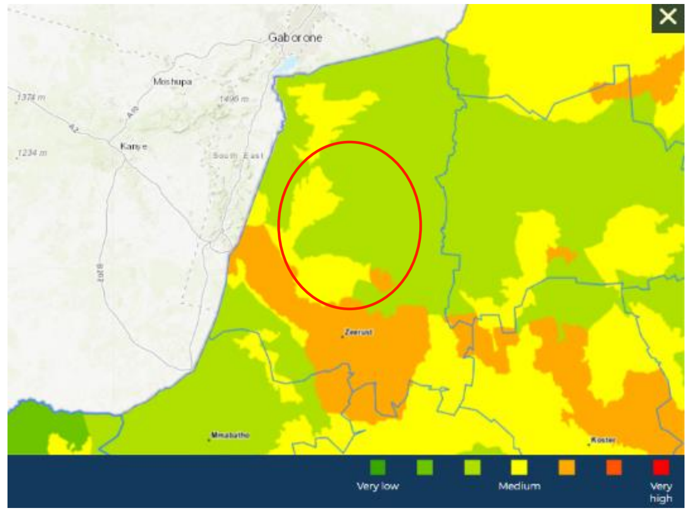
### 4.5.5 Exposure Assessment for Ngaka Modiri Molema DM

The resultant level of flooding exposure, associated with the Ngaka Modiri Molema DM, is presented in Figure 4-81. The flood hazard analysis for the priority QCs (i.e. QC D41B and A31H) within **Ngaka Modiri Molema DM** indicates that the FHI ranges from medium to low across most of both QCs, with signs of an increased FHI towards the south of catchment A31H.

***Ngaka Modiri Molema DM Flood Exposure***




Ratlou LM (D41B)




Ramotshere Moiloa LM (A31H)

*Figure 4-81: Current flood hazard index for Ngaka Modiri Molema DM*

*Source: (Engelbrecht et al., 2019)*

**Exposure to Fluvial Flooding**

As presented in Figure 4-82, QC A31H appears to have limited exposure to fluvial flooding, however, QC D41B has two areas of concern. In these areas, settlement areas appear to be in close proximity to the main drainage lines traversing the catchment. As mentioned previously, it is recommended that a more detailed analysis of fluvial flooding in these areas is undertaken during the feasibility phase of this study.

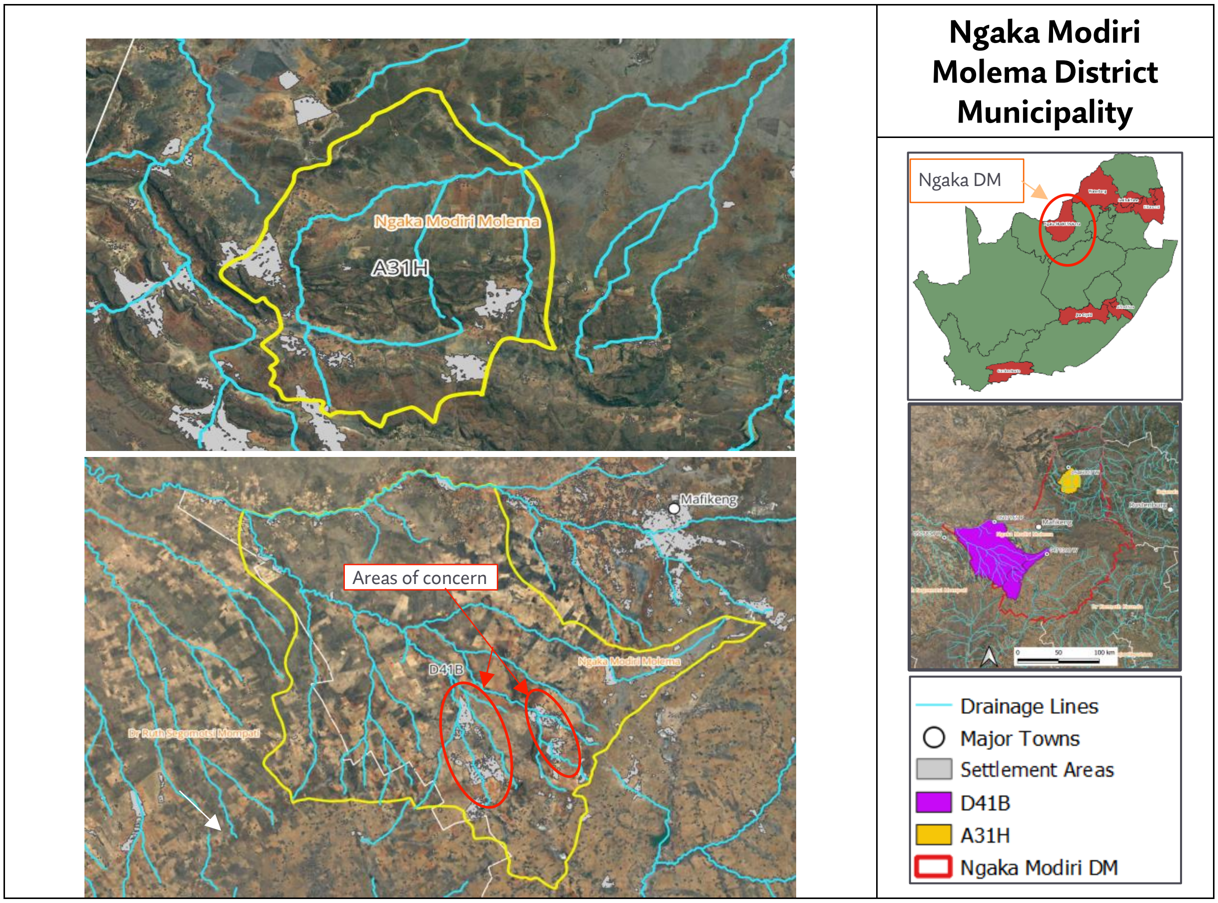



*Figure 4-82: Distribution of settlements in relation to main drainage lines across priority catchments in the Ngaka Modiri Molema DM*

### Exposure to Drought

According to the WWF Water Risk Filter water scarcity index (proxy for exposure to drought), as described in Section 3.4.2, the Ngaka Modiri Molema DM has moderate to high level of exposure to drought. This is illustrated in Figure 4-83, which also shows that the Ngaka Modiri Molema DMs has one of the highest levels of vulnerability when being compared to the other selected priority DMs across South Africa.

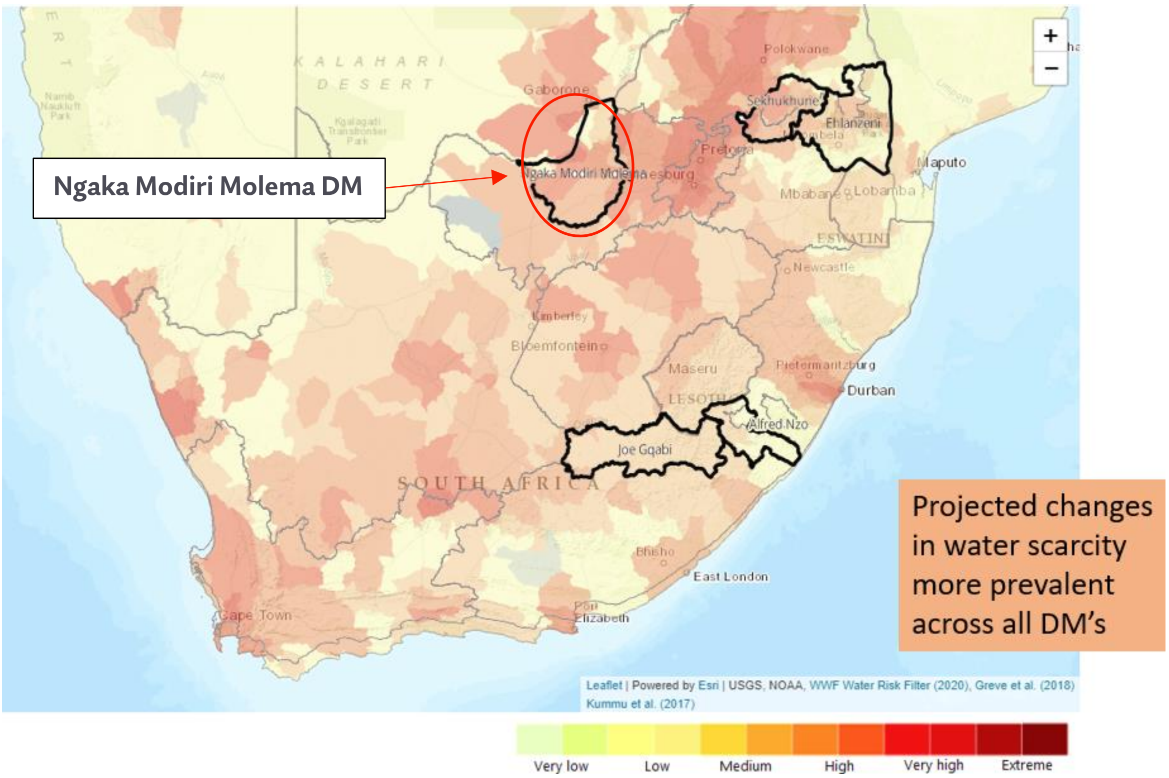



*Figure 4-83: WWF Water Risk Filter - Water Scarcity Index, Proxy for Drought Exposure (Ngaka Modiri Molema District Municipality)*

# 5 Conclusion and Recommendations

South Africa, including the 5 DMs selected for analysis in this CRVA study, have experienced extensive and expensive flood damage over the past few decades. Nationally, climate projections have indicated that flooding is expected to increase in frequency and severity in the future. According to the latest IPCC AR6 climate scenarios for South Africa, both the number of very hot days and the maximum daily rainfall will increase, suggesting an increased risk of flooding, particularly for the eastern half of South Africa. Furthermore, while there are uncertainties in rainfall under future climates with different models and different emission scenarios, there is general agreement that rainfall intensities will increase over most of South Africa which contributes towards flooding (Le Maitre, et al., 2019). This is echoed in South Africa's TNC to the UNFCCC and the LTAS which highlights the increasing risk of flooding in the future due to increasing climate risks as well as other socio-economic pressures (Republic of South Africa , 2018; DEA, 2013; USAID, 2015).

At a district level, results from the regional and local climate change analysis as well as the hazard, vulnerability and exposure analysis undertaken for each of the priority DMs as part of this CRVA study, indicate that there is clear evidence of a likely climate change induced increase in flood related hazards. This is coupled with significant levels of underlying vulnerability and exposure in each of the five DMs. This would support the need for the implementation of Eco-DRR approaches that reduce the impact of flooding on vulnerable communities as well as strengthening the enabling environment for continued investment in the management, upscaling and development of Eco-DRR approaches.

The sections below provide a brief summary of the results of the CRVA undertaken for each of five DMs:

## 5.1 ALFRED NZO DM

The DM is located in the Eastern Cape Province with a population of 800 000 people. Approximately 80% of the population was below 35 years of age coupled with very low levels of access to piped water and sanitation. The Alfred Nzo DM often experiences heavy rainfall during the summer months, which commonly leads to flooding in low-lying areas. A number of significant historical flood events have occurred in the DM over the past two decade, particularly in 2023, 2019, 2017, 2014, 2011 and 2002 – all of which caused significant damage to homes and infrastructure with people either losing their lives or being displaced. At each rainfall station for the DM, trends of the AMS and the 1:10 and 1:C50 year design rainfall depths showed a very clear increasing trend, demonstrating changes in the hazard associated with extreme rainfall, which would result in more severe floods. Projections of anomalies in extreme rainfall, based on CMIP6, also indicated an increase in the depth of rainfall associated with the 1:100-year return period storm event. Within the DM, the population is highly vulnerable to flooding, and this is reflected through the high levels of unemployment, low levels of education and high dependency ratio. This supports the identification of the Alfred Nzo DM as a priority for the Eco-DRR project as the DM has a clear history of flooding, which is likely to become worse in the future.

The drought hazard and exposure analysis, based on forecasted climate scenarios, indicated that the Alfred Nzo DM will have limited increases in the climate hazards associated with droughts. Similarly, the level of exposure to droughts is also expected to be moderate to low, as a result of climate change.

A summary of the observed climate and projected climate changes and extreme events in the DM is presented in the table below.

*Table 5-1: Observed climate and projected climate changes and extreme events in Alfred Nzo DM (GCI & SANBI, 2024)*

| Climate variable / hazard | Observed climate (1981-2000) | Near future projected change (2021-2040) | Mid-future projected change (2041-2060) | Far-future projected change (2081-2099) | Summary |
|---|---|---|---|---|---|
| **Annual mean rainfall** | Annual mean precipitation from 600 mm in the northern interior to above 1100 mm over the coastal regions. | -10 – 70mm / year | 10 – 70 mm / year | -100 – 10 mm / year | Projected increases in near- and mid-future annual mean rainfall (low confidence); projected decreases in far-future (medium confidence). |
| **Extreme rainfall days** | Observed annual number of extreme rainfall days ranging from 2 days over the northern interior to more than 12 days over the coastal strip. | 0 – 1.5 days / year | 0 – 1.5 days / year | 0 - >2 days / year | Projected increase in frequency of extreme rainfall events (high confidence). |
| **Annual mean temperature** | Mean temperature ranges from 14 °C over the northern interior to more than 20 °C over the coastal strip. | 0 – 2.2 °C / year | 2.2 – 3.2 °C / year | 2.2 – 4.2 °C / year | Projected increase in annual mean temperature from near into far-future (virtually certain) |
| **Very hot days** | Very hot days ranges from 1 day over the north to 5 days over the SW interior regions. | -8 – 8 days / year | 0 – 16 days / year | 0 – 32 days / year | Projected increase in warm extremes (virtually certain) |

A summary of the hazards, impacts and possible adaptation activities for Alfred Nzo DM is presented in the table below.

*Table 5-2: Summary of hazards, impacts and adaptation activities for Alfred Nzo DM*

| Alfred Nzo DM | | |
|---|---|---|
| **Hazard** | **Impact** | **Adaptation Activity** |
| Increased intensity of single-event rainfall occurrences increases the risk of both **pluvial and fluvial flooding** (Engelbrecht, et al., 2019; World Bank, 2021; Le Maitre, et | Direct threat to life and livelihoods (Let's Respond Toolkit, n.d.). | • **Disaster risk reduction preparedness and response measures**: The development of technologies and approaches that improve the dissemination of early warning products and messages related to floods are critical to protect communities. This can be maintained and tested through simulation drills in which communities are supported to practice evacuation routes, communication procedures and emergency response actions. This supports community preparedness which can also entail educating communities on disaster preparedness and response. |

| Alfred Nzo DM | | |
|---|---|---|
| **Hazard** | **Impact** | **Adaptation Activity** |
| al., 2019; GCI & SANBI, 2024) | Direct threat to infrastructure within flood-prone areas and increased insurance premiums (Let's Respond Toolkit, n.d.). | • **Clearing of IAP:** The removal of non-indigenous herbaceous IAPs and woody plants (including trees and bushes) to enhance the hydrological functioning of rivers and wetlands, especially winter baseflows, improves the water yield (Le Maitre, et al., 2020). Removal of this biomass can develop various value-adding opportunities (Irlich, et al., 2014). |
| | Physical isolation of rural communities during flooding events due to damage to roads and bridges (Let's Respond Toolkit, n.d.). | • **Improved rangeland management**: Rotational grazing and resting will reduce overgrazing that currently occurs in the DM which will have benefits in terms of livestock productivity, increasing infiltration and reducing runoff, and increased biodiversity in rangelands. Where the condition of rangelands is particularly poor, interventions including revegetation, reseeding, brushpacking and zai pits to facilitate water ponding are also used to improve the condition of grassland and soils. |
| | Decreased water quality in ecosystems due to floods (Let's Respond Toolkit, n.d.). | |
| | Erosion and sedimentation which can alter landscapes, contribute to landslides, harm ecosystems and negatively impact water quality (Let's Respond Toolkit, n.d.). | • **Wetland and riverine rehabilitation**: The use of brushpacks and vegetative strips, fencing and revegetation as well as harder approaches such as earth berms or gabions can be used to ensure infrastructural integrity is re-established and hydrological functioning is improved in rivers and wetlands. |
| | Crop damage from heavy rain leading to increased risk of crop failure; threats to subsistence agriculture, rural livelihoods and food security (Let's Respond Toolkit, n.d.). | |
| Increase in the **frequency of fire weather occurrence**, including an increase in temperature and greater variance in rainfall (Think Hazard, 2020; FCSIR, 2019). | Direct threat to human life, livelihoods and infrastructure (Let's Respond Toolkit, n.d.). | • **Disaster risk reduction preparedness and response measures**: The development of technologies and approaches that improve the dissemination of early warning products and messages related to wildfires are critical to protect communities. This can be maintained and tested through simulation drills in which communities are supported to practice evacuation routes, communication procedures and emergency response actions. This supports community preparedness which can also entail educating communities on disaster preparedness and response. |
| | Risk of major loss of livestock and grazing, crops which creates threats to financial sustainability of subsistence farming operations and rural livelihoods – thereby also reducing food security (Let's Respond Toolkit, n.d.). | • **Clearing of IAP:** IAPs increase the risk and intensity of wildfires by changing local vegetation structures, and providing denser fuel loads (van Wilgen, 2015). Thus, their removal will reduce the impact associated with wildfires.<br>• **Improved rangeland management**: Improved rangeland management such as rotational grazing resting, revegetation, reseeding, brushpacking and zai pits reduces fuel loads and disrupts fuel continuity which decreases ignition and the initial spread of fires (Wollsteain & Johnson, 2022). |
| | Loss of biodiversity as wildfires destroy habitats, threatening plant and animal species (Let's Respond Toolkit, n.d.). | |

## 5.2 JOE GQABI DM

The Joe Gqabi DM lies within the Eastern Cape Province with a population of 350,000 individuals. The average income for households was approximately R15 000 per annum, indicating that which is below the poverty line. The DM has experienced several significant floods in the past including floods in 2018, 2011, 2001, 1988, 1974 and 1968. These floods caused extensive damage to property and infrastructure such as roads, bridges and houses as well as the loss of lives. While the analysis of trends in the AMS was more subtle, the trend of increasing 1:10 and 1:50 year design rainfall depths was more obvious, indicating an increasing flooding hazard. Projections of anomalies in extreme rainfall, based on CMIP6, also indicated an increase in the depth of rainfall associated with the 1:100-year return period storm event. Additionally, the DM's population is highly vulnerable to flooding due to high levels of unemployment, low levels of education and high dependency ratio with many households being dependent on ecosystems for water supply. As such, the selection of the Joe Gqabi DM for the Eco-DRR project is appropriate as the evidence shows a clear history of flooding that is expected to worsen in the future.

Similar to the Alfred Nzo DM, the results of the drought hazard and exposure analysis indicated that the Joe Gqabi DM will have limited increases in the climate hazards associated with droughts. However, the level of exposure to droughts is higher than that of the Alfred Nzo area, although the level of exposure is moderate.

A summary of the observed climate and projected climate changes and extreme events in the DM is presented in the table below.

*Table 5-3: Observed climate and projected climate changes and extreme events in Joe Gqabi DM (GCI & SANBI, 2024)*

| Climate variable / hazard | Observed climate (1981-2000) | Near future projected change (2021-2040) | Mid-future projected change (2041-2060) | Far-future projected change (2081-2099) | Summary |
|---|---|---|---|---|---|
| **Annual mean rainfall** | Annual mean precipitation ranges from about 400 mm in the west to more than 800 mm over the eastern mountains. | -20 – 60mm / year | 0 – 60 mm / year | -80 – -20 mm / year | Projected increase in annual mean precipitation in near- and mid-future (low confidence); projected decrease in the far-future (medium confidence). |
| **Extreme rainfall days** | Observed number of heavy precipitation days range from about 1 in the west to about 7 over the eastern mountains. | 0 – 1.5 days / year | 0 – 2 days / year | 0.5 - >2 days / year | Projected increase in the frequency of heavy precipitation events (high confidence). |
| **Annual mean temperature** | Annual mean temperature ranges from about 10 °C over the eastern mountains to about 18 °C in the west. | 0 – 1.5 °C / year | 1.5 – 3.5 °C / year | 2.5 – 4.5 °C / year | Projected increase in annual mean temperature (virtually certain). |
| **Very hot days** | Annual mean number of very-hot days range from less than 1 over | -15 – 15 days / year | -15 – 30 days / year | -15 – 60 days / year | Projected increase in warm extremes (virtually certain). |

| Climate variable / hazard | Observed climate (1981-2000) | Near future projected change (2021-2040) | Mid-future projected change (2041-2060) | Far-future projected change (2081-2099) | Summary |
|---|---|---|---|---|---|
| | the eastern mountains to about 5 in the west. | | | | |

A summary of the hazards, impacts and possible adaptation activities for Joe Gqabi DM is presented in the table below.

*Table 5-4: Summary of hazards, impacts and adaptation activities for Joe Gqabi DM*

<table>
<tr><th colspan="3">Joe Gqabi DM</th></tr>
<tr><th>Hazard</th><th>Impact</th><th>Adaptation Activity</th></tr>
<tr><td rowspan="6">Increased intensity of single-event rainfall occurrences increases the risk of both pluvial and fluvial flooding (Engelbrecht, et al., 2019; World Bank, 2021; Le Maitre, et al., 2019; GCI & SANBI, 2024)</td><td>Direct threat to life and livelihoods (Let's Respond Toolkit, n.d.).</td><td>• Disaster risk reduction preparedness and response measures: The development of technologies and approaches that improve the dissemination of early warning products and messages related to floods are critical to protect communities. This can be maintained and tested through simulation drills in which communities are supported to practice evacuation routes, communication procedures and emergency response actions. This supports community preparedness which can also entail educating communities on disaster preparedness and response.</td></tr>
<tr><td>Direct threat to infrastructure within flood-prone areas and increased insurance premiums (Let's Respond Toolkit, n.d.)</td><td rowspan="5">• Clearing of IAP: The removal of non-indigenous herbaceous IAPs and woody plants (including trees and bushes) to enhance the hydrological functioning of rivers and wetlands, especially winter baseflows, improves the water yield (Le Maitre, et al., 2020). Removal of this biomass can develop various value-adding opportunities (Irlich, et al., 2014).<br>• Improved rangeland management: Rotational grazing and resting will reduce overgrazing that currently occurs in the DM which will have benefits in terms of livestock productivity, increasing infiltration and reducing runoff, and increased biodiversity in rangelands. Where the condition of rangelands is particularly poor, interventions including revegetation, reseeding, brushpacking and zai pits to facilitate water ponding are also used to improve the condition of grassland and soils.<br>• Wetland and riverine rehabilitation: The use of brushpacks and vegetative strips, fencing and revegetation as well as harder approaches such as earth berms or gabions can be used to ensure infrastructural integrity is re-established and hydrological functioning is improved in rivers and wetlands.</td></tr>
<tr><td>Physical isolation of rural communities during flooding events due to damage to roads and bridges (Let's Respond Toolkit, n.d.).</td></tr>
<tr><td>Decreased water quality in ecosystems due to floods (Let's Respond Toolkit, n.d.).</td></tr>
<tr><td>Erosion and sedimentation which can alter landscapes, contribute to landslides, harm ecosystems and negatively impact water quality (Let's Respond Toolkit, n.d.).</td></tr>
<tr><td>Crop damage from heavy rain leading to increased risk of crop failure; threats to subsistence agriculture, rural livelihoods and food security (Let's Respond Toolkit, n.d.).</td></tr>
<tr><td>Increase in the frequency of fire weather occurrence, including an</td><td>Direct threat to human life, livelihoods and infrastructure (Let's Respond Toolkit, n.d.).</td><td>• Disaster risk reduction preparedness and response measures: The development of technologies and approaches that improve the dissemination of early</td></tr>
</table>

| Joe Gqabi DM | | |
|---|---|---|
| **Hazard** | **Impact** | **Adaptation Activity** |
| increase in temperature and greater variance in rainfall (Think Hazard, 2020; FCSIR, 2019) | | warning products and messages related to wildfires are critical to protect communities. This can be maintained and tested through simulation drills in which communities are supported to practice evacuation routes, communication procedures and emergency response actions. This supports community preparedness which can also entail educating communities on disaster preparedness and response. |
| | Risk of major loss of livestock and grazing, crops which creates threats to financial sustainability of subsistence farming operations and rural livelihoods – thereby also reducing food security (Let's Respond Toolkit, n.d.). | • **Clearing of IAP:** IAPs increase the risk and intensity of wildfires by changing local vegetation structures, and providing denser fuel loads (van Wilgen, 2015). Thus, their removal will reduce the impact associated with wildfires.<br>• **Improved rangeland management**: Improved rangeland management such as rotational grazing resting, revegetation, reseeding, brushpacking and zai pits reduces fuel loads and disrupts fuel continuity which decreases ignition and the initial spread of fires (Wollstein & Johnson, 2022). |
| | Loss of biodiversity as wildfires destroy habitats, threatening plant and animal species (Let's Respond Toolkit, n.d.). | |

## 5.3 EHLANZENI DM

The Ehlanzeni DM is located in the north-eastern part of the Mpumalanga Province with a population of approximately 1,7 million individuals and a population density of 61 people per km2. As of 2011, the district had a 66% unemployment rate as well as low levels of education. The DM is home to many low-lying areas, which are particularly impacted by flood hazards. Over the past decade, the frequency and intensity of flooding events in the DM have increased, causing significant damage to homes, infrastructure, and agricultural land as well as loss of life. Past flood incidents include floods in 2023, 2018, 2012 and 2000. For one rainfall station, the trends in AMS and the 1:10 and 1:50 year design rainfall depths is subtle, but still increasing. However, there is clear increase for the AMS data and the design rainfall depths for the other rainfall station, showing a clear increasing trend of extreme rainfall. Projections of anomalies in extreme rainfall, based on CMIP6, also indicated an increase in the depth of rainfall associated with the 1:100-year return period storm event. Of note is the high economic, socio-economic and physical vulnerability of Bushbuckridge LM while the Thaba Chweu LM has a high environmental vulnerability. Noting the above, the selection of the Ehlanzeni DM for the Eco-DRR project is justified considering its history of flooding and the projected increase in future flooding events.

An assessment of change in drought hazard for the Ehlanzeni DM indicated that projections for 2050 suggest that QC B60H will have an increase in drought tendencies per 10 years, however, QC X32F will have a reduced drought tendency per 10 years. The Ehlanzeni region has areas of both moderate and low levels of exposure to drought. It is noted that the Ehlanzeni DM has a lower level of exposure than the Sekhukhune DM, which is located in to the immediate West of the Ehlanzeni DM.

A summary of the observed climate and projected climate changes and extreme events in the DM is presented in the table below.

*Table 5-5: Observed climate and projected climate changes and extreme events in Ehlanzeni DM (GCI & SANBI, 2024)*

| Climate variable / hazard | Observed climate (1981-2000) | Near future projected change (2021-2040) | Mid-future projected change (2041-2060) | Far-future projected change (2081-2099) | Summary |
|---|---|---|---|---|---|
| **Annual mean rainfall** | Annual mean precipitation ranges from 450 mm over the northern Lowveld to more than 1 000 mm over the SW Highveld. | 0 – 60 mm / year | 30 – -60 mm / year | 0 – -90 mm / year | Projected decrease in annual mean rainfall (medium confidence in the near- to mid-future, high confidence in the far-future). |
| **Extreme rainfall days** | Average annual number of days with heavy precipitation ranges from 3 days over the northern Lowveld to 10 days over the SW Highveld. | -0.5 – 1 days / year | -0.5 – 2 days / year | -1.5 – 1 days / year | Projected general increase in the frequency of heavy rainfall events (medium confidence). |
| **Annual mean temperature** | Annual mean temperature ranges from 14 °C over the SW Highveld to 24 °C over the eastern Lowveld. | 0 – 2.2 °C / year | 1.2 – 3.2 °C / year | 3.2 – 4.2 °C / year | Projected increase in annual mean temperature (virtually certain) |
| **Very hot days** | Average annual number of very hot days ranges from less than 1 day over the SW Highveld to more than 40 days over the eastern Lowveld. | -20 - 40 days / year | -20 – 40 days / year | 0 - >80 days / year | Projected increase in warm extremes from near into far-future (high confidence). |

A summary of the hazards, impacts and possible adaptation activities for Ehlanzeni DM is presented in the table below.

*Table 5-6: Summary of hazards, impacts and adaptation activities for Ehlanzeni DM*

| Ehlanzeni DM | | |
|---|---|---|
| **Hazard** | **Impact** | **Adaptation Activity** |
| Increased intensity of single-event rainfall occurrences increases the risk of both **pluvial and fluvial flooding** (Engelbrecht, et al., 2019; World Bank, 2021; Le Maitre, et al., 2019; GCI & SANBI, 2024) | Direct threat to life and livelihoods (Let's Respond Toolkit, n.d.). | • **Disaster risk reduction preparedness and response measures**: The development of technologies and approaches that improve the dissemination of early warning products and messages related to floods are critical to protect communities. This can be maintained and tested through simulation drills in which communities are supported to practice evacuation routes, communication procedures and emergency response actions. This supports community preparedness which can also entail educating communities on disaster preparedness and response. |

| Ehlanzeni DM | | |
|---|---|---|
| **Hazard** | **Impact** | **Adaptation Activity** |
| | Direct threat to infrastructure within flood-prone areas and increased insurance premiums (Let's Respond Toolkit, n.d.). | • **Improved landscape management in upper catchment areas:** Improved management of upper catchment areas to reduce erosion and siltation, improve groundwater recharge, and improve downstream hydrological response.<br>• **Improved rangeland management:** Rotational grazing and resting will reduce overgrazing that currently occurs in the DM which will have benefits in terms of livestock productivity, increasing infiltration and reducing runoff, and increased biodiversity in rangelands. Where the condition of rangelands is particularly poor, interventions including revegetation, reseeding, brushpacking and zai pits to facilitate water ponding are also used to improve the condition of grassland and soils.<br>• **Wetland and riverine rehabilitation**: The use of brushpacks and vegetative strips, fencing and revegetation as well as harder approaches such as earth berms or gabions can be used to ensure infrastructural integrity is re-established and hydrological functioning is improved in rivers and wetlands. |
| | Physical isolation of rural communities during flooding events due to damage to roads and bridges (Let's Respond Toolkit, n.d.). | |
| | Decreased water quality in ecosystems due to floods (Let's Respond Toolkit, n.d.). | |
| | Erosion and sedimentation which can alter landscapes, contribute to landslides, harm ecosystems and negatively impact water quality (Let's Respond Toolkit, n.d.). | |
| | Crop damage from heavy rain leading to increased risk of crop failure; threats to subsistence agriculture, rural livelihoods and food security (Let's Respond Toolkit, n.d.). | |
| Increase in the **frequency of fire weather occurrence**, including an increase in temperature and greater variance in rainfall (FCSIR, 2019; Think Hazard, 2020). | Direct threat to human life, livelihoods and infrastructure (Let's Respond Toolkit, n.d.). | • **Disaster risk reduction preparedness and response measures**: The development of technologies and approaches that improve the dissemination of early warning products and messages related to wildfires are critical to protect communities. This can be maintained and tested through simulation drills in which communities are supported to practice evacuation routes, communication procedures and emergency response actions. This supports community preparedness which can also entail educating communities on disaster preparedness and response. |
| | Risk of major loss of livestock and grazing, crops which creates threats to financial sustainability of subsistence farming operations and rural livelihoods – thereby also reducing food security (Let's Respond Toolkit, n.d.). | • **Improved landscape management in upper catchment areas:** Improved management of upper catchment areas to reduce erosion and siltation, improve groundwater recharge, and improve downstream hydrological response. |
| | Loss of biodiversity as wildfires destroy habitats, threatening plant and animal species (Let's Respond Toolkit, n.d.). | |
| Increase in **intensity and frequency of drought** (Engelbrecht, et al., | Threat to human life and livelihoods by contributing to water insecurity (Let's Respond Toolkit, n.d.). | • **Disaster risk reduction preparedness and response measures**: The development of technologies and approaches that improve the dissemination of early warning products and messages related to droughts are critical to protect communities. This can be maintained and tested through simulation drills in which |

| Ehlanzeni DM | | |
|---|---|---|
| **Hazard** | **Impact** | **Adaptation Activity** |
| 2019; World Bank, 2021; WWF, 2023) | | communities are supported to practice evacuation routes, communication procedures and emergency response actions. This supports community preparedness which can also entail educating communities on disaster preparedness and response. |
| | Decreased water quality in ecosystem due to increased concentrations of effluent (Let's Respond Toolkit, n.d.). | • **Improved landscape management in upper catchment areas:** Improved management of upper catchment areas to reduce erosion and siltation, improve groundwater recharge, and improve downstream hydrological response.<br>• **Improved rangeland management:** Rotational grazing and resting will reduce overgrazing that currently occurs in the DM which will have benefits in terms of livestock productivity, increasing infiltration and reducing runoff, and increased biodiversity in rangelands. Where the condition of rangelands is particularly poor, interventions including revegetation, reseeding, brushpacking and zai pits to facilitate water ponding are also used to improve the condition of grassland and soils.<br>• **Wetland and riverine rehabilitation**: The use of brushpacks and vegetative strips, fencing and revegetation as well as harder approaches such as earth berms or gabions can be used to ensure infrastructural integrity is re-established and hydrological functioning is improved in rivers and wetlands impacting on water security within communities and across landscapes. |
| | Increased evaporation, reduced soil moisture, reduced runoff and river base flow. Compounded by reduced mean annual precipitation, systemic water shortages will limit economic growth (Let's Respond Toolkit, n.d.). | |
| | Increased risk / frequency of dry land crop-failure coupled with increased mortality and reduced productivity among livestock. Threatens subsistence agriculture, rural livelihoods and food security (Let's Respond Toolkit, n.d.). | |
| | Loss of biodiversity as drought leads to a decrease in plant growth (Let's Respond Toolkit, n.d.). | |

## 5.4 SEKHUKHUNE DM

The Sekhukhune DM is located in the Limpopo Province with a population of just under 1,1 million individuals and a population density of 80 people per km². There was a 79% unemployment rate in 2011 with only 36% of this group having received a high school education. The Sekhukhune DM has a history of severe flooding. Due to the district being characterised by rugged terrain, it is particularly vulnerable to flash floods and fluvial flooding. Some of the most devastating floods occurred in 2021 and 2014 which resulted in significant damage to infrastructure, and livelihoods of local communities. Based on the analysis of two rainfall stations in the DM, a subtle increase in AMS and the 1:10 and 1:50 year design rainfall depth is evident for one station while the other shows a clear increasing trend in extreme rainfall. Further to the above, projections of anomalies in extreme rainfall, based on CMIP6, indicated an increase in the depth of rainfall associated with the 1:100-year return period storm event. Medium to high socio-economic, economic, physical, and environmental vulnerability is observed across the LMs in the Sekhukhune DM and future projections indicate that the LMs will have an increasing growth pressure. Considering the above, the DM is an appropriate choice for the Eco-DRR project – noting its history of flooding as well as future projections indicating increasing flooding.

The assessment of change in drought hazard for the Sekhukhune DM indicated that both potential locations for intervention implementation can be associated with an increase drought tendency per 10 years, in the future. According to the WWF Water Risk Filter water scarcity index (proxy for exposure to drought), the Sekhukhune region has areas of moderate and high levels of exposure to drought. The Sekhukhune DM has one of the highest levels of exposure to drought across the selected priority DMs.

A summary of the observed climate and projected climate changes and extreme events in the DM is presented in the table below.

*Table 5-7: Observed climate and projected climate changes and extreme events in Sekhukhune DM (GCI & SANBI, 2024)*

| Climate variable / hazard | Observed climate (1981-2000) | Near future projected change (2021-2040) | Mid-future projected change (2041-2060) | Far-future projected change (2081-2099) | Summary |
|---|---|---|---|---|---|
| **Annual mean rainfall** | Annual mean precipitation ranges from 450 mm over NW parts to 750 mm in the SE. | -30 – 30 mm / year | -60 – 30 mm / year | -120 – -30 mm / year | Projected decrease in annual mean precipitation (high confidence). |
| **Extreme rainfall days** | Annual number of heavy precipitation events ranges from 2-4 days across the district, and reaches 6 days in the far SE. | -0.5 – 1 days / year | -0.5 – 2 days / year | -1 – 1.5 days / year | Projected increase in the frequency of heavy precipitation events (medium confidence). |
| **Annual mean temperature** | Annual mean temperature ranges from 14 °C over the SE highlands to 22 °C in the NW. | 1 – 2 °C / year | 2 – 3 °C / year | 3 - >4 °C / year | Projected increase in annual mean temperature (virtually certain) |
| **Very hot days** | Annual mean number of very hot days ranges from 2 days over the highlands in the SE to more than 12 days in the NW. | -25 – 25 days / year | -25 – 50 days / year | 0 - >100 days / year | Projected increase in warm temperature extremes (virtually certain). |

A summary of the hazards, impacts and possible adaptation activities for Sekhukhune DM is presented in the table below.

*Table 5-8: Summary of hazards, impacts and adaptation activities for Sekhukhune DM*

| Sekhukhune DM | | |
|---|---|---|
| Hazard | Impact | Adaptation Activity |
| Increased intensity of single-event rainfall occurrences increases the risk of both **pluvial and fluvial flooding** (Engelbrecht, et al., 2019; World Bank, | Direct threat to life and livelihoods (Let's Respond Toolkit, n.d.). | • **Disaster risk reduction preparedness and response measures**: The development of technologies and approaches that improve the dissemination of early warning products and messages related to floods are critical to protect communities. This can be maintained and tested through simulation drills in which communities are supported to practice evacuation routes, communication procedures and emergency response actions. This supports community preparedness which |

| Sekhukhune DM | | |
|---|---|---|
| **Hazard** | **Impact** | **Adaptation Activity** |
| 2021; Le Maitre, et al., 2019; GCI & SANBI, 2024) | | can also entail educating communities on disaster preparedness and response. |
| | Direct threat to infrastructure ~~within~~ flood-prone areas and increased insurance premiums (Let's Respond Toolkit, n.d.). | • **Clearing of invasive woody alien plants**: The removal of IAPs and woody plants (including trees and bushes) to enhance the hydrological functioning of rivers and wetlands, especially winter baseflows, improves the water yield (Le Maitre, et al., 2020). Removal of this biomass can develop various value-adding opportunities (Irlich, et al., 2014).<br>• **Improved rangeland management:** Rotational grazing and resting will reduce overgrazing that currently occurs in the DM which will have benefits in terms of livestock productivity, increasing infiltration and reducing runoff, and increased biodiversity in rangelands. Where the condition of rangelands is particularly poor, interventions including revegetation are also used to improve the condition of grassland and soils.<br>• **Wetland and riverine rehabilitation**: The use of brushpacks and vegetative strips can be used to ensure hydrological functioning is improved in rivers and wetlands. |
| | Physical isolation of rural communities during flooding events due to damage to roads and bridges (Let's Respond Toolkit, n.d.). | |
| | Decreased water quality in ecosystems due to floods (Let's Respond Toolkit, n.d.). | |
| | Erosion and sedimentation which can alter landscapes, contribute to landslides, harm ecosystems and negatively impact water quality (Let's Respond Toolkit, n.d.). | |
| | Crop damage from heavy rain leading to increased risk of crop failure; threats to subsistence agriculture, rural livelihoods and food security (Let's Respond Toolkit, n.d.). | |
| Increase in the **frequency of fire weather occurrence**, including an increase in temperature and greater variance in rainfall (Think Hazard, 2020; FCSIR, 2019) | Direct threat to human life, livelihoods and infrastructure (Let's Respond Toolkit, n.d.). | • **Disaster risk reduction preparedness and response measures**: The development of technologies and approaches that improve the dissemination of early warning products and messages related to wildfires are critical to protect communities. This can be maintained and tested through simulation drills in which communities are supported to practice evacuation routes, communication procedures and emergency response actions. This supports community preparedness which can also entail educating communities on disaster preparedness and response. |
| | Risk of major loss of livestock and grazing, crops which creates threats to financial sustainability of subsistence farming operations and rural livelihoods – thereby also reducing food security (Let's Respond Toolkit, n.d.). | • **Clearing of invasive woody alien plants:** IAPs increase the risk and intensity of wildfires by changing local vegetation structures, and providing denser fuel loads (van Wilgen, 2015). Thus, their removal will reduce the impact associated with wildfires.<br>• **Improved rangeland management**: Improved rangeland management such as rotational grazing resting and revegetation reduces fuel loads and disrupts fuel continuity which decreases ignition and the initial spread of fires (Wollstein & Johnson, 2022). |
| | Loss of biodiversity as wildfires destroy habitats, threatening plant and animal species (Let's Respond Toolkit, n.d.). | |
| Increase in **intensity and frequency of drought** | Threat to human life and livelihoods by contributing to water insecurity (Let's Respond Toolkit, n.d.). | • **Disaster risk reduction preparedness and response measures**: The development of technologies and approaches that improve the dissemination of early warning products and messages related to droughts are |

| Sekhukhune DM | | |
|---|---|---|
| **Hazard** | **Impact** | **Adaptation Activity** |
| (Engelbrecht, et al., 2019; World Bank, 2021; WWF, 2023) | | critical to protect communities. This can be maintained and tested through simulation drills in which communities are supported to practice evacuation routes, communication procedures and emergency response actions. This supports community preparedness which can also entail educating communities on disaster preparedness and response. |
| | Decreased water quality in ecosystem due to increased concentrations of effluent (Let's Respond Toolkit, n.d.). | • **Clearing of invasive woody alien plants:** IAPs consume more water than indigenous plants which results in dried up watercourses, damage to the ecological functioning of natural systems, and reduced productivity of land. Their removal supports water security (Imvelisi, n.d.; Rebelo, et al., 2022).<br>• **Improved rangeland management:** Rotational grazing and resting will reduce overgrazing that currently occurs in the DM which will have benefits in terms of livestock productivity, increasing infiltration and reducing runoff, and increased biodiversity in rangelands. Where the condition of rangelands is particularly poor, interventions including revegetation are also used to improve the condition of grassland and soils.<br>• **Wetland and riverine rehabilitation**: The use of brushpacks and vegetative strips can be used to ensure hydrological functioning is improved in rivers and wetlands. |
| | Increased evaporation, reduced soil moisture, reduced runoff and river base flow. Compounded by reduced mean annual precipitation, systemic water shortages will limit economic growth (Let's Respond Toolkit, n.d.). | |
| | Increased risk / frequency of dry land crop-failure coupled with increased mortality and reduced productivity among livestock. Threatens subsistence agriculture, rural livelihoods and food security (Let's Respond Toolkit, n.d.). | |
| | Loss of biodiversity as drought leads to a decrease in plant growth (Let's Respond Toolkit, n.d.). | |

## 5.5 NGAKA MODIRI MOLEMA DM

The Ngaka Modiri Molema DM is located in the North West Province with a population under 1 million and a population density of 32 people per km2. As of 2011, there was a 70% unemployment rate and low levels of education. The DM has experienced several significant historical flooding events. In 2014 and 2017, heavy rains caused flooding in several areas of the district which caused significant damage to infrastructure, homes, and crops, and resulted in the displacement of people and loss of life. While one rainfall station showed a decline in in both AMS and 1:10- and 1:50-year design rainfall, the other station indicated an increasing trend of extreme rainfall – showcasing an increasing flood hazard for QC D41B. The hydrological complexity of this area will require further consideration through the feasibility study to understand the nature of flood events. Projections of anomalies in extreme rainfall, based on CMIP6, also indicated an increase in the depth of rainfall associated with the 1:10- year return period storm event. Furthermore, the LMs in the DM have medium to high socio-economic, economic and physical vulnerabilities. The selection of the DM for the Eco-DRR projects can be supported by the clear history of past floods in the area coupled with evidence that indicates worsening floods in the future.

According to the WWF Water Risk Filter water scarcity index the Ngaka Modiri Molema DM has areas of moderate and high levels of exposure to drought. The Ngaka Modiri Molema DM also has one of the highest levels of vulnerability when being compared to the other selected priority DMs across South Africa.

A summary of the observed climate and projected climate changes and extreme events in the DM is presented in the table below.

*Table 5-9: Observed climate and projected climate changes and extreme events in Ngaka Modiri Molema DM (GCI & SANBI, 2024)*

| Climate variable / hazard | Observed climate (1981-2000) | Near future projected change (2021-2040) | Mid-future projected change (2041-2060) | Far-future projected change (2081-2099) | Summary |
|---|---|---|---|---|---|
| **Annual mean rainfall** | Annual mean precipitation ranges between 360 mm in the west to 660 mm in the east. | -75 – 0 mm / year | -50 – 25 mm / year | <-100 – -50 mm / year | Projected decrease in annual mean precipitation (high confidence). |
| **Extreme rainfall days** | Observed number of heavy precipitation days ranges on average from 1 day in the west to 5 days in the east. | -0.8 – 0.5 days / year | -0.4 – 0.8 days / year | -0.4 - >0.8 days / year | Projected general increase in the frequency of extreme rainfall events (low confidence for the near-future, high confidence for the mid- to far-future). |
| **Annual mean temperature** | Annual mean temperature ranges from 17 °C in the south to 21 °C in the north. | 1.2 – 2.2 °C / year | 2.2 – 3.2 °C / year | > 4.2 °C / year | Projected increase in annual mean temperature (virtually certain). |
| **Very hot days** | Annual mean number of very hot days ranges from 4 days in the south to more than 16 days in the north. | 0 – 30 days / year | 0 – 60 days / year | 30 – 120 days / year | Projected increase in warm extremes (virtually certain). |

A summary of the hazards, impacts and possible adaptation activities for Ngaka Modiri Molema DM is presented in the table below.

*Table 5-10: Summary of hazards, impacts and adaptation activities for Ngaka Modiri Molema DM*

| Ngaka Modiri Molema DM | | |
|---|---|---|
| **Hazard** | **Impact** | **Adaptation Activity** |
| Increased intensity of single-event rainfall occurrences increases the risk of both **pluvial and fluvial flooding** (Engelbrecht, et al., 2019; World Bank, 2021; Le Maitre, et al., 2019; GCI & SANBI, 2024) | Direct threat to life and livelihoods (Let's Respond Toolkit, n.d.). | • **Disaster risk reduction preparedness and response measures**: The development of technologies and approaches that improve the dissemination of early warning products and messages related to floods are critical to protect communities. This can be maintained and tested through simulation drills in which communities are supported to practice evacuation routes, communication procedures and emergency response actions. This supports community preparedness which can also entail educating communities on disaster preparedness and response. |
| | Direct threat to infrastructure within flood-prone areas and increased insurance premiums (Let's Respond Toolkit, n.d.). | • **Improved rangeland management:** Rotational grazing, fencing and resting will reduce overgrazing that currently occurs in the DM which will have benefits in terms of livestock productivity, increasing infiltration and reducing runoff, and increased biodiversity in rangelands. Where the condition of rangelands is particularly poor, interventions including revegetation |
| | Physical isolation of rural communities during flooding events due to damage | |

| Ngaka Modiri Molema DM | | |
|---|---|---|
| **Hazard** | **Impact** | **Adaptation Activity** |
| | to roads and bridges (Let's Respond Toolkit, n.d.). | and zai pits to facilitate water ponding are also used to improve the condition of grassland and soils.<br>• **Wetland and riverine rehabilitation**: The use of brushpacks and vegetative strips can be used to ensure hydrological functioning is improved in rivers and wetlands. |
| | Decreased water quality in ecosystems due to floods (Let's Respond Toolkit, n.d.). | |
| | Erosion and sedimentation which can alter landscapes, contribute to landslides, harm ecosystems and negatively impact water quality (Let's Respond Toolkit, n.d.). | |
| | Crop damage from heavy rain leading to increased risk of crop failure; threats to subsistence agriculture, rural livelihoods and food security (Let's Respond Toolkit, n.d.). | |
| Increase in the **frequency of fire weather occurrence**, including an increase in temperature and greater variance in rainfall (Think Hazard, 2020; FCSIR, 2019) | Direct threat to human life, livelihoods and infrastructure (Let's Respond Toolkit, n.d.). | • **Disaster risk reduction preparedness and response measures**: The development of technologies and approaches that improve the dissemination of early warning products and messages related to wildfires are critical to protect communities. This can be maintained and tested through simulation drills in which communities are supported to practice evacuation routes, communication procedures and emergency response actions. This supports community preparedness which can also entail educating communities on disaster preparedness and response. |
| | Risk of major loss of livestock and grazing, crops which creates threats to financial sustainability of subsistence farming operations and rural livelihoods – thereby also reducing food security (Let's Respond Toolkit, n.d.). | • **Improved rangeland management:** Improved rangeland management such as rotational grazing resting, revegetation, reseeding, brushpacking and zai pits reduces fuel loads and disrupts fuel continuity which decreases ignition and the initial spread of fires (Wollsteain & Johnson, 2022). |
| | Loss of biodiversity as wildfires destroy habitats, threatening plant and animal species (Let's Respond Toolkit, n.d.). | |
| Increase in **intensity and frequency of drought** (Engelbrecht, et al., 2019; World Bank, 2021; WWF, 2023) | Threat to human life and livelihoods by contributing to water insecurity (Let's Respond Toolkit, n.d.). | • **Disaster risk reduction preparedness and response measures**: The development of technologies and approaches that improve the dissemination of early warning products and messages related to droughts are critical to protect communities. This can be maintained and tested through simulation drills in which communities are supported to practice evacuation routes, communication procedures and emergency response actions. This supports community preparedness which can also entail educating communities on disaster preparedness and response. |
| | Decreased water quality in ecosystem due to increased concentrations of effluent (Let's Respond Toolkit, n.d.). | • **Improved rangeland management:** Rotational grazing, fencing and resting will reduce overgrazing that currently occurs in the DM which will have benefits in terms of livestock productivity, increasing infiltration and reducing runoff, and increased biodiversity in |
| | Increased evaporation, reduced soil moisture, reduced runoff and river | |

| Ngaka Modiri Molema DM | | |
|---|---|---|
| **Hazard** | **Impact** | **Adaptation Activity** |
| | base flow. Compounded by reduced mean annual precipitation, systemic water shortages will limit economic growth (Let's Respond Toolkit, n.d.). | rangelands. Where the condition of rangelands is particularly poor, interventions including revegetation and zai pits to facilitate water ponding are also used to improve the condition of grassland and soils.<br>• **Wetland and riverine rehabilitation**: The use of brushpacks and vegetative strips can be used to ensure hydrological functioning is improved in rivers and wetlands. |
| | Increased risk / frequency of dry land crop-failure coupled with increased mortality and reduced productivity among livestock. Threatens subsistence agriculture, rural livelihoods and food security (Let's Respond Toolkit, n.d.). | |
| | Loss of biodiversity as drought leads to a decrease in plant growth (Let's Respond Toolkit, n.d.). | |

The feasibility report provides the justification for the implementation of site-level interventions in each DM.

## 5.6 POSSIBLE INTERVENTIONS

Based on this CRVA report, potential interventions required to address vulnerability to flooding are aligned with the Theory of Change (Figure 1-1). While there a range of interventions that can be undertaken to reduce the vulnerability of communities, there is also a need to address a range of issues in the enabling environment, that would include improvements in planning, governance and institutional capacity as well as ensuring that financial resources are sufficient to undertake the interventions needed, sustainably over time.

Community focused interventions include improving agricultural and rangeland management practices to strengthen communities' adaptive capacity through strengthening and further developing sustainable livelihood options (see Output 1.2 in Figure 1-1). Additionally, undertaking capacity building, environmental education and awareness raising of communities will be critical in ensuring that community mobilisation measures are put in place to reduce vulnerability to flooding. In these deeply rural contexts, these improvements will save lives and livelihoods. A strong focus on women and marginalised groups will be needed to promote inclusion and gender equality, and noting the important role of women in these communities, will be an essential dimension of ensuring community mobilisation.

Further to the above, there is need for implementation of ecosystem-based approaches to secure and develop EI such as wetland rehabilitation and/or restoration, rehabilitation of rivers and streams and improved slope management through vegetation cover as well as interventions to reduce erosion and the formation of dongas (Output 1.1 in Figure 1-1). There is also the opportunity to implement climate-smart infrastructure approaches and to look towards integrated solutions that effectively combine the use of ecological and built infrastructure. To support local level interventions, the development of community-based, cross-sectoral extension support systems would provide assistance to communities to develop ecosystem-based adaptation approaches and would assist in monitoring and evaluating the state of ecosystems and ecological infrastructure. The provision of this extension service would therefore have an important community lens whilst providing guidance and insight to the LMs that undertake planning for the implementation of interventions to reduce community vulnerability to the impacts of increased flooding.

While the previous interventions focus on local-level and site-specific interventions, it is equally vital to strengthen the enabling environment for continued investment in the management, upscaling and development of Eco-DRR approaches (Outcome 2 in Figure 1-1). Crucial to this is the need to improve settlement planning that supports sustainable and resilient housing. This will require engagement with a range of government actors, both horizontally across sectors and vertically between spheres of government. This should be paired with the mainstreaming of Eco-DRR approaches into planning, policy and regulatory instruments such that built infrastructure and ecological infrastructure are more effectively integrated to reduce the risk of disasters linked to flooding. Considering that much of the enabling environment is managed by government, training and capacity building of local- and district-level municipal government is critical in ensuring that these interventions are sustained in the long-term. Moreover, developing an appropriately designed knowledge sharing system will enhance spatial planning and promote upscaling and knowledge sharing.

The last suite of possible interventions speaks to development of innovative finance mechanisms to sustain and upscale Eco-DRR approaches. In these rural municipalities the financial constraints are considerable and often restrictive for the introduction of innovative solutions. The rural economies of these areas are often not strong enough to underpin such Eco-DRR interventions, but the introduction of new livelihood options together with innovative financing options could provide the basis for transformational changes in these areas. This would therefore include the development of business cases to support the financial and operational sustainability of integrated ecological and built infrastructure solutions, as well as looking to the development and establishment of public and private partnerships and financing mechanisms.

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# APPENDIX A Fact Sheets

**Alfred Nzo District Municipality climate fact sheet**

*(Eastern Cape Province, South Africa)*

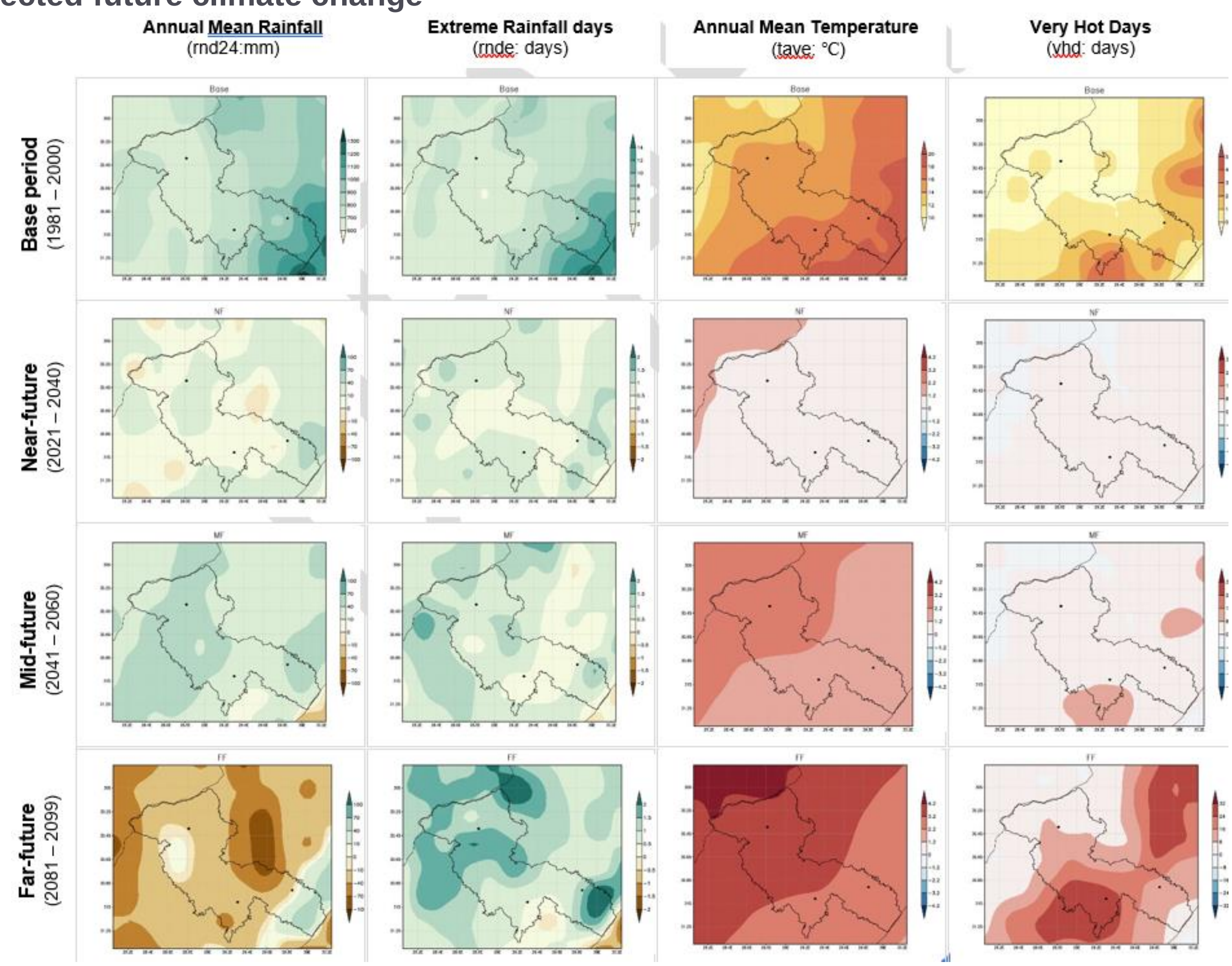
## 1. Observed trends in climate – district level

- Observed general increase in annual mean precipitation (*low confidence*).
- Observed increases in the frequency of heavy precipitation events (*medium confidence*).
- Observed increases in annual mean temperature and warm extremes (virtually certain).

## 2. Projected climate change overview – district level

- Projected increases in near- and mid-future annual mean precipitation (low confidence); projected decreases in the far-future (medium confidence).
- Projected increase in frequency of heavy precipitation events (high confidence).
- Projected increase in annual mean temperature from near into far-future (virtually certain)
- Projected increase in warm extremes (virtually certain).

## 3. Projected future climate change

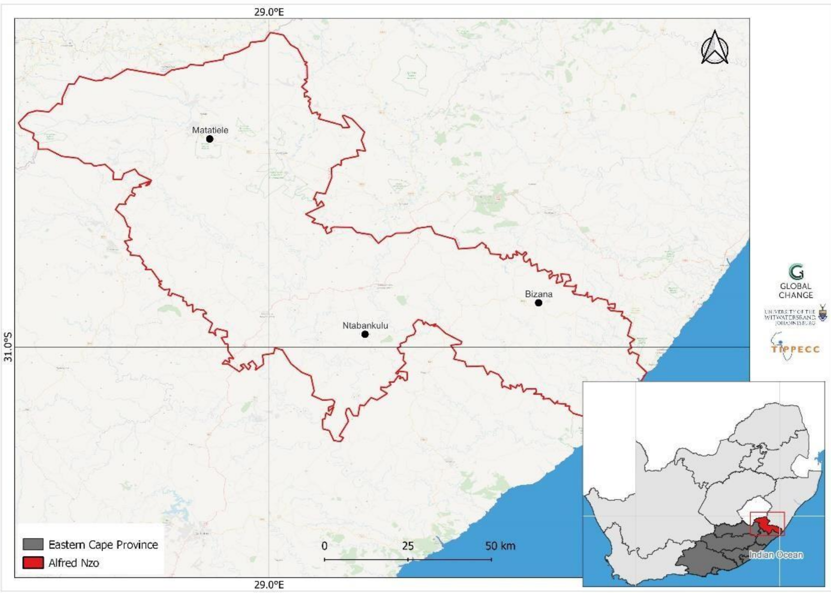


## Projected future climate change *(continued)*

- Near- and mid-future
  - Projected increases in annual precipitation totals (*low confidence*).
  - Projected increase in heavy precipitation events (*high confidence*).
  - Projected increase in temperature and warm extremes (*virtually certain*); projected decreases in cold extremes (*high confidence*).
- Far-future
  - Projected decreases in precipitation (*medium confidence*) but with increases along the coastal strip (*low confidence*).
  - Projected increases in heavy precipitation events (*high confidence*)

  Projected increases in temperature and warm extremes (*virtually certain*) and decrease in cold extremes (virtually certain).

## 4. District Map




## 5. Observed Climate (1981 – 2000)

**Annual Mean Rainfall**

Annual mean precipitation ranges between 600 mm in the northern interior to above 1100 mm over the coastal regions

**Extreme Rainfall Days**

Observed annual number of extreme rainfall days ranging between 2 over the northern interior to more than 12 over the coastal strip.

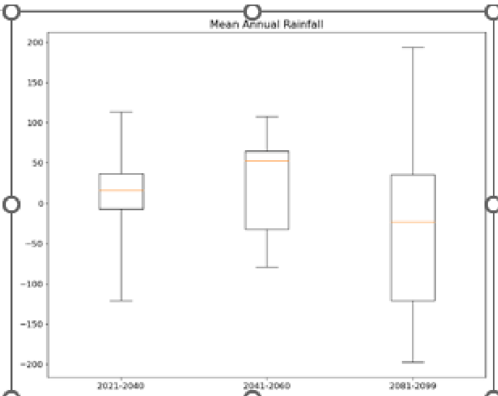
**Annual mean temperature**

Mean temperature ranges from about 14 ℃ over the northern interior to more than 20 ℃ over the coastal strip.

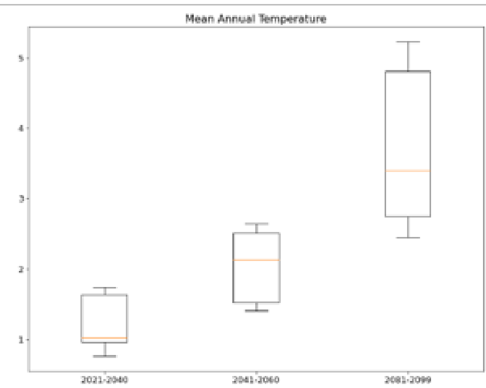
**Very hot days**

Very hot days range between 1 over the north to about 5 days over the southwestern interior regions.

## 6. Projection Uncertainties




- Most climate models project rainfall increases with the district, consistent with recent multi-decadal trends.
- General rainfall increases are *likely* in the mid- to far-future
- Rainfall decreases are *likely* in the far-future.




- Temperature increases in the near-future are *virtually certain*.
- Under low mitigation further temperature increases will *likely* be above 3 °C in the far-future and may be higher than 5 °C.
- Larger increases over the interior vs the coast (*virtually certain*).

## 7. Contact Details

Global Change Institute (GCI), University of the Witwatersrand, Johannesburg, South Africa.
South African National Biodiversity Institute (SANBI)

# Ehlanzeni District Municipality
# climate fact sheet

*(Mpumalanga Province, South Africa)*

## 1. Observed trends in climate overview – district level

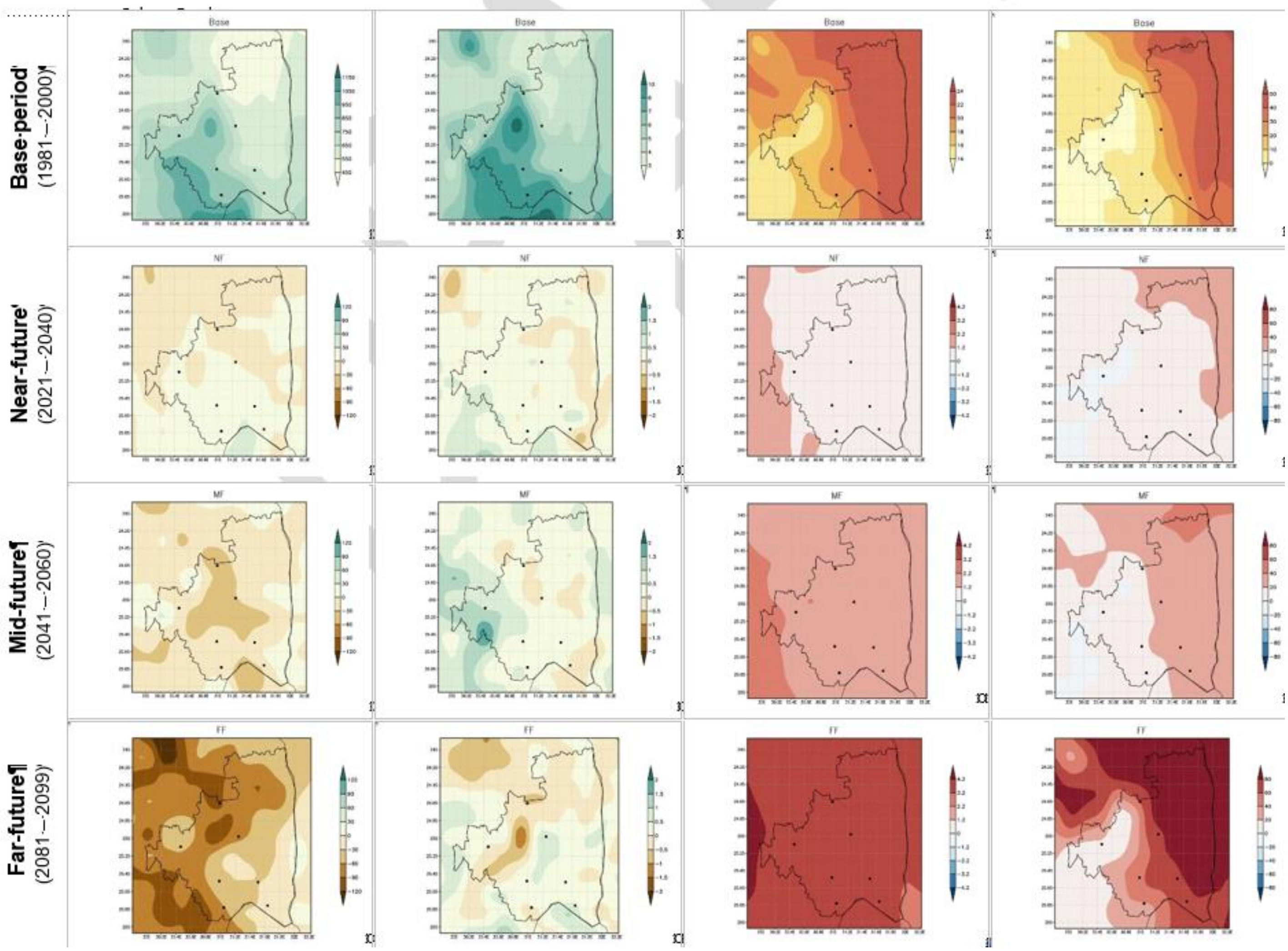
- Observed decrease in annual mean precipitation (*medium confidence*).
- Observed decrease in the frequency of extreme rainfall events (*low confidence*).
- Observed increases in annual mean temperature and warm extremes (*high confidence*).

## 2. Projected climate change overview – district level

- Projected decrease in annual mean precipitation (*medium confidence* in the near- to mid-future, *high confidence* inthe far-future).
- Projected general increase in the frequency of heavy rainfall events (*medium confidence*).
- Projected increase in annual mean temperature (*virtually certain*)
- Projected increase in warm extremes from near into far-future (*high confidence*).

## 3. Projected Climate

| Annual Mean Rainfall (rnd24: mm) | Extreme Rainfall days (rnde: days) | Annual Mean Temperature (tave: °C) | Very Hot Days (vhd: days) |
|---|---|---|---|

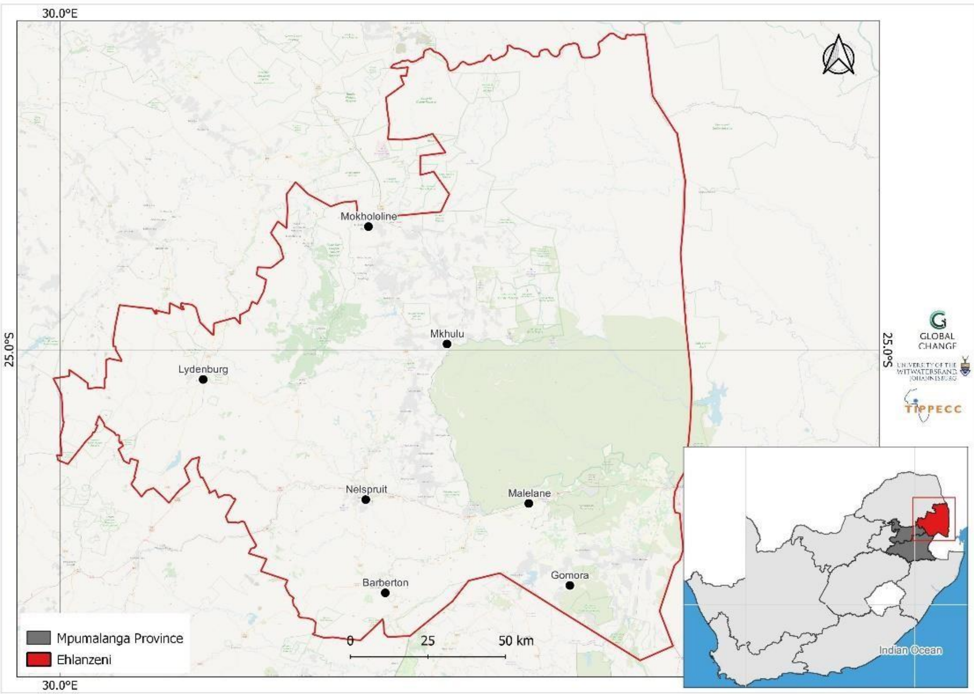



**Projected Climate** *(continued)*

- Near- and mid-future
  - Projected decrease in precipitation, but with modest increases over the southern Lowveld and southwestern Highveld in the near-future (*medium confidence*).
  - Projected general increase in extreme precipitation events (*medium confidence*).
  - Projected increase in temperature and warm extremes (*virtually certain*); general decrease in cold extremes (*virtually certain*).

- Far-future
  - Projected general and substantial decrease in annual precipitation (*high confidence*).
  - Projected increase in heavy precipitation events in the south *(medium confidence)*.
  - Projected increase in temperature (*virtually certain*).
  - Projected increase in warm extremes (*virtually certain) and decrease in cold extremes (virtually certain)*.

## 4. District Map




## 5. Observed Climate (1981–2000)

**Annual mean rainfall**

Annual mean precipitation ranges from 450 mm over the northern Lowveld to more than 1 000 mm over the southwestern Highveld.

**Extreme rainfall days**

Average annual number of days with heavy precipitation range from 3 days over the northern Lowveld to 10 days over the southwestern Highveld.

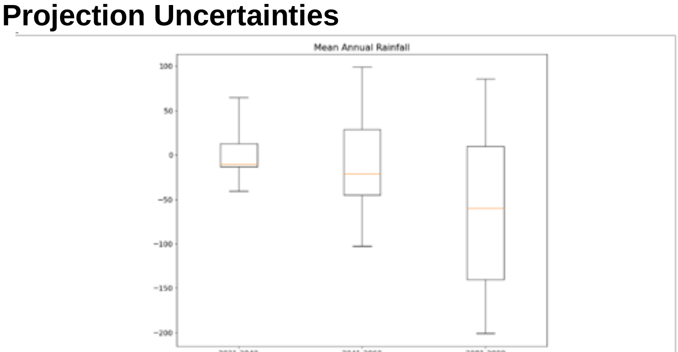
**Annual mean temperature**

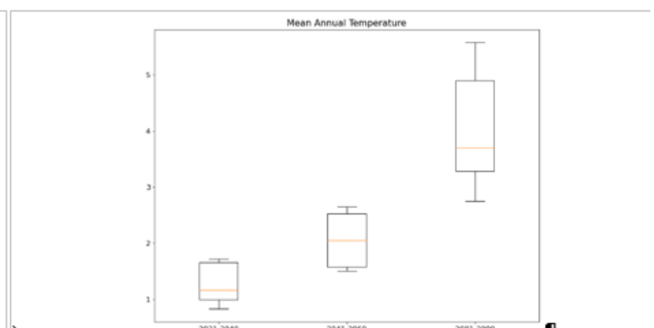
Annual mean temperature range from 14 °C over the southwestern Highveld to 24 °C over the eastern Lowveld.

**Very hot days**

Average annual number of very hot days range from less than 1 over the southwestern Highveld to more than 40 over the eastern Lowveld.

## 6. Projection Uncertainties




- Projected decrease in annual mean precipitation in the near- and mid-future (*medium confidence*).
- Substantial decreases in annual mean precipitation projected for the far-future (*high confidence*).

- Temperature increases in the near-mid future are *virtually certain*.
- Under low mitigation drastic temperature increases by the far-future are virtually certain, possibly exceeding 4 °C (*medium confidence*) with respect to the 1981-2000 baseline.

## 7. Contact Details

- Global Change Institute (GCI), University of the Witwatersrand, Johannesburg, South Africa.
- South African National Biodiversity Institute (SANBI)

# Joe Gqabi District Municipality climate fact sheet

*(Eastern Cape Province, South Africa)*

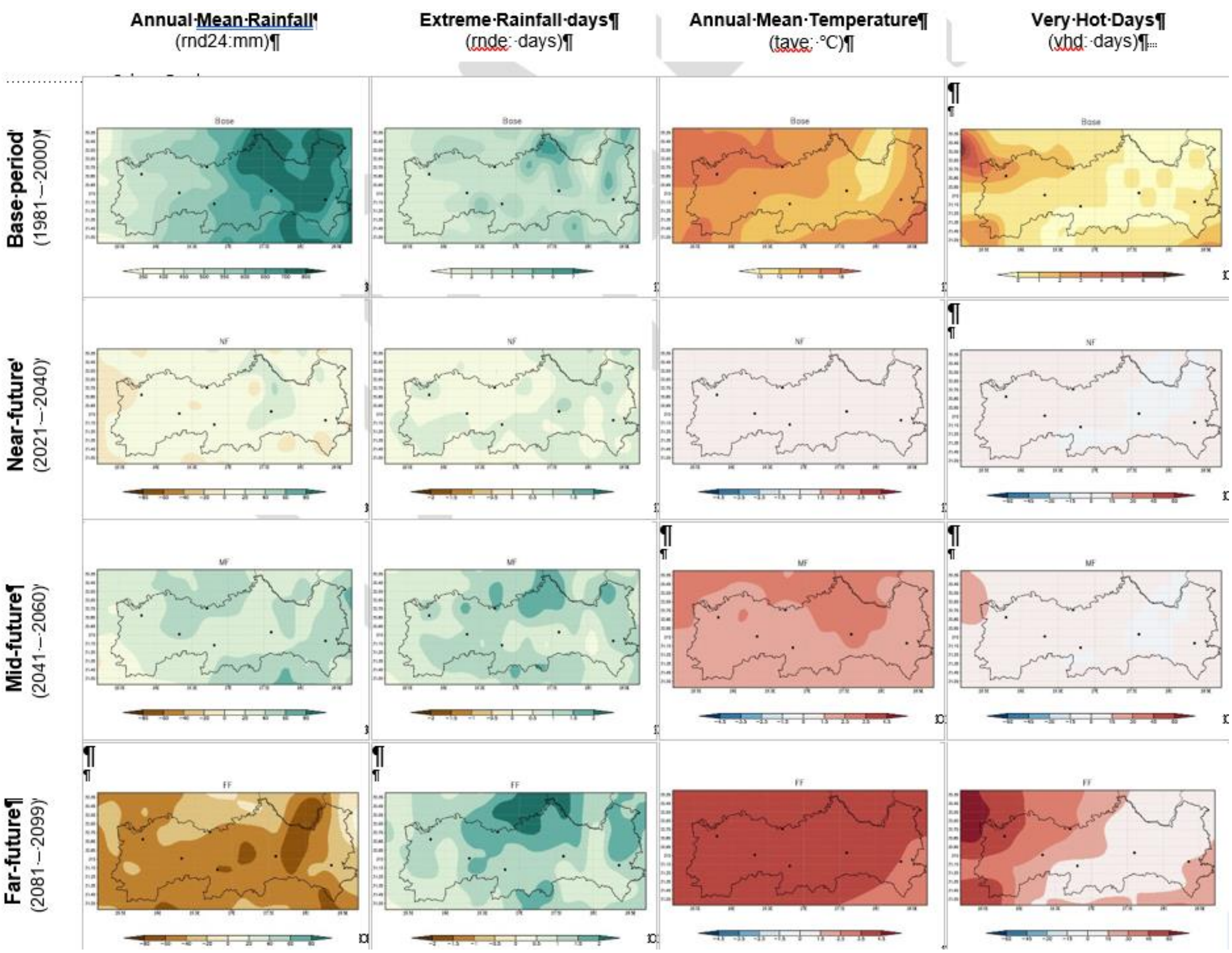
## 1. Observed trends in climate – district level

- Observed general increase in annual mean precipitation (*low confidence*).
- Observed increase in the frequency of heavy precipitation events (*low confidence*).
- Observed increase in annual mean temperature and warm extremes (*virtually certain*).

## 2. Projected climate change overview – district level

- Projected increase in annual mean precipitation in near- and mid-future (*low confidence*); projected decrease inthe far-future (*medium confidence*).
- Projected increase in the frequency of heavy precipitation events (*high confidence*).
- Projected increase in annual mean temperature (*virtually certain*).
- Projected increase in warm extremes (*virtually certain*).

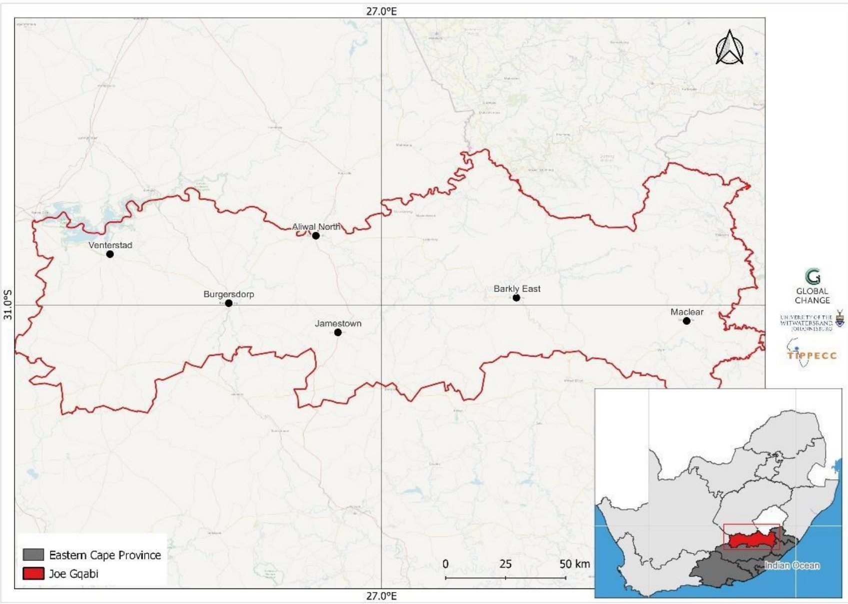
## 3. Projected Climate




**Projected climate change** *(continued)*

- Near- and mid-future
  - Projected increase annual mean precipitation (*medium confidence*).
  - Projected increase in heavy precipitation events (*medium confidence*).
  - Projected increase in temperature and warm extremes (*virtually certain*); decrease in cold extremes (*high confidence*).
- Far-future
  - Projected decrease in annual mean precipitation (*medium confidence*).
  - Projected increase in the frequency of heavy precipitation events (*high confidence*).
  - Projected increase in temperature (*virtually certain*).
  - Projected increase in warm extremes (*virtually certain*); decreases in cold extremes (*virtually certain*).

## 4. District Map




## 5. Observed Climate (1981–2000)

**Annual mean rainfall**

Annual mean precipitation ranges from about 400 mm in the west to more than 800 mm over the eastern mountains.

**Extreme rainfall days**

Observed number of heavy precipitation days range from about 1 in the west to about 7 over the eastern mountains.

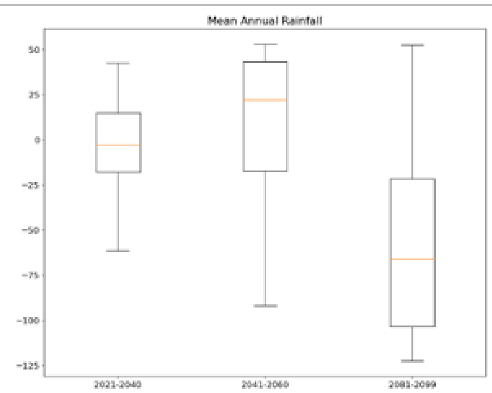
**Annual mean temperature**

Annual mean temperature ranges from about 10 °C over the eastern mountains to about 18 °C in the west.

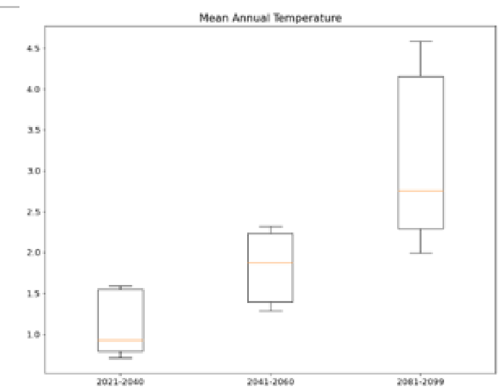
**Very hot days**

Annual mean number of very-hot days range from less than 1 over the eastern mountains to about 5 in the west.

## 6.Projection Uncertainties




- *Medium confidence* in projected rainfall increased in the near- to mid-future.
- Projected substantial decrease in mean annual precipitation in the far-future (*medium confidence*).




- Temperature increases in the near- to mid-future are *virtually certain*.
- Under low mitigation temperature increases in the far-future may be as high as 3-4.5 °C (*medium confidence*).

## 7.Contact Details

- Global Change Institute (GCI), University of the Witwatersrand, Johannesburg, South Africa.
- South African National Biodiversity Institute (SANBI)

# Ngaka Modiri Molema District Municipality climate fact sheet

*(North-West Province, South Africa)*

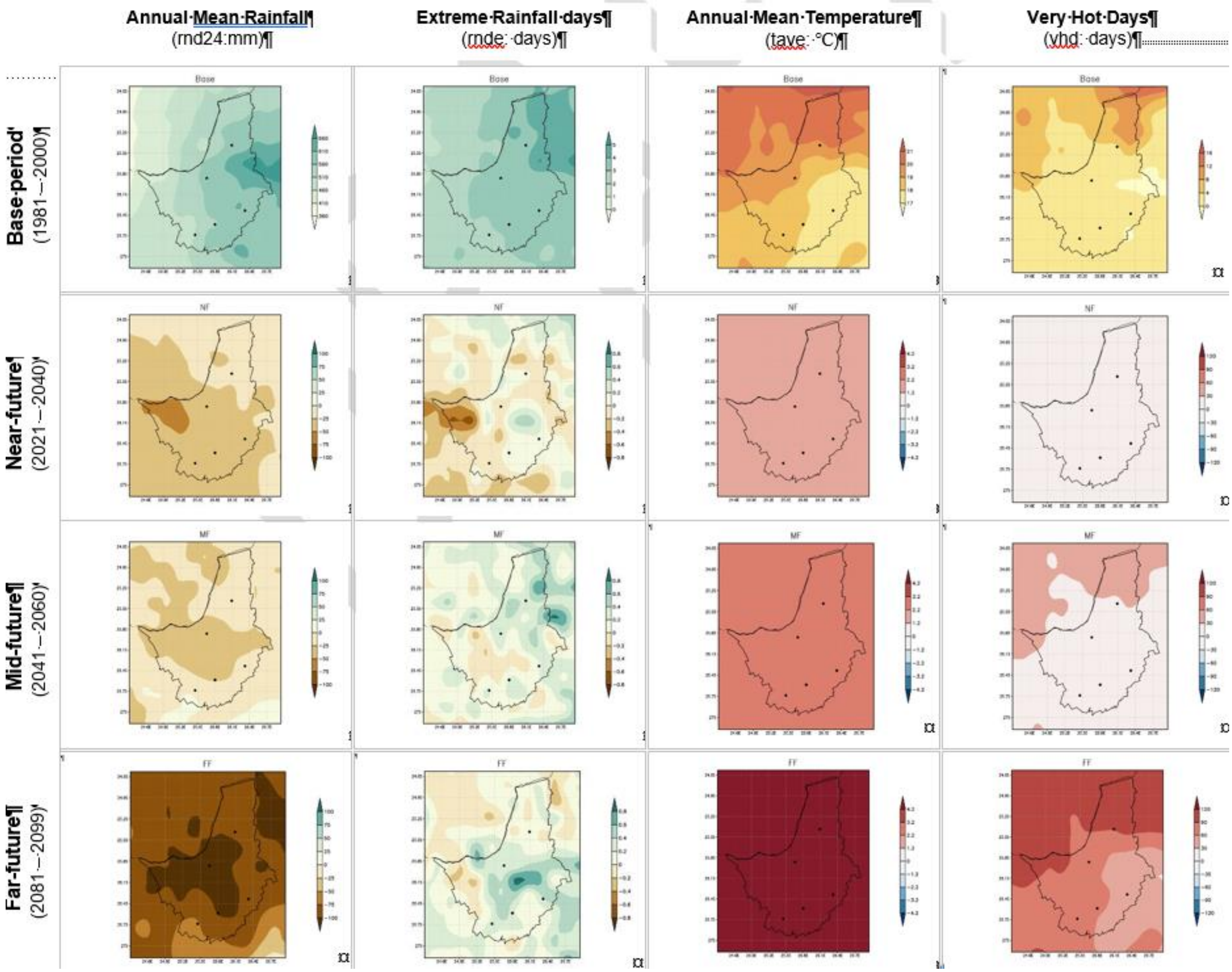
## 1. Observed trends in climate – district level

- Observed decrease in annual mean precipitation (*low confidence*).
- Observed increase in the frequency of heavy rainfall events (*low confidence*).
- Observed increases in annual mean temperature and warm extremes (*virtually certain*).

## 2. Projected climate change overview – district level

- Projected decrease in annual mean precipitation (high confidence).
- Projected general increase in the frequency of extreme rainfall events (low confidence for the near-future, high confidence for the mid- to far-future).
- Projected increase in annual mean temperature (virtually certain).
- Projected increase in warm extremes (virtually certain).

## 3. Projected Climate

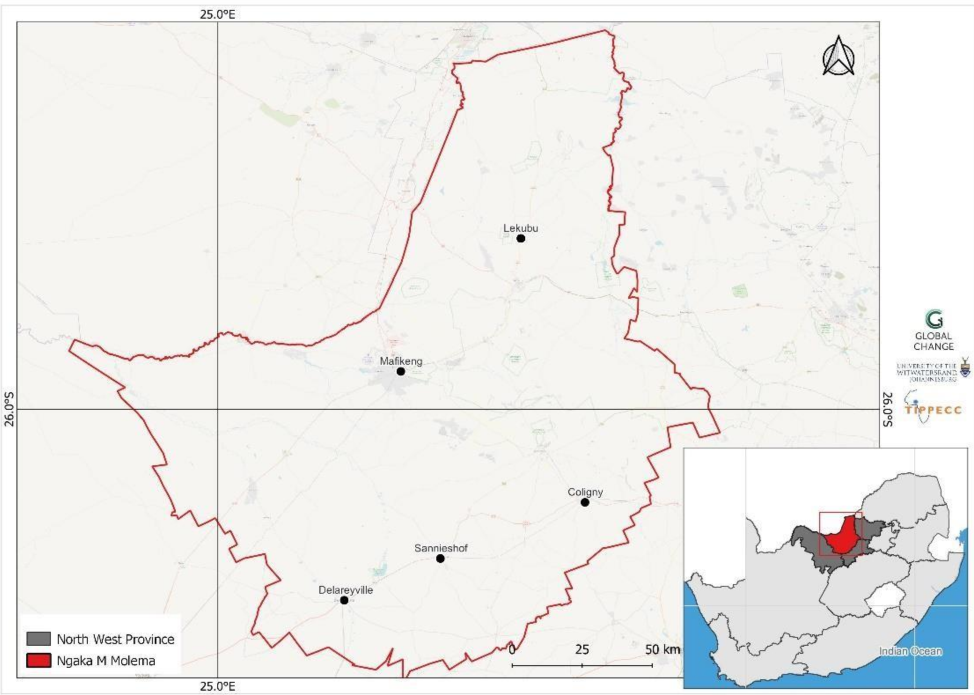



**Projected climate change** *(continued)*

- Near-Future
  - Projected decreases in mean annual precipitation is *likely*.
  - Projected increase in heavy precipitation events (*low confidence*).
  - Projected increase in temperature and warm extremes (*virtually certain*); decrease in cold extremes (virtually *certain*).

- Mid- and far-future
  - Projected decrease in mean annual precipitation in the mid-future, with substantial losses by the far-future *(high confidence)*.
  - Projected increase in heavy precipitation events is *likely*.
  - Projected increase in temperature (virtually *certain*).
  - Projected increase in warm extremes (*virtually certain*), decrease in cold extremes (*virtually certain*).

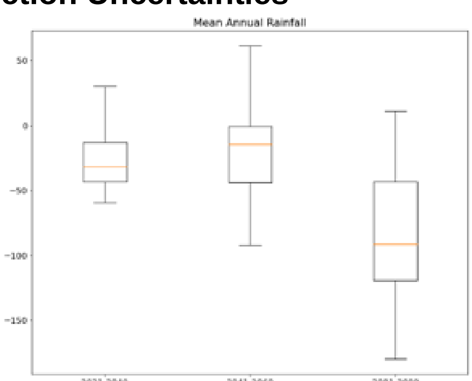
## 4. District Map

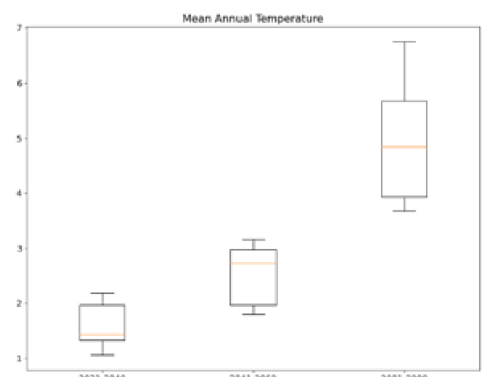



## 5. Observed Climate (1981-2000)

| |
|---|
| **Annual Mean Rainfall**<br>Annual mean precipitation ranges between 360 mm in the west to 660 mm in the east. |
| **Extreme Rainfall Days**<br>Observed number of heavy precipitation days range on average from 1 in the west to 5 in the east. |
| **Annual mean temperature**<br>Annual mean temperatures ranges from 17 °C in the south to 21°C in the north. |
| **Very hot days**<br>Annual mean number of very hot days range from 4 in the south to more than 16 in the north. |

## 6. Projection Uncertainties




- Projected decrease in annual mean precipitation is *likely*.
- Decreases in annual mean precipitation in the far-future will be substantial (*high confidence*).

- Temperature increases in the near to mid future are *virtually certain*.
- Under low mitigation drastic temperature increases are *virtually certain* and may be higher than 5 °C (*medium confidence*).

## 7. Contact Details

- Global Change Institute (GCI), University of the Witwatersrand, Johannesburg, South Africa.
- South African National Biodiversity Institute (SANBI)

# Sekhukhune District Municipality climate fact sheet

*(Limpopo Province, South Africa)*

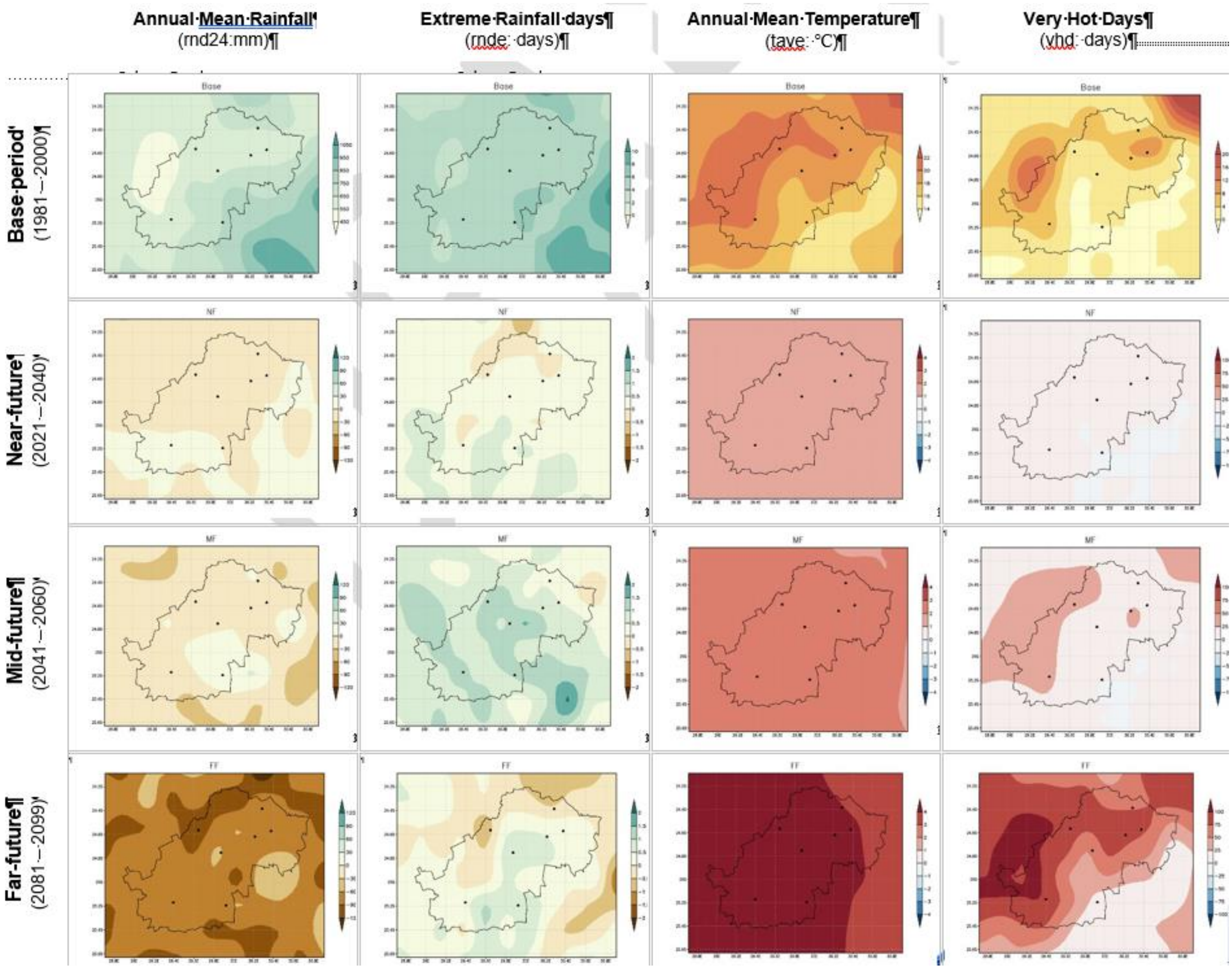
## 1. Observed trends in climate – district level

- Observed decrease in annual mean precipitation (*medium confidence*).
- Observed increase in the frequency of heavy precipitation events (*medium confidence*).
- Observed increases in annual mean temperature and warm extremes (*virtually certain*).

## 2. Projected climate change overview – district level

- Projected decrease in annual mean precipitation (high confidence).
- Projected increase in the frequency of heavy precipitation events (medium confidence).
- Projected increase in annual mean temperature (virtually certain)
- Projected increase in warm temperature extremes (virtually certain).

## 3. Projected Climate

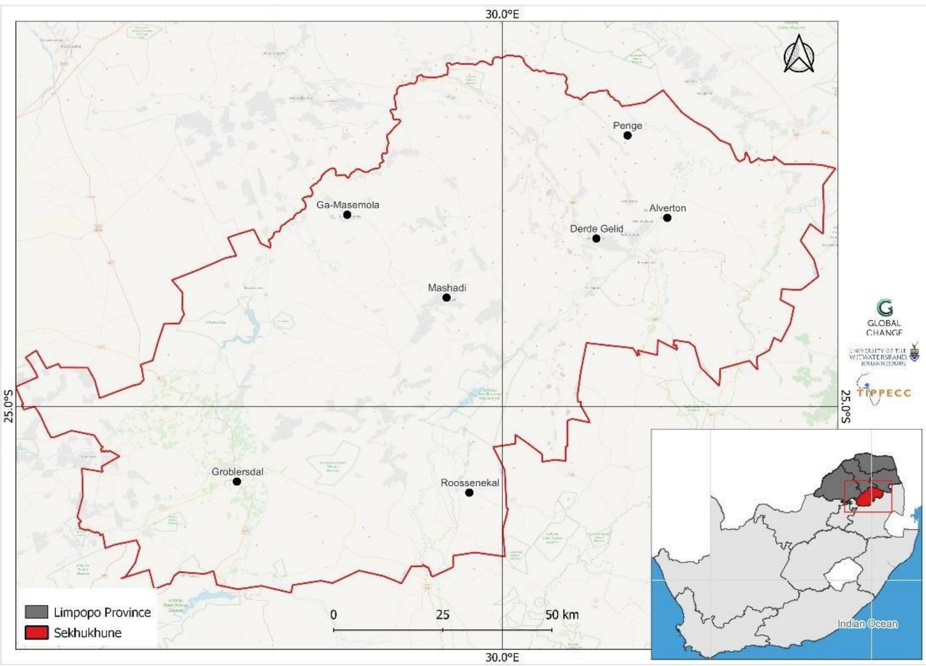


## Projected climate change *(continued)*

- Near-Future
  - Projected decreases in precipitation (*high confidence*).
  - Projected increase in heavy precipitation events, predominantly in the form of thunderstorms (*medium confidence*).
  - Projected increase in temperature and warm extremes (virtually certain); decrease in cold extremes (*high confidence*).

- Mid- and far-future
  - Projected substantial decreases in mean precipitation (*high confidence*).
  - Projected increases in heavy precipitation events, predominantly in the form of thunderstorms (*medium confidence*).
  - Projected increase in temperature and warm extremes (*virtually certain*).
  - Projected increase in cold extremes (*virtually certain*).

## 4. District Map




## 5. Observed Climate (1981-2000)

**Annual Mean Rainfall**

Annual mean precipitation ranges from 450 mm over northwestern parts to about 750 mm in the southeast, towards the escarpment.

**Extreme Rainfall Days**

Annual mean number of heavy precipitation events range from 2-4 across the district, and reach 6 days in the far south-east.

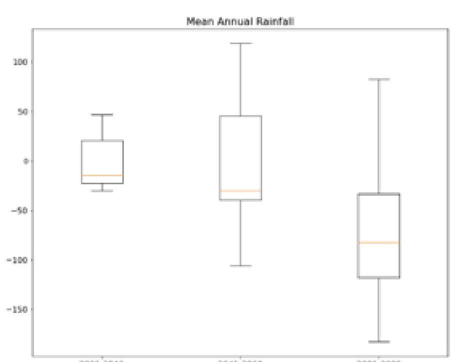
**Very Hot Days**

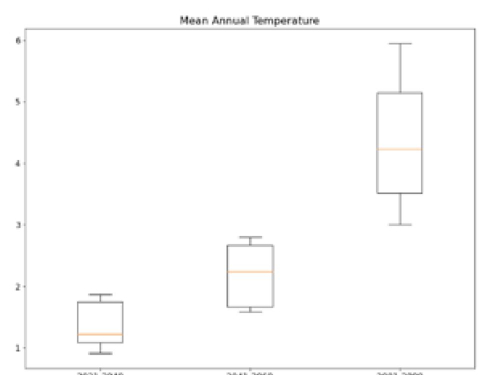
Annual mean number of very-hot days range from 2 days over the highlands in the southeast to more than 12 days in the northwest.

**Annual Mean Temperature**

Annual mean temperature ranges from about 14 °C over the southeastern highlands to about 22 °C in the northwest.

## 6. Projection Uncertainties




- Projected decreases in mean precipitation in the near- and mid-future are *likely*.
- General decreases in precipitation in the far-future (*very likely*), which may be substantial (*likely*).

- Temperature increases in the near- and mid-future are *virtually certain*.
- Warming in the far-future will be substantial (*virtually certain*), *likely* exceeding 4 °C with respect to the 1981-2000 baseline.

## 7. Contact Details

- Global Change Institute (GCI), University of the Witwatersrand, Johannesburg, South Africa.
- South African National Biodiversity Institute (SANBI)