GOVERNMENT OF WESTERN AUSTRALIA

GOLDFIELDS ESPERANCE DEVELOPMENT COMMISSION

GOLDFIELDS-ESPERANCE DEVELOPMENT COMMISSION

Drought Vulnerability Assessment of the Goldfields-Esperance Region

AN EVIDENCE BASE TO SUPPORT THE GOLDFIELDS-ESPERANCE REGIONAL DROUGHT RESILIENCE PLAN

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Contents

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Introduction

The Australian Government's Future Drought Fund (FDF) provides secure, continuous funding for drought resilience initiatives, including the development of regional drought resilience plans across Australia. These plans focus on innovative ways to build resilient communities, industries and landscapes, through a triple bottom line, collaborative, and evidence-based approach.

The Goldfields-Esperance Regional Drought Resilience Plan (RDRP) aims to present a coordinated approach to building drought resilience in the region with a strong focus on water security. The Plan has been informed by both empirical and anecdotal evidence to ensure that this approach is not only underpinned by a robust evidence base but tested against and reflective of the region's lived experience. The plan has three foundational elements:

1. A Drought Vulnerability Assessment: which was developed through the vulnerability assessment framework established during the WA pilot Regional Drought Resilience Planning program and in line with theories of resilience thinking (this document).

2. A Community consultation program: that captured the priorities and needs of stakeholders representing varying industries, communities, governments and specific interests from across the region to ensure the plan was community-led and regionally specific.

3. An action plan: that presents priorities, actions and implementation pathways across a range of future climate scenarios to guide the region in building water security and addressing drought resilience.

This Drought Vulnerability Assessment (DVA) has been informed through a desktop review of historic and likely future drought related impacts, an assessment of water resources, availability and scarcity across the region and anecdotal evidence gathered during consultations that identifies the region's perceptions and lived experience.

This document is a supporting document for the Goldfields-Esperance Regional Drought Resilience Plan and was compiled to serve as an evidence base for the findings of the Plan. The document should be read in the context of the FDF's, Regional Drought Resilience Planning program, and in conjunction with the Goldfields-Esperance Regional Drought Resilience Plan.

Defining Drought and Water Security

To appropriately assess the region's vulnerability to drought, regionally specific definitions of drought and water security were developed. These definitions are informed by other nationally accepted terminologies, including the Australian Government's definition of water security, the Bureau of Meteorology and the *Defining Drought in Western Australia,* report produced by Curtin University (Mastrantonis 2022) (Aither 2023) (Bureau of Meteorology 2024).

The proposed definitions were tested with the Plan's project advisory group and the Goldfields Voluntary Regional Organisation of Councils (GVROC) to ensure the phrasing resonated with stakeholders' lived experiences of drought and understanding of water security challenges. The definitions were also tested to ensure alignment with and support of the visions, aspirations and objectives of the Plan.

WATER SECURITY HAS BEEN DEFINED BY THE REGION AS:

"Ensuring that needs for water – encompassing quantity, quality, and affordability and access – can be met, over time and under changing supply and demand profiles. And, that this is achieved by investment coordination and operations that are economically efficient, financially and environmentally sustainable, culturally appropriate, and resilient to shocks."

DROUGHT HAS BEEN DEFINED BY THE REGION AS:

"A prolonged period of abnormally dry conditions that negatively impacts on water availability in a region and, consequently, affects the economy – including missed opportunities for growth – and environment of the region, and the health and well-being of its residents."

Defining what drought and water security looks like for the region helps assess the region's vulnerability and resilience to future climates. Stakeholders were asked to reflect on what a resilient region looked like in the context of these definitions, where liveability and opportunities for growth were highlighted as key components of the region's resilience.

Approach

The resilience assessment has been undertaken using an approach aligned with the Drought Vulnerability Assessment (DVA) requirements of the RDRP process (Figure 1). Definitions used in this framework are aligned with the Intergovernmental Panel on Climate Change (IPCC) and WA's Climate Adaptation Strategy.

EXPOSURE: the degree to which region and priority area/theme is affected.

SENSITIVITY: the degree to which region and priority area/theme is harmed.

IMPACTS: described as a consequence of exposure and sensitivity.

ADAPTIVE CAPACITY: capability and capacity to adjust and manage impacts.

VULNERABILITY: summary risk assessment considering exposure, sensitivity & adaptive capacity.

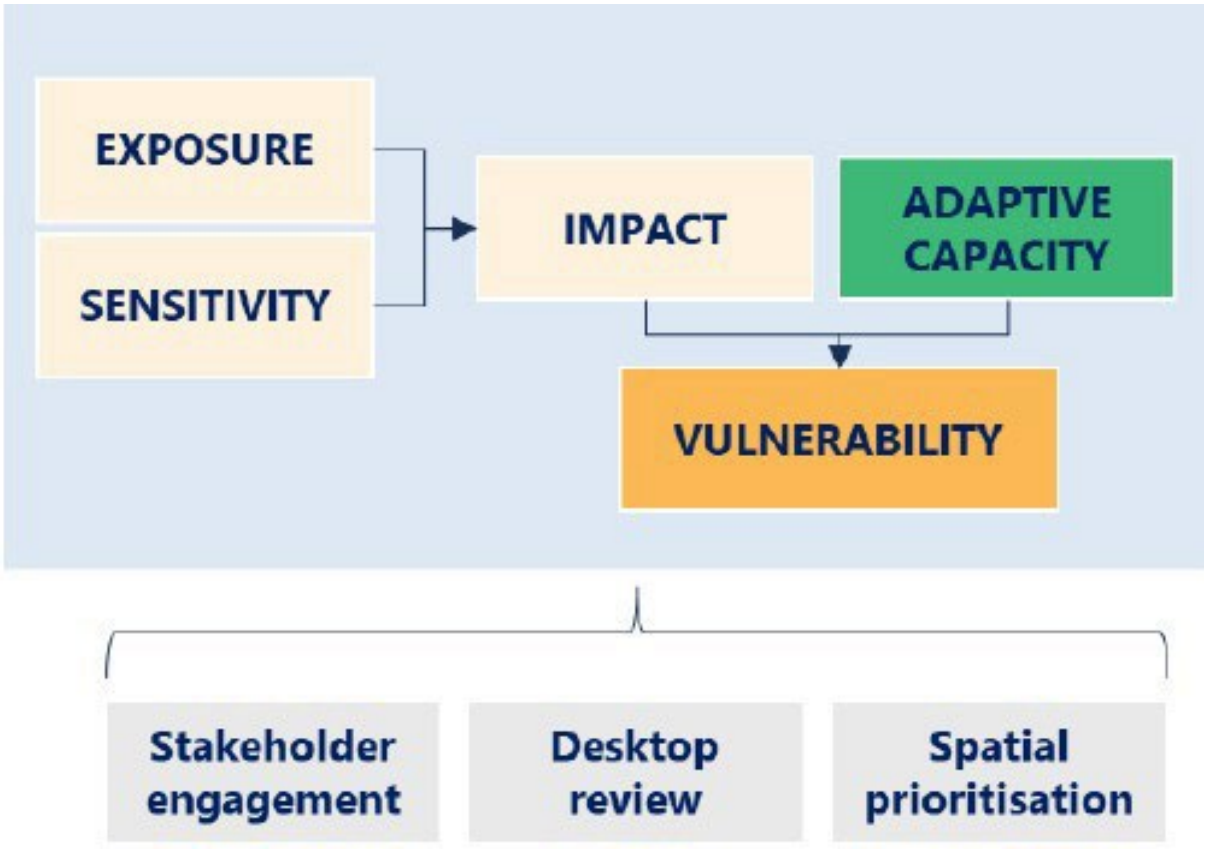


Figure 1.Conceptual overview of the resilience assessment framework developed in the pilot round of the Regional Drought Resilience Planning program in Western Australia developed by DPIRD.

The resilience assessment has been undertaken at both a regional and sub-regional level (Figure 2). Resilience was assessed for six key sectors affected by water security and drought in the Goldfields-Esperance region, as agreed to by stakeholders through the consultation process. The six sectors are:

- **MINING**
- **PASTORAL**
- **REMOTE COMMUNITIES**
- **COMMUNITY WATER SUPPLY**
- **CONSERVATION AND LAND MANAGEMENT**
- **BROADACRE**

A summary vulnerability assessment has been included for each sector that identifies the key components at risk, and ranks their exposure, sensitivity, adaptative capacity, and vulnerability. This vulnerability assessment is used to inform the actions presented in the RDRP. A description of the stakeholder engagement process undertaken to inform the vulnerability assessment is also provided in the Plan.

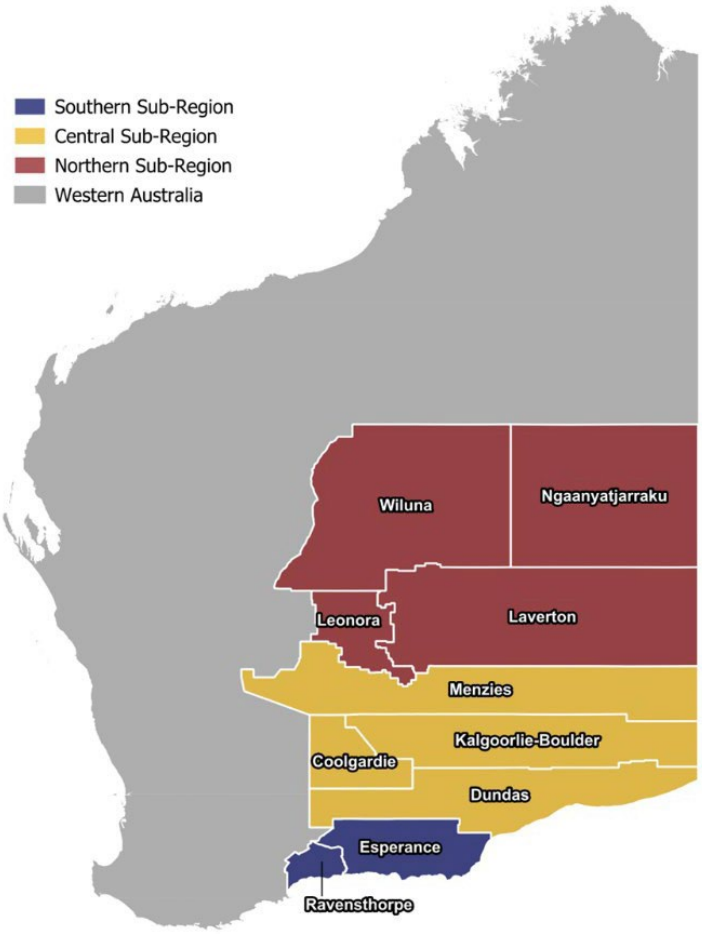


Figure 2. Sub-regional boundaries of the Goldfields-Esperance Regional Drought Resilience Plan.

Exposure

The following sections describe the overall exposure of the Goldfields-Esperance region to key climate hazards that contribute to drought and water security risk:

- long-term changes in average annual rainfall
- increasing drought severity
- increasing temperatures

Climate projections are simulated based on a multi-model different combination of regionally downscaled climate models and Representative Concentration Pathways (RCPs)[1]. Rainfall and temperature projections are based on four input General Circulation Models (GCM) under RCP 4.5 and RCP 8.5[2] emission scenarios that have been corrected and scaled ready for use in applications. These models include:

- ACCESS 1.0
- CNRM-CM5
- GFDL-ESM2M
- MIROC5

Data and products have been sources from CSIRO and the Bureau of Meteorology (BoM) through the Climate Change in Australia platform[3]. These are part of the CMIP5[4] suite of climate models as hosted by CSIRO. Selection has been informed by the Department of Water and Environmental Regulation (DWER) Guide to future climate projections for water management in Western Australia[5]. They represent broadly, likely modelled future scenarios from a hotter and drier future to a relatively warmer and wetter future.

Regionally corrected and downscaled data, to a resolution of 5km^2, has been processed against a climate baseline, representative of a current scenario. This, for the data source, was for a 1981 to 2010 30-year period as sourced from the BoM and their Australian Gridded Climate Data and as supplied through the Climate Change in Australia platform.

The figures in the following section describe the 50th percentile point from the multi-model combination.

---

[1] Scenarios of future greenhouse gas and aerosol concentrations, together with land use change, are known as representative concentration pathways

[2] RCP 4.5 represents medium future concentrations while RCP 8.5 is very high future concentrations, now considered an unlikely worse case pathway

[3] CSIRO and Bureau of Meteorology, Climate Change in Australia website (http://www.climatechangeinaustralia.gov.au/)

[4] CSIRO and Bureau of Meteorology 2015, Chapter 9: Using Climate Change Data in Impact Assessment and Adaptation Planning in Climate Change in Australia Information for Australia's Natural Resource Management Regions: Technical Report, CSIRO and Bureau of Meteorology, Australia

[5] https://www.wa.gov.au/system/files/2024-09/guide-to-future-climate-2024.pdf

Current Climate

The Goldfields-Esperance region is affected by a range of climate drivers and frontal systems, leading to diverse conditions between the north and the south of the region.

The southern sub-region is dominated by winter rainfall and cool climates. In the more coastal areas of this part of the region, rainfall is relatively consistent, providing ~600mm of annual rainfall on average, mostly falling between April and October (Figure 4). Temperatures fluctuate between 17 and 26 degrees across the year, occasionally reaching above 35°C for approximately 11 days per year on average (Figure 3) (CSIRO and Bureau of Meteorology 2015).

In contrast, the central and northern sub-regions are relatively dry, with extreme heat days being a common experience and the majority of rainfall occurring over the summer months. Rainfall in these areas is typically low, averaging between 200 to 300 mm annually but often reaching as low as 120 mm (Grower Group Alliance 2022). Rainfall averages in these regions are skewed by occasional high rainfall years that can reach over 500 mm.

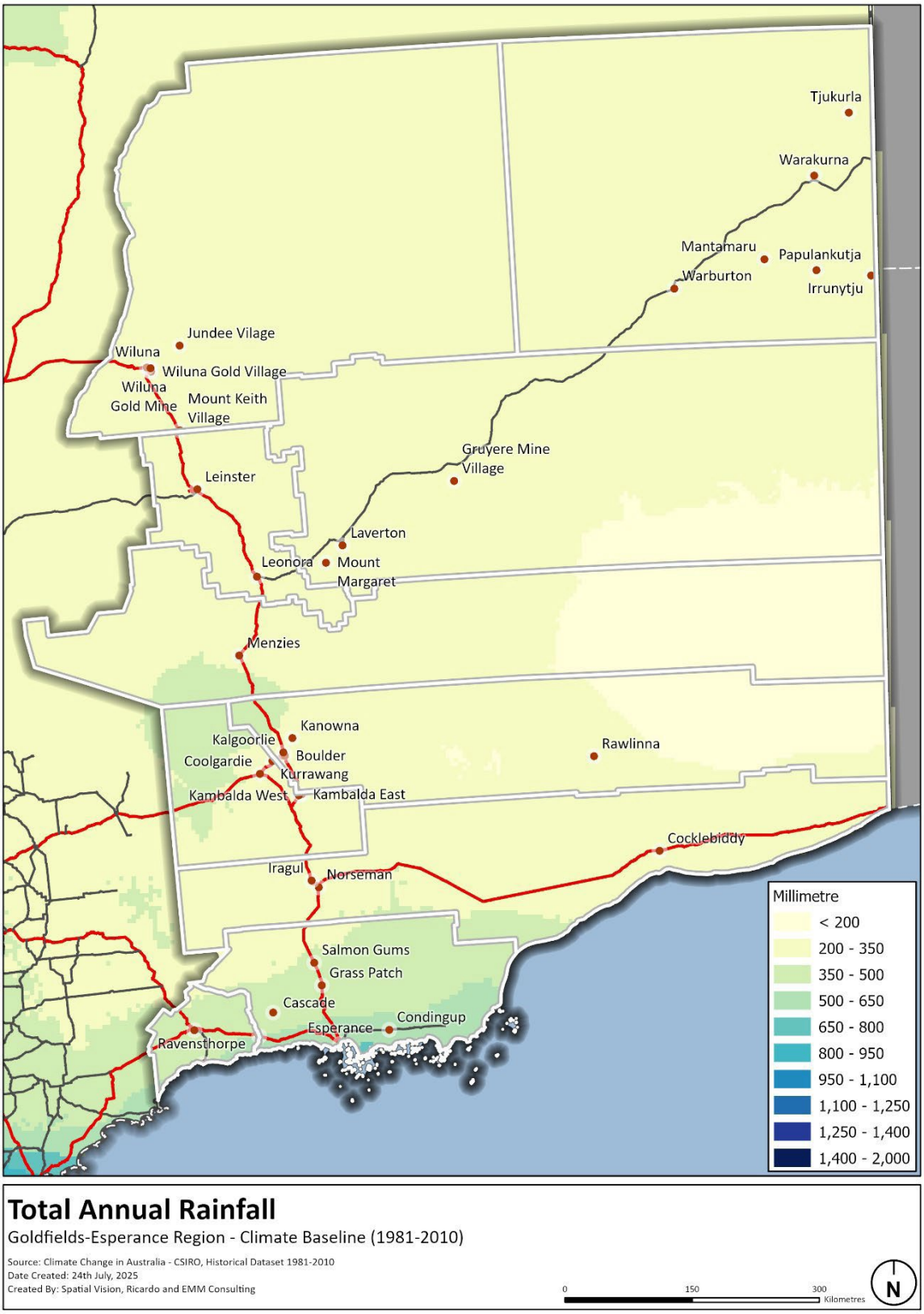


Figure 3. Total annual rainfall across the Goldfields-Esperance region of Western Australia from historic baseline 1981 – 2010. Sourced from: CSIRO.

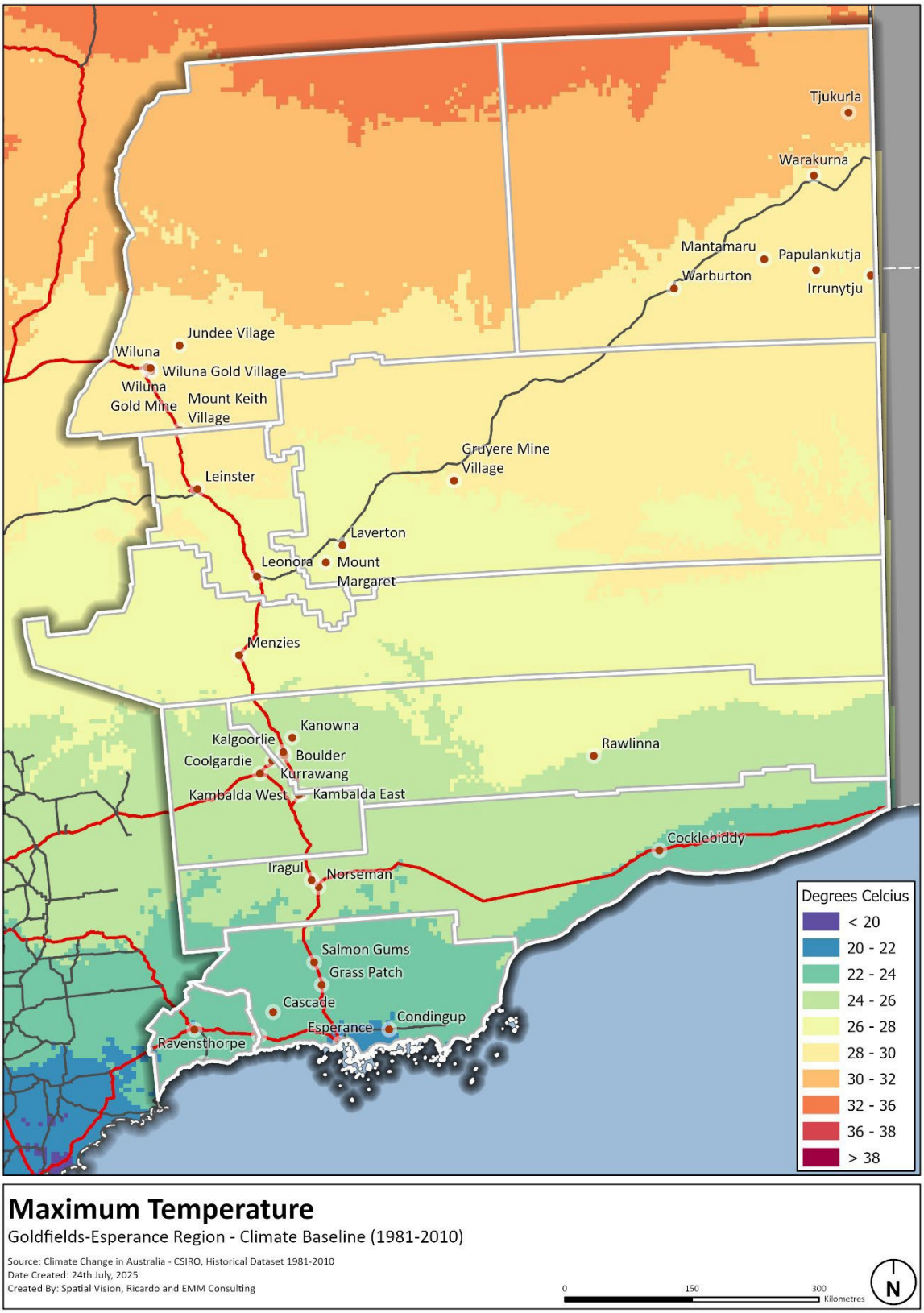


Figure 4. Maximum temperature across the Goldfields-Esperance region of Western Australia from historic baseline 1981 – 2010. Sourced from: CSIRO.

Climate Projections

Changes to Average Annual Rainfall

Under the modelled approach[6] changes in average annual rainfall will vary across the region, ranging from 20 – 30% declines in the southern sub-region to 10 – 20% increases in the north-east of the region (Figure 5).

The southern sub-region, particularly the south-west, is expected to experience a 10-20% decrease in average annual rainfall by 2050, representing a 50mm to 100mm decline. The decline in annual rainfall is already impacting the broadacre agricultural community who are observing “lighter, patchier and less reliable rainfall,” events that are failing to convert to runoff in on-farm and community dams (Goldfields-Esperance Development Commission 2024).

A small increase in average annual rainfall is expected in the remote north-east of the region, whereas minor changes are expected in the remainder of the northern and central sub-regions. The lived experiences of stakeholders reflect these rainfall projections, with stakeholders citing concerns over the increased frequency and intensity of short-lived but high-volume rainfall events, particularly those driven by cyclones in the north of the state.

The whole region could likely experience a 20-30% decline in average rainfall, impacting shallow aquifer recharge, natural surface water resources, and the efficacy of surface water storage options such as dams into the future.

[6] A multi-model combination at a median 50th percentile point

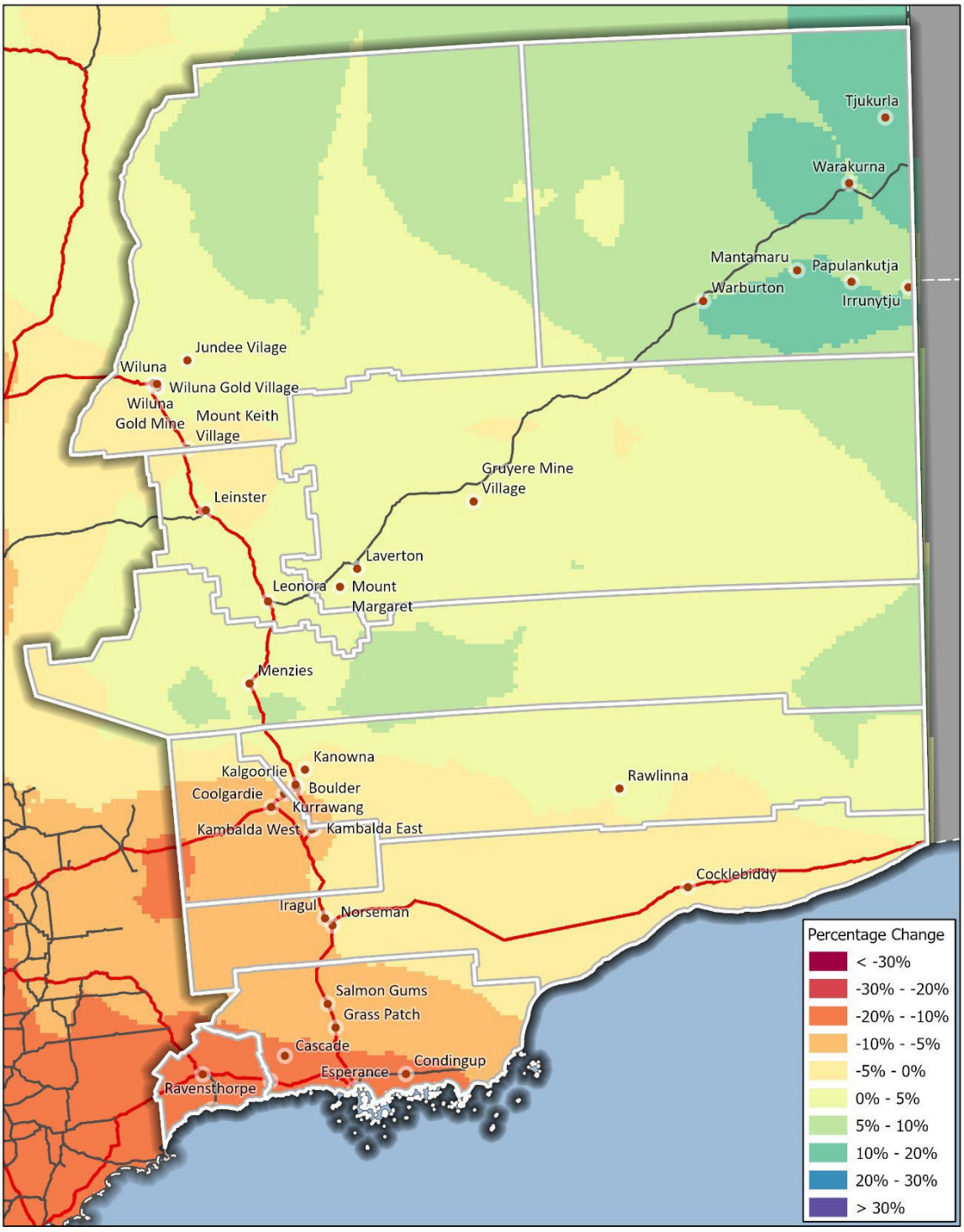


Figure 5. Percent change in average annual rainfall across the Goldfields-Esperance region of Western Australia from historic baseline (1981 – 2010) to 2050. Sourced from: CSIRO.

Changes to Drought Severity and Frequency

Changes in total annual rainfall closely align with expected changes in drought severity across the region. In this document, drought severity is defined by the amount of rainfall that falls in an area in the driest 10% of years (decile 1 rainfall years) within a historical baseline and into likely climate futures. The application and definition used in this report aligns with applications within Defining Drought in Western Australia[7] and through BoM[8].

Communities in the southern sub-region are expected to receive 20 to 40 mm less rainfall during decile 1 rainfall years (Figure 6). Under a hotter and drier climate scenario, for example, Esperance could experience up to 150mm less rainfall in drought years.

Isolated parts of the central and northern sub-regions are also expected to experience more severe droughts with an expected decline of around 10 – 20mm from a historic decile range. The frequency of droughts (compared to a 1981-2010 baseline) is also expected to increase across most of the southern sub-region and around Kalgoorlie-Boulder.

As communities in the northern and north-eastern areas of the region may likely experience an increase in annual average rainfall (Figure 5) it is also expected that drought severity for these areas could lessen, potentially providing an additional 10 – 20mm in the driest years (Figure 6).

[7] Mastrantonis, S. (2022). Defining Drought in Western Australia. Centre for Crop and Disease management, School of Molecular and Life Science, Curtin University, Bentley, WA.

[8] http://www.bom.gov.au/climate/drought/#tabs=Summary

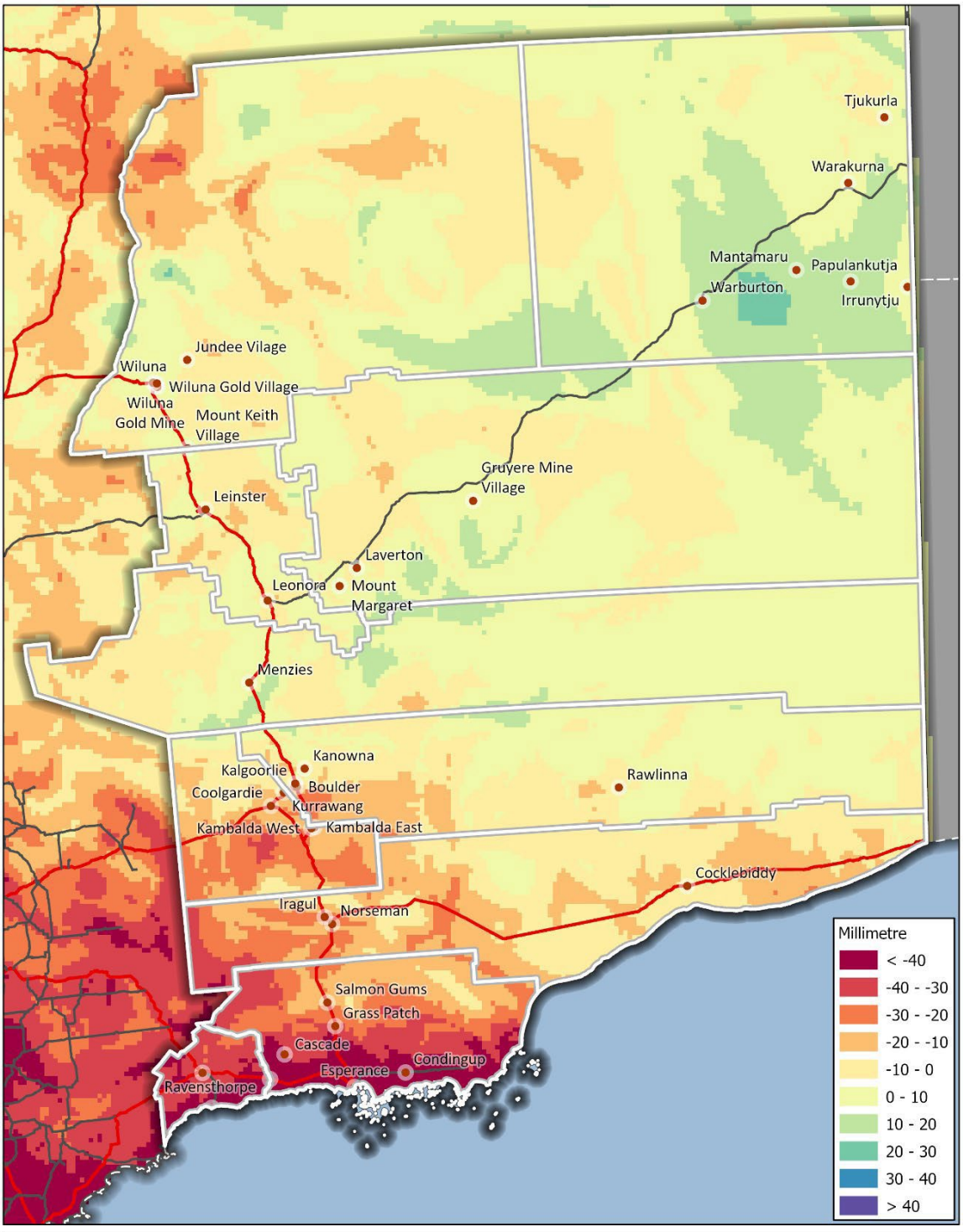


Figure 6. Change in drought severity (change in rainfall in lower 10% of years) across the Goldfields-Esperance region of Western Australia from historic baseline (1981 – 2010) to 2050. Sourced from: CSIRO.

Increasing Temperatures

Across the region, the hottest 1% of days are expected to increase in temperature by around 1-2°C, leading to more extreme heat days where maximum temperatures will exceed 35°C. Communities in the north and north-east will be the most affected, with the number of extreme heat days expected to increase by 30 – 40 per year (Figure 7).

The central sub-region will experience an increase of up to 30 more extreme heat days per year, whilst the southern sub-region will be mostly unaffected, with only around an additional 5 – 10 extreme heat days per year (Figure 7).

Higher temperatures are likely to increase demand for water in towns and on farm during droughts. Hotter, drier summers may also contribute to increased bushfire risk in grass and shrublands that are prevalent across the region, as well as health and welfare risks relating to heat stress particularly for those living in the northern sub-region.

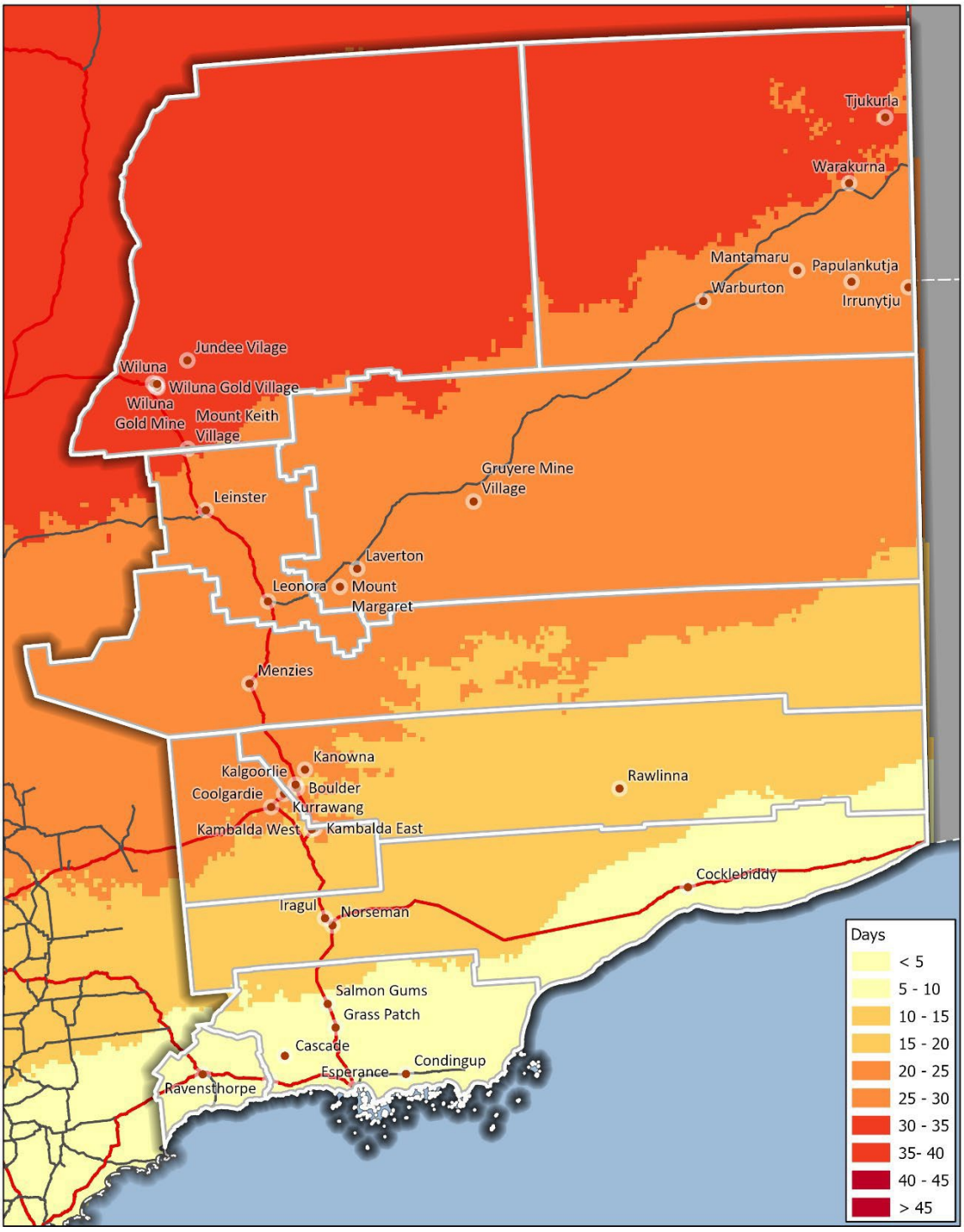


Figure 7. Change in the number of days above 35°C across the Goldfields-Esperance region of Western Australia from historic baseline (1981 – 2010) to 2050. Sourced from: CSIRO.

Water Resources

Water resources in the Goldfields-Esperance region include extensive and important sources of both potable and non-potable water. Potable water supply in the region is predominantly sourced from a large network of groundwater resources. The primary exception are those areas connected to the Goldfields Agricultural Water Supply Scheme (GAWSS). Non-potable water is an important supply of water across the region and includes recycled wastewater schemes and stormwater capture and use.

The GAWSS

The GAWSS sources water from Mundaring Weir in Perth and services customers across the Wheatbelt and central Goldfields, including Kalgoorlie-Boulder, Coolgardie, Menzies and Norseman (Figure 8). The GAWSS, operated by the Water Corporation, supplies ~28,000 ML/year of potable water across 9,601km of water mains. Across the Wheatbelt and Goldfields-Esperance regions the scheme supplies more than 100,000 residential customers (36%), agriculture (19%), mining (22%) and other enterprises (23%) (Water Corporation n.d.).

The scheme is connected to Perth's Integrated Water Supply System which can draw on groundwater, recycled water, and seawater desalination in addition to surface water in Mundaring Weir if needed (Department of Planning; WA Planning Commission 2015).

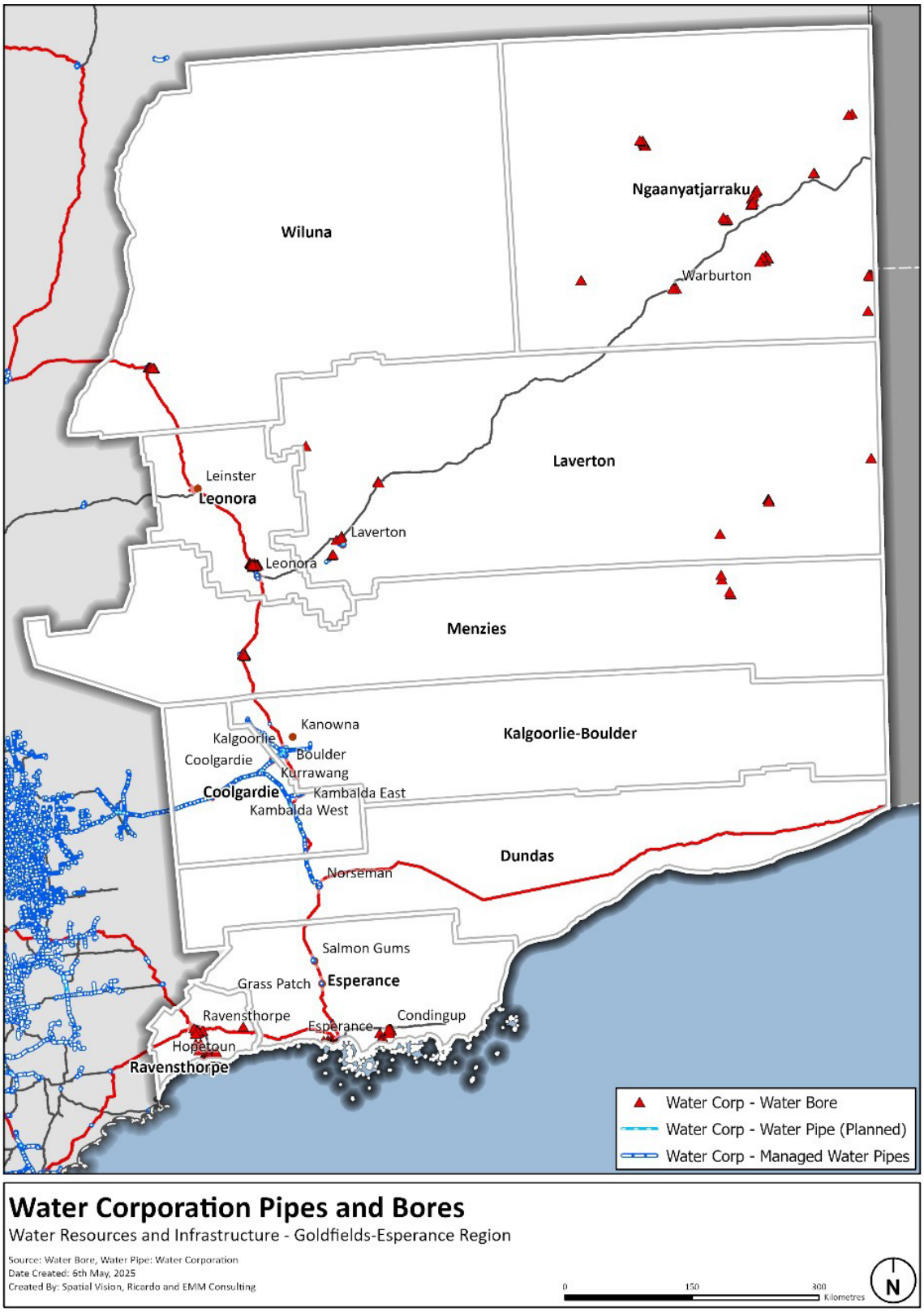


Figure 8. Water Corporation owned assets across the Goldfields-Esperance region of Western Australia. Sourced from Water Corporation

Groundwater

Groundwater is the primary potable water supply for towns and industries outside of the central goldfields, including Ravensthorpe, Esperance, Leonora, Laverton, Wiluna and the communities across the Ngaanyatjarra Lands and eastern parts of the central goldfields (Figure 9). Bores accessing shallow aquifers and deep paleochannels are common where towns, mines and pastoral stations are located and are often coupled with desalination or reverse osmosis units where groundwater is too saline.

Surface Water

Surface water resources are scarcely utilised throughout much of the region, inhibited by inconsistent or low rainfall patterns and high evaporation rates particularly in the central and northern goldfields. However, surface water assets, primarily captured in dams are an integral resource in the Esperance and Ravensthorpe Shires where broadacre enterprises and associated rural communities exist.

The pastoral industry accesses a mix of surface and groundwater resources, informed by local conditions and resource availability.

Non-Potable Resources

Non-potable water supplies are highly dependent on the local context across users and landscapes of the region. In larger population centres, wastewater treatment and stormwater capture and reuse have been used for a number of years.

Barriers to the adoption of non-potable water alternatives have left many communities and industries of the region reliant on potable water supplies for non-potable activities. Access to and use of non-potable water supplies is an important opportunity to increase water security access the region.

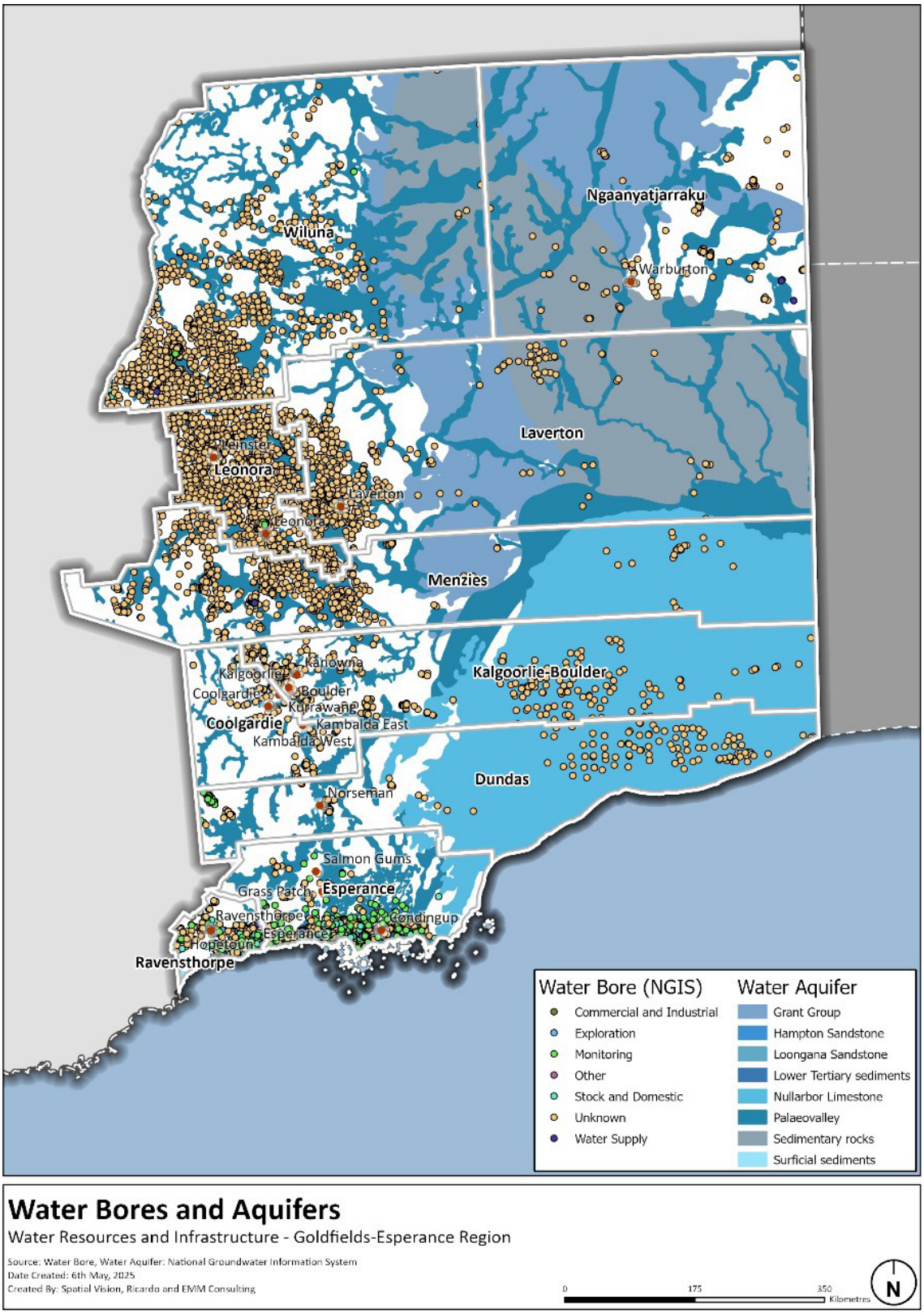


Figure 9. Groundwater bores and resources across the Goldfields-Esperance region of Western Australia. Sourced from the National Groundwater Information System.

Vulnerability

A vulnerability assessment is provided for each sector with findings applied to sub-regions. A high-level summary of key findings from the sector resilience assessment is provided in Table 1 below.

Table 1. Summary of the Goldfields-Esperance regional drought vulnerability assessment by sector

Sector	Exposure	Sensitivity	Adaptive Capacity	Vulnerability
Mining	Mines in the central sub-region will be exposed to declining annual average rainfall, with opportunistic summer rainfall. Mines in the northern sub-region are likely to experience longer extended dry periods broken by short intense rainfall events.	Most water dependent sources used for mining activities (deep and extensive paleochannels) are not sensitive to changes in rainfall, temperature or potential drought occurrences.	As water security is generally dealt with up front through the identification of secure water there is little need for ongoing capacity to address changes in water supply.	Drought periods are unlikely to significantly impact the mining industry directly. There are other water security vulnerabilities that stem from drought which require mines to manage the degree to which mining water use interacts or is perceived to interact with other water sources or water dependent values.
Pastoral	Pastoralists in the west of the central sub-region (Nullarbor) and the northern sub-region are likely to be exposed to more severe droughts and reductions in long-term average rainfall.	Severe droughts and extreme heat will affect pastoralists' ability to meet stock watering requirements, particularly if they have limited groundwater resources or rely on shallow aquifers.	Access to emergency water resources and adaptive farm management strategies are limited by pastoralists' remoteness and capacity.	Greater drought exposure will limit grazing availability and increase the vulnerability of pastoral land to long-term degradation.
Remote communities	Remote communities are already exposed to significant water related risks. In the arid north region where these communities are located, climate change is expected to lead to increased rainfall and decreased drought severity. However, it is unclear what affect this will have on the groundwater supplies these communities depend on. Increased rainfall may also lead to flood impacts, including risks to critical transport infrastructure	Remote communities have a high sensitivity to water-related stress, compounded by other sensitivities including poor health outcomes, social connectivity and local economic opportunities.	Remote communities are some of the most socio-economically disadvantaged in the Goldfields-Esperance Region - climate risks are likely to compound these disadvantages and have a negative impact on liveability. Water Corporation's Aboriginal Community Water Supply Program is supporting adaptive capacity through the provision of water services to remote Aboriginal communities and progressing infrastructure upgrades to deliver safer and more reliable water services.	Infrastructure uplift is critical to address water quality issues from contaminants and salinity issues and improve the condition and suitability of existing infrastructure. Significant investment and planning are required to improve infrastructure.

Community Water Supply	Towns will experience increased supply pressure from a hotter, drier climate as well as increased demand in line with projected population and economic activity growth. This presents a key risk to water supply in the Esperance area, driving reduced groundwater recharge and saline intrusion risks to coastal aquifers and putting pressure on treated wastewater to supply economic activity, parks, gardens and schools.	A hotter, drier climate will increase water supply and quality issues in small communities in the southern sub-region with limited groundwater and high reliance on rainfall. The Esperance area also remains vulnerable to these climatic effects. Water supply and quality is a challenge for multiple small towns dependent on local groundwater and with limited freshwater sources, sporadic recharge, and declines in the availability of high-quality groundwater. Water carting is already required to supply potable water to some of these communities on a regular basis.	Significant infrastructure investment is needed to increase adaptive capacity to drought. Improvements to sewerage and wastewater infrastructure are needed to increase use of recycled water and stormwater.	Town water supply arrangements have been developed to manage some drought, high temperature and variable rainfall conditions. However, infrastructure uplift is necessary to adapt to future, increasing and sustained variable rainfall and high temperatures. More frequent, extended and severe droughts will put demand pressure on the key supply schemes of GAWSS and Esperance, and on wastewater and storm water supplies used for non-potable uses as other availability of other climate sensitive sources is reduced.
Conservation and land management	There are large areas of conservation reserves, indigenous protected and/or managed areas and Unallocated Crown Land (UCLs) across the region that are naturally adapted to drought, but climate change may mean significant changes to these asset's condition.	More prolonged and severe droughts can impact fire regimes, particularly in the central and southern sub-region, and demonstrate a dependency on sufficient water access to maintain and protect critical infrastructure, and environmental and cultural assets. Increasing severity of large rainfall events in the northern and central sub-regions can impact runoff and recharge cycles and may contribute to erosion and landscape degradation. Water insecurity and landscape degradation in culturally significant areas impact Aboriginal communities' ability to maintain traditional land management practices and connection to Country.	Adaptive land management is key to building landscape resilience.	Managing long-term climate variability is important for sustainability across land areas during drought and as climate changes.

Broadacre	Broadacre farming in the southern sub-region will be highly exposed to reducing average rainfall and increasing drought severity	Farmers in the far north of the southern sub-region near Salmon Gums and in the far west near Ravensthorpe will be the most sensitive to increased drought risk. These areas already receive relatively low rainfall and have lower yield potential than farming areas in higher rainfall zones closer to the coast. Livestock producers in the low rainfall areas will be more sensitive to reduced rainfall with increased demand for fodder and water for animal welfare.	Broadacre producers generally have high adaptive capacity with a range of opportunities to improve the water efficiency and resilience. Prioritisation of and investment in adaptive capacity measures is impacted by a range of factors including availability of capital.	Broadacre is highly susceptible to drought with seasonal reliance on rainfall to achieve seasonal crop yields and maintain healthy stock. Farmers in the north and west of the southern sub-region are expected to be particularly vulnerable to future droughts due to high exposure, high sensitivity and reliance on external emergency water resources.

Mining

Summary

- Mines in the central sub-region will be exposed to declining annual average rainfall, with opportunistic summer rainfall. Mines in the northern sub-region are likely to experience more extended dry periods broken by short intense rainfall events.
- Drought periods are unlikely to significantly impact the mining industry because most water dependent sources used for mining activities (deep and extensive paleochannels) are not sensitive to changes in rainfall, temperature or potential drought occurrences.
- Water security is generally dealt with up front through the identification of secure water resources, so there is little need for ongoing capacity to address changes in water supply.
- There are likely to be water security vulnerabilities for other regional water users which require mines to manage how mine water use interacts, or is perceived to interact, with other water sources or water dependent values.

Sector Overview

Western Australia is consistently ranked as one of the most attractive mining jurisdictions in the world, with the largest, rare-earth deposits outside of China, abundant gold and nickel resources and significant lithium and cobalt deposits (Mejia and Aliakbari, 2023). It is a critical industry for supporting the regional economy and providing opportunities for growth.

The recent nickel industry downturn illustrates some of the economic and social challenges that the region can face because of its reliance on mining activity. Equally

however, there are numerous emerging opportunities that will leverage changing demand for different types of commodities.

Water supply has been a challenge for mining in this arid region ever since gold was first discovered in the 1890s and the Goldfields Pipeline (now the Goldfields and Agricultural Region Water Supply Scheme) was constructed to replace water condensers, irregular rainfall events and water trains.

Exposure

Water is used throughout the mineral exploration and mine operation stages, for mineral processing, dust suppression, dewatering and camp water use. Water for mining is almost entirely self-supplied using local groundwater aquifer resources. The total annual licensed volume was 123 gigalitres in 2021, an increase of 15% from 2013 (DWER, unpublished data).

The main water sources for mining activities comprise of mine dewatering from mineralised fracture zones within the region's greenstone belts, and supply abstraction from extensive paleochannels that are found throughout the northern and central sub-regions.

Paleochannels are large, deep, water resources with varying water quality (fresh to hypersaline) that have sustained much of the industry's water supplies for decades. Research and development have allowed the industry to develop innovative new treatment processes to better utilise saline water supplies, such as in the process of gold separation. Significant volumes of water are also recycled in mines, through the processing plant and from tailings.

Other smaller or supplementary freshwater requirements may be met from local calcretes and alluvials, however these resources are typically very limited in the volume they can yield. These freshwater supplies are often important resources for stygofauna and riparian vegetation, and as such are generally avoided by mining companies.

Mines located in the central sub-region are likely to be exposed to declining annual average rainfall, with opportunistic summer rainfall. Mines located in the northern sub-region are likely to experience longer extended dry periods broken by short intense rainfall events. Some water is also provided to mines in the central sub-region primarily for mineral processing through Water Corporation's GAWSS. The GAWSS is climate independent so mines using this water source are not exposed to drought risks.

Sensitivity

Mining operations are generally not sensitive to the effects of drying conditions. The dominate water resource, deep paleochannels, are relatively climate independent, as is the GAWSS that some mines may access. It is likely that management of surface water impacts from floods is more of an issue than drought.

Industry stakeholders have identified the use of paleochannel water resources as a key water security strategy, given they are deep, confined and not affected by drought

periods. The paleochannels' poor water quality means they are also a fit for purpose source generally not used by other local users.

Sensitivity to drying conditions may change in the long term if depletion of these aquifers becomes an issue, and climatic variability and drought conditions compound. Areas where the channels are shallow may be more sensitive to depletion in the long term, if the central, deeper areas around Coolgardie and Laverton are overused. There is currently no clear regional picture of the status of these water resources despite extensive localised monitoring and management being carried out by mining companies. Understanding the region's water resources such as hydrology patterns, recharge and extraction demand will support water use decision-making for stakeholders into the future.

Mining, particularly in the northern and central sub-regions, is highly influential in how water security is perceived by stakeholders. Stakeholders identified the development of new mines as a major trigger influencing changes in their priorities. There are high levels of uncertainty among stakeholders in how mines influence their access to water both now, and into the future. The industry must manage the degree to which mining water use interacts or is perceived to interact with other water resources and users. This includes community, pastoralists and local government, who typically rely on access to the smaller, shallower and fresher water resources which can be influenced by abstraction in deeper paleochannels. Stakeholders consulted for this plan identified huge water and non-water related opportunities for collaboration with mining companies. However, stakeholders lack clarity in knowing how to negotiate public benefit outcomes with new or existing mining projects when actions from mining companies are largely voluntary.

The interactions between mining and other water users has been explored in localised contexts in the northern Goldfields. The Water Resources Situational Analysis of the northern Goldfields, conducted in 2023 was an important piece of work that highlighted this challenge (Curtin University; Umwelt 2023). Local stakeholders have observed changes in the surface environment such as pool water levels, vegetation condition and spring flow that may result from changing climatic conditions, mining activities or both.

Stakeholder consultation suggest there are opportunities for improved information transparency between the mining industry and community to better understand water security implications and licensing arrangements. Building transparent and collaborative relationships between industry and communities is seen as an important factor in mining's water security.

Adaptive Capacity

As water security is generally dealt with up front through the identification of secure water sources (in most cases paleochannels) there is little need for ongoing capacity to address changes in water supply. Mining operators generally plan for and are issued enough licensed water to account for contingencies in the event of increased demand associated with drought conditions such as increased dust suppression or greater evaporation of tailings water. Although rarely accessed there are also opportunities to

take unused water at neighbouring mines (depending on their location) or water stored in pits either from dewatering or rainfall. Stakeholders also identified research opportunities for local government to access and use historical mine pits.

Adaptive capacity is important in managing potential impacts, reducing costs over time, and continuing to demonstrate that best practice water management is happening, and water is not being wasted.

Vulnerability

Overall, droughts and increasing dry conditions are unlikely to significantly impact the mining industry directly (Table 2). There are however other vulnerabilities in relation to water security which stem from the effect drought and other climatic changes are having on local environments and other stakeholders and water users in the region, and their concerns about long term sustainability of fit for purpose local water supplies.

Although there are limited users or dependent values of the aquifers accessed by mining companies, abstraction in these groundwater resources can impact local, shallow water resources, resulting in the drying up of bores and changes in water quality in some bores. If these challenges are not managed properly, mine operations can be affected through negative stakeholder relations and the impact this can have on compliance, approvals, and increasing corporate sustainability expectations.

Table 2. Mining sector drought vulnerability assessment

Element at Risk	Exposure	Sensitivity	Adaptive Capacity	Vulnerability
Groundwater Dependent Mines in the central sub-region	Moderate exposure to increasing drought severity. Low exposure to mines who get water provided through GAWSS.	Low sensitivity Use of saline water from deep, climate independent sources	Moderate adaptive capacity Effective planning	Low
Groundwater Dependent Mines in the northern & southern sub-region	Moderate exposure to increasing drought severity.	Low sensitivity Use of saline water from deep, climate independent sources	Moderate adaptive capacity Effective planning	Low
Deep paleochannel supplies	Moderate exposure to decreasing rainfall	Low sensitivity Deep and extensive climate independent reserves	Adaptive Capacity unknown	Low
Shallow paleochannel supplies	Moderate exposure to decreasing rainfall	Low sensitivity Climate independent reserves (extraction of deep paleochannels can influence)	Adaptive Capacity unknown	Low – Moderate

Pastoral

Summary

- Pastoralists in the west of the central sub-region are likely to be exposed to more severe droughts and reductions in long-term average rainfall. Pastoralists in east of the central sub-region (Nullarbor) and the northern sub-region may also be exposed to these risks.
- Greater drought exposure in combination with grazing pressure will increase the vulnerability of pastoral land to long-term degradation. This has been demonstrated by recent dry conditions across the Southern Rangelands.
- Severe droughts and extreme heat will affect pastoralists' ability to meet stock watering requirements, particularly if they have limited groundwater resources or rely on shallow aquifers.
- Access to emergency water resources and adaptive farm management strategies are limited by pastoralists' remoteness and capacity to invest.
- Many pastoralists may need to reduce stocking rates over the long-run due to a combination of the above factors. However, most pastoralists have access to diversified income streams which may reduce financial impacts.

Sector Overview

The northern and central sub-regions are some of the largest areas of pastoral activity in the state and are home to around 20% of the registered pastoral stations in WA (85 out of 434) (Grower Group Alliance 2022). This highlights the large stewardship responsibility that pastoralists have across the region and state.

Stocking rates are low in comparison to the southern sub-region due to the difficulties of operating in an arid environment (Department of Primary Industries and Regional Development 2018). The potential carrying capacity (PCC) of pastoral land in the northern and central sub-regions can range between 5 and 20 hectares per dry sheep equivalent (DSE) depending on pasture type (Waddell, et al. 2023).

Pastoralists in the region own a mix of cattle and sheep. In the west of the region in the pastoral land use zone in the Goldfields, cattle are the most common animal, whereas sheep are more common in the Nullarbor pastoral areas. In recent years, the number of cattle has been increasing whilst sheep numbers have declined (Department of Primary Industries and Regional Development 2018).

Natural feed and pasture growth is controlled by rainfall and climate. The natural cycles that affect pastoralism are different between the north and south of the Goldfields-Esperance region, with pasture growth resulting mainly from summer rainfall in the north and winter rainfall in south. Pastoralists consulted for this plan identified water security as integral to business viability, and a key constraint to growth.

Exposure

Pastoralists in the region will be exposed to reductions in long-term average rainfall and further increases in temperatures. These changes will likely affect feed availability and animal health and welfare. Those in the northern and central sub-regions will be exposed to more severe droughts in particular (Figure 6). The projected increase in heavy rainfall and river flooding, and greater variability in weather and climate (more-intense rainfalls and variation between years) will also affect pastoralists.

Self-supply groundwater bores are the main water source for livestock and are abundant across all pastoral areas in the region (Figure 9). These bores access shallow alluvial, calcrete and water table aquifers that are directly recharged by rainfall. Groundwater resources in the central sub-region may be exposed to reducing average rainfall (Figure 5) and as a result bores may dry up more frequently.

Some pastoralists also have access to surface water resources (e.g. river pools) and small on-farm dams. These water resources are unreliable and tend to deplete quickly in drought conditions. More severe and frequent droughts in the northern and central sub-regions are likely to decrease the reliability of these water sources further.

Minimal emergency water provisions exist for pastoralists, and stakeholders identified that those driven to water carting is a last resort and not economically viable beyond the short term.

Sensitivity

Increasing drought severity

Pastoral land is highly sensitive to increasing drought severity which contributes significantly to lower land productivity. The 2023 assessment of landscape conditions and risk in the Southern Rangelands found that most of the pastoral areas in the northern and central sub-regions had total vegetation cover that was very much below average. Low vegetation cover was still occurring when stocking rates were only 50-60% of potential carrying capacity, which is relatively low by historic standards (Department of Primary Industries and Regional Development 2023). The assessment suggests that stocking rates in the Southern Rangelands are above the potential carrying capacity of pastoral land and likely require further downward adjustment to mitigate risk of deteriorating landscape condition.

Pastoralists generally have lower profit margins than broadacre enterprises in higher rainfall areas, making it more difficult for them to absorb reductions in land and stock productivity due to drought. ABARES farm modelling suggests that a typical farm in the northern and central sub-regions has a profit margin at full equity of $1/ha to $80/ha, compared to broadacre farms in the southern sub-region which can make up to $640/ha.

Pastoral businesses that are reliant on shallow aquifers for stock watering will be more sensitive to severe droughts that affect aquifer recharge. In the absence of adaptive management strategies, declining water yields from groundwater aquifers may require

pastoralists to destock if alternate water sources cannot be found. Stakeholders consulted for this plan noted that a number of pastoralists in the central sub-region have limited access to stock-quality groundwater due to salinity issues.

Increasing average temperatures

Heat stress can cause pain, injury, or death to livestock in extreme cases. Cattle are at high risk of heat stress at temperatures above 31°C, whereas sheep are at high risk at temperatures above 29°C (Department of Primary Industries and Regional Development 2022). Livestock are particularly susceptible to heat stress during transport and sale, and persons responsible for sheep or cattle can be held liable for health issues under the Animal Welfare Act 2002.

Risks to livestock from hot weather can exacerbate water availability issues. Sheep and cattle drink up to double the amount of water in hot weather and may require spraying and water cooling to manage heat load (Department of Primary Industries and Regional Development 2022).

Rising temperatures and altered rainfall seasonality will have variable consequences for pastoral lands and may contribute to habitat loss, affect vegetation and pastoral fodder sources, increase fire risk and impact access to water.

Communities reliant on pastoralism

A significant proportion of the working population in the relevant pastoral areas of the northern and central sub-regions are employed in an agricultural industry. These communities also tend to be relatively remote and have low adaptive capacity.

Adaptive Capacity

Pastoralists' capacity to adapt to drought risk is likely to be limited by poor individual capacity to invest or absorb reductions in land and stock productivity, isolation, information barriers, and poor access to alternate water sources. Stakeholders consulted for this plan suggested that many pastoralists have off-farm income streams to offset these risks, however those that aren't well diversified are likely to be highly vulnerable.

Alternative water resources

Pastoralists have access to a minimal range of alternative water resources in the event of drought. Some pastoralists will engage in water sharing arrangements with neighbouring farmers if their groundwater resources cannot meet their stock watering requirements. Stakeholders consulted for this plan suggested that on-farm dams and innovative solutions such as desalination for groundwater are generally not financially viable for pastoral stations. Stakeholders consulted for this plan suggested that new groundwater bores are likely to be a viable option for pastoralists. However, pastoralists generally do not have access to the specialist geophysical information and skillset required to successfully locate new groundwater resources.

There are a range of on-farm measures pastoralists can use to manage the impacts of drought. These include strategies to improve growth of desirable pasture species, pasture rotation, purchasing fodder, and supporting animal health by building shelters. Stakeholders consulted for this plan suggested that relatively simple management strategies, such as landscape condition monitoring with drones (away from station roads), can have a significant impact on the sustainability and productivity of pastoral land.

Financial capacity

Many of the adaptive water, land and stock management measures available to pastoralists come at a high cost. Stakeholders consulted for this plan stated that many pastoralists in the northern and central sub-regions have minimal access to capital and may not be able to bear these costs. Research published by MLA suggests that the long-term average earnings of many Australian pastoral businesses are near or below zero which may affect their ability to adapt (McLean, et al. 2018).

Comments from stakeholders consulted for this plan align with these findings. Stakeholders suggested that many pastoralists are struggling due to 6 years of drought and would not have the capacity for significant business investments. Some stakeholders also noted that grants and financial support are less accessible for pastoralists than broadacre farmers in the South-West.

Off-farm diversification is a critical strategy for pastoralists. Stakeholders consulted for this plan suggested that many pastoralists are well diversified and have reliable income streams from off-farm activities. A small portion of pastoralists are likely to be highly vulnerable due to poor diversification.

Access to collaboration and market opportunities

Remoteness is also a key barrier to adaptation for many pastoralists, particularly in the Nullarbor. Stakeholders consulted for this plan suggested that many pastoralists regularly travel thousands of kilometres to do business and attend industry events. Remoteness can affect a pastoralist's ability to access alternate water resources, share knowledge and resources with others in the industry, and access other services to support their mental, physical and financial wellbeing.

Destocking is a critical strategy for pastoralists who are unable to meet the water requirements of their herd. However, it is not always possible for pastoralists to destock during severe or widespread droughts due to a lack of demand and risk of heat stress during transport. Distance to market can also have a significant impact on the cost and feasibility of selling stock.

Vulnerability

Overall, pastoralists in the Goldfields are highly vulnerable to acute and chronic drought risks (Table 3). Pastoralists in the central sub-region will be most exposed to decreasing average rainfall, whereas pastoralists in the northern sub-region will be most exposed to increasing temperatures. Climate change may also lead to new risks to supply chains, infrastructure and biosecurity, increasing pastoralists vulnerability to climate change.

Sensitivity and adaptive capacity will vary based on individual circumstances. However, most pastoralists are likely to be highly sensitive and have low capacity to adapt. Pastoralists that rely on vulnerable water resources (such as shallow aquifers), have low profit margins, and are more remote are likely to be most vulnerable to increasing drought risk.

Table 3. Pastoral sector drought vulnerability assessment

Element at Risk	Exposure	Sensitivity	Adaptive Capacity	Vulnerability
Pastoralists across the Goldfields (western side of the central and northern sub-regions)	Moderate exposure to increasing drought severity. High exposure to increasing temperatures	High sensitivity. Landscape condition can deteriorate rapidly in drought conditions, some may not be able to absorb long-term financial losses. Significant animal welfare risks due to large increase in days above 35°C.	Moderate adaptive capacity. Some strategies will be available to offset drought risk, but they will not always be feasible	Moderate – High Vulnerability
Pastoralists across the Nullarbor (eastern side of the central sub-region)	Moderate exposure to increasing drought severity and increasing temperatures. Low exposure to decreasing average rainfall	High sensitivity. Some may be unable to absorb long term losses from more severe and frequent droughts	Low adaptive capacity. Highly remote, poor access to new water resources and financially constrained	High vulnerability

Remote Communities

Summary

- Climate change, particularly rising temperatures, will exacerbate existing water supply and quality issues in remote communities. While rainfall is expected to increase and drought severity to decrease across most remote community locations, it is unclear what affect this will have on groundwater supplies. Rainfall changes may also result in more extreme and unpredictable flood events which impact critical transport infrastructure.
- These remote communities are some of the most socio-economically disadvantaged in the Goldfields-Esperance Region and have a high level of sensitivity to water-related stress, compounded by other sensitivities including poor health outcomes, social connectivity and local economic opportunities. Climate risks are likely to compound these disadvantages and have a negative impact on liveability.
- Infrastructure uplift is critical to address water quality issues from naturally occurring contaminants and salinity issues and improve the condition and suitability of existing infrastructure. There are opportunities for significant investment and planning to improve and further develop fit-for-purpose infrastructure.

Sector Overview

Remote communities in the Goldfields-Esperance Region are situated in some of the most arid and water-scarce parts of Western Australia (Figure 10). There are 18 permanent remote communities located across the Goldfields with a significant proportion of the region's 6,000 Aboriginal and Torres Strait Islander people living at least part of the year in these communities, the largest of which is Warburton with a population of between 500 and 600 people (Department of Planning, Lands and Heritage 2019).

The scarcity of accessible, appropriate quality water in this region is exacerbated by the complexities of supplying very remote communities that are often only seasonally populated leading to variable demand.

Remote communities rely on local groundwater sources that generally occur in shallow calcrete, fractured rock and alluvial aquifers. These aquifers often contain naturally occurring nitrate and other contaminants and have varied but generally high salinity. Security of water supply and water quality from these groundwater sources is a long-standing and growing concern, and treatment is often needed to make them acceptable under Australian Drinking Water Guidelines.

In addition to naturally occurring salinity and contaminants, and concerns over salinity impacts from extraction (Curtin University; Umwelt 2023), water quality is also impacted by the condition and suitability of water infrastructure (such as bores located too close to septic tanks). Drinking water has been reported to be supplemented by bottled water due to the poor quality from some bores (Searson 2022).

Water Corporation has recently taken on responsibility for water services for remote communities under the Aboriginal Communities Water Services Program (ACWS). Important maintenance and monitoring services for remote water infrastructure involves Ngaanyatjarra Essential Services, an Aboriginal business with an equity focus which is currently funded through the Remote Area Essential Services Program (RAESP).

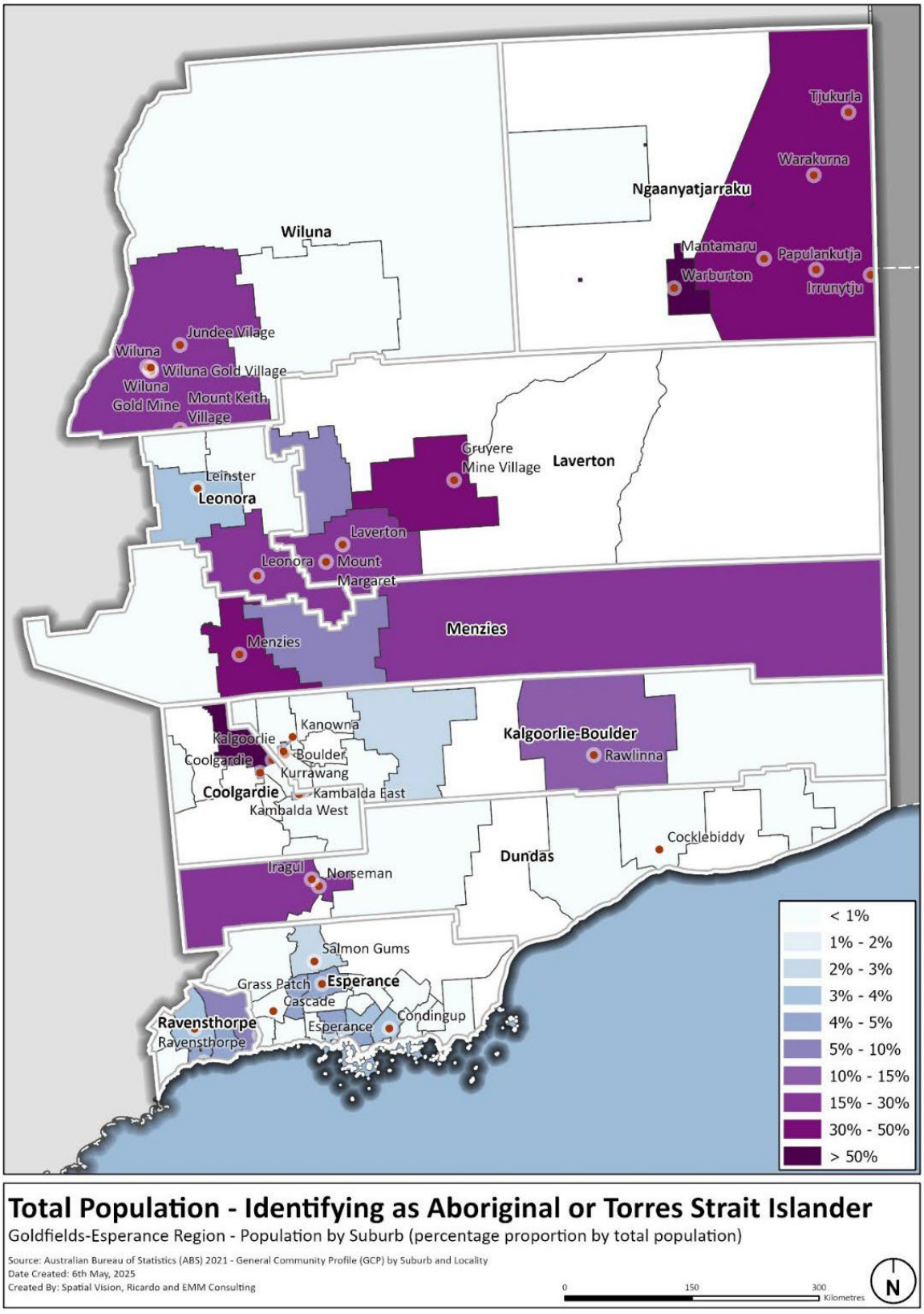


Figure 10. Total Population Identifying as Aboriginal or Torres Strait Islander in the Goldfields-Esperance region.

Exposure

The remote communities are located in desert climates where high temperatures, particularly in summer, are common. Heat events are likely to become more severe and frequent, which will increase demand on water supplies and will likely affect when, and for how long, seasonally populated communities are occupied (Figure 7). Rising temperatures will likely exacerbate existing concerns about water supply and quality (Department of Planning; WA Planning Commission 2015).

Unlike the rest of the Goldfields-Esperance Region, rainfall is expected to increase (Figure 5) and drought severity is expected to decrease (Figure 6) in the arid northern sub-region where these communities are located. It is unclear what affect these changes will have on the groundwater supplies these communities rely on. With the overall increase in rainfall, extreme and unpredictable events such as flooding are likely to occur more often and may result in remote communities being cut off.

Sensitivity

Remote communities are sensitive to the impacts of climate change which are likely to compound existing water supply and quality issues. The liveability, health and wellbeing of residents is highly dependent on the provision of secure and potable water. Stakeholders consulted for this plan expressed concerns over water quality and its associated impacts on human health. These health impacts disproportionately impact Aboriginal people in remote communities, including an increased risk of stillbirth, birth defects, thyroid disease, type 2 diabetes and kidney disease (Searson 2022). Alternative water supplies, such as bottled water are not affordable for all community members (Searson 2022). These remote communities are already highly exposed to shortcomings in water infrastructure which may need to be upgraded, and in some instances relocated, to provide adequate water security and quality into the future.

Extreme and unpredictable rainfall events and flooding are likely to occur more often across the region and may impact transport infrastructure. Stakeholder consultation indicated concerns that these events could result in communities being cut off, impacting food security, access to health and other essential services, and social connectivity.

Adaptive capacity

These remote communities are some of the most socio-economic disadvantaged in the Goldfields-Esperance Region (Figure 11). This disadvantage means communities have a high level of sensitivity to water-related stress and low adaptive capacity to respond to further changing climates. Other sensitivities include health outcomes, social connectivity and local economic opportunities. Overall, climate risks are likely to compound these disadvantages and have a negative impact on liveability.

Infrastructure investment (for example replacing damaged pipes, installing water treatment services, and relocating assets away from septic tanks and other contaminants) is critical for improving adaptive capacity. Significant investment and planning are required. Stakeholders also identified opportunities for fit-for-purpose

infrastructure development in strategic locations to better support remote communities to remain on Country.

Water Corporation has recently taken on responsibility for water services in remote communities through the ACWS and is putting a focus on increasing adaptive capacity. This presents an opportunity for stakeholders to influence Water Corporation's planning for remote communities in the northern and central sub-regions and ensure it meets community interests and water demands whilst accounting for future climate change. Possible adaptive mechanisms to consider include opportunities to diversify sources, manage demand, and introduce more emergency response arrangements in extreme conditions.

Monitoring water quality at remote communities is used to inform ongoing management and planning for water supplies and is reported on the WA Government website (Government of WA 2023).

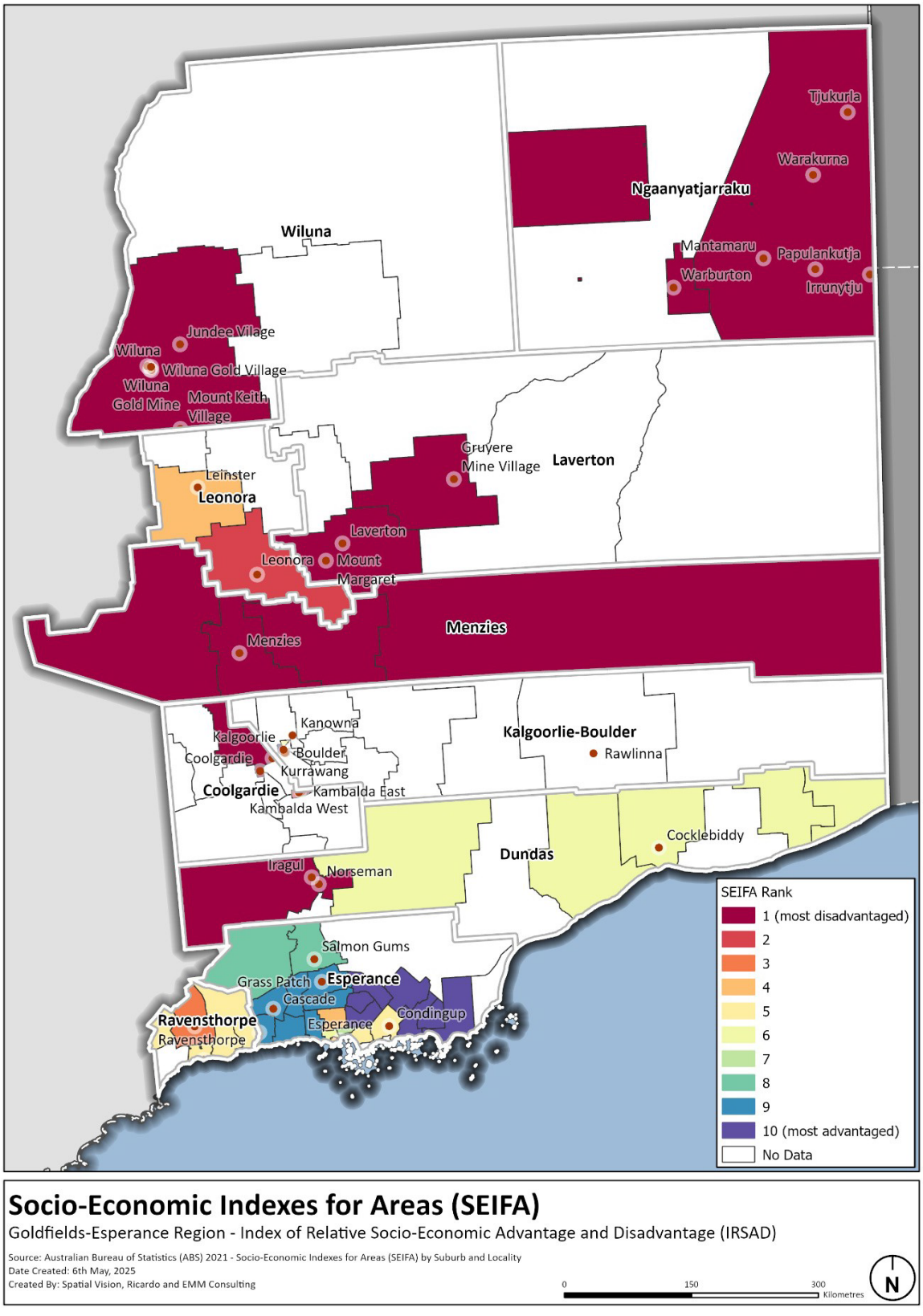


Figure 11. Goldfields-Esperance Region – Index of Relative Socio-Economic Advantage and Disadvantage

Vulnerability

While remote communities are accustomed to managing drought conditions and high temperatures, they have a high degree of vulnerability to changing or extreme conditions under climate change, which will place increased pressure on water supplies, quality, and infrastructure (Table 4). Existing water supply arrangements are less reliable than in other parts of the Goldfields-Esperance Region and water quality remains a long-standing issue. Prolonged drought periods and rising temperatures will affect overall liveability and may impact some groundwater supplies in shallow aquifers.

The remoteness of these communities further contributes to vulnerability due to the challenges of delivering support services for regular maintenance and emergency assistance.

Table 4. Drought vulnerability assessment for Remote Communities in the Goldfields-Esperance region

Element at Risk	Exposure	Sensitivity	Adaptive Capacity	Vulnerability
Remote community liveability and wellbeing in the northern and central sub-region.	High exposure to increasing temperatures.	High sensitivity.	Limited existing adaptive approaches available.	High vulnerability.

Community Water Supply

Summary

- Towns supplied by the GAWSS, as part of the IWSS, have a diversified water source and a high degree of water security to climate change. However, these towns will experience increased supply pressure from a hotter, drier climate as well as increased demand in line with projected population and economic activity growth. This includes greater pressure on non-potable water supplies critical for liveability and economic activity. Significant infrastructure investment is needed to increase adaptive capacity to drought. Stage 1 of GAWSS improvements have been funded. Improvements to sewerage and wastewater infrastructure are needed to increase use of recycled water and stormwater.
- Water supply and quality is a challenge for multiple small towns across the region dependent on local groundwater and with limited freshwater sources, sporadic recharge, and declines in the availability of high-quality groundwater. Declining and sporadic rainfall and rising temperatures will further exacerbate these challenges.
- A hotter, drier climate will increase water supply and quality issues in the southern sub-region. Small communities with limited groundwater and high reliance on rainfall will remain exposed and water carting is already required to

supply potable water for some of these communities on a regular basis. The Esperance area is experiencing groundwater recharge and saline intrusion risks to coastal aquifers and putting pressure on treated wastewater to supply economic activity, parks, gardens and schools. The long-term options for water supply in the Esperance region are under investigation.

- There is a high degree of interest among local governments for smaller communities across all sub-regions in building local water security and adaptive capacity by diversifying water sources and ensuring water sources are matched to suitable uses, such as using alternate sources for non-potable uses. Local governments identified that more clarity is needed on their future water supplies and needs under climate change, and the policy and regulatory requirements for pursuing these initiatives.

Sector Overview

The Goldfields-Esperance Region covers some of the most water-scarce areas in Western Australia in terms of both groundwater (Figure 9) and ability to capture surface water (Figure 5). Communities are located across all sub-regions and vary greatly in water security depending on water sources, population and industry/commercial needs.

Given the varied attributes of towns, geography and geology across the Goldfields-Esperance region and the scarcity of natural potable water sources, there is a diverse array of supply arrangements in place to supply communities' residential and commercial use. Fit-for-purpose supply arrangements to make appropriate use of available resources are important for supporting liveable communities. These arrangements are also required to provide these communities with the same amenity and facilities as larger Western Australian communities with more readily available potable water sources. Community water supply is also important for industrial uses which underpin community centres and economic activity, such as mining operations in Kalgoorlie and shipping operations in the Port of Esperance.

The reliability of community water supplies is shaped by very different water resources and climate patterns across the sub-regions. Communities in the northern and southern sub-regions, not connected to the GAWSS, are generally reliant on local groundwater sources, often coupled with desalination or reverse osmosis units to treat saline groundwater. The Esperance scheme, managed by the Water Corporation, sources local coastal groundwater aquifers shared with other licensed users. Esperance has historically used treated wastewater on public parks and gardens; however, wastewater is currently unable to be used due to the significant upgrades required.

Smaller communities in the northern and southern sub-regions generally rely on groundwater for all uses and do not use non-potable water alternatives such as wastewater treatment and stormwater capture. Many towns have declared public drinking water source areas and water source protection plans in place to separate groundwater sources from incompatible land uses. Town supply in Leinster is operated by BHP, which sources water for the township and for industrial use at the BHP mine

site from a groundwater bore (BHP Nickel West Leinster Operations 2021). Roadhouses along the Eyre Highway in the Nullarbor area are in unproclaimed areas and generally access groundwater in small volumes or capture rainwater in tanks. For these groundwater-dependent communities, declining or irregular rainfall patterns may impact aquifer recharge and therefore groundwater supply and quality. Rising temperatures will increase demand for water, including for non-potable uses such as public parks, sporting grounds, private gardens, dust suppression and road maintenance.

Across all sub-regions, water carting is often relied upon for town potable water supply to some communities where there is limited groundwater and high reliance on rainfall. These arrangements range from occasional to ongoing. Menzies is permanently supplied by water carting from the GAWSS in Kalgoorlie. Ravensthorpe also carts water from Hopetoun, Esperance or the Wheatbelt for town water supply during low rainfall years. The need for water carting is likely to rise as reduced rainfall and higher temperatures increase demand and further reduce already limited surface water availability.

Communities across the Wheatbelt and central sub-region of the Goldfields are largely serviced by the GAWSS and enjoy a high degree of water security. However, Local Governments serviced by the GAWSS note that until the planned infrastructure upgrades are completed, potable water supplies are fully allocated and cannot accommodate any increased demand or growth in their communities.

Across all sub-regions, increasing drought periods and more frequent, intense and lengthy heat events will impact liveability for most communities. Demand for water to irrigate public open spaces, sporting grounds and private gardens is likely to increase as a result of hotter, drier conditions (Figure 7). This will place further pressure on already-limited non-potable water supplies, for example smaller groundwater-dependent towns without wastewater for non-potable use. Access to reliable, alternative and fit-for-purpose water supplies to for non-potable use is recognised by stakeholders as a key constraint to community resilience, and an inhibitor to economic growth (Goldfields Esperance Development Commission 2024). Local government stakeholders engaged for this assessment reported that they have limited understanding of the likely impact of climate change on water supplies. They reported that more transparency in their water outlook would reduce uncertainty about whether water supplies will meet future needs and empower local planning and management.

This is summarised in Table 5 below, which details the current supply and demand profiles of the region's towns and maps the vulnerabilities and current/future planning underway to increase water security. The table has been informed by stakeholder consultations with Local Governments and Water Corporation.

Table 5. Summary of town water supply arrangements and long-term planning arrangements at a local government level across the Goldfields-Esperance region informed by stakeholder consultations with Local Governments and Water Corporation

Towns	Current Supply	Projected Demand	Vulnerabilities	Future planning	Recent & Current actions
GAWSS Dependent Communities					
Kalgoorlie-Boulder	Portion of 28,000 ML/yr GAWSS Stormwater capture & wastewater treatment and recycling active	Demand increasing from industry & urban greening	GAWSS considered climate independent Deficit each year during summer due to seasonal outmigration – reduces wastewater production constraining services to public spaces Population fluctuations with industry influence	GAWSS planning to 2040+ factoring in capacity constraints	Stage 1 GAWSS upgrades being planned
Coolgardie	Portion of 28,000 ML/yr GAWSS	demand influenced by mining industry	GAWSS considered climate independent	GAWSS planning to 2040+ factoring in capacity constraints	Stage 1 GAWSS upgrades being planned
Norseman	Portion of 28,000 ML/year from GAWSS. Eucla is groundwater dependent Wastewater treatment and stormwater capture active	Meeting demand at high costs Changes in demand influenced by mining industry	GAWSS considered climate independent No appropriate alternative water supply available for non-potable uses	GAWSS planning to 2040+ factoring in capacity constraints	Stage 1 GAWSS upgrades being planned Recent funding via the Community Water Supplies Program

Menzies	19 ML/yr GAWSS Water carting from Kalgoorlie Rainwater capture is active	Demand influenced by mining industry Supply from GAWSS at capacity	GAWSS considered climate independent No appropriate alternative water supply available & limited storage capacity	GAWSS planning to 2040+ factoring in capacity constraints	Stage 1 GAWSS upgrades being planned Recent funding via Community Water Supplies Program Climate project to deliver scheme reliability
Groundwater Dependent Communities in the Northern Sub-Region					
Leonora	310 ML/year Local groundwater sources Wastewater treated but not active due to insufficient volumes	Potable supply currently meets all demand Population is fluctuant and is influenced by mining activities	Water quality decline, extended droughts No appropriate alternative water supply available		Long term planning to 2040+ underway by Water Corporation
Laverton	182 ML/ year Local groundwater sources treated with reverse osmosis Water carted from Leonora as alternative supply	Potable supply currently meets all demand Population is fluctuant and is influenced by mining activities	Water quality decline, extended droughts No appropriate alternative water supply available	Long term planning completed 2040+ by Water Corporation	Capital projects to deliver water quality improvement Water Corporation provided 3 bores to Shire of Laverton to increase supply of non-potable resources for recreation

Wiluna	85 ML/year Local groundwater sources	Potable supply meets current demand Population is fluctuant and is influenced by mining activities	Water quality decline, extended droughts Flooding events as a result of increasing short-lived, intense rainfall No appropriate alternative water supplies available		Long term planning to 2040+ underway by Water Corporation Shire is developing an application to the Community Water Supplies Program
Ngaanyatjarraku	Local groundwater resources across the communities Reverse osmosis units active	Supply exceeds demand & not considered constraint to growth	Water quality decline, extended droughts Flooding events as a result of increasing short-lived, intense rainfall No appropriate alternative water supplies available		Groundwater resource mapping completed by BHP
Groundwater Dependent Communities in the Southern Sub-Region					
Esperance	1,800 ML/year Esperance coastal aquifers Wastewater treatment historically active, recycling of wastewater currently inhibited Farming communities access 5 – 7 ML/yr via bores or carting	Potable supply currently meets demand – however population and tourism growing Constraint to economic growth & developme nt in Esperance Low population growth projected in rural ward	Limited provision for emergency response - bushfires Reduced groundwater recharge due to drying climate Saline intrusion to town aquifers from ocean and lakes systems No appropriate alternative water supply available as wastewater treatment plant requires significant upgrades	Water Corporation planning to 2050+ complete for Esperance Water Corporation planning for Salmon Gums and Grass Patch being finalised	Aquifers to west of townsite under investigation for sustainable source into future Shire led installation of emergency response tanks and standpipes across rural wards – funding from Community Water Supply Program (DWER) Shire led planning for wastewater treatment infrastructure upgrades

Ravensthorpe	Ravensthorpe – 50 ML/yr surface water (carting from Hopetoun/Esperance, 2024) Munglinup 6ML/yr surface water (carting from Esperance 2024) Hopetoun – 220ML/yr local groundwater Wastewater treatment & recycling active Some commercial/residential rainwater capture	Slow population growth Ravensthorpe & Munglinup demand peaks in dry years - increase pressure on Hopetoun and Esperance resources	Ravensthorpe & Munglinup – drought and climate change for surface water capture & storage Hopetoun – saline intrusion risk No appropriate alternative water supply available	Water Corporation led planning in place to upgrade Ravensthorpe source – dependent on population growth Water Corporation led planning for Hopetoun in progress & planning for Munglinup being finalised	Floating covers in dam to reduce evaporation Shire led application for standpipes and tanks under DWER's Community Water Supply Program Infrastructure at Munglinup dam completed in partnership with the Shire, DWER and Water Corporation

Exposure

All communities in the Goldfields-Esperance region are highly exposed to drought. Reduced rainfall and the increased number of hot days will make most towns more difficult to live in. For towns not connected to the GAWSS who rely on local groundwater, variable surface water capture and water carting, ongoing monitoring and planning for new or alternative supplies will be a challenge.

Larger population centres around Kalgoorlie-Boulder and Esperance will experience increased demand on water supplies in line with population and economic activity growth, exacerbated during droughts by increased demand for water particularly on hot days.

Consultations have identified that seasonal fluctuations in population will expose different parts of the region at different times of the year. Outmigration from Kalgoorlie-Boulder during hotter summer months reduces the volume of treatable wastewater available for urban greening programs during this time. Conversely, an influx of visitors to the coastal areas during summer increases the demand for potable water supplies in drier months (Goldfields Esperance Development Commission 2024).

While Water Corporation has arrangements in place for towns across the region to monitor, protect and plan for potable town water supply for critical human use, communities are likely to be exposed to the negative impacts of drought and water restrictions. Water-reliant commercial/industrial activities are exposed to drought through water access, availability and restrictions which may limit commercial viability or inhibit growth. This has flow on effects to workforce development and retaining skilled labour within the region.

Local government stakeholders engaged for this review reported that they have limited understanding of their exposure to climate change and how it is likely to impact future water supplies. They feel that more transparency of current and future exposure would reduce uncertainty about whether water supplies will meet future needs and help inform planning for new or alternative supplies.

Sensitivity

All towns in the Goldfields-Esperance region have some sensitivity to drought and are likely to be impacted by future drought severity, although factors influencing sensitivity will vary across communities. Likely impacts range from reduced health in areas facing water insecurity and water quality challenges, to a reduction in wellbeing and liveability from impacts on amenity and recreation.

Towns reliant on groundwater are sensitive to reduced rainfall levels during drought, especially over a prolonged period, which may reduce the average annual recharge levels needed to replace average annual abstraction.

Water quality is a challenge not only for the region's remote Aboriginal communities, but for a number of towns and smaller groundwater systems in the northern sub-region as well. Limited freshwater sources, sporadic recharge, and declines in the availability of high-quality groundwater are already being observed in these places and are likely to be exacerbated by future drought conditions.

Temperature increases will drive peak demand for water supplies. Those communities which lack alternate water supplies for non-potable activities like urban greening may suffer greater impacts to water security during drought and dry conditions.

Changing population and economic activity also affects demand, and thus the extent to which towns will be affected by drought. Population and economic activity in most small towns is projected to remain steady or decline while growth areas such as Esperance and the GAWSS region are anticipated to experience greater water demand to meet commercial needs (Water Corporation n.d.).

Adaptive capacity

The region's sheer isolation and low population base present challenges for local governments and communities to build and implement adaptation measures. Further, the difficulty of delivering required services in an efficient manner can hinder responsiveness to changing climate conditions.

Water restrictions are a widely recognised response to dry conditions. The City of Kalgoorlie-Boulder recently implemented five months of restriction from February-June 2023 after storage dams (recycled water and stormwater) almost ran dry during a period of low rainfall (City of Kalgoorlie Boulder 2023). Permanent water restrictions are also in place for scheme and garden bore users across the region (Department of Water and Environmental Regulation 2024).

In the southern sub-region, a declaration of water deficiency status can be made to trigger water carting arrangements to rural communities that are experiencing water shortages (Water Corporation n.d.).

There has been significant recent investment in infrastructure upgrades to increase adaptive capacity of the Wheatbelt and central Goldfields to drought. The 2024-2025 state budget included an initial $15 million investment in upgrades to the GAWSS to increase water security, which leverages desalination investment in Perth (Government of Western Australia 2024). A further $543 million has been committed in the 25-26 State Budget to increase the capacity and reliability of the GAWSS (Government of Western Australia 2025). Local governments engaged for this review reported a high degree of interest in building local adaptive capacity by diversifying water sources and better aligning water supplies to use. For example, there is interest in using alternative water sources such as recycled wastewater, surface water runoff and water from mine pit voids and mine discharge, for non-potable uses such as public parks, sporting grounds, private gardens, dust suppression and road maintenance. Local governments identified several barriers to these initiatives, including uncertainty about their future water supplies and needs and limited understanding of the policy and regulatory requirements for accessing alternative water supplies.

Alternate water sources to increase town and industry water security have been discussed over time, but there has been limited traction so far. Large scale infrastructure investments are acknowledged as a possible future solution to securing water for the region, but the Goldfields-Esperance RDRP lays out a clear and exact plan to present practical actions that can be taken in the short and medium term to build resilience.

Vulnerability assessment

Overall, town water supply arrangements have been developed to manage long periods of drought, high temperatures and variable rainfall, but climate change is likely to increase the severity and frequency of these conditions and put more pressure on existing arrangements (Table 6).

More frequent, extended and severe drought conditions will put demand pressure on the key supply schemes of GAWSS and Esperance, and on wastewater and storm water supplies used for non-potable uses as availability of other climate sensitive sources are affected. Local groundwater supplies used in smaller towns are likely to be affected by long-term changes in climate, but the extent is unclear. Long-term water security planning is seeking to manage these issues and is critical for water security.

Table 6. Drought vulnerability assessment for Community Water Supply in the Goldfields-Esperance region

Element at Risk	Exposure	Sensitivity	Adaptive Capacity	Vulnerability
Town amenity and community wellbeing larger towns in the southern (Esperance) and central (Kalgoorlie-Boulder) sub-region	High exposure to increasing drought severity High exposure to increasing temperatures	Moderate sensitivity Have capacity to utilise alternative water supplies, however Esperance currently highly vulnerable without the use of its wastewater treatment plant	High adaptive capacity Already well adapted to drought through effective water management practices for parks, open spaces and schools	Moderate – High vulnerability
Critical human water needs in groundwater-dependent towns in the southern and northern sub-region	High exposure to increasing drought severity High exposure to increasing temperatures	High Sensitivity	Low adaptive capacity Current practices are increasingly challenged	High vulnerability
Critical human water needs in towns in all sub-regions partly or fully reliant on water carting	High exposure to increasing drought sensitivity High exposure to increasing temperatures	High sensitivity.	Low adaptive capacity Current practices likely to come under increasing strain	High vulnerability
Water-dependent economic industries & economic growth	Moderate exposure to increasing drought severity	Moderate sensitivity	Adaptive capacity unknown	Moderate Vulnerability

Conservation and Land Management

Summary

- There are large areas of conservation reserves, Indigenous Protected and/or Managed Areas and Unallocated Crown Land (UCLs) across the region that are naturally adapted to drought, but climate change may mean significant changes to these assets' condition.
- Climate change and more prolonged and severe droughts are likely to have significant impacts on fire regimes in the southern and central sub-regions and demonstrate a dependency on sufficient water access to maintain and protect critical infrastructure, and environmental and cultural assets.
- Climate change may result in possible increase of annual rainfall in parts of the northern sub-region; however, the rainfall will be highly episodic. Increased episodic rainfall may lead to higher impacts from flood events, particularly when they follow droughts due to decreased vegetation that exacerbate the impact of flood events including erosion and landscape degradation.

- Water insecurity and landscape degradation in remote areas that hold cultural significance to Indigenous communities impact their ability to maintain traditional land management practices and uphold the value of a healthy, culturally connected Country.
- Managing longer-term climate variability is important for sustainability across land areas during drought and as climate changes and adaptive land management practises are key to building landscape resilience.

Sector Overview

The Goldfields-Esperance region hosts a number of very large conservation reserves, indigenous protected and/or managed areas, and Unallocated Crown Land (UCL). Pastoral and mining activities also cover and manage significant areas of land across the region. Ecosystem health is very important to all the region's stakeholders. And as a result, adaptive land management is an important asset management strategy for the region and one that could be of increasing importance with increasing drought severity and climate change.

Land in the western parts of the southern sub-region have been largely altered by broadacre farming but there are some highly diverse coastal conservation reserves. Landscapes across this sub-region have high levels of endemism and some natural adaptations to drought, fire and salinity.

Aboriginal Lands Trust Reserves and dedicated indigenous protected areas cover significant land in the northern and central sub-regions along the South Australian border and north-east from Laverton (Department of Planning, Lands and Heritage 2019). Native title also exists across majority of the Goldfields-Esperance region (National Native Tribunal 2024).

Water in the landscape is essential for Indigenous water security as it supports healthy Country and sustains cultural values and practices tied to the land and its ecosystems, particularly water bodies. There is strong Aboriginal community presence in relation to land management, some of which is run through indigenous ranger and fire programs that provide strong social and cultural outcomes.

Exposure

There are large areas of protected reserves, indigenous protected or managed areas and UCLs across the region that are exposed to climate change and drought.

Some landscapes are naturally drought adapted in the north, central and eastern parts of the region. However, climate change may result in more frequent drought periods and bushfires placing increased pressure on natural systems. In particular, there is likely to be increased exposure to changes to extreme weather event patterns such as fire and flood. With the possible increase of annual rainfall in the northeast of the region, the impacts of flood events on soil erosion is an increasing challenge. Vegetation decline during longer periods of dry conditions will exacerbate the impacts of floods, which are recognised to often follow droughts (Goldfields Esperance Development Commission 2024).

Average rainfall is projected to decrease across less drought adapted ecosystems in the southern sub-region with biodiverse coastal conservation reserves exposed to increased drought severity and bushfire. The ability to sustain ecosystem and landscape health may be threatened by this, impacting important environmental assets where cultural, recreational and tourism values are associated.

Sensitivity

Prolonged drought could cause detrimental changes to the natural ecology of the region including more frequent or larger bushfires, and the cumulative effects of climate change on already water-stressed landscapes will increase the sensitivity of ecosystems to extreme weather events in the future. Many parts of the southern sub-region draw visitors with their coastal shrublands and woodlands. Esperance, Dundas and Ravensthorpe have a very rugged and remote coastline, as well as some highly endemic vegetated reserves such as Cape Arid National Park, the Fitzgerald Biosphere and the Great Western Woodlands, where the consequence and likelihood of bushfire is very high. Increased winds and drying conditions projected for the region demonstrate a dependency on sufficient water access to maintain and protect environmental and cultural assets.

Pastoral landscape scale monitoring data from 2020 identified much of the region is at moderate risk of vegetation condition decline and soil erosion, particularly the north-eastern Goldfields and Nullarbor – Eyre Highway areas. Climate driven changes across conservation reserves, UCLs or indigenous protected areas in the region are not monitored routinely at a large scale (Department of Primary Industries and Regional Development 2021).

Climate change and more prolonged and severe droughts are likely to have significant impacts on fire regimes particularly in the southern sub-region where increasing frequency and intensity of wildfires including the increase of dry lightning storms leading to fire events, will drive landscape fragmentation and threaten native species. Increased frequency and intensity of fires make it hard for native vegetation to regenerate and may result in long-term vegetation shifts, loss of unique biodiversity and contribute to the process of desertification.

Emergency management arrangements to combat bushfires often mean individuals, communities and local governments need to be engaged. However, often natural landscapes can be difficult to access across a vast and sparsely populated region with an absence of strategically located fit for purpose firefighting resources, including adequate water supply. Stakeholders consulted for this plan reported that bushfire management and response would benefit from a range of interventions such as improving water capture to support bushfire fighting and improved water access points.

Major roads, railways and pipelines across the region are critical to the vulnerability of region as essential arteries for the movement of freight, people and resources across the state. Roads are also essential for emergency responses in the event of bushfires. Many routes in the remote regions have low levels of investment and infrastructure development due to minimal traffic use, leaving them sensitive to climate-driven

impacts. When extreme weather events, such as drought or bushfires, compromise these access points, it not only hampers tourism and community connectivity but also impedes efforts for land management and fire management in areas crucial for cultural heritage and biodiversity conservation.

Environmental and cultural assets play an important role for community well-being and Indigenous land management. Large areas under land management and conservation in the central and northern sub-region are also indigenous protected areas and hold significant cultural value for local Indigenous communities, contributing to the region's rich heritage and ecological stewardship. Water insecurity and landscape degradation impact the ability for Aboriginal people to carry out traditional land management practices and impede on Aboriginal economic development. However, this also presents opportunities to develop and enhance traditional owner partnerships and programs to manage land and build resilience.

Adaptive capacity

Land management practises are key to managing resilient landscapes and environments during drought and as climate changes. Recovery of historically degraded and eroded areas in the Southern Rangelands is particularly challenging due to the heterogenous nature of the vegetation communities that require adaptive management strategies (Department of Primary Industries and Regional Development 2020). Currently, DPIRD monitor and regulate landscape management on pastoral leases (as a result of fire, pasture rotation, stocking rates) and the Parks and Wildlife Service at DBCA are responsible for managing fire in parks and nature reserves.

Pastoral landscape scale monitoring of condition shows stability in vegetation cover in recent years in the region however climate driven changes across conservation reserves, UCLs or indigenous protected areas in the region are not monitored routinely at a large scale (Department of Primary Industries and Regional Development 2021). The absence of data and information on the condition of assets within the region has been identified in multiple elements of this assessment as a key inhibitor to informed decision making and henceforth the adaptive capacity of the region.

Sustainable stock and fire management are the two most important land practices in building landscape resilience. It is also important to ensure land managers (rangers) have access to water to undertake on Country activities, however other short-term adaptations are unlikely. Holistic land management, conservation and adaptation strategies are integral to balance environmental, social and cultural values and economic opportunities.

Vulnerability assessment

While some land across the region is naturally adapted to long periods of drought, high temperatures and variable rainfall climate change is expected to lead to significant changes in these cycles. These changes (longer droughts, more infrequent but larger rainfall events) are likely to result in environmental changes that compound over time as highlighted in Table 7. Overall, managing longer-term climate variability is important for sustainability across land areas.

Table 7. Drought vulnerability assessment for Conservation and Land Management in the Goldfields-Esperance region

Element at Risk	Exposure	Sensitivity	Adaptive Capacity	Vulnerability
Conservation reserves, Indigenous Protected/Managed areas and Unclaimed Crown Land in the northern sub-region	High exposure to increasing temperatures Unknown exposure to increasing rainfall Exposure to flood impacts including erosion and landscape degradation	Low sensitivity Generally, already drought-adapted landscapes low lying shrublands and sparse vegetation	Moderate adaptive capacity Effective land and water management practices in place	Low vulnerability
Conservation reserves, Indigenous Protected/Managed areas and Unclaimed Crown Land in the C-central sub-region	Moderate exposure to increasing drought severity and temperatures	Low sensitivity Generally, already drought-adapted landscapes	Moderate adaptive capacity Effective land and water management practices in place	Low vulnerability
Cultural and natural environmental assets and landscapes in the southern sub-region	High exposure to bushfire and increased drought severity Moderate exposure to declining rainfall	Moderate sensitivity Highly diverse woodlands and shrublands dependent on water access to protect unique biodiversity, critical infrastructure and cultural assets exposed to bushfires	Moderate adaptive capacity Effective land and water management practices in place	Moderate – High Vulnerability

Broadacre

Summary

- Broadacre farming in the southern sub-region will be highly exposed to reducing average rainfall and increasing drought severity.
- Farmers in the far north of the sub-region near Salmon Gums and in the far west near Ravensthorpe will be the most sensitive to increased drought risk. These areas already receive relatively low rainfall and have lower yield potential than farming areas closer to Esperance. Broadacre farms in higher rainfall zones will be less sensitive as their current yield potential is higher.
- Broadacre farmers rely predominantly on the capture of rainfall in on-farm dams to provide their water needs (e.g. stock watering, spray water). Supplementary groundwater access is very limited and often saline. In drought conditions farmers can access water via strategic water sources provided by DWER with the support of local shires. There are opportunities to improve the overall drought resilience of the southern sub-region by improving a mix of water resources, including community and on-farm infrastructure.
- Broadacre producers generally have high adaptive capacity and there are a range of opportunities to improve the water efficiency and resilience of broadacre farms. Farmers in the far north and far west of the region may have less capacity to invest in adaptation due to increased exposure to dry conditions in these low rainfall areas.

Sector overview

Broadacre farming predominantly occurs in the southern sub-region. Aside from mining, broadacre is one of the largest contributors to the region's economy and workforce and accounts for 13% of Western Australia’s broadacre agricultural production (Department of Primary Industries and Regional Development 2021). Stakeholders consulted for this plan noted that many farmers in the southern sub-region are transitioning from livestock to cropping due to a range of economic, social and environmental factors, including increasing water insecurity (Goldfields Esperance Development Commission, 2024).

The climate in the southern sub-region is characterised by hot, dry summers and cool wet winters. On occasion the area experiences some summer rain when weather systems originating in the north move south through interior parts of the state. These are very unreliable systems. Autumn break, growing seasons and reliable stock rainfall and water supplies are influenced by westerly frontal systems.

Broadacre farmers rely predominantly on the capture of rainfall in on-farm dams to provide their water needs (e.g., stock watering, spray water). Supplementary groundwater access is very limited and often saline. In drought conditions farmers can access water via strategic water sources provided by DWER with the support of local shires.

Exposure

Less rainfall is projected to fall in winter, spring and likely autumn across the southern sub-region, and drought severity is projected to increase. Broadacre farmers in the northern and western areas including Salmon Gums, Grass Patch, Munglinup and Ravensthorpe, will be more exposed to increasing drought risk as they already receive less than 300mm of growing season rainfall on average (Figure 12). Producers near Salmon Gums will be the most exposed to drying conditions as they are already receiving less than 200mm of growing season rainfall on average. Broadacre communities closer to Esperance will also be exposed to reducing average rainfall, however these areas are expected to continue receiving above 300mm per year (Figure 5).

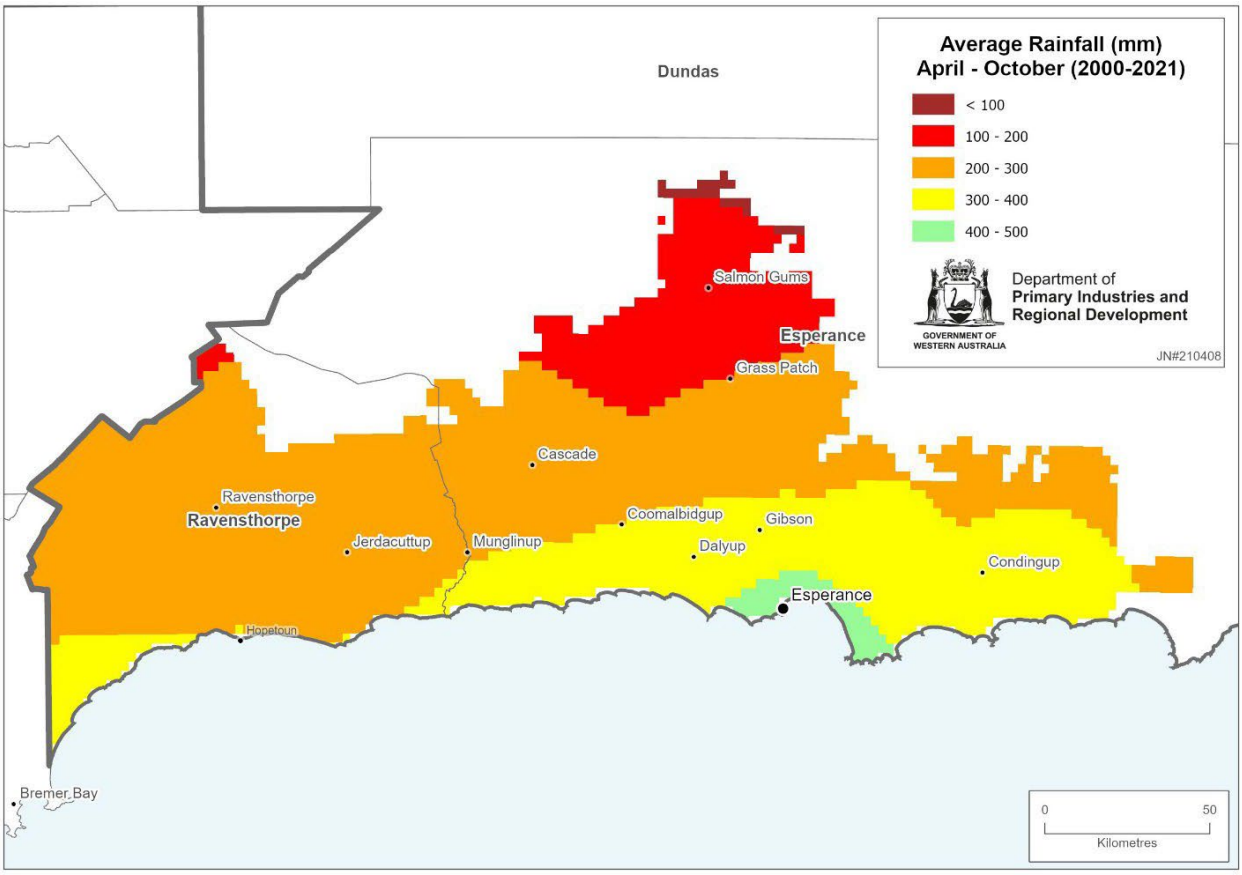


Figure 12. Average April - October Rainfall (winter rainfall) in the Esperance Port Zone (2000-2021).

Farmers in the region rely on a mixture of on-farm and community water resources for stock water, such as on-farm dams, groundwater bores, water carting arrangements and Strategic Community Water Supplies (SCWS). These water resources are put under stress during drought periods.

Sensitivity

Broadacre cropping is highly sensitive to drought. Cropping yields and financial performance are heavily affected by water availability (Hughes, Galeano and Hatfield-

Dodds 2023). Analysis undertaken by DPIRD suggests that wheat yield potential has shifted southward by as far as 25km over the last 40 years across the southern sub-region (Figure 13 and Figure 14). Despite this trend, actual yields have increased over this time-period due to production efficiencies and on-farm innovation (see Adaptive Capacity section).

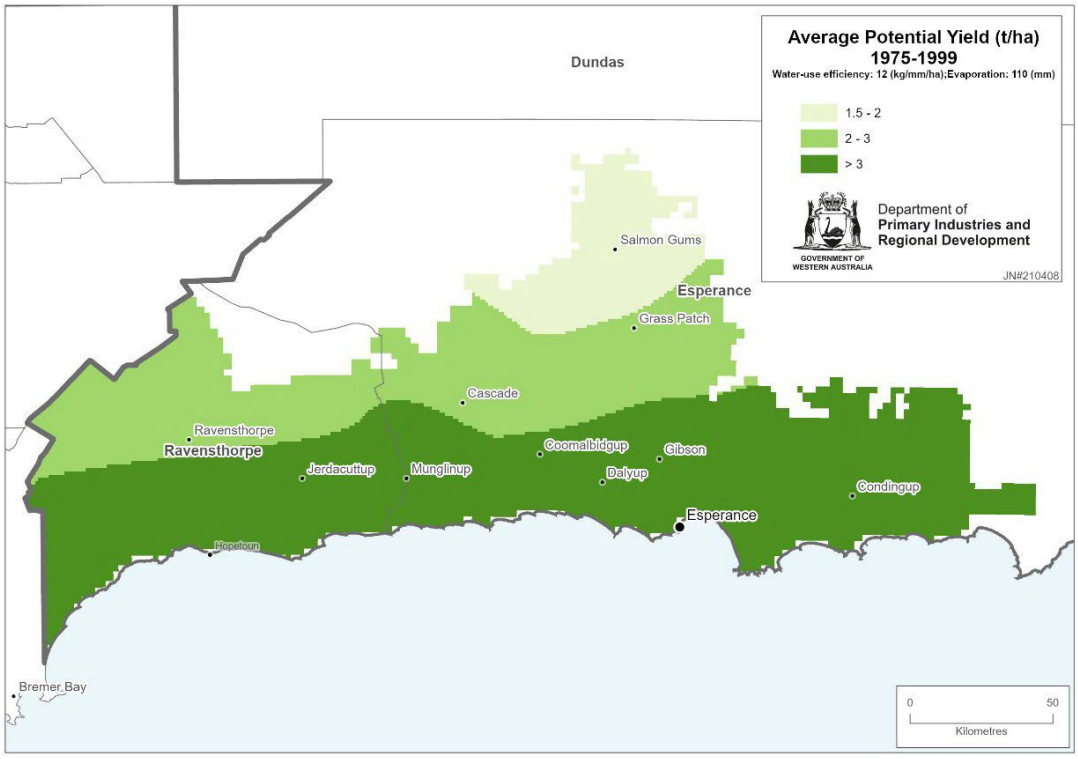


Figure 13. Shift in wheat yield potential in the Esperance Port Zone (southern sub-region) between 1975-1999

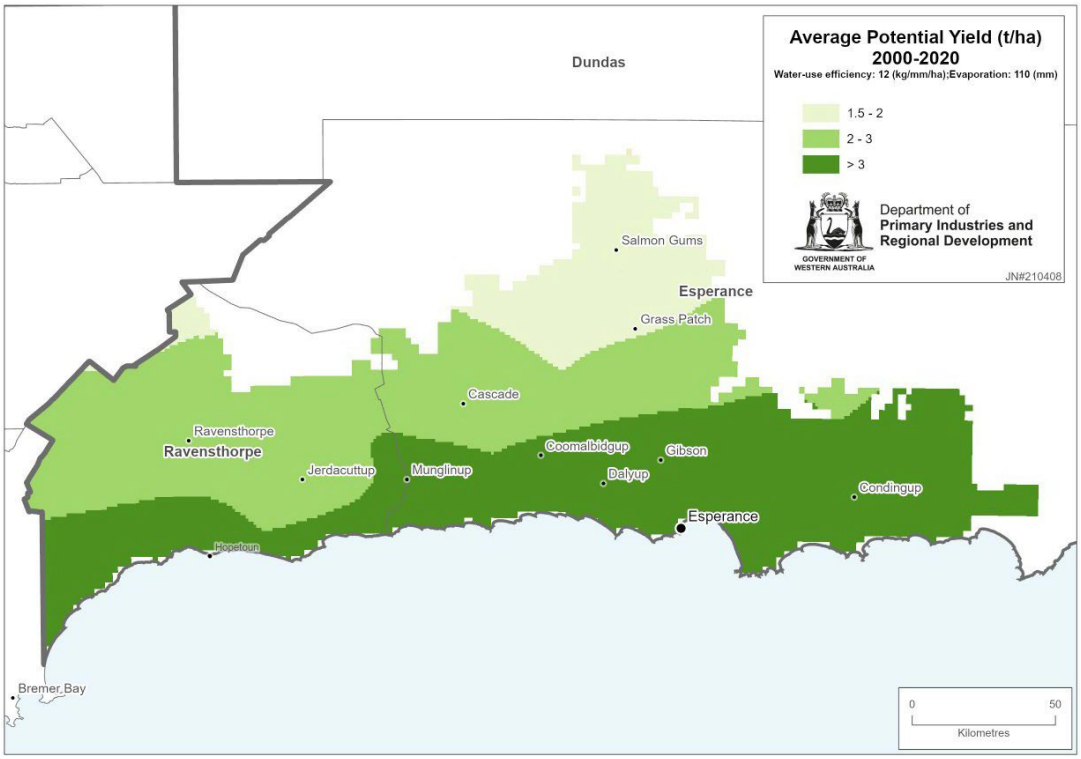


Figure 14. Shift in wheat yield potential in the Esperance Port Zone (southern sub-region) between 2000-2020

Broadacre livestock can be less sensitive to moderate drought conditions than cropping (Hughes et al. 2023). Broadacre livestock businesses have a number of options to manage low seasonal rainfall reactively, such as purchasing feed and water and moving or selling livestock. These livestock businesses are still very sensitive to extreme droughts that require stock to be sold or moved, as well as reductions in land productivity. In severe droughts, emergency stock water is a critical resource for these businesses.

Stakeholders consulted for this plan noted that many broadacre farmers near Esperance are high yielding and are unlikely to be put under financial stress due to increasing drought risk. This view is supported by Planfarm benchmarks, which suggest that farms in high rainfall areas of the southern sub-region made an average operating surplus of between $260/ha and $490/ha between 2018 and 2022 (Planfarm 2024).

Stakeholder consultation and analysis undertaken for this plan both suggest that small agricultural communities such as Salmon Gums, Grass Patch, and Ravensthorpe are highly dependent on broadacre agriculture and are therefore very sensitive to drought. Stakeholders suggested that broadacre farms further inland also tend to have lower yield potential than farmers closer to Esperance. This indicates that these farmers will be more sensitive to drought risk. These communities are also highly exposed to projected changes in drought risk.

Stakeholders consulted for this plan suggested those broadacre farmers with high capital investment and who are highly leveraged may be very sensitive to financial risks arising from consecutive dry years.

Adaptive capacity

Production efficiency

Broadacre farmers in the region have been managing the challenges of drought, climate change, and water scarcity for some time. A drying trend has been evident in southwestern parts of WA since the 1970s (Department of Water 2009). Broadacre farmers have managed this drying trend through a number of adaptation strategies including:

- improvements in crop genetics and cropping techniques
- crop intensification
- better business management
- increased use and availability of weather and climatic information

Increasing CO_2, warmer growing seasons, and less water logging are also likely to have had positive effects on broadacre productivity. As a result of these combined factors, wheat yields have increased since 1990 despite reducing rainfall and yield potential (CSIRO 2020).

Water storages and resources

Broadacre farmers in the southern sub-region typically have access to self-supply rain-fed dams and/or groundwater bores in local aquifers to supplement on-farm rainfall. These water sources are abundant but are typically very small, low yielding, or low quality. Stakeholders consulted for this plan suggested that many rain-fed dams in the region are only 1.5 ML in volume and are insufficient for supporting crops and livestock during dry periods. These dams are largely ineffective in capturing increasingly light rainfall events and are often prone to evaporation and siltation in hot, dry conditions. Groundwater resources in the northern portion (Mallee) of the southern sub-region tend to be highly saline and can reach 3.2 pH, making them unsuitable for stock watering or crop spraying. Groundwater resources in the southern portion (Sandplain) of the sub-region are brackish to saline and have a neutral to slightly alkaline pH, and areas closer to the coast utilise the groundwater resource for stock watering.

Agricultural communities can access emergency water for farming and emergency stock water through the Strategic Community Water Supplies (SCWS). SCWS has been set up with good coverage across the southern sub-region and comprise of reliable agricultural area dams, recently built community dams and groundwater bores. Vesting varies for each SCWS depending on land tenure; however they are administered by DWER through the Rural Water Program and water supply and carting is managed by Water Corporation.

Water carting arrangements may be established if a Water Deficiency Declaration (WDD) is made by the Minister for Water. The use of WDD for emergency stock water requires large volumes of water to be carted up to 40kms, which community generally views to be inefficient, unsustainable, and unsafe for other road users.

Whilst the WDD arrangement is recognised as an important emergency water supply for livestock, water carted under WDD is not accessible for cropping purposes and stakeholders view that the current emergency water supply arrangements are not ideal for supporting long term water security. Stakeholders acknowledge the importance of investing in individual on-farm water efficiency measures, such as on-farm dam refurbishments and upgrades, to reduce reliance on carting, which may prove more cost effective over the long term.

Stakeholders still view SCWS and WDD arrangements as a necessary water resource for agriculture, despite raising various concerns about current arrangements such as the limited applicability of the WDD. Stakeholders suggested a number of opportunities to improve the capacity and reliability of community water supplies which could improve drought resilience, particularly if they are complimented by on-farm investment.

Financial capacity

In severe drought, broadacre croppers have limited options to improve production and rely on drawing down on savings such as farm management deposit (FMD) accounts and reducing costs. Stakeholders consulted for this plan suggested that broadacre farmers typically make use of their FMD accounts and have good access to financial capital in comparison to farmers in more arid sub-regions.

Some stakeholders consulted for this plan suggested that a small proportion of broadacre croppers may not be able to manage the financial impacts of severe multi-year droughts without drawing down on assets or external intervention. This view is supported by indicators of debt serviceability in 2023 Planfarm benchmarks (Planfarm 2024). 2023 was a low-income year for most farms in high and medium rainfall areas in the southern sub-region, and as a result indicators of debt serviceability were low. The bottom 25% of farms in these areas had very high debt to income ratios (1.12 and 0.81 in high and medium rainfall areas, respectively), meaning that some farms' finance costs were higher than their operating income. This suggests that some broadacre farmers may not be able to service debt in drought years without drawing down on assets or external intervention. However, the benchmarks also suggest that average and high-performing farms in these areas have high value assets, high equity ratios, and low debt to income ratios in average years.

Vulnerability assessment

Broadacre is highly susceptible to drought with seasonal reliance on rainfall to achieve seasonal crop yields (Table 8). Farmers in the north and west of the southern sub-region are expected to be particularly vulnerable to future droughts due to high exposure, high sensitivity and reliance on external emergency water resources.

Broadacre farmers continue to adopt strategies that improve their overall efficiency and production, but in severe and prolonged droughts many farmers may still be reliant on community solutions and external interventions. Farmers have demonstrated an ability to adapt to changing conditions and this will need to continue in relation to water security. Continued on-farm improvements to farm water planning, the capture and storage of water, and water use efficiency have the potential to significantly increase water security even with increasing drought exposure.

Table 8 Drought vulnerability assessment for the broadacre sector in the Goldfields-Esperance region

Element at Risk	Exposure	Sensitivity	Adaptive Capacity	Vulnerability
Inland cropping systems N and NW areas of the southern sub-region (Salmon Gums, Grass Patch, Munglinup Ravensthorpe etc)	High exposure to decreasing average rainfall and increasing drought severity	High sensitivity, yield potential will decrease and croppers tend to have high capital investment	Moderate adaptive capacity, some strategies will be available to offset drought risk but they will not always be feasible	High vulnerability
Inland livestock systems N and NW areas of the southern sub-region (Salmon Gums, Grass Patch, Munglinup Ravensthorpe etc)	High exposure to decreasing average rainfall and increasing drought severity	Moderate to high sensitivity, yield potential will decrease, and costs will increase. Increased purchases of fodder and water required for livestock	Moderate adaptive capacity, some strategies will be available to offset drought risk but they will not always be feasible Access to emergency water supplies	High - Moderate vulnerability
Coastal cropping systems Particularly in the Esperance area of the southern sub-region (Condingup, Dalyup, Neridup etc)	Moderate exposure to decreasing average rainfall and increasing drought severity	Moderate sensitivity, producers in high rainfall coastal areas likely to be affected but remain profitable	Moderate adaptive capacity, some strategies available to offset drought risk	Moderate Vulnerability
Coastal livestock systems Particularly in the Esperance area of the southern sub-region (Condingup, Dalyup, Neridup etc)	Moderate exposure to decreasing average rainfall and increasing drought severity	Moderate sensitivity, producers in high rainfall coastal areas likely to be affected but remain profitable	Moderate adaptive capacity, some strategies available to offset drought risk	Moderate Vulnerability

Conclusions

The region is highly vulnerable to changing climate conditions, with each sub-region facing unique challenges. Vulnerability by sector is highly variable and the relationships between sectors will influence individual water user's resilience. This assessment provides the platform for action, as presented in the Goldfields-Esperance Regional Drought Resilience Plan.

Vulnerability by Sector

Mining

The mining sector is the most resilient to the projected impacts of a drying climate, with rainfall independent water resources that are generally "exclusive" to mines, and sufficient capacity, planning and data to ensure resource availability in the long term. However, this sector has its own water challenges, particularly in its interactions with other water users. The extraction of deep paleochannels, which mines typically access, can potentially influence the availability of water resources in shallower aquifers, typically used for community water supply. This relationship could be further challenged in a drying climate where recharge patterns are affected by declining rainfall.

Broadacre and Pastoralists

The broadacre and pastoral industries are the most vulnerable to changing climates, as highly climate dependent, annual production systems. Both industries have their own unique challenges. While pastoralists are faced with the remoteness and scale of infrastructure investment required for stations, broadacre systems are more exposed to declining rainfall, which is projected to be more pronounced across the broadacre areas, and extreme weather events, including wildfires.

Individual adaptive capacity is highly variable, but these industries as a whole have a long-standing history of innovation and research and development. Cropping systems today are producing more tonnes with less rainfall than ever before, highlighting the ability to mitigate climate impacts through advancements in crop genetics, phenotypes and soil management strategies.

Remote Communities

Remote Aboriginal communities in the Goldfields-Esperance region are highly exposed to extreme temperatures, however with forecasted increases in rainfall predicted across much of the remote communities in the north-east, it is unclear what future climate impacts may look like. Water quality is the greatest vulnerability in these communities which are highly sensitive due to extreme isolation and limited accessibility to services.

Community Water Supply

Water supply for towns and communities across the region itself is highly variable, as is local government's capacity to plan for and respond to changing climate conditions. In

recent times, there has been increased effort and investment into planning for and implementing programs of works and discrete projects to increase the capacity of water supplies in communities. The relationships between local government, state departments, industry and service providers are essential in continuing this effort, driving positive outcomes for local communities and unlocking economic opportunities.

Conservation and Land Management

Natural landscapes across the region are historically adapted to dry conditions and many species have a range of adaptation measures, such as fire-activated seed banks, to ensure species survival in drought. The increasing frequency of extreme weather events will likely threaten the viability of some landscapes, and some particular species of flora and fauna may be more threatened than others.

Vegetation decline and landscape degradation will have impacts to recharge patterns and maintaining or improving cover of grasses and other vegetation in the northern Goldfields will be key to mitigating this.

Significantly, the protection of ecosystems is important for cultural practices and wellbeing of First Nations groups, however it will also be essential for the region to capitalise on emerging tourism opportunities. This is particularly relevant in the southern sub-region, which is renowned for its spectacular natural assets and high biodiversity.

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