Grampians Region Climate Adaptation Strategy: Situation Analysis

Centre for Urban Research

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Glossary

3CA - Community Climate Change Adaptation

ABS – Australian Bureau of Statistics

CMA – Catchment Management Authority

CSOs - Community Service Organisations

DELWP – Department of Environment, Land Water and Planning

DET – Department of Education and Training

GHCMA – Glenelg Hopkins Catchment Management Authority

GRCAS – Grampians Region Climate Adaptation Strategy

ICM - Integrated Catchment Management

IPCC – Intergovernmental Panel on Climate Change

LGA – Local Government Area

NCCMA – North Central Catchment Management Authority

PPWCMA – Port Phillip and Westernport Catchment Management Authority

REZ - Renewable Energy Zone

SES - Socio-Economic Status

WCMA – Wimmera Catchment Management Authority

WSUD – Water Sensitive Urban Design

1 Introduction

1.1 Overview

This *Situation Analysis* provides background information for the Grampians Region Climate Adaptation Strategy (GRCAS). It is designed to complement other work (e.g. the DELWP Climate Projections) with a methodical analysis of the core Adaptation Themes in the GRCAS. The Situation Analysis was produced after the Draft GRCAS and takes a slightly different approach, including separating out the Adaptation Themes in the GRCAS into six sector-based Adaptation Focus topics (e.g. Agriculture) and five Hazards (e.g. Fire). For each Adaptation Focus topic, it consistently outlines the existing vulnerabilities and adaptive capacities of the region (independent of climate change), major climate change risks, key adaptation needs, existing adaptation actions in the region and other relevant adaptation actions occurring elsewhere. For each Hazard topic, climate change projections, regional vulnerability, observed impacts, projected impacts, interactions with other hazards and cross-sectoral adaptation needs are presented.

As the GRCAS is about the unique Grampians region – in keeping with the 'place-based adaptation' approach encouraged by DELWP (2020a) - the report begins with a brief overview of relevant aspects of the region. The report also highlights relevant adaptation actions and research underway in other regions to point to both adaptation possibilities for the region (noting nothing is directly transferrable), and its adaptation context.

The report does not seek to replicate the 2019 *Victorian Climate Projections* report and presumes readers have read it and understand the general nature of climate change, including its dependence on emissions scenarios and its combination of background trends and extremes or "hazards". Each section of this *Situation Analysis* provides key information in a structured way, and points to relevant existing work. The approach taken is informed by the Intergovernmental Panel on Climate Change (IPCC) thinking about climate change risks and impacts. It should be noted that this approach needs to be complemented with collaborative, multi-stakeholder processes that collectively explore deeper, and more transformative change in the region.

To begin, we provide a brief introduction to some key adaptation challenges.

1.2 Adaptation Challenges

This section provides some brief reflections on what climate change adaptation requires. It is included here as it helps inform the approach taken in the rest of the report.

1.2.1 Conceptualising risk

Climate change risks are caused by altered climatic conditions and/or their flow-on effects intersecting with other dynamic factors "on the ground". The IPCC suggests that climate change risk can be usefully understood as the intersection of a hazard (e.g. bushfire, pest outbreak), spatial exposure to the hazard (e.g. property in fire zone, being on a road at a certain moment), and pre-existing vulnerability (e.g. susceptibility of structures to combustion, lack of social support[i] (Figure 1). Risk is dynamic and how, where and to what effect a given risk manifests as actual impacts can be highly uncertain.

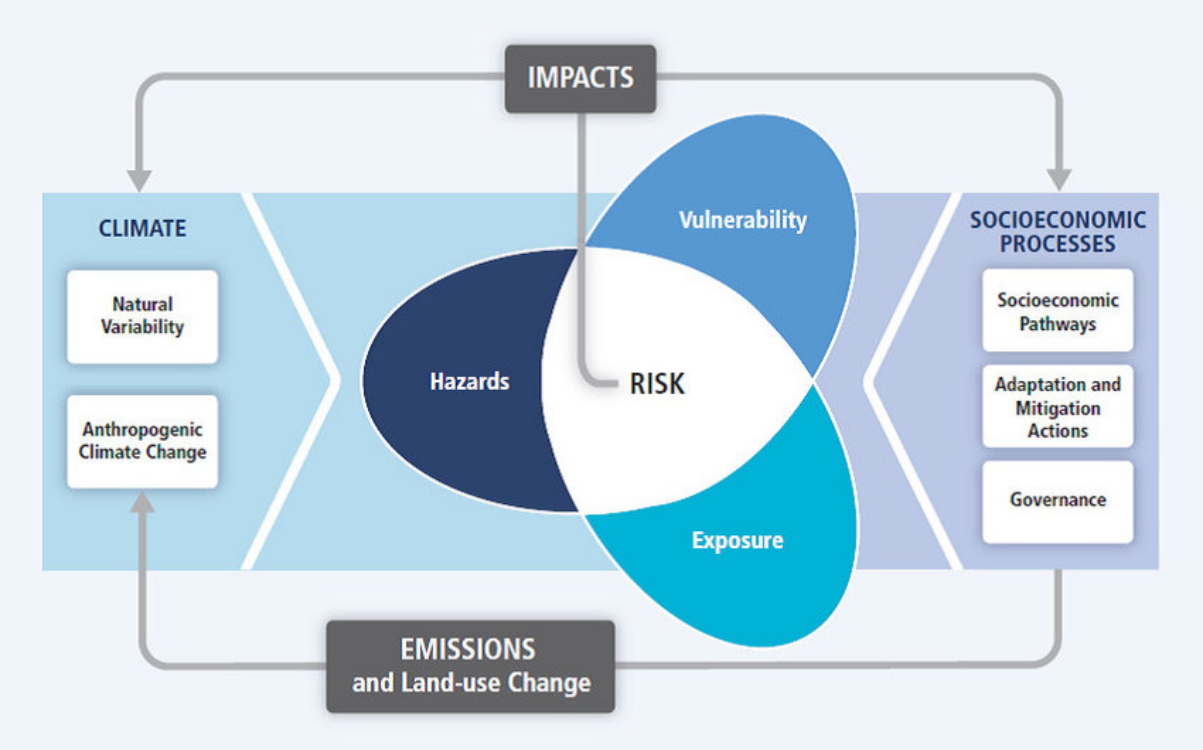

Figure 1: The IPCC AR5 conceptual framework of climate change risk (IPCC, 2014)

Risk can also be understood as Likelihood x Consequences. Actual consequences and perception of them differ between groups, who therefore assess risks differently. Further complexity emerges because risk assessments are not only partly subjective (dependent on assumptions and points of view) but change as conditions alter (Minteer and Collins, 2010).

For the sake of this report "hazard" refers to a climatic/biophysical stress associated with climate change. This includes extreme weather events, climatic extremes (e.g. droughts, heat) and shifts in long term trends, including generally hotter, generally drier and far more variable weather and climatic conditions (e.g. across an hour, one season, or a decade). While climate changed-conditions often do not look different in kind from the climate we have experienced before humans began to affect it by adding extra greenhouse gases to the atmosphere, they do differ in the intensity, frequency, timing and co-occurrence of different phenomena. Past rules of thumb about when winter rains begin or how long droughts go for or how storms behave, for example, are increasingly less reliable. At the same time, climate change is helping drive the emergence of new climatic phenomena and challenges, such as pyrocumulonimbus storms generated by bushfires (Dowdy et al. 2017) or thunderstorm asthma (Campbell et al 2019). Over time, as climate change alters landscapes, hydrological regimes, ecologies, economies and society in general, and these then interact with altered climatic conditions, its effects will grow in scope and scale. The aim of adaptation is to make changes in society as positive as possible in order to reduce negative outcomes.

1.2.2 Existing vulnerability and adaptive capacity

The impact of hazards depends on what existing challenges the group or system in general is facing (e.g. difficulties posed by COVID-19 pandemic) and thus how well they can cope and adapt. In the IPCC framework (Figure 1), *vulnerability* refers to *existing, non-climatic*

vulnerabilities. It is a system's propensity to be adversely affected by an "external" stress or disruption at a given moment in time. Vulnerability encompasses sensitivity to specific harms (e.g. an embodied, biological sensitivity to smoke), and more generic factors such as a lack of financial resources or political representation, or lack of redundancy or flexibility. Differences in vulnerability mean that any particular hazard event or climate change stressor affects different systems unevenly and in a time-dependent way (Department of Home Affairs, 2018). Climate change is deepening existing inequalities (e.g. lower socioeconomic groups or businesses that are highly geared tend to be disproportionately affected by most climate change stressors) but is also creating new types of risk and disadvantage. For example, some characteristics presumed to be advantageous until now (e.g. high tech centralised systems) may prove disadvantageous in some situations (e.g. when there is a systemic infrastructure failure). High consumption lifestyles can seem desirable, but set people up for greater losses in the event of a disaster, particularly if people are unaware of the fragility of such systems. As Bosomworth et al. (2016: 309) found, in Australia:

> *The country's strategic emergency managers are […] concerned that the growing interdependence between infrastructural, social, and technical systems is boosting vulnerabilities to hazards. Interdependencies between energy, transport, and food production systems, for instance, mean that the disaster impacts experienced in one community can affect many other communities Despite the sometimes fragile nature of essential critical infrastructure services during disaster events, industrialised societies expect that they will be available during extreme events.*

The fragility of critical infrastructure systems illustrates the way that vulnerability needs to be understood at different scales. Besides the individual and household scale, vulnerabilities exist at higher social and spatial scales such as watersheds and social-ecological systems, electricity grids, road networks, governance systems, and global supply chains (Department of Home Affairs, 2018).

The inverse of vulnerability is adaptive capacity: the ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences (IPCC, 2018). Levels, sources or types of adaptive capacity vary greatly between individuals, communities, ecosystems, and sectors, and are shaped dynamically by ever altering contexts. Besides individual capacities (e.g., skills in drought management), there are many social and environmental variables that shape adaptive capacities – e.g., access to collective resources, services and infrastructure, as well as levels of social capital in the form of community cohesion, relationships, and trust.

Some of the skills and capacities needed for adaptation and disaster resilience (e.g., electricity-free food preservation methods, mechanical skills, resourcefulness, frugality) are not those typically valued in society but may be widespread among some marginalised groups (e.g. elderly migrants) (Head et al. 2021). The complexity and variability of climate change and its countless flow-on effects means that people will be particularly vulnerable in some ways and at some times, but in other ways and at other times they will find themselves better equipped than most.

1.2.3 Different types of impacts

The complex, systemic character of the world means climate change impacts are not just climatic but encompass:

- **First order risks and impacts are "direct" ones** and receive the most attention, particularly in disaster risk reduction work. This is about the most immediate, tangible and clearly causal relationships, such as the biophysical effects of increased temperatures on exposed people, animals, vegetation, water bodies and machinery.

- **Second order risks and impacts are "indirect" ones**, caused by the flow-on effects of first order impacts. Examples include the additional pressure that a spike in heat-related illnesses puts on the health system, reducing its ability to provide support.
- **Third order risks and impacts are "distant" ones** that originate elsewhere but affect a region via disruptions to normal flows (e.g. supply chains, commuters, tourists) or effects on wider systems (e.g. on the national economy or OHS requirements).

Cascading impacts occur when second and third order impacts of various sorts are generated quickly (e.g. disease and pest outbreaks in the aftermath of a flood). These flow on effects can then compound initial impacts, by making flood waters unsafe, for example.

The recent Black Summer (2019-2020) demonstrated the range of flow on effects one "event" can have (Figure x).

1.2.4 Climate change adaptation

Climate change adaptation is about continuously adjusting to unfolding and expected climate change and its myriad flow-on effects. In human systems, effective adaptation avoids or moderates these costs and harms and may exploit beneficial opportunities. Human adaptation efforts can help some natural systems adjust to some effects.

Risk reduction is the dominant paradigm of climate change adaptation. Each of the three 'petals' in Figure 1 points to opportunities to reduce climate change risks:

- Reducing the likelihood and consequences of specific *hazards* (e.g. flood management works, fuel reduction burning)
- Reducing one's *exposure* to a hazard (e.g. via land use planning, evacuation)
- Reducing one's *vulnerability* to a hazard event or climate change stressor (e.g. fire, flood or heat resistant buildings, low reliance on water, strong social support).

Climate change adaptation incorporates a range of objectives and areas of effort. While it necessarily involves "coping" at any moment in time, it is also about changing now to better "fit" emerging and future conditions and proactively and positively shaping them.

1.2.4.1 Towards better adaptation

Besides more climate change adaptation, society needs to get better at adapting because 'not every response to climate change is a good one' (Erickson et al 2014) and adaptations that adequately reduce risk today may not do so in the future. Criteria of ''good adaptation" include the following 5E's:

- **Effectiveness**: how effective was the intervention at reducing potential harm?
- **Efficiency**: what time, effort and resources were needed? Could the same outcome have been achieved more efficiently?
- **Equity:** who and what were advantaged or disadvantaged? How inclusive and equitable were the process and outcomes?
- **Externalities**: what risks and harms were generated (e.g. greenhouse gas emissions, biodiversity losses, community or staff stress and conflict)?
- **Extended time horizon**: to what extent does the intervention help adapt a system to not just the near term but the long-term future? Does it place the system on the right "adaptation pathway"?

Adaptation is never perfect or cost-free. The more severe a climatic impact or flow-on effect, the less likely adaptation will be able to fully avoid or neutralise the harms involved. Adaptation always leaves a 'residual risk' Already it is apparent that even "well managed" extreme events often involve human fatalities and other losses given the scale and character of the event. Losses and successes also alter over time and scale.

Adaptation takes effort and resources and comes with an opportunity cost. Yet these costs are relative. Adaptation will reduce the far larger costs and constraints of inaction, including the cost of dealing with future disasters in the absence of adaptation. In 2050 the total cost of disasters in Australia per annum is estimated to jump to $33 billion (up from $9 billion in 2015), unless steps are taken to reduce risk, increase resilience and adapt to long term changes (Deloitte Access Economics, 2016). These costs are substantially larger again when far-reaching indirect losses are included, generating second and third order impacts. Future financial costs of disasters in Australia may threaten government fiscal stability.

Climate change adaptation actions are unlikely to benefit different groups or environments in the same way and some can generate new problems or injustices (Bunner & Lynch, 2010). For example, some efforts to provide farmers with access to seasonal climate forecasts to help them manage increased climatic variability have inadvertently deepened gender and class inequities in some farming communities because they are not equally available (Rickards et al., 2014). Adaptation needs to look 'beyond simple cause-and-effect relationships, to identify and address economic, political, social, and technological drivers of current challenges' (Rubenstein et al, forthcoming). The inverse of good adaptation is maladaptation: actions that may lead to increased risk of adverse climate related outcomes, increased vulnerability to climate change, or diminished welfare, now or in the future (Barnett & O'Neill, 2010).

1.2.4.2 Types of adaptation

There are many adaptation options available. Some changes are already apparent. Most of these are incremental (minor changes) and reactive (in response to observed shifts in conditions). But some adaptations (e.g. the relocation of mainland wineries to cooler climates) are more transformational (major changes) and anticipatory (initiated prior to the manifestation of possible impacts). Transformational adaptation includes large scale spatial reorganisation and landscape changes. Such adaptation has a long lead time (Stafford-Smith, et al., 2011) and failure to commence them now may mean that the opportunity to pursue them is lost, especially if adaptive capacity is eroded over time and people are forced into reactionary coping mode.

Other categories of adaptation include hard adaptations (physical changes, notably protective structures such as dams or tougher buildings) and soft adaptations ("social" changes such as alterations in policies, ambitions and relationships, including new building codes, improved collaboration and new ways of thinking) (Sovacool, 2011). Some adaptations build "specific" resilience (the capacity to cope with a given (climatic) impact such as fire) while others build "generic resilience" (the capacity to cope with any disruption or stressor) (van de Merwe et al., 2018)

As mentioned above, the three components of climate change risk are a good starting point for thinking about the adaptation approaches available. Adaptations can also tackle first, second or third order impacts.

1.2.4.3 Adaptation limits and barriers

Adaptation also faces limits. As climate change worsens, it is likely aggregate impacts will exceed the capacity of some systems and groups to manage them. For example, some ecosystems may fundamentally alter as species go locally extinct due to an inability to move or evolve quickly enough, and humans face biological thermal thresholds as discussed above (Eisenack et al, 2014). Any individuals' or groups' capacity to cope at any one moment varies over time, dependent on circumstances. Uneven structural vulnerabilities and engrained issues such as downplaying climate change risks means some groups are continually or regularly unable to cope or adapt well.

In Australia, climate adaptation and the related field of disaster risk reduction increasingly take a 'shared responsibility' approach in recognition of the fact that everyone, everywhere, needs to do their part. However, uneven capacity means that caution is needed. Some research suggests that 'communities often are left to manage residual risks shifted towards individuals, whether or not they have the financial, physical, mental, or social capacity to manage them'. (Deloitte Access Economics, 2016)

Numerous barriers to adapting well need to be overcome (Eisenack et al, 2014). While knowledge and information are important, analysis of barriers to adaptation suggests that institutional barriers (e.g., lack of clear mandate, low willingness to act) are often more significant (Biesbroek et al., 2013). Enablers of good quality adaptation include a collaborative, learning based approach.

Integrated decision-making is also increasingly recognised as a guiding principle for adaptation decision-makers, reflecting the pervasive risks climate change poses to all aspects of society including the social and economic spheres (IPCC 2014). Integrated decision making is the policy position of the Victorian Government through *Victoria's Climate Change Adaptation Plan 2017-2020* (DELWP 2016d) and the *Climate Change Act 2017* (Vic) 4. It encourages the systematic mainstreaming of climate change adaptation into existing policies and decision-making processes. How to do this well itself remains an area where social learning and high level support (resourcing, coordination, culture change) is needed (Runhaar et al. 2018).

2 The Regional Context

The diverse Grampians Region (DELWP) extends from the Wimmera and Victoria's Southern Mallee region east to include Ballarat, the surrounding Central Highlands and Melbourne's western peri-urban areas, encompassing eleven local government areas. It encompasses a wide range of socio-economic and bio-physical considerations. The region's characteristics represent an important context for climate change impacts and adaptation, pointing to some existing vulnerabilities and adaptive capacities.

Relevant characteristics are as follows:

2.1 Population

- The Traditional Owners of the Grampians Region extend from the Wotjobualuk people in the Wimmera region to the western fringes of the Kulin nation – the Registered Aboriginal Parties are mapped on Figure 2.1 below
- Moderate rates of population growth are evident in the larger regional centres in the west of the Grampians Region (e.g. Horsham, Stawell and Ararat). There is a long term trend of population decline and population ageing in many of the smaller towns. This is coupled with the centralisation of services and employment in fewer centres, leading to 'stretched' regional catchments for jobs and services. These regions have experienced growth well below the Victorian average for decades (ABS, 2020) and the centralisation of population, coupled with decline is forecast to continue (DELWP, 2019g). The growth of Horsham has slowed since 2010 and surrounding Wimmera communities have experienced a reduction in the rate of population decline (ABS, 2020).
- Population projections suggest that over 30% of the population will be aged over 65 years by 2036 in several of the region's local government areas (DELWP, 2019g). The ageing of the population is not only occurring in those areas experiencing population loss. For example, Hepburn Shire is projected to have 35% of the population in this age group, but this is driven by inward migration, rather than the loss of younger populations occurring in the Wimmera region (except for Horsham). All local government areas in the region are projected to have older population profiles than the overall Victorian population.
- Median household incomes in the region are lower than the overall state population (ABS, 2017), and this is particularly apparent in the Wimmera region and in Pyrenees Shire. Average household size is also smaller than across Victoria. Both of these features are consistent with older population profiles and with static or declining populations, especially in smaller towns.
- The smaller communities vary considerably in a range of key characteristics – there are over 30 towns in the region with populations of under 1000 people (ABS, 2017) - and a greater number of small rural communities. These communities generally have an older age structure and lower incomes than larger centres (such as Ballarat). This in turn suggests a varied range of capacities and vulnerabilities in smaller communities as they plan adaptation to climate change.

2.2 Housing and urbanisation

- Population and housing growth in Ballarat and the smaller towns in the Central Highlands are linked to processes of urbanisation and peri-urban housing growth, as well as to trends in lifestyle, including retirement-aged migration. Rates of housing development in Ballarat and Moorabool are high and commuting practices increasingly connect this part of the region to a metropolitan job market. This subregion has experienced population growth in excess of the Victorian average for the past decade (ABS, 2020). This has resulted in an increasing diversity of rural land uses (beyond traditional agriculture).
- In many parts of the region there are high housing vacancy rates and low levels of development. With the exception of Hepburn, this indicates of a slower market and less investment in new development or renovations, limiting opportunities for adaptive forms of housing design. In Hepburn, vacancy rates are associated with a tourism economy, and in consequent impacts on local housing affordability.

2.3 Biophysical features and water catchments

- The region has a diverse set of topographical and biophysical characteristics. The predominantly hot and dry Wimmera Southern Mallee is characterised by large areas of cleared cropping land and remnant Mallee vegetation, which is also prominent in some smaller townscapes. There are some significant areas of high biodiversity value, including the Grampians, St Arnaud Ranges and Little Desert National Parks, plus State Forests such as the Wombat and Mt Cole State Parks, areas of remnant grasslands and forests in the Central Highlands, and Ramsar-listed wetlands such as Lake Albacutya. High levels of public access to these areas ensure they are valued, but present challenges to their management. More scattered, relictual native vegetation in agricultural landscapes and along waterways remains under significant threat.
- The region includes critical water catchments for urban and agricultural use. In the Ballarat and Central Highlands this includes important potable water catchments for urban, stock and domestic systems extending beyond the region. Water supplies in the region are classed as Vulnerable due to their almost complete dependence on rainfall (not groundwater), notably reliable cool season rainfall and runoff to maintain flow in waterways (DELWP, 2016a). Capital-intensive systems for urban and agricultural use, such as the Wimmera Mallee Pipeline, are reliant on rainfall in catchments within and beyond the region.
- Rivers and creeks, wetlands, lakes and reserves exist across the region, including Victoria's largest freshwater lake, Lake Hindmarsh. Northern catchments in the region, including the main waterway, the Wimmera River, are part of the Murray Darling Basin and are thus subject to tri-state decisions made about its management. A section of the Wimmera River is a Victorian Heritage River and is under native title by Traditional Owners. The upper Wimmera River and its tributaries has been selected as the site of one of the state's Flagship Waterways Project that is committed to long term, large scale restoration. Some lakes and waterways are used heavily for boating and other recreation. Some have high biodiversity value, locally or further afield, such as creeks in the west of the region that flow into Ramsar-listed sites in South Australia. Many of the waterways are already under threat from grazing pressure and other stressors, leading to reduced flows, sedimentation, gully and land erosion, pest invasion and declining water quality. By returning some water to the natural waterways, the Wimmera Mallee Pipeline Project has helped reverse or slow some negative trends.

- The area overlaps with all of the Wimmera Catchment Management Authority (CMA) region, and parts of the Mallee, North Central, Corangamite, Port Phillip and Westernport and the Glenelg Hopkins CMA regions (see https://viccatchments.com.au/about-us/our-cma-regions/).

2.4 Energy infrastructure

- The region is predominantly reliant for electricity on the major power corridor that connects Latrobe Valley's coal-fired power stations to Portland, via Melbourne, including the major south-north transmission line running from Melbourne to Ballarat to Horsham to Red Cliffs.
- Much of the region is specifically identified as a Renewable Energy Zone (REZ) under current discussion (DELWP, 2021b). This builds on the development of wind power developments in recent decades in areas, including Waubra and Ararat. It also includes scope for large-scale solar in the Wimmera Southern Mallee, although state grid improvements will be required to fully realise this. Emerging energy landscapes present opportunities for land owners, but also signal shifting priorities and challenges in some areas, over and above the need for electricity grid development.

2.5 Transport infrastructure

- Road transport remains dominant for passengers and freight, with most settlements diffuse and car-dependent. However, improvements to passenger rail since 2005 and several smaller rail projects that encompass areas within the region, such as standard and dual gauge rail improvement projects through Ararat and Murtoa over the past decade, mean that rail transportation is not insignificant. Freight from the region goes to one of three ports: Portland, Geelong or Melbourne.
- The region has three airports – in Horsham, Stawell and Warracknabeal. Horsham and Stawell airports are currently being upgraded to improve safety and ensure they are fit for purpose during emergencies.

2.6 Economic base

2.6.1 Agriculture

- Agriculture is the main land use in the region. The Wimmera Southern Mallee is characterised by large areas of cleared mainly cropping land (mostly grains, oilseeds and legumes) with some remnant Mallee vegetation. Central Highlands includes more grazing (sheep meat, wool, beef) and a wider range of agriculture enterprises, including some large businesses in Nursery Production and Vegetable Growing (ABS, 2018). In addition to the continuity of high-value agricultural enterprises in the Central Highlands and Grampians, including Wagyu Beef, there is now also a proliferation of smaller and sub-commercial farming operations, notably in beef cattle but also intensive horticulture and dairy. In the Central Highlands, over half of the farm businesses have an annual turnover below $200,000, suggesting comparative low farm incomes. Small commercial farm businesses include mixed organic farms and viticulture, olive, berry and nut production, as well as small-scale grazing activities.
- Ongoing increases in the scale of agricultural businesses in dryland cropping and grazing areas across the region, particularly in the Wimmera Southern Mallee. This continues to lead to fewer, larger farms across most of the region, although different trends are experienced closer to Ballarat and Melbourne. In this region over 30% of farm businesses

have a turnover in excess of $500,000 annually, and a higher proportion in the Grains industry (ABS, 2018).

- Areas of 'transitional' farming (Barr, 2009), including traditional sheep grazing areas in decline, are a feature of several areas in the region, especially those between the peri-urban regions and the dryland cropping regions. For example, most sheep grazing business surrounding Avoca and St Arnaud have an annual turnover of below $200,000 (ABS, 2018). In some locations this has resulted in under-investment in land management, challenges to traditional inter-generational transfer, and a push for the development of non-agricultural land uses. In the region a number of these areas include landscapes that feature a land ownership mosaic of post-goldmining public lands, extant forests and areas of fragmented property ownership.
- Intensive pig and poultry (meat and egg) enterprises are evident in several clusters within the region, as are food processing facilities, which are a key feature of Ballarat's manufacturing economy.

2.6.2 Mining

- The region includes notable areas of active mineral sands extraction in the Wimmera (including Titanium) as well as the Stawell Goldmine, among other smaller operations.
- The Goldfields part of the region including around Ballarat was heavily mined by small scale artisanal gold miners in the nineteenth century and into the twentieth century. The use of mercury and other chemicals was widespread and largely unregulated. Large amounts of mercury and other heavy metals remain in the soil and have spread throughout the surrounding environment areas, including urban environments (Abraham et al 2018a, 2018b, Lawrence and Davies 2020).

2.6.3 Services sectors

- Retail and service sector employment is evident throughout the region, with key locations for government employment and large retail clusters in Ballarat and Horsham. These sectors, along with health, represent the largest employers in urban areas.
- The Grampians Region is part of the Victorian Department of Education and Training's South Western Victoria region (made up of Wimmera South West and Central Highlands subregions), which has 416 government schools with 173, 434 students (as of Feb 2020). Rural/remote parts of Victoria are more likely to have difficulty attracting and retaining teaching staff and in keeping with this the Wimmera South West subregion has one of the highest levels of primary school teacher attrition and of secondary school rates of unfilled vacancies. As of Feb 2020, there were 183 and 254 primary school teacher vacancies in the Wimmera South West and Central Highlands respectively. (DET, 2020).
- In addition to early childhood and school education, the Grampians Region is home to various further education facilities and four university campuses: Federation University and Australian Catholic University in Ballarat, Federation University in Horsham, and University of Melbourne in Creswick. All attract university students and staff to the region and the University of Melbourne's Creswick campus offers conference facilities and so contributes to business tourism in the region. Longerenong agricultural college is an independent entity near Horsham, including a 1070ha mixed farm and an associated Data Farm Innovation Centre to trial and showcase digital agricultural technologies and management.
- The health sector is a significant employer in the region, whether at larger regional facilities or small, local services in small towns. Health networks in the region include major hospitals (including Ballarat Base, commencing major redevelopment) as well as localised networks of community facilities, nursing homes and other services.

- Emergency management in the region is heavily reliant on the volunteer-based services of the Victorian State Emergency Services (notably the Mid-West region) and the Country Fire Authority (notably the Grampians fire region). Ambulance response times in the region vary widely, with Ballarat among the fastest in the state, and some outlying areas, notably West Wimmera Local Government Area (LGA), among the poorest serviced areas.
- The Grampians Region has a range of sporting facilities including football ovals, indoor sports and aquatics centres, golf courses, mountain bike, horse and greyhound racing tracks, and rail trail bike tracks. It also hosts some major annual sporting events such as the Stawell Gift.

2.6.4 Tourism

- Some parts of the region (e.g. around the Grampians National Park and Mount Arapiles, Goldfields country around Ballarat, Spa Country around Daylesford and Clunes) are home to well-known tourism destinations and are economically reliant on tourism (day trips, domestic overnight and international overnight). The tourism appeal of these areas is strongly related to the area's amenity values. The region offers a range of accommodation types, from caravan parks to luxury accommodation and dining. Regular events such as the Grampians Grape Escape to celebrate local wines and the Horsham Fishing Competition attract local and other visitors to this recreation economy. Tourism operators have been severely impacted by the COVID-19 pandemic and its flow-on effects on visitor movement, with domestic tourism in regional Victoria down by over a third and international tourism down by nearly half.
- The region also has a range of conference centres (e.g. Norval in Halls Gap, Peppers Mineral Springs Hotel in Daylesford, Longerenong College) and other facilities for business visitors. Hepburn Shire is a popular destination for wellness activities and weddings.

Figure 2.1 Grampians Region map with Registered Aboriginal Parties and local government areas

Having provided an overview of climate change adaptation, including the key role played by the specific characteristics of a given area or group, and the specific characteristics of the Grampians Region, we turn now to look in turn at identified “adaptation foci” and key climate hazards.

4 Adaptation Focus – Agriculture

4.1 Introduction

In the Grampians Region agricultural systems and landscapes face significant climate change challenges. These include the projected impacts of changing temperatures, more intense rainfall events, and more frequent and intense droughts and their many flow-on effects. The diversity of the region's agricultural systems and biophysical environments, and differences in their adaptive capacities now and in the future, means they will experience and respond to climate change-related stressors differently.

4.2 Existing vulnerabilities and adaptive capacities

4.2.1 Existing vulnerabilities of agriculture

- **Limited crop diversity in the northwest of the region**: Broadscale agriculture in the Wimmera Southern Mallee is strongly focussed on dryland grains (wheat and barley), oilseeds and legumes (Yarriambiack Shire Council, 2015).
- **Vulnerable water supplies and waterways:** Although the Wimmera Mallee pipeline has improved water security, agricultural water supplies across the region remain vulnerable (DELWP, 2016a), especially as many areas are reliant on individual landholder systems (DELWP 2016b). Total water availability has already fallen in terms of both precipitation and waterway flows. River and waterway health is generally poor, with rivers rated as healthy for only 0-10% of their length (DELWP 2016b, p50). Current environmental flows into the MacKenzie River are not sufficient to meet ecological requirements (Ehsan *et al* 2020).
- **Limited transport infrastructure:** Despite some recent improvements, rail and road infrastructure in the region remains a constraint, particularly on those areas furthest from regional cities. Most agriculture relies on long supply chains for inputs and access to market.
- **Soil quality and biodiversity**: Parts of the region's agricultural landscapes are characterised by low levels of biodiversity and low-quality soil. Some of the region's soil types are naturally saline and susceptible to erosion. Cleared uplands and other soils with little vegetation (e.g. around Nhill) are particularly susceptible to and already damaged by water erosion (DELWP 2018a; 2018b).
- **Market volatility and price trends:** Like all agriculture, many producers in the Grampians Region have to grapple with volatile commodity prices and a long-term trend of rising costs.
- **Competition for land:** Some areas of farmland in the region are under pressure from competing land uses, such as urbanisation around Ballarat and peri-urban land markets in surrounding areas. Infrastructure such as high voltage electricity lines planned to transmit renewable energy north of Ballarat threatening potato farming are examples of the tensions between productive activities within the rural landscape (Bell & McNaughton, 2021).

4.2.2 Existing adaptive capacities of agriculture

- **Experiential knowledge of climate variability:** Agricultural producers in the region have had to manage climate variability, including extremes, for a long time. They are generally alert to the challenges climatic factors pose, which research suggests increases their capacity and willingness to adapt (Reser et al, 2010).

- **Climate risk management and sustainable farming techniques:** There is already strong uptake among farmers in the Wimmera of innovative approaches to reducing sustainability problems and climate risks, including no till/zero till crop management.
- **Indigenous and local land management knowledge:** There is a wealth of historical knowledge amongst land managers within the region. Traditional Owners Indigenous knowledge is a valuable source of ecological knowledge about land and water management (Morton *et al*, 2014).
- **Agricultural research and extension capabilities**: The Grampians Region is home to some high quality local agricultural research facilities and services, including the Horsham Grains Innovation Park, Birchip Cropping Group, the Data Farm at Longerenong and research and extension conducted by catchment management authorities. Agricultural research tailored to local conditions, including those associated with climate change, enables producers and others in agricultural value chains to adapt more effectively.
- **Grains storage and logistics:** Being part of an established grain region, the Grampians Region generally has the advantage of advanced grains storage and logistics facilities.
- **High amenity landscapes:** The southern part of the region enjoys high amenity landscapes which creates opportunities for agricultural businesses to diversify into high quality value adding or farm tourism enterprises.
- **Renewable energy potential:** The region is physically well-suited to the generation of solar energy (particularly in the north of the region) and wind energy (particularly in the south of the region) (Chen 2019). Renewable energy generation by agricultural businesses increases the reliability and affordability of their electricity and, as a zero carbon source, offers marketing appeal, given the crucial role of energy sector transition away from fossil fuels to help mitigate climate change. If connected to the grid, this energy generation can also provide an alternative income source, further increasing business financial security. Some parts of the region have been zoned as a *Renewable Energy Zone* to expedite the planning processes and transmission line needed to enable new providers to feed electricity into the grid (DELWP 2021b).

4.3 Major climate change risks for agriculture in the Grampians region

Projected and observed climate change (see Hazards sections), combined with existing vulnerabilities and adaptive capacities (outlined above), result in the following major risks to agriculture posed by climate change:

1. **Fast onset climate change hazards:** Climate change means more frequent, intense and intersecting climatic extremes that exceed historical experience and present new difficulties, even for highly experienced landholders. Combined with the ways in which the agricultural system in the region is already somewhat precarious (e.g. vulnerable water supplies, limited transport options, low crop diversity within cropping), this means that single or compounding climatic events (e.g. drought, heatwave, fire, flood) may overwhelm the coping and adaptive capacity of some agricultural businesses, leading to flow-on effects for local areas and agricultural subsectors.

   Different aspects of agriculture are sensitive to different climatic extremes/hazards. For example, accumulative and extreme heat especially affects some crops (e.g. wine grapes, young crops), livestock (dark coloured cattle) and people (e.g. those doing physical work outside), causing potentially severe animal welfare and occupational health and safety issues. Agriculture is especially exposed to grassland fires and bushfires and its production base (plants, animals and soil) is susceptible to flames, ash and smoke. In the Grampians,

wine grapes are especially susceptible to smoke taint as well as temperature changes (Santillán et al. 2019). Storms and floods may directly impact the sector (e.g. hailstorms damaging crops) and indirectly by disrupting water, energy and transport infrastructure and services (DELWP, 2020, p40; DELWP, 2019a). Energy and water are often especially important for intensive agriculture and food processing, which relies, for example, on refrigeration.

Extreme events that occur beyond the Grampians Region can disrupt the supply chains of agriculture in the region, interrupting the ability to receive inputs or get goods to market. This risk is especially acute for agricultural businesses in the most remote parts of the Grampians Region and for those businesses reliant on international suppliers and/or markets.

Cascading impacts from extreme events include blackouts and related disruptions to telecommunications, liquid fuel supplies, emergency services, health facilities and other services. These can acutely impact agricultural businesses and value chains, and the communities and sectors they are part of. Impacts include food loss (e.g. due to delays in harvesting, issues with harvest storage or disrupted transport to market), and competing demands on some agriculturalists created by the need to protect their own property while also helping the Country Fire Authority or State Emergency Service respond to call outs.

2. **Generally hotter conditions:** Increases in average temperatures pose a risk to agriculture because it is primarily conducted outdoors and is reliant on good growing conditions. Although most crops are more sensitive to water than temperatures, the two are interconnected. Heat may not kill plants but may lower their yield and quality. Some crops, notably wine grapes, are very heat-sensitive (Santillán et al. 2019) and many plants' flowering time and other key periods are triggered by temperature signals. Higher night temperatures and lack of night chilling is a problem for some horticultural crops (Steffen *et al* 2011). Heat is also an issue after production. For example, stored grain can be negatively impacted by high temperatures in direct and indirect ways, reducing the proportion of grain that is usable and saleable (Moses et al. 2015). Heat and solar radiation are serious risks for livestock producers in terms of animal welfare, reduced productivity and long-term reductions in fertility. Extensive production systems are especially exposed to hot environmental conditions and radiation, but intensive production systems can suffer from additional heat if buildings are not adequately ventilated or climate controlled.

   The general warming trend, combined with drier conditions (discussed below) means that there is a general southward movement in climatic zones (Sposito, 2006). This means the broadacre cropping in the north of the region may increasingly expand southwards, competing with grazing for land and potentially adding to pressure on biodiversity as a result.

   Flow-on effects include warmer water, increased evaporation and a greater risk of poor water quality caused by eutrophication and other factors. Heat and ultraviolet radiation also increase the rate of deterioration of built structures and equipment, increasing maintenance costs. Some equipment, notably electrical equipment, is particularly constrained by thermal limits (Madonna et al. 2019).

3. **Less reliable rainfall and water supplies:** There is a serious risk that changes in rainfall (lower overall rainfall, more variable and intense rainfall events, a shift to summer rainfall, and more intense meteorological droughts) across the region and its wider catchments, means that agricultural producers and others will have to manage with far less reliable supplies of water, which is significant given that water availability is already a major limit on production in the region. Drier climates are projected to lower soil carbon, which could require livestock producers to lower stocking rates (Meyer et al. 2018). For agricultural producers reliant on not just the magnitude but the timing of

rainfall, such as wheat growers needing winter-spring rains or vulnerable to intense rains prior to harvest, these projected changes are especially consequential (Beer et al 2013). Unless they diversify to more suitable crops, parts of the Wimmera, Mallee and parts of the North Central areas are highly vulnerable to the effects of climate change on water supplies (Faggian *et al*, 2014; Beer *et al,* 2013). Projected lower water flows across the region increase the risk of worse salinity, lower quality (including unsafe) water in smaller and warmer water bodies, and altered, less biodiverse freshwater ecologies. As demand for water exceeds supplies, there may also be more conflict between regional stakeholders (commercial, residential, agricultural and recreational) and environmental needs (DELWP, 2016b; 2016c).

4. **High atmospheric CO2 levels:** Agriculture is unusual in being affected by not only climate change, but the increasing levels of carbon dioxide (CO2) in the atmosphere helping drive climate change. Elevated CO2 is combining with climatic changes to affect crops and pastures. In particular, while high CO_2 levels increase yields up to a point (offering a benefit), they reduce grain protein, nitrogen, functional qualities and usability (Nuttall et al. 2017, O'Leary et al. 2015, Asseng et al. 2019). Reductions in grain protein would lower the marketing grade and price of wheat. This is especially consequential for those farmers targeting Australian Hard and Australian Premium White wheat marketing grades, as many in Victoria's wheat belt do. A recent study concludes that, while regionally variable, by 2050 climate change and ongoing rises in CO_2 will overall 'have a large negative impact on Victorian wheat yield and quality' (Korte *et al*. 2019, p.935).
5. **Changing species distributions:** Interactions between the above and other factors are altering the viability and distribution of both original/native species and introduced/pest species and pathogens (DELWP, 2017; Hayward *et al*, 2016; Steffen, 2009). Some pests and diseases are likely to become more prevalent as: their climate envelope shifts southward, host species become weaker/more susceptible to attack, predator species decline, and post-disaster environments (e.g. decomposing vegetation or stagnant water pools after floods) provide habitat. For example, climate change is projected to increase the prevalence of deleterious fungus and associated mycotoxin infections of grain during post-harvest storage. Levels of fungus tend to increase with warmer and wet conditions (Mannaa & Kim, 2017), as post-flood conditions in NSW illustrated (Barkat *et al*. 2016). Pathogens like fungus also interact with other organisms (e.g. vector, virus, crops, predators) that are changing under climate change, making actual crop outcomes highly uncertain. Migratory birds to wetlands in the Grampians, which are an important predator of crop pests, are projected to be negatively impacted by climate change and so may become less prevalent (Hoffmann et al., 2008). Climate change is also projected to expand the range of tropical livestock diseases. For example, Ross River Virus is expanding southward as warmer conditions and floods expand the range of mosquito vectors (Koolhof et al., 2020; Tall and Gatton, 2020). Following floods in 2010/11 and 2016/17 Victoria had the highest burden of RRV in Australia (Koolhof et al., 2020). The virus seems to be evolving to enable it to use horses, pigs, cattle and other introduced animals as host species (Flies et al., 2018; Shocket et al., 2018; Stephenson et al., 2018).

4.4 Key Adaptation Needs and Opportunities

Each of the above climate change risks to agriculture in the Grampians Regions points to the need and opportunity for specific adaptation strategies and actions. There are countless adaptations needed by all actors from the regional scale to the individual. What is provided here are just some of the most obvious areas for adaptation effort to focus on.

Table 4.1 Identified climate change risks for Grampians agriculture and related adaptation needs and opportunities

IDENTIFIED RISKS	KEY ADAPTION NEEDS AND OPPORTUNITIES
Fast onset climate change hazards	**Coordinated local and regional hazard management and emergency responses.** For example, each shire or municipality needs to have an up-to-date Municipal Emergency Plan in line with the SES guidelines, up-to-date Flood Plan in line with Victorian Floodplain Management Strategy's systematic approach (DELWP, 2016c), and up-to-date Heat(wave) Plan in line with other legislative and policy frameworks. Shires/municipalities and individual producers also need to have fire management and drought management plans.
	Robust and resilient electricity and ICT systems and communications To reduce impacts during disaster events, reliable electricity and ICT services are needed. This requires prior preparation, such as alternative electricity supplies and communication options. The region needs to ensure agricultural producers and others can access the communications they need.
	Robust and resilient supply chains and reduced reliance on them The vulnerability of agricultural businesses to disrupted transportation routes and supply chains underlines the need for whole-of-supply-chain adaptation approaches and resilience thinking that builds in redundancy and resilience. It also underlines the value of limiting reliance on external inputs and long-distance transportation networks in order to reduce vulnerability to such disruptions.
	Erosion prevention and land restoration Ongoing work with catchment management authorities, Landcare, the Victorian No-Till Association, Birchip Cropping Group and others to reduce the risk of water and wind erosion (including during extreme events) and to restore already eroded areas offers important climate adaptation benefits.
	Biosecurity management systems: Producers and others in the region need to have up to date processes for preventing and managing acute biosecurity outbreaks of the sort that can follow climatic extremes.
	Farm level planning for extremes: Whole farm planning is a known adaptation tool in agriculture [refs], helping land managers to adapt to emerging and potential challenges and opportunities in the near and long term. Under climate change, this planning process needs to encompass deliberate strategies to manage the risk posed by extreme conditions (including droughts) and disasters. For example, landholders need to address the risk of flooding on their properties, including the way in which farm dams may create localised flooding risks. For animal welfare and land management reasons, livestock managers need to have specific plans in place for their livestock during extreme events and recovery periods, including feed, agistment and transport options.
Generally hotter conditions	**Shading and/or climate-controlled environments for livestock and high-value crops:** Shading can reduce the impact of heat and radiation and is an important and increasingly scrutinised element of animal welfare for livestock producers. Shading can also be cost effective for high value crops. Similarly, physical enclosures can reduce exposure and climate control technology systems can create cooler micro-climates (noting the need to avoid negative side effects such as high electricity bills or greenhouse gas emissions).

	More heat tolerant plants and animals: Some varieties of crops, pastures and livestock are more heat tolerant than the main species mainly grown in the Grampians Region at present. Changing varieties (e.g. to Bos indicus cattle), or enterprises (e.g. from berries to olives), to better match emerging new climate conditions is an important adaptation approach for the region and could lead to landscape and sectoral level change.
	Changed cropping practices: In addition to altering crop varieties, croppers can adjust their cropping practices in numerous other ways, such as by altering timing, adopting precision agriculture and no-till/zero-till techniques that cope with increased evapotranspiration by conserving soil moisture and reducing water demand (see below), and growing deeper rooted crops such as perennial wheat or trees.
	Relocation and/or diversification of farm businesses: Some northern parts of the region may become too hot for existing agricultural enterprises to remain profitable. Combined with the benefits offered from new approaches, landholders could look at diversifying into value adding (e.g. food manufacture), energy production (e.g. solar, mallee for biofuel), or afforestation (mallee for conservation, carbon sequestration or forestry purposes). Some producers may stay in farming but partially or wholly relocate their businesses to cooler climates in the south of the state.
Less reliable rainfall and water supplies	**Reduce water demand:** In keeping with the broader strategy of limiting dependence on external inputs (mentioned above), reducing reliance on rainfall or irrigation is the most fool-proof way for an agricultural producer to reduce their vulnerability to lower and less reliable water availability. There is an opportunity to build on the substantial water-efficiency measures that exist, including more drought-tolerant plant and animal varieties, better soil management (e.g. zero or no till crop management), covered waterways and storage to reduce evaporation and leakage, drip irrigation and precision agriculture techniques.
	Increase alternative water supplies: Water supply can be increased by expanding and/or diversifying water sources, such as expanding rainwater capture at the business level, or developing new urban and agricultural water reuse approaches at the regional level driven by government and/or industry (Tapsuwan *et al*, 2018). To help facilitate the approval of recycled water supply projects, better streamlining of policy is needed (VicWater, 2020).
	Increase monitoring of water quantity and quality: Greater unpredictability of water means that short to medium term rainfall forecasts are increasingly important to guide agricultural decision making. Australia's variable seasonal rainfall can be projected with reasonable skill months in advance, meaning that seasonal climate forecasts can be valuable if combined with other factors and communicated effectively (Prosser, 2011). Monitoring of soil moisture levels provides insight into soil water storage and plant needs. Monitoring of water quality also facilitates its effective and responsible use.
	Alteration, relocation and/or diversification of farm businesses: Some parts of the region may become too dry for existing agricultural enterprises to remain profitable. To manage, producers could periodically or permanently reduce farming intensity (e.g. decreasing stocking rates (Meyer et al. 2018)). Or, combined with the benefits offered from new approaches, landholders could look at diversifying into new agricultural enterprises, value adding (e.g. food manufacture), energy production (e.g. solar, mallee for biofuel), or afforestation (mallee for conservation, carbon sequestration or forestry

	purposes). Some producers may stay in farming but partially or wholly relocate their businesses to wetter climates in the south of the state.
High atmospheric CO2 levels	**New atmospheric-controlled grain storage technologies and infrastructure:** To reduce the negative impact of high CO2 levels on grain quality, new grain storage techniques and technologies that protect the grain from such conditions and exacerbating factors such as heat, are needed. Improved grain storage could also reduce the risk of fungus infections and other post-harvest threats to quantity and quality. Reducing post-harvest losses illustrates the sort of whole of supply chain approach to agriculture that is needed for effective adaptation (mentioned above).
	Alternative markets for different grain qualities: To the extent that the qualities and quality of grain may alter substantially under climate change in the region, new uses and markets for the resultant types of grain could be developed.
Changing species distributions	**Integrated pest management:** Managing the Region's land and water bodies in a way that provides quality habitat for beneficial predator species (insects, birds, reptiles, mammals) can help keep pest insects and the viruses and diseases they may be carrying under control. This involves limiting their exposure to pesticides. There is an opportunity to build on existing efforts to promote Integrated pest management uptake by landholders.
	Biosecurity: Farmer education about how to monitor and respond to diseases and viruses including previously uncommon ones.

4.5 Existing adaptation actions

There are a range of adaptation actions underway (or getting underway) in the agricultural sector in the Grampians region that address the key adaptation needs and opportunities identified above. Some initiatives are identified in the Draft Grampians Region Climate Adaptation Strategy (DELWP 2021a) and on the adapt.grampians.com.au website, and a range of others are mentioned in Table 3.2.

Table 4.2 Example existing adaptation actions in the Grampians relevant to agriculture

KEY ADAPTION NEEDS	EXAMPLES FROM THE REGION
Municipal emergency management plans for each local government in the region	Ararat Council: https://www.ararat.vic.gov.au/sites/default/files/document/2017%20MEMPC%20Community%20Copy.pdf City of Ballarat: https://www.ballarat.vic.gov.au/sites/default/files/2019-08/Municipal%20Emergency%20Management%20Plan%202019-2021.pdf Golden Plains Shire Council: https://www.goldenplains.vic.gov.au/sites/default/files/MEMP%20Version%202.docx%20%28Public%29.pdf Hepburn Shire Council:

	https://www.hepburn.vic.gov.au/wp-content/uploads/2020/01/Public-Version-Municipal-Emergency-without-Appendices-Adopted-21-August-2018-97-pages.pdf Hindmarsh Shire Council: https://www.hindmarsh.vic.gov.au/content/images/Emergency/Hindmarsh%20MEMP%20Public%20V2.1%20Nov%202019%20MEMP%20Version%202019%2011%2019.pdf Horsham Rural City Council: https://www.hrcc.vic.gov.au/files/assets/public/document-resources/emergency-management/documents/horsham-municipal-emergency-management-plan-v2_update2020.pdf Moorabool Shire Council https://www.moorabool.vic.gov.au/sites/default/files/MEMP%202020%20to%202023%20V8%202020%20REDACTED%20version.pdf Northern Grampians Shire Council: https://www.ngshire.vic.gov.au/files/assets/public/document-resources/corporate/docs-for-public-inspection/public-ngs-memp-v4.0-june-2020.pdf Pyrenees Shire Council: https://www.pyrenees.vic.gov.au/files/assets/public/emergencies/2020.05.19-memp-2020-final-adopted.pdf West Wimmera Shire Council: https://www.westwimmera.vic.gov.au/files/assets/public/documents-amp-publications/plans-amp-strategies/municipal-emergency-management-plan-2017-2020.pdf Yarriambiack Shire Council: https://yarriambiack.vic.gov.au/wp-content/uploads/YSC_MEMP_V2_March_2017Updated060320Public.pdf
Municipal heat(wave) plans for each local government throughout the region	Hepburn Shire Council (No – but info page on website): https://www.hepburn.vic.gov.au/heatwave/ Hindmarsh Shire Council (Yes – but inaccessible on website) Horsham Council (No – but info page on website): https://www.hrcc.vic.gov.au/Emergency-Management/Heatwave Moorabool Shire Council https://www.moorabool.vic.gov.au/sites/default/files/Moorabool%20Shire%20Heatwave%20Plan%20-%20Adopted%20MAY2019%20MEMPC.pdf Northern Grampians Shire Council (Yes – but currently under review) Yarriambiack Shire Council: https://yarriambiack.vic.gov.au/wp-content/uploads/YSC-heatwave-plan-2020-21.pdf
Flood plans	Some municipalities and towns in the region have Flood Wardens/Observers to observe flood behaviour and inform future planning (NGSC & VICSES, 2014; CGS & VICSES, 2019). Local flood planning is important because local knowedge greatly improves the plans' accuracy and relevance (DELWP 2016c, p13). All five of the CMAs that overlap with the Grampians Region have flood plans and provide flood advice, reflecting their statutory responsibility for floodplain management. These need to be kept up to date to reflect changes to climate projections, observed weather and climate, and catchment conditions (e.g. replacement of grazing land with cropping land, altering local hydrology).
Changing cropping practices	The Sustainable Cropping Rotations in a Mediterranean Environment (SCRIME) trial was established in 1998 by Agriculture Victoria in the Wimmera Mallee, and was conducted over part of the Millenium Drought (Victorian Catchment Management Authorities 2020). The data from this trial therefore covers both dry and wetter periods, with potential lessons

	for rotations and tillage systems (Victorian Catchment Management Authorities 2020). In 2017 Agriculture Victoria partnered with University of Melbourne, Birchip Cropping Group and Wimmera CMA to showcase the SCRIME results to farmers (Victorian Catchment Management Authorities 2020).
Improve water use efficiency	Irrigation modernisation at the farm and regional scales is reducing water losses to evaporation, leakage and runoff. Further pilots are underway to improve the efficiency of use further. For example, the Corangamite CMA is working with DELWP, Southern Rural Water, community, farmer groups, agricultural industry, educational institutions and the retail sector to test the "viability and effectiveness of modernised on-water capture technologies" to improve on-farm water efficiency (DELWP, 2019, Victorian Catchment Management Authorities 2020).
Increase alternative water supplies	Urban and agricultural water reuse , for example: 1. The Stawell Stormwater Alternative Natural Solutions project uses stormwater to drought-proof community assets. The project saves over 74 megalitres per year through series of water quality treatment ponds, storage dams and transfer infrastructure – reclaimed water from this infrastructure is used to irrigate sporting facilities, gardens and public open spaces. 2. In 2020, recycled water regulations were streamlined as part of a recycled water guidelines review undertaken by VicWater. These include streamlined audit obligations, fewer and more risk-based scheme approvals and reduced red tape (VicWater, 2020)
Increase access to seasonal forecasts	The BoM and the CSIRO have jointly developed and launched Weather Together, which is a forecasting service offering both spatially and temporally variable forecasting, tailored to agricultural stakeholders: https://www.csiro.au/en/Research/AF/Areas/Digital-agriculture/New-opportunities/Weather-Together?ref=/CSIRO/Website/Research/Drought-resilience/Forecasting-and-monitoring/Weather-Together This can be extremely fine-grain (down to the individual property scale) and at a range of temporal scales (from daily to yearly) and is available on monthly subscription.
Increase flexibility in water allocations	The *Water Act 1989* and recent *Water for Victoria Plan* include 'flexibility' as a key component of the overall approach to water allocation in Victoria (DELWP, 2016b).
Increase modularity of water reserves and infrastructure	Rural and municipal water corporations are required to provide irrigation, drainage and storage services, and are responsible for the diversion of water from waterways and groundwater extraction, at a municipal/ regional scale. Examples of urban/rural water reuse are investigated in the draft DELWP (2020) Strategic Agricultural Lands Review, with locations such as Bacchus Marsh within scope, and the NCCMA (2015) *Climate Change Adaptation and Mitigation Plan* which identifies the need to consider groundwater potential in the upper Loddon and Campaspe catchments as a climate adaptation strategy.
Increase environmental water flows into 'at-risk' waterways	Regulatory improvement 1. The recent State Environment Protection Policy (SEPP) (Water) is a State regulatory framework to address competing waterway uses and prioritise the environmental health of waterways. It is designed to: • confirm the beneficial uses of Victorian groundwater and surface water, and where these uses apply • set water quality indicators and objectives to protect beneficial uses • establish a modern, risk-based framework to manage unlicensed point and diffuse pollution sources in rural and urban areas • develop regional target settings and plans to improve water quality

	• ensure water quality offsets can be used within catchments to maintain regulatory compliance within waterways. 2. Water agencies (GWMwater WCMA and DELWP) plan to share their flow release plans to enable better coordination and 'more effective use of all water releases' (p195). This integration across agencies and of consumptive and environmental flows will help achieve better ecological outcomes, reducing the vulnerability of related ecosystems (Ehsan et al 2020). Local programs 1. *Dja Dja Wurrung/ North Central Catchment Management Authority/ Trust for Nature – Putting the swamp back into Long Swamp* (1 of 11 pilot projects around Victoria) (DELWP 2018b, p5) 2. Wimmera Catchment Management Authority - Northern Dunmunkle Creek restoration plan (as above) (DELWP 2018b, p5).
Identify and redress main non-climatic drivers of declines in waterway health	A number of waterways in and near the region (including Campaspe River and the Murray Floodplain) are earmarked for significant State funding. The SEPP program mentioned above is also helping reduce pressure on waterways. Regional catchment strategies and the on-ground work undertaken within these frameworks address waterway health through land use change, strategic revegetation, the removal of streamside grazing, research into water and floodplain management and changing the management status of waterways and wetlands. For example, the 2020 Draft North Central Regional Catchment Strategy (2021) includes a focus on waterway (and wetland) connectivity and the protection of riparian land. The most recent Wimmera Regional Catchment Strategy (2013-2019) includes works on stream banks and channels as an approach to addressing flow and water quality.
Improve integrated catchment management	The ongoing implementation of the *Our Catchments Our Communities* plan (DELWP, 2019b) aims to implement a clear Integrated Catchment Management (ICM) approach. The goal is to involve regional partners and community networks in its implementation, along with DELWP and CMAs.
Economic diversification of areas heavily dependent on agriculture	Ararat City Council (Partly): Such a focus is evident here: https://www.ararat.vic.gov.au/sites/default/files/Council%20Plan%202017-2021%20Year%204.pdf Golden Plains Shire (Partly): Eco. Dev. Plan has little focus on this https://www.goldenplains.vic.gov.au/sites/default/files/Economic-Development-Tourism-Strategy20172021_FINAL.pdf Hepburn Shire Council: https://www.hepburn.vic.gov.au/wp-content/uploads/2016/07/Economic-Development-Strategy-2016-21.pdf Hindmarsh Shire (Partly): the 'Economic Development Strategy 2015 – 2020' focusses on the existing economic strengths of the area, rather than diversification - with the exception of a stated focus on increasing tourism https://www.hindmarsh.vic.gov.au/content/images/What%20we%20do/Business%20support/Economic%20Development%20Strategy%202015_2020.pdf Horsham Rural City Council (Partly): focuses largely on the existing economic strengths of the area (ie agriculture), rather than diversification, but does focus on increasing health services, education and tourism https://www.hrcc.vic.gov.au/Our-Council/Public-Documents/Council-Publications/Economic-Development-Strategy?BestBetMatch=economic%20development|d13b95b2-5146-4b00-9e3e-a80c73739a64|4f05f368-ecaa-4a93-b749-7ad6c4867c1f|en-AU Northern Grampians Shire: Eco. dev. plan underway, but background research demonstrates a clear awareness https://www.ngshire.vic.gov.au/Have-Your-Say/Economic-Development-Strategy-and-Action-Plan-2021-31

	Moorabool Shire Council: the Eco.Dev. Plan acknowledges both the strong economic diversity that already exists and a focus on increasing/promoting this diversity https://www.moorabool.vic.gov.au/sites/default/files/largefiles/Moorabool%20Shire%20Economic%20Development%20Strategy%20%28Geografia%2C%20October%202015%29.pdf West Wimmera Shire: a clear focus on economic diversification in evidence https://www.westwimmera.vic.gov.au/Council/Documents-Publications/Plans-Strategies?BestBetMatch=%22economic%20development%20plan%22|8baa1aaf-8b63-4531-89b6-66e96bacefde|e8ea7ded-2029-4a48-af87-d1a116abbc49|en-AU Yarriambiack Shire Council: Eco. dev. plan clearly focusses on the historical and wider-scale contexts, including challenges https://yarriambiack.vic.gov.au/wp-content/uploads/EDS_2015.pdf

4.6 Examples of adaptation from other places

There is an opportunity to learn from agricultural adaptation activities and research in other parts of Victoria and Australia where similar or interconnected risks are being managed. In recognition of the value of learning across contexts, groups such as Agriculture Victoria already offer a wide variety of case studies of good climate risk management (e.g. drought management case studies from across Victoria) (DJPR, 2021b, https://agriculture.vic.gov.au/support-and-resources/case-studies/water-case-studies).

In the Goulburn Murray Irrigation District, the value of whole farm planning for adaptation, and the need to adapt such plans to changing conditions, is being recognised and promoted. Agriculture Victoria are offering an incentive to landholders to help them develop a new whole farm plan or renew an outdated plan following the modernisation to water infrastructure that has occurred across the Goulburn Murray Irrigation District (DJPR, 2019 https://agriculture.vic.gov.au/about/media-centre/media-releases/farm-plan-funding-still-available-in-north-central). The scheme illustrates how a region wide adaptation (in this case, modernising irrigation infrastructure to improve water use efficiency) can create a need for adaptation at the level of farm businesses and households. More specifically it points to how adaptation of water infrastructure (of the sort that has also happened in the Grampians region) enables and even requires changes in water and land management at the farm scale.

Other insights are offered by wider academic research. For example, a recent review of best management practice in primary industries, incorporating findings from the grains industry, calls for more focus on how adaptation is planned for, recognised, monitored and evaluated in primary industries, and for farmers and researchers to work more closely together (George a al. 2019).

Illustrating how to bring together scientific, technical knowledge and organisational knowledge is the Embedding Climate Adaptation in Agriculture (ECAiA) program led by the North East Catchment Management Authority. ECAiA is a four-year project utilises tools and climate projections to guide discussions with partners from the industry sectors of cropping, grazing, forestry, horticulture, viticulture, dairy, and six local governments. The tools are developed in response to industry engagement and needs to model industry relevant impacts including agricultural productivity and water system balance, presented spatially. The project aims to improve knowledge and capacity of landholders and local councils about regional climatic conditions and projections, to support discussions about adaptation pathways.

Case Study: Embedding Climate Adaptation in Agriculture in North East Victoria

North East Victoria

Lead Agency: North East Catchment Management Authority; funded by the Australian Government's National Landcare Program

- Utilise industry knowledge about relevant temperature, precipitation, and other conditions for industries in the region to develop models that are relevant and practical for local agricultural practice.
- Develop spatial tools, to allow farmers and other stakeholders to explore projections locally and regionally.
- Build the capacity of local agricultural industries to develop adaptation pathways.

Project link: https://www.necma.vic.gov.au/Solutions/Climate-Change/Embedding-Climate-Adaptation-in-Agriculture

5 Adaptation Focus – Economy

5.1 Introduction

In terms of wealth generation, much of the economic base of the Grampians region is linked to agricultural production and its value chain, including manufacturing, transport and, in some places, tourism. Yet service sector roles in health, retail, tourism and education provide more jobs. Existing vulnerabilities of the regional economy include population decline in some areas, and population growth and land use competition in others. The observed and projected impacts of climate change create significant impacts and risks for all economic activities in the Grampians region, including increased business costs across sectors and especially acute risks in agriculture and tourism.

5.2 Existing vulnerabilities and adaptive capacities

5.2.1 Existing vulnerabilities of the economy

- **Limited economic diversity in some parts of the region:** while the original settlement basis of many towns across the region was agricultural production (and in particular, dryland cropping) (Beer *et al* 2013, p43-44) the economic base of settlements across the region is not uniform:
    - The Wimmera Southern Mallee economy is heavily dependent on agriculture, and that agriculture is narrowly focussed on dryland grains (wheat and barley) (Yarriambiack Shire Council, 2015b). Communities and value chains reliant on agriculture are economically exposed to risks to the sector.
    - Ballarat is more diversified. Nevertheless, manufacturing is a significant element of the city's economic activity (34.3%) and it is declining in competitiveness and is facing predicted job losses despite the city's strong population growth (DELWP, 2014).
    - Elsewhere in the Central Highlands area, tourism (at 14.3% of total economic output of the Hepburn local government area) (DELWP, 2014) and short-term accommodation rental (much of this catering to high-SES Melbourne residents) is a much more significant element of the local economy (DELWP, 2018c). There has also been strong employment growth in: Accommodation and Food Services, Health Care and Social Assistance and Professional and Scientific and Technical Services (Hepburn Shire Council, 2016).
- **Exposure to global and national conditions:** Examples include: the decline of the manufacturing industry in Ballarat due to its exposure to global competition (DELWP, 2014); the exposure of agricultural producers in the Wimmera Southern Mallee on fluctuating global commodity prices (Yarriambiack Shire Council, 2015b) and global trade agreements/disagreements; and the effect of Covid19 and lockdowns on both regional and global tourism (particularly in the Central Highlands).
- **Economic focus and specialisation**: The northwest of the Grampians region is a highly specialised agricultural region, focussing on grains (wheat and barley), oilseeds and legumes. This specialisation into a specific crop type constitutes a clear vulnerability in the face of climate change - changing rainfall and water supply patterns are predicted to shift the suitability of crops grown southwards, meaning that the Wimmera, Mallee and parts of the North Central areas are vulnerable to the effects of climate change on water supplies unless they diversify to more suitable crops (Faggian *et al*, 2014). Currently, this region faces multiple stresses including the possibility of further long-term drought, susceptibility to water erosion, remoteness, declining rural populations, decreasing terms of trade, falling social services provision and an ageing

population (Sposito, 2006). These stresses all constitute a level of economic vulnerability (and thus social and Health and Wellbeing vulnerability)

- **Rapidly increasing population in some areas:**
    - Ballarat has strong population growth, attracting 'tree changers' (DELWP, 2014; City of Ballarat (2015) and 'Covid escapees' from Melbourne. Nonetheless, the loss of young residents (youth) to Melbourne is an issue (City of Ballarat, 2015).
    - In the Central Highlands, the Hepburn/Daylesford/Castlemaine region has strong population growth (DELWP, 2014).
    - Potential flow on effects of rising populations include increasing gentrification (rising house and rental prices), particularly in tourist areas such as the Central Highlands where house prices are growing at or above the Victorian average (which includes central Melbourne) (DELWP, 2014). This increase in the cost of living can push longstanding local residents out of the area, changing the overall settlement culture (DELWP, 2014) and lead to greater demand for social services (VCOSS, 2019). This is a concern in Ballarat where pockets of disadvantage exist (VCOSS 2019).
- **Resource and infrastructure demands:** Population growth is increasing demand for resources and products such as water, energy, food, internet, telecommunications and consumer goods, putting more pressure on existing transport and logistics systems and infrastructure, all of which are interconnected in complex ways. Where increased demand pushes the system towards its full capacity (e.g. in the electricity grid) this leaves it more susceptible to further, temporary spikes in demand. Although improvements to the electricity grid are proposed, they are yet to be implemented.
- **Decreasing and ageing population in many areas:**
    - Other than the Hepburn/Daylesford area and areas within Ballarat's functional region, the Central Highlands population is generally ageing and falling, as it is in the Wimmera Southern Mallee (DELWP, 2014); Yarriambiack Shire Council, 2015b).
    - Flow on effects of falling/ageing populations include: a declining working age population and a resultant decline in economic activity and growth (Yarriambiack Shire Council, 2015b); the lack of social opportunities for younger residents drives them to leave the region for opportunities elsewhere, only accentuating this overall trend (Yarriambiack Shire Council, 2015b); falling house prices. Although the latter can improve housing affordability and attract new residents, these may be from lower-SES situations and thus often do not stimulate the economic renewal that higher-SES 'tree-changers' can (Yarriambiack Shire Council, 2015b).
- **Lack of opportunities and support for young people**
    - In the Central Highlands area, approximately 1,100 young people are not in work or education. VCOSS (2019) has identified a number of social service gaps around post-secondary education that need to be addressed if younger residents are to be retained in the region. In particular there is a need for more funding to meet demand for programs such as the Navigator program by the Central Highlands Children and Youth Area Partnership that aims to improve Year 12 retention rates and create pathways to work, to improve the quality of university and TAFE courses, and to meet demand for parenting programs and family support (VCOSS 2019).

  - In the Wimmera Southern Mallee, students' learning outcomes and engagement are being negatively affected by housing and other cost of living pressures. As in the Central Highlands, there is not enough relevant training (according to local organisations) and a need for greater collaboration between TAFEs and other training providers and the community services industry (VCOSS 2019).

- **Economic development planning pressures:** Rural and smaller councils may lack the resources and capacity to access available economic grants (Yarriambiack Shire Council, 2015b; VAGO, 2018). The usual 4-year Council terms do not lend themselves to the longer timeframes necessary for effective economic development (Yarriambiack Shire Council, 2015b; VAGO, 2018).

5.2.2 Existing adaptive capacities of the economy

- **Economic diversity in some parts of the region**: some parts of the region demonstrate a relatively diverse economic base. Fifty percent of economic activity in the Hepburn Shire for example is spread amongst Manufacturing, Agriculture, Tourism and Construction, with remaining 50% consisting of a wide range of diverse sectors and industries (Hepburn Shire Council, 2016). Such diversity is, in and of itself, a source of adaptive capacity and resilience in the face of external economic shocks or trends.
- **Rising populations (in some parts of the region)** driven by a trend of metropolitan 'escape' to parts of the region (City of Ballarat, 2015; ABS, 2020). This has driven economic diversification and activity, bolstering the economic growth and development of these towns and regions (City of Ballarat, 2015). Such diversification builds economic resilience and rising populations lead to increasing economic growth.
- **Strong regional loyalty**. There is strong community support for the region, with many organisations focussed on engaging young people in education and employment, including developing supported pathways into work in the region.
- **Geographic advantage as an energy landscape**: Many locations within the region have, and will continue to be, potential locations for wind and solar electricity production (Chen 2019) and are part of the wider ranging transition occurring in the energy production mix in south eastern Australia as part of mitigating climate change.

5.3 Major climate change risks for the Grampians economy

Combined with existing vulnerabilities and adaptive capacities, projected and observed climate change means that the major risks posed by climate change to the economy include:

1. **Direct and indirect economic costs of acute climate-related events:** This includes the costs of damage caused by and the costs of responding to localised or widespread damage to built structures, roads and other infrastructure caused by one or more extreme events (e.g. floods, storms, fires) and their flow-on effects (Steffen *et al*, 2015; Bosomworth *et al*, 2013; Norton *et al*, 2013; Balston *et al*, 2013). It also includes the costs of disrupted economic activity and services caused by climate-related events such as extreme heat and droughts (Steffen *et al*, 2015, DELWP, 2016b). Flow-on effects include disruption to systems reliant on damaged infrastructure, such as electricity lines broken by fires, floods or storms, or overwhelmed by spikes in demand (Beer *et al*, 2013; NCCARF, 2018). Other flow-on effects include the longer-term costs of disaster recovery and rebuilding (Mason *et al*, 2012), a loss of tourism customers due to restricted access or perceived reduction in the aesthetic or recreational value of sites (DELWP, 2017), increased insurance

premiums for regional businesses and residents, and the economic repercussions of far-reaching physical and health impacts (Balston *et al*, 2013).

2. **Direct and indirect economic costs of chronic climate change stressors**. This includes lost income and additional costs created by a slowing of economic activity and service provision due to rising heat, more variable rainfall, and shortages in water or other climate-sensitive resources (Steffen *et al*, 2015, DELWP, 2016b). This risk is exacerbated by increased pressure on services and infrastructure in areas of population growth, or where funding has declined. Flow-on effects include a loss of tourism customers due to perceived reduction in the aesthetic or recreational value of sites (DELWP, 2017), and the economic repercussions far-reaching physical and health impacts (Balston *et al*, 2013). They also include further losses in productivity and enterprise options in agriculture and related industries as businesses close/move and leave others isolated. More broadly, there is a risk of continued or accelerated population decline in some parts of the region due to a negative feedback loop in which a lack of economic and social opportunity leads to economic contraction and loss of jobs and opportunities, which then accentuates the drivers of that decline. Further flow on effects of this loss of working age residents including young people include a decline in community participation (such as in sporting teams and community organisations) and volunteerism, reducing the sustainability of some emergency services and in turn multiplying the effects of disasters (CFA, 2015; Calcutt, 2019).
3. **External climate change-related economic shocks or trends:** as mentioned above, the Grampian's local and regional economies are embedded in state, national and global contexts and most are reliant on long value chains. This means they are exposed to distant climate change-related events, trends or shocks that can temporarily or permanently disrupt access to inputs and/or markets. For example, factories in China (which supply inputs such as glyphosate to agriculture and take Australian products such as wheat) are heavily reliant on hydroelectricity which has already proven susceptible to drought (Mori 2018), and shipping routes are increasingly disrupted by wild weather (Becker et al. 208, Verschuur et al 2020).

5.4 Key adaptation needs

Each of the above climate change risks to the region's economy points to the need and opportunity for specific adaptation strategies and actions (Table 5.1). The economic impacts of climate change on the economy threaten to be significant without substantial adaptation.

Table 5.1 Identified climate change risks for the Grampians economy and related adaptation needs and opportunities

IDENTIFIED RISKS	KEY ADAPTION NEEDS AND OPPORTUNITIES
Direct and indirect economic costs of acute climate-related events	**Local and municipal disaster plans**. Municipal councils are responsible for coordinating recovery at the local level for affected individuals and communities and must create Municipal Emergency Management Plans which are multi-agency plan, and include local risk management, preparedness and response activities (Victorian Government, 2018)
	Better integration of climate change within Council economic development plans. The direct (and indirect or cascading) effects of climate change need to be acknowledged in Council plans for economic development (Balston *et al*, 2013).
Direct and indirect economic costs of	**Economic diversification**. Climate and weather are a particular challenge for "[t]he large dry-land farming parts of the [Grampians] region", which, given the economic importance of agriculture in the region, poses a challenge for regional economic

chronic climate change stressors	development (DJPR 2021a). The climate sensitivity of agriculture is one reason economic diversification offers climate adaptation benefits. More diverse agricultural systems and better links to metropolitan economies offer advantages for the whole region. In the Wimmera Southern Mallee, this could include a focus on the 'health care and social assistance' sector, which is now the second largest economic sector after agriculture (and one of the few sectors that is growing) (Yarriambiack Shire Council, 2015b). Around Ballarat there is an opportunity further develop strong links to Melbourne's employment market (helped by strong and convenient transport links) and expand its service base by focussing on education and information technology to expand its services base (DELWP, 2014; City of Ballarat, 2015). Strengthening tourism in the Central Highlands offers diversification benefits but needs to be paired with explicit efforts to adapt tourism operations themselves to the acute and chronic impacts of climate change.
	Retention of population, particularly younger residents. While this is recognised as a challenge even by Ballarat (the fastest growing city in the region) (City of Ballarat, 2015), the demographic (and thus economic) survival of towns in the Wimmera Southern Mallee depends on the retention of younger (economically productive) residents (Yarriambiack Shire Council, 2015b). This requires increased economic or social opportunities to either retain younger residents, or attract them back after they have often completed their study in metropolitan areas (Yarriambiack Shire Council, 2015b)
	Increase in economic investment. Councils across the region need to continue to work to attract inwards investment, whether through accessing relevant Government grants or through the operation of economic markets (DELWP, 2014; Yarriambiack Shire Council, 2015b; VAGO, 2018)
	Increase alternative water supplies. This can include such examples as urban and agricultural water reuse (and examples such as sporting facilities), or rainwater capture (Tapsuwan *et al*, 2018). The latter appears more likely to occur at a larger organisational scale (i.e. councils and municipalities) while the former can be implemented at more modular/local level. As with reducing water demand (below) there is a clear connection between residents' awareness of water vulnerabilities, and willingness to install rainwater tanks (Tapsuwan *et al*, 2018). Finally, there is a need to better streamline policy to allow more flexibility with regard to the approval of recycled water supply projects (VicWater, 2020).
External climate change-related economic shocks or trends	**Economic diversification**. *As above*
	Place-based economic modelling and contingency planning that accounts for external factors. Councils need to clearly model and understand the larger scale systemic challenges that they may be facing (VAGO, 2018) including the far-reaching effects of climate change (Balston *et al*, 2013).
	Adaptation of value chains. Whole of value chain adaptation is needed to reduce the risks to all within the chain. This includes working with transport, ports and others involved in logistics to manage climate change related risks.

5.5 Existing adaptation actions

A wide range of relevant actions are underway or getting underway in the Grampians region that help redress climate change risks to its economy (Table 5.2)

Table 5.2 Example existing adaptation actions in the Grampians relevant to the economy

KEY ADAPTION NEEDS	EXAMPLES FROM THE REGION
Local and municipal emergency management plans	All Municipalities have an Emergency Management Plan in place of under development, as required under the *Emergency Management Act* 1986 (Vic)
Better integration of climate change adaptation within local government economic development plans	Yarriambiack Shire Council: Economic development plan incorporates greenhouse gas mitigation (sustainable development) and climate change adaptation (a 'driver of change' identified in the plan) https://yarriambiack.vic.gov.au/wp-content/uploads/EDS_2015.pdf City of Ballarat (Partly): There is a sentence on climate change in the Economic Program https://www.ballarat.vic.gov.au/sites/default/files/2019-04/Economic%20Program%202015-19.pdf Hindmarsh Shire (Partly): the 'Economic Development Strategy 2015 – 2020' acknowledges a 'changing climate' https://www.hindmarsh.vic.gov.au/content/images/What%20we%20do/Business%20support/Economic%20Development%20Strategy%202015_2020.pdf
Examples of strategies for economic diversification	Ararat City Council (Partly): there is such a focus in evidence here https://www.ararat.vic.gov.au/sites/default/files/Council%20Plan%202017-2021%20Year%204.pdf City of Ballarat: a clear focus on economic diversification in evidence https://www.ballarat.vic.gov.au/sites/default/files/2019-04/Economic%20Program%202015-19.pdf Hepburn Shire Council: https://www.hepburn.vic.gov.au/wp-content/uploads/2016/07/Economic-Development-Strategy-2016-21.pdf Horsham Rural City Council (Partly): https://www.hrcc.vic.gov.au/Our-Council/Public-Documents/Council-Publications/Economic-Development-Strategy?BestBetMatch=economic%20development|d13b95b2-5146-4b00-9e3e-a80c73739a64|4f05f368-ecaa-4a93-b749-7ad6c4867c1f|en-AU Hindmarsh Shire (Partly): the 'Economic Development Strategy 2015 – 2020' focusses on the existing economic strengths of the area, rather than diversification - with the exception of a stated focus on increasing tourism https://www.hindmarsh.vic.gov.au/content/images/What%20we%20do/Business%20support/Economic%20Development%20Strategy%202015_2020.pdf Moorabool Shire Council: the economic development plan acknowledges both the strong economic diversity that already exists and a focus on increasing/promoting this diversity https://www.moorabool.vic.gov.au/sites/default/files/largefiles/Moorabool%20Shire%20Economic%20Development%20Strategy%20%28Geografia%2C%20October%202015%29.pdf Northern Grampians Shire (Partly): Economic development plan underway, and background research demonstrates a clear awareness https://www.ngshire.vic.gov.au/Have-Your-Say/Economic-Development-Strategy-and-Action-Plan-2021-31 West Wimmera Shire: a clear focus on economic diversification in evidence

	https://www.westwimmera.vic.gov.au/Council/Documents-Publications/Plans-Strategies?BestBetMatch=%22economic%20development%20plan%22|8baa1aaf-8b63-4531-89b6-66e96bacefde|e8ea7ded-2029-4a48-af87-d1a116abbc49|en-AU Yarriambiack Shire Council: Economic development plan clearly focusses on the historical and wider-scale contexts, including challenges https://yarriambiack.vic.gov.au/wp-content/uploads/EDS_2015.pdf
Examples of retention of population, particularly younger residents	Councils across the region are focussing on social, cultural engagement, recreational and employment activities for youth. Examples include: • Yarriambiack Shire Council's **Youth Engagement Strategy**, which aims to provide 'a strategic direction for the development and coordination of youth services and infrastructure' within the shire https://yarriambiack.vic.gov.au/wp-content/uploads/Youth_Strategy_2019-22.pdf • **Hammon Park Trail Head Community and Youth Hub:** Mountain bike trail development in the Hepburn Shire - has $2.5 million of funding from Victorian Government and council. Aims to drive mountain bike tourism in the region, but also provide economic and recreational opportunities for local youth. https://www.hepburn.vic.gov.au/wp-content/uploads/2020/07/Hepburn-Shire-Priority-Projects-2020-2021-Hammon-Park-Trail-Head-Community-and-Youth-Hub.pdf
Increased social service delivery capacity	While there are clearly social service providers working across the region, VCOSS (2019) has identified numerous social service shortfalls including a lack of: • social and transitional housing • crisis accommodation • employment opportunities • affordable and frequent transport • student support services • funding for food insecurity programs and Food Bank hubs • mental health services including case management (particularly in the Central Highlands)
Increase alternative water supplies	Urban and agricultural water reuse 1. **The Stawell Stormwater Alternative Natural Solutions project** uses stormwater to drought-proof community assets. The project saves over 74 megalitres per year through series of water quality treatment ponds, storage dams and transfer infrastructure – reclaimed water from this infrastructure is used to irrigate sporting facilities, gardens and public open spaces. 2. In 2020, **recycled water regulations were streamlined** as part of a recycled water guidelines review undertaken by VicWater. These include streamlined audit obligations, fewer and more risk-based scheme approvals and reduced red tape (VicWater, 2020)
Place-based economic modelling that accounts for these external factors	Central Highlands regional Council https://www.centralgoldfields.vic.gov.au/files/sharedassets/public/council-plans-documents-strategies-policies/policies/economic-development-strategy.pdf West Wimmera Shire https://www.westwimmera.vic.gov.au/Council/Documents-Publications/Plans-Strategies?BestBetMatch=%22economic%20development%20plan%22|8baa1aaf-8b63-4531-89b6-66e96bacefde|e8ea7ded-2029-4a48-af87-d1a116abbc49|en-AU Horsham Rural City Council https://www.hrcc.vic.gov.au/files/assets/public/document-resources/our-council/publications/horsham-eds-background-discussion-paper.pdf

	Ararat City Council https://www.ararat.vic.gov.au/sites/default/files/EconomicPathway%202017_0.pdf City of Ballarat https://www.ballarat.vic.gov.au/sites/default/files/2019-04/Economic%20Program%202015-19.pdf Golden Plains Shire https://www.goldenplains.vic.gov.au/sites/default/files/Economic-Development-Tourism-Strategy20172021_FINAL.pdf Hepburn Shire Council https://www.hepburn.vic.gov.au/wp-content/uploads/2016/07/Economic-Development-Strategy-2016-21.pdf Hindmarsh Shire https://www.hindmarsh.vic.gov.au/content/images/What%20we%20do/Business%20support/Economic%20Development%20Strategy%202015_2020.pdf Northern Grampians Shire: Eco. dev. plan underway: demonstrates a clear awareness of external factors and challenges (including climate change) https://www.ngshire.vic.gov.au/Have-Your-Say/Economic-Development-Strategy-and-Action-Plan-2021-31 Moorabool Shire Council https://www.moorabool.vic.gov.au/sites/default/files/largefiles/Moorabool%20Shire%20Economic%20Development%20Strategy%20%28Geografia%2C%20October%202015%29.pdf Yarriambiack Shire Council: https://yarriambiack.vic.gov.au/wp-content/uploads/EDS_2015.pdf

Because of the generic nature of the economy, adaptations to reduce climate change risks to it necessarily overlap with not only those discussed in other parts of this report but many actions not labelled as climate change adaptation. For example, economic activity such as diversification is often framed through the lens of economic development, rather than adaptation *per se,* even though they can have positive adaptation outcomes. There are advantages and disadvantages of approaching climate change adaptation as a dedicated activity versus mainstreaming it into existing policies and practices (Runhaar et al. 2018, Table 4.4). Both are important and can be complementary. Managing the economic risks of climate change is one area in which there is particular value in mainstreaming adaptation into all decisions and policies, demonstrating the principle of integrated decision making on adaptation advocated by the Victorian Government.

Table 5.3 Advantages and challenges of mainstreaming climate adaptation identified in the literature (Runhaar et al. 2018)

Advantages	**Challenges**
• Identifying actions which achieve co-benefits – for instance, urban greening as flood mitigation as well as community infrastructure. • Resource efficiency – for instance, taking advantage of asset renewal to integrate adaptation actions. • Promoting innovation in sectorial plans/policies.	• Reduced visibility / attention to adaptation issues when compared to a dedicated adaptation approach. • A need for targeted support and action for mainstreaming climate adaptation.

5.6 Examples of adaptation from other places

There is an opportunity to learn from adaptation activities and research in other parts of Victoria and Australia where similar or interconnected economic climate change risks are being managed. This includes an explicit attempt to assess cross-sectoral economic risks posed by climate change (see Alpine Resort Futures case study below) and to integrate climate change into a high-level governance process (council plans) and across multiple councils in a region (see Port Phillip Regional Adaptation Strategy case study below).

Case Study: Alpine Resort Futures - A Cross-sectoral Assessment of Social and Economic Vulnerability Assessment to Climate Change

This work has informed the Alpine Resorts Strategic Plan (2020), including consideration of climate change, and discussions of ways to both diversify offerings in the snow season for visitors to activities less dependent on traditional snow cover, and encouraging and promoting 'green season' visitation (Alpine Resorts Coordinating Council 2020) with the following considerations:

- Primary industries, tourism, resource and other sectors are particularly exposed to climate change (Deloitte Access Economics 2020).
- The Alpine Resorts Co-ordinating Council commissioned research in 2016 to examine the biophysical impacts of climate change.
- Following this assessment. The council commissioned further research into the social and economic aspects.
- This research included requirements to improve understanding of stakeholder values and their vision for the future.
- Uncovering values can be helpful in understanding which adaptation actions will be appropriate for the context (Strategic Plan, Alpine Resorts Co-ordinating Council, 2020)

Case study: Port Phillip Regional Adaptation Strategy - Embedding climate change in the Council Plan process

Location: Melbourne

Lead Agency: Vic. Gov. DELWP (funding partner, project delivered under the Port Phillip RAS); Northern Alliance for Greenhouse Action

- The project aims to embed climate change across councils at the governance level through the Council Plan development process.
- Climate change is not a 'special issue,' but rather it has relevance for the overarching governance of Council.
- This project may have valuable lessons for the embedment of climate change across councils.

6 Adaptation Focus – Management of the Natural Environment

6.1 Introduction

The Grampians region includes a range of magnificent and significant biophysical and natural environmental systems, some of which are managed as National Parks and other public land reservations, some privately. Existing vulnerabilities are associated with competing uses and the fragmentation of vegetation and habitat. Key challenges from observed and projected climate change include stress to waterways, further stress on remnant habitat and biodiversity hotspots in the region and broader changes to regional ecosystems from a drier, hotter climate.

Climate change poses a significant challenge for natural environment managers, including significant threats to biodiversity which will be influenced by a range of factors, including "exposure to climate change and associated ecosystem shifts, sensitivity due to particular traits, and capacity to adapt to those changes" (DELWP 2017, p.16). Moreover, as noted in the Draft Grampians Region Climate Adaptation Strategy, socio-economic factors including land-use change and economic development is and will be significant in the management of the natural environment, and multiple values will determine land and water use (DELWP 2020).

6.2 Existing vulnerabilities and adaptive capacities

6.2.1 Existing vulnerabilities of the natural environment and its management

- **Ecosystems' reliance on variable and heavily exploited water supplies:** Water supplies across the region are already rated as vulnerable, being dependent on reliable cool season rainfall and runoff to maintain flow in waterways (DELWP, 2016a). River and waterway health is also poor, with rivers rated as healthy for only 0-10% of their length (DELWP 2016b, p50). Environmental flows have decreased (Morton *et al*, 2014; Prosser, 2011) and a range of historical and contemporary water uses have contributed to erosion, increased salinity and loss of riverine vegetation (DELWP, 2016b; DDWCAC, 2014; Morton *et al*, 2014). Water demand is high and there is competition between stakeholders (commercial, residential, agricultural and recreational, environmental managers) (DELWP, 2016b; 2016c; 2018b).
- **Habitat fragmentation and degradation and biodiversity loss:** Some of the natural vegetation and ecosystems in the region are highly fragmented and degraded, reducing their ecological health and putting species and ecological services at risk. In the Wimmera alone, there are more than 50 threatened animal species (https://wcma.vic.gov.au/threatened-plants-animals#:~:text=Threatened%20Fauna%20List%20in%20the%20Wimmera%20%20,%20Near%20threatened%20%2031%20more%20rows%20)
- **Lack of awareness or prioritisation of ecological services and biodiversity**. Ecological services and biodiversity are neither widely understood by relevant stakeholders or generally prioritised over economic or agricultural concerns (Morton *et al*, 2014; Steffen, 2009; DELWP, 2017).

6.2.2 Existing adaptive capacities of the natural environment and its management

- **Adaptive capacity of original/native species:** Original/natural species and biotic communities in the region are adapted to past climatic conditions, including climatic variability and extreme events such as floods and fires. They therefore have a certain

capacity to cope with certain climatic shifts and may even benefit from changes such as larger floods.

- **Experience and expertise in catchment management authorities:** The Grampians region can draw on the decades of expertise about the region's landscape and catchments, and the existing programs and networks, represented by its various CMA's and associated agricultural groups (e.g. Landcare).
- **Indigenous and local land management knowledge:** there is a wealth of historical knowledge amongst land managers within the region, with Indigenous knowledge in particular being a valuable source of ecological knowledge and techniques (such as cultural burning) (Morton *et al*, 2014). These stores of knowledge need to be acknowledged and accessed by decision-makers within the region.

6.3 Major climate change risks for management of the Grampians' natural environment

When combined with existing vulnerabilities and adaptive capacities, projected and observed climate change pose major risks to the Grampians region natural environment and its management. Risks include:

1. **Worsened waterway health:** The interconnected effects of ongoing climate change threaten to worsen waterway health and increase aquatic ecosystem stress, particularly given the already very poor state many of the region's waterways are already in (DELWP, 2016a, DELWP, 2016b; Morton *et al*, 2014).
2. **Accelerated habitat and biodiversity degradation and loss:** Chronic stressors such as hotter temperatures and acute climatic events such as intense fires threaten to exacerbate the existing trend of habitat and biodiversity degradation and loss. Original/natural ecosystems in the area are adapted to certain climatic conditions, including climatic variability and extreme events such as floods and fires. However, the increased frequency, intensity and co-occurrence of such events, their shifting seasonality, and their coincidence with other non-climatic stressors means that they may precipitate immediate habitat and wildlife loss (DELWP, 2020c) or erode adaptive capacity due to ongoing changes in environmental parameters (DELWP, 2017; Steffen, 2009; DELWP, 2020c). Changing rainfall and water supply patterns are predicted to impact the range and quality of habitat and refugia (DELWP, 2017; Hayward *et al*, 2016; Steffen, 2009). Flow on effects include a loss of ecological services (DELWP, 2017), and a loss of recreational, economic or cultural amenity (DELWP, 2017) and unwanted changes to environmental tourism attractions, such as the Grampians National Park (Gariwerd).

   Complex ecologies mean that there are many feedbacks and other relations involved. For example, climate change may negatively impact herbivorous species, which reduces their capacity to keep fuel loads down, accentuating fire risks (Hayward *et al*, 2016). It is also projected to increase the threat of pests and disease, including invasive species (Morton *et al*, 2014; DELWP, 2017; Steffen, 2009).
3. **Changes in regional ecosystem structure, composition and function:** Even those natural ecosystems that remain relatively healthy, and those that are already highly modified such as agroecosystems, are likely to change substantially under climate change as species adapt in various ways. Migration of some species southward to track their climatic window will bring new species into contact with each other and create new ecological assemblages that may require new management strategies (DELWP, 2017, Faggian *et al*, 2014; Beer *et al*, 2013).

4. **Agricultural and economic resource uses prioritised over environmental health:** Climate change may intensify competition for land, water and resources between natural resource management and other uses, notably agriculture, as the latter comes under pressure from climate change. Water plans across Australia generally: '*tend to pass on impacts of reduced flows to regions downstream. They were not designed to deal with long-term reductions in runoff due to climate change. Under the plans, long-term reductions in runoff would be largely borne by the environment and downstream regions'* (Prosser 2011, p43). There is danger of a feedback here in which a focus on agricultural or economic concerns, at the expense of the regional environment, only accentuates the environmental/ecological degradation and thus increases the negative effects on both agriculture and regional economies.

6.4 Key adaptation needs

Given the major climate change risks identified above, what adaptation is needed? Although adaptations are countless, and natural organisms and species have some capacity to adapt to some climate changes, some specific needs and opportunities for adaptation to human management of the natural environment in the region can be identified (Table 6.1).

Table 6.1 Identified climate change risks for the Grampians natural environment and its management, and related adaptation needs and opportunities

IDENTIFIED RISKS	KEY ADAPTION NEEDS AND OPPORTUNITIES
Worsened waterway health	**Increase environmental water flows into 'at-risk' waterways:** This involves State-level regulation to better manage conflicting stakeholder interest in waterways (DELWP, 2016b; 2016c; 2018b; Ehsan *et al*, 2020; Prosser, 2011). It also involves more localised projects and policies that increase or protect environmental water flows.
	Improve integrated catchment water management: This includes improved stakeholder engagement and more effective regulatory oversight. The current understanding is that this is best achieved through an **Integrated Catchment Management (ICM)** approach which uses catchments as one of the 'logical ways to plan and manage the landscape in an integrated way. This approach recognises that land, water and biodiversity are all part of connected systems, from the top of the catchment, down through receiving waters and landscapes, to the coast and marine environments. It emphasises the value of joined-up planning and management.' (DELWP, 2019b, p7)
	Identify and redress main non-climatic drivers of declines in waterway health. Examples include pollution and run-off from industry, agriculture and urbanised areas (Prosser, 2011; WCMA 2006); excessive extraction and management for other uses (Prosser, 2011) and (in the northwest of the region) declines in waterway health due to: • Altered drainage and flow regimes. • Changed channel form. • Deficient floodplain management (WCMA 2006, p3).
Accelerated habitat and biodiversity degradation and loss	**Reduce non-climatic pressures on natural terrestrial systems.** To improve the adaptive capacity of ecosystems in the face of climate change it is vital to reduce other stressors on them as part of an 'integrated regional biodiversity response strategy' (Steffen, 2009). This involves bolstering much of the existing work, and the organisational capacity, of CMA's, Landcare, and environmental NGO's.
	Restoration of existing habitat: interventions to restore habitat and reverse biodiversity loss and/or ecosystem damage in specific high value areas (Morton *et al*, 2014), including

	in the wake of damage from particular climatic extremes or events. This is particularly important for areas that provide habitat connectivity in the landscape and thus allow for future climate migrations. Revegetation is also especially important in highly disturbed areas such as past gold mining landscapes where there is risk that polluted soil will be disturbed by climate change related events such as fires or floods, or increased heat will make toxins more volatile, all of which presents risks to both human and ecosystem health.
	Planned adaptation for some species and ecosystems: Careful interventions will likely be needed to promote the adaptive capacity of targeted ecosystems and species that are unlikely to be able to adapt quickly or significantly enough on their own (Jordan & Hoffmann, 2017; Hughes *et al*, 2010; Steffen, 2009, DELWP, 2017). This includes species translocations and assisted migration, including the establishment of large new multi-species plantings based on projected climatic zones and species distributions.
	Embed ecosystem priorities in local and municipal disaster plans and fire management. Ensuring that the protection of high value natural assets and protection of ecological services are included in Municipal Emergency Management Plans and fire management approaches.
Changes in regional ecosystem structure, composition and function	**Adaptive management of shifting species assemblages across the region**. Environmental managers need to monitor ongoing shifts in species, such as the appearance of previously rare species (e.g. migratory birds, weeds) as warmer climate zones move south, and adjust their management accordingly. This includes monitoring the existing reserve network and considering the possible need for new reserves or altered management priorities in existing reserves, given shifting species distributions and future needs. It may require new partnerships with different agencies and public and private land managers.
Agricultural and economic resource uses prioritised over environmental health	**Engagement and education of land and water managers:** Continue to develop strong relationships between different land and water managers. In particular, engage farmers and others in the benefits of ecosystem-based adaptation. Use the need for businesses to respond to climate change to progress Landcare and other good land management practices.
	Ensure policy and management decisions are informed by up-to-date science. Understanding of ecological services and up-to-date data about ecosystem health and climate futures: Such an approach is crucial to address a longstanding lack of awareness of the importance of biodiversity and ecosystem services amongst many Victorian stakeholders (Prosser, 2011; DELWP, 2017).

6.5 Existing adaptation actions

Given all the efforts of CMA's, Landcare groups and others, and the strong overlap between good environmental practice and ecosystem-based adaptation, there are already many actions underway in the Grampians region that have climate adaptation benefits for natural systems (Table 6.2).

Table 6.2 Example existing adaptation actions in the Grampians relevant to management of the natural environment

KEY ADAPTION NEEDS	EXAMPLE EFFORTS
Increase environmental water flows into 'at-risk' waterways	**Regulatory improvement** 1. The recent State Environment Protection Policy (SEPP) (Water) is a State regulatory framework to address competing waterway uses, and prioritise the environmental health of waterways. It is designed to:

	• confirm the beneficial uses of Victorian groundwater and surface water, and where these uses apply • set water quality indicators and objectives to protect beneficial uses • establish a modern, risk-based framework to manage unlicensed point and diffuse pollution sources in rural and urban areas • develop regional target settings and plans to improve water quality • ensure water quality offsets can be used within catchments to maintain regulatory compliance within waterways. **Examples of local programs** 1. *Dja Dja Wurrung/ North Central Catchment Management Authority/ Trust for Nature – Putting the swamp back into Long Swamp* (1 of 11 pilot projects around Victoria) (DELWP 2018b, p5) 2. Wimmera Catchment Management Authority - Northern Dunmunkle Creek restoration plan (as above) (DELWP 2018b, p5)
Improve integrated catchment water management	The ongoing implementation of the *Our Catchments Our Communities* plan (DELWP, 2019b) aims to implement a clear Integrated Catchment Management (ICM) approach. The goal is to involve regional partners and community networks in its implementation, along with DELWP and CMAs, including those working the Grampians region. A number of waterways in the region (including the Wimmera River and Campaspe River) are earmarked for significant State Government funding to 27 eligible local governments.
Identify and redress main non-climatic drivers of declines in waterway health	In addition to the above, many of the existing efforts of groups such as CMA's, Landcare, Parks Victoria, Friends of Grampians Gariwerd and others are working to reduce non-climate related pressures on waterways in the region. For example, education about and on-ground riparian management work to fence off waterways to control erosion and restore riparian vegetation by groups such as the Buloke and Northern Grampians Landcare Network improves the adaptive capacity of those ecosytems.
Reduce non-climatic pressures on natural terrestrial systems	As above, many of the existing efforts of groups such as CMA's, Landcare, Parks Victoria, Friends of Grampians Gariwerd and others are working to reduce non-climate related pressures on natural ecosystems/agroecosystems in the region. For example, the Wimmera CMA's Wimmera Invasive Plant and Animal Management Strategy is working to reduce the negative impacts of invasive species in the Wimmera region.
Restoration of existing habitat	There are many examples here across the work of Landcare networks, CMA biodiversity plans, the Grampians to Pyrenees Biolinks Alliance and others in the region. For example, the Woorndoo Land Protection Group have been working with DELWP funding to enhance and expand a native grassland community on the Woorndoo-Streatham road corridor.
Planned adaptation for some species and ecosystems.	Conservation is becoming more interventionist to help adapt species to climate change. Within the Grampians region, for example, there have been a significant number of plant species translocations (Silock et al. 2019, Figure 6.1 below)
Embed ecosystem priorities in local and municipal disaster plans and fire management	The *Dja Dja Wurrung in Landscape* project has led to the implementation of Djandak Wii (cultural burning practices) in private land in the region which is helping prioritise and protect ecological health. See DELWP (2018d)

Adaptive management of shifting species assemblages across the region	NCCMA (2015) identifies the need to consider active efforts to increase planting of drier species beyond their historical range, and the development of biolinks through private land (utilising the relevant planning schemes) to increase specifies movement and the quality or refugia
Ensure policy and management decisions are informed by up-to-date science	DELWP (2017) has introduced two specific spatial tools for environmental management and decision-making: • **Change in Suitable Habitat**: to assess options for improving the future of native species across the state • **Strategic Management Prospects (SMP)** an expert-based scenarios modelling tool for biodiversity Importantly, both of these tools, which will form the backbone of Victorian environmental management going forward, clearly focus on the shifting environmental parameters caused by climate change. The question will be to what extent these tools are used by decision makers within the region.

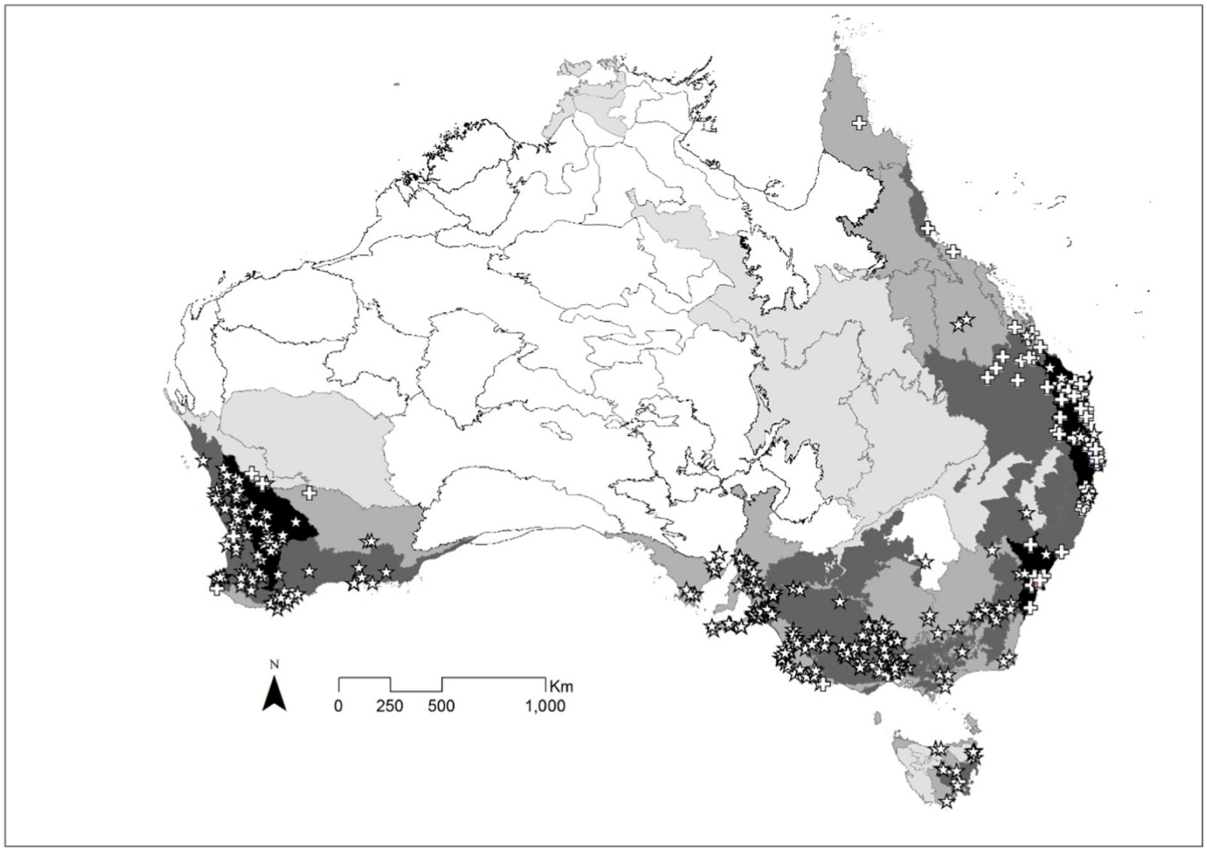

Figure 6.1 Plant species translocations to date (from Silcock et al. 2019, p.214). Stars represent translocations for conservation reasons, crosses represent translocations to mitigate land development projects.

Existing examples of adaptation include activities involving Traditional owners and community Landcare groups that seek to address vegetation loss and waterway health as well as research and field trial activities led by government and research institutions. These each present opportunities and challenges to address issues of scale, and cross over tenure and land management boundaries.

The role of biodiversity in the landscape, and beyond just public land, is a growing area of research and policy interest (Grau et al., 2013; Morton et al, 2014; Steffen, 2009). Land use sharing (rather than typical land 'sparing' responses) is a particularly important consideration in areas of the Grampians region undergoing land use transition, including peri-urban areas close to Melbourne and Central Highlands and areas that feature agricultural under-investment, such as parts of the Pyrenees Ranges where sheep grazing business are in decline.

6.6 Examples of adaptation from other places

The case study below demonstrates the approach taken by the Corangamite CMA (which is partly outside, partly inside the Grampians region) in the Western District Lakes. It demonstrates awareness that strategic (as opposed to reactive) planning is especially important in adaptation of environmental management (Bosomworth et al. 2015). Embracing the complexity of the socio-ecological systems of the Lakes, the Corangamite District Lakes Adaptation Pathways project is piloting the use of the concept of adaptation pathways to plan for the management of natural assets with landholders, government representatives, community groups, researchers and Aboriginal groups (Corangamite CMA 2021). An adaptation pathways approach is used not only to help facilitate robust and flexible management solutions in the context of uncertainty, but because such a collaborative approach to planning can improve understanding, identify and negotiate stakeholder preferences, encourage social learning amongst participants, and clarify roles, responsibilities, and responses (Bosomworth *et al*. 2015; Wise e*t al*. 2014).

Such an overall approach is also being implemented (in a range of ways) by DELWP through Victoria's most recent Biodiversity Plan (DELWP 2017), although there is acknowledgement that this cannot be achieved by state-level activity alone. Local initiatives are also crucial, including activities of 'Friends' and Landcare groups and individual landholders.

There is a plethora of other work embedding climate change adaptation in environmental management that offers insights for the Grampians region. Some of these are listed in Table 6.3.

Case study: Western District Lakes Adaptation Pathways

Location: Western District Lakes (acknowledging that Corangamite CMA covers part of the Grampians region)

- A series of workshops with regional stakeholders to contribute to adaptation pathways for the management of the Western District Lakes.
- Exploring multiple possible futures for the region, in order to test the robustness and or flexibility of different management options.
- Considering how the Lakes are valued and managed, and how this might need to change in the context of climate change.

Lead Agency: Corangamite CMA, in collaboration with RMIT

Table 6.3 Examples of relevant adaptation actions in other places

Project/ example name	Where from	Why this is worthy of note	Link
Weeds & climate change	Australia; CSIRO	• The AdaptNRM Initiative developed a Technical Guide, synthesising impacts and adaptation, to assist with regional weed management in the context of climate change.	Scott *et al* (2014): https://adaptnrm.csiro.au/wp-content/uploads/2014/08/Adapt-NRM_M2_WeedsTechGuide_5.1_LR.pdf
The NRM Adaptation Checklist	Australia; CSIRO & NCCARF	• The NRM adaptation checklist is designed to help with the adjustment and amendment of NRM plans, provide supplementary information, and design evaluation.	Rissik *et al* (2014): https://adaptnrm.csiro.au/wp-content/uploads/2014/06/AdaptNRM-Adapt-Planning-Tech-Guide1.pdf
Adaptation Pathways: a playbook for developing robust options for climate change adaptation in Natural Resource Management (NRM)	South East Australia: RMIT University, University of Tasmania, and Monash University.	• This 'playbook' was designed with Natural Resource Managers from: Corangamite CMA, Cradle Coast NRM, East Gippsland CMA, Glenelg Hopkins CMA, Local Land Services SE NSW, NRM North, NRM South, Port Phillip Westernport CMA, and West Gippsland CMA. • It provides guidance for NRM to plan with uncertainty in a way that is strategic and robust. • It can also facilitate collaboration and buy-in through engaging a range of stakeholders needed to ensure the sustainability of NRM practices and solutions.	Bosomworth *et al* (2015): https://www.researchgate.net/publication/272158438_Adaptation_Pathways_a_playbook_for_developing_robust_options_for_climate_change_adaptation_in_Natural_Resource_Management_Southern_Slopes_Climate_Change_Adaptation_Research_Partnership
The Biodiversity Adaptation Toolbox	Australia; CSIRO	• The AdaptNRM Initiative align strategic goals and actions with principles for managing biodiversity in our changing climate. • It is designed to stimulate thinking, as well as to act as a practical starting point for current biodiversity planning.	The Biodiversity Adaptation Toolbox (AdaptNRM website): https://adaptnrm.csiro.au/biodiversity-options/the-biodiversity-adaptation-toolbox/
Climate Future Plots	Greening Australia, DELWP, others	• Climate Future Plots (CFPs) are experimental modular reserves to build genetic diversity in specific regeneration areas (Jordan & Hoffmann, 2017) by planting species based on future climate zones and monitoring their performance. One exists near Bendigo and the aim is to establish a network of such plots around Victoria.	Climate Future Plots Guide https://www.greeningaustralia.org.au/climate-future-plots/

7 Adaptation Focus – Health & Wellbeing

7.1 Introduction

All observed and anticipated impacts of climate change in the Grampians region have health and wellbeing implications, including the direct and indirect impacts of increased temperatures and heatwaves, bushfire, drought and floods, and longer term, socioeconomic aggregate impacts. The experience of this across the region will differ. Different areas and groups need to manage specific risks and vulnerabilities, sometimes at different times. For example, people in the north of the Grampians and in older age groups are generally more exposed or susceptible to heat stress, and across the region at any one moment there may be more than one hazard event unfolding, with implications for the health and wellbeing of those in affected areas.

Protecting the health and wellbeing of members of the Grampians region is crucial because health and wellbeing is key to the adaptive capacity of the region. That is, good health and wellbeing is an enabler of adaptation in other sectors, across stressors.

Regional adaptation needs to manage impacts (including second and third order impacts) on the community in general, including increased pressure on health and emergency services. Helping health and emergency services keep up with increasing and altered demand, at local to regional scales, is a significant challenge. Besides such services and Municipal Health and Wellbeing Plans, other important adaptations to improve health and wellbeing in the Grampians region include reducing existing health vulnerabilities (e.g. those associated with an ageing population), ensuring access to high quality food and water, managing the risk of infectious diseases and pests, and improving the quality of housing stock and environmental amenity.

7.2 Existing vulnerabilities and adaptive capacities

7.2.1 Existing vulnerabilities of human health and wellbeing

- **Poor health status among some groups** – there are generally higher rates of obesity and other chronic diseases, and lower life expectancy in parts of the Grampians region (Western Alliance, 2016), in part due to limited access to healthy food in some places (Love *et al*, 2018).
- **High proportion of older people**– older people tend to have existing health challenges and sensitivities, such as to heat (Harvison *et al* 2011).
- **Some groups physically exposed to the elements –** Due to the outside character of their jobs (e.g. in the agricultural sector), some individuals are especially exposed to hazardous climatic conditions. Others have relatively high exposure due to the poor quality of the buildings they live or work in, such as poor thermal insulation of housing (McMichael *et al*, 2006; DHHS, 2017). In the Grampians region the capacity to adapt the built environment varies, with limited investment in the urban realm or opportunities to retrofit older housing stock.
- **Limited access to health services in more remote areas and towns –** In the Grampians region many rural and remote residents face difficulties accessing healthcare due to their location, with lower numbers of healthcare workers and professionals per 100,000 than in cities[1] and limited access to some services including dentistry (Tham & Hardy, 2013) and mental health support (Loi *et al*, 2017; DELWP, 2018c). The need for people to travel long distances combines with poor public transport to increase reliance on car transportation, increasing the financial and time costs, safety

risks and inequalities for those affected, thus disincentivising them from accessing the treatment and support they need and worsening their health conditions.

7.2.2 Existing adaptive capacities around human health and wellbeing

- **Awareness and experience of climatic stressors:** Many residents of the Grampians Region have a long history of managing climate variability and natural disasters. In Australia, and especially rural and regional Victoria, awareness of climatic stressors and disruptions and experience in managing them is correlated with greater awareness of and concern about climate change, adding a sense of climate change effects being 'more immediate and closer to home' (Reser *et al*, 2010, p27) and increasing the capacity and willingness to adapt to future climate change.
- **Community cohesion and social capital**: Despite health challenges, many rural and regional areas have higher levels of wellbeing, reducing their susceptibility to climate change impacts (AIHW REF). Although population decline and ageing are challenging many smaller Grampians communities, some are experiencing retirement migration (Winterton *et al*, 2019) and many have strong community lives, presenting valuable opportunities to collectively address adaptation needs locally.
- **Existing health services**: the region includes a range of high-quality health services and networks, and current investments in new services such as at Ballarat Base Hospital. While stretched over wide regions, health care in the Wimmera offers some services at a greater level than found in urban centres, albeit for a narrow range of treatments.

7.3 Major climate change risks for Grampians health and wellbeing

When the above vulnerabilities and capacities are combined with the observed and projected climate change pressures (see Hazard section), it is apparent that the Grampians region faces the following risks to health and wellbeing:

1. **Increase in mortality and morbidity due to temperature, including intensity and length of heatwaves:** these events have a direct effect on the health of the region, leading to significant increases in heat-related illnesses and deaths (Steffen *et al*, 2015; Beer *et al*, 2013; DHHS, 2019a; Environmental Health Unit, 2009; Fünfgeld *et al*, 2014). Flow on effects include isolation amongst vulnerable residents (such as the elderly, low Socio-Economic Status (SES) households and children) (DHHS, 2019b); breakdowns in public transport, making it difficult for vulnerable people (i.e. the elderly) to get to hospitals or air-conditioned places (Steffen *et al*, 2015); increased stress on health and emergency services (DHHS, 2019a; 2019b OCHO, 2009); increased risk of poor food hygiene (in the event of power blackouts leading to loss of air-conditioning and refrigeration) causing outbreaks of gastroenteritis and food poisoning (Fünfgeld *et al*, 2014; Steffen *et al*, 2015).

   There are direct vulnerabilities within the region regarding increasing temperatures, with effects including heat-related illnesses, exacerbation of existing health conditions, and more premature deaths (Steffen *et al*, 2015; Beer *et al*, 2013; DHHS, 2019a; 2019b).

   Finally, there are also flow on health impacts from the effects of increasing heat across the region, including an increase in the frequency of Blue Green Algae outbreaks; this will impact drinking water quality (DELWP, 2018a).

2. **Increase in direct and indirect impacts from other climatic extremes and events including fire, flood and storms:** such events can cause injury or death (Steffen *et*

al, 2015; Beer et al, 2013), and their incidence and severity will rise within the region due to climate change (DHHS, 2019). Flow on effects include increased stress on health and emergency services during such emergency events (DHHS, 2019a; 2019b; OCHO, 2009); increased respiratory problems due to smoke or thunderstorm asthma (DHHS, 2019a; Steffen *et al*, 2015); and possible shortages of essential goods such as power, water and food (Mallon *et al*, 2013).

3. **Insufficient healthcare capacity to address climate change effects:** it is clear that previous climate change-related events and disasters in the region have challenged healthcare providers to address direct effects such as injury and disease (OCHO, 2009). At the same time, the effect of climate change on the social determinants of health (e.g., affordable and suitable housing, access to nutritious food, water and power; childcare and other forms of social support) will stretch the ability of community service organisations (CSOs) to meet these community needs (Mallon *et al*, 2013; Fünfgeld *et al*, 2014). In addition to demand 'surges' due to emergencies, there are a range of slower climate change impacts that threaten to place healthcare services under stress. This includes expansion in the geographical 'range' of tropical (mosquito borne) diseases such as Ross River Virus (DHHS, 2019; Fünfgeld *et al*, 2014). There are also many mental health consequences of climate change. These include the immediate and ongoing mental health challenges of extreme events combined with slower stressors. Mental health issues are exacerbated by the poor mental health provision available for some rural communities and low SES households (Steffen *et al*, 2015; Beer *et al*, 2013; Fünfgeld *et al*, 2014; DELWP, 2018c) and can lead to increases in the incidence of suicide, domestic violence, car accidents, and problematic drug and alcohol use, impacting a far wider group including children.[2]

7.4 Key adaptation needs

The above climate change risks to human health and wellbeing in the Grampians region point to some key adaptation needs and opportunities (Table 7.1).

Table 7.1 Identified climate change risks for health and wellbeing in the Grampians and related adaptation needs and opportunities

IDENTIFIED RISKS	KEY ADAPTION NEEDS AND OPPORTUNITIES
Increase in mortality and morbidity due to intensity and length of heatwaves	**Local and municipal heatwave plans**. These may include identification of cool shelters (i.e. airconditioned premises) for vulnerable populations, the maintenance of a register of such residents, and a focus on community information and awareness (Yarriambiack Shire Council, 2015a; Moorabool Shire, 2019)
	Improvement of town infrastructure to mitigate the impacts of heat and other interconnected hazards. Primary effects of climate change on buildings in the region (Guilding *et al*, 2013) are: • increased energy consumption due to higher temperatures. • increased damage from flooding. • increased bushfire risk. • human health effects resulting from over-heating. Possible techniques for addressing these (Guilding et al 2013, p25) include residential and commercial building design for passive solar access/prevention and ventilation and air conditioning upgrades (reflecting design). However, in a number of communities in the

	Grampians region investment and reinvestment in housing stock is limited, presenting challenges to adaptation through redesign. Adaptive urban planning may include implementing shade plans (Bosomworth *et al*, 2013) and the use of 'hard' and 'green' shade infrastructure for shade, strategic planting for shady routes and improved infrastructure such as bus shelters and access to drinking taps.
Increase in direct and indirect health impacts from hazards such as fire, floods and storms	**Community-based disaster risk reduction and resilience programs:** Understanding and avoiding how disasters are created and working collectively to avoid the worst impacts is vital to long-term management of climate change. This includes community education about how to manage climatic extremes, general resilience programs, increasing access to and uptake of insurance, and building social capital and bolstering community organisations to enable cooperation and support.
	Improved capacity for emergency services in the region: There are clear challenges with achieving such an increase, including: funding; the challenge of maintaining volunteer organisations such as the SES and the CFA in the face of population ageing, less social connection and increasing social diversity (CFA, 2015; Calcutt, 2019)
	Local and municipal disaster plans: Municipal councils are responsible for coordinating response and recovery at the local level for affected individuals and communities. They need multi-agency Municipal Emergency Management Plans that include local risk management, preparedness and response activities (Victorian Government, 2018)
Insufficient healthcare capacity to address climate change effects	**Improved health provision for rural/remote communities**: While much of the responsibility for healthcare provision (i.e. hospitals) lies with the Victorian Government Department of Health, local community service organisations (CSOs) play an important role in the maintenance and promotion of the social determinants of health (drug and alcohol rehabilitation, housing and refuge for domestic violence victims, access to nutritious food, community legal and advocacy services etc) (Mallon *et al*, 2013). Many of these will struggle to meet either the sharp demand caused by emergencies, or a steady increase in demand caused by slower-acting effects of climate change (Mallon *et al*, 2013).
	Promotion of telehealth options across the region: This is an approach to health provision through internet or telephone connection - it offers a way to overcome the challenges of distance across the region and Victoria.

7.5 Existing adaptation actions

A range of existing initiatives in the Grampians region have begun to address the health challenges of climate change (Table 7.2). Changes to emergency management and disaster planning has largely adopted approaches that recognise the adaptation challenges. Some local areas have developed heatwave plans, and it is anticipated that this issue will be more evident in the upcoming round of municipal health and wellbeing plans. Examples of changes to health service delivery (described below) offer evidence of a recognition of local challenges in the disparate areas of the region. Support for alterations to housing to local infrastructure and to urban environments is being undertaken, but not at the scale required, especially in areas with older housing stock and limited investment in retrofitting, and in local government areas where investment in urban or small town redesign is financially challenging.

Table 7.2 Example existing adaptation actions in the Grampians relevant to health and wellbeing

KEY ADAPTION NEEDS	EXAMPLES / FURTHER INFO
Local and municipal heatwave plans	**Moorabool Shire Council:** https://www.moorabool.vic.gov.au/sites/default/files/Moorabool%20Shire%20Heatwave%20Plan%20-%20Adopted%20MAY2019%20MEMPC.pdf **Hindmarsh Shire Council** **Hepburn Shire Council (No – but info page on website):** https://www.hepburn.vic.gov.au/heatwave/ **Horsham Council (No – but info page on website):** https://www.hrclimatechange.vic.gov.au/Emergency-Management/Heatwave **Northern Grampians Shire Council (Yes – but currently under review)** **Yarriambiack Shire Council:** https://yarriambiack.vic.gov.au/wp-content/uploads/YSC-heatwave-plan-2020-21.pdf
Improvement of town infrastructure to mitigate the impacts of heat and other interconnected hazards	**Retrofitting buildings:** is an expensive process, and not the direct responsibility of local government (apart from council offices etc) (Guilding et al, 2013) Environmental Upgrade Finance are council-based allows Victorian business owners and homeowners to make sustainability and climate adaptation building upgrades. According to Sustainability Victoria (March 2020) Horsham Rural City and Hepburn Shire of councils offer Environmental Upgrade finance to businesses within their municipality. **Greening/shade:** Ballarat Council has implemented a greening project, focussing specifically on reducing the Heat Island effect and increasing tree cover by 40% by 2040: https://www.ballarat.vic.gov.au/growing-our-tree-canopy **Cool It Stage 1 & 2:** The Cool It project involved a number of areas in the Grampians region (Ballarat, Ararat and Pyrenees) as well as other local governments with the aim of research and strategies to understand and address heat vulnerability and potential responses in a variety of settings.
Community-based disaster risk reduction and resilience programs	There is a large number of important existing programs designed to improve community and regional resilience. Some of these include: • Primary Care Partnerships for Community Resilience, e.g. http://sggpcp.com/primary-care-partnerships-for-community-resilience/ • Sector specific programs, such as the Wimmera Development Association Building Resilience in Farming program. https://wda.org.au/special-projects/building-resiliencein-farming-vasp/67-building-resilience-in-farming • Group specific programs, such as the BY FIVE program run by the Wimmera Southern Mallee Partnership to assist new parents and help them meet each, building social capital other https://www.rdv.vic.gov.au/__data/assets/pdf_file/0009/1858185/2019-RP-A4-Fact-Sheet_WSM_web.pdf • The Community Resilience Framework for Emergency Management in the Wimmera https://centreforparticipation.org.au/2017-volunteering-recognition-volunteering-awards-nominations-now-open-2-2-2-2-2/

Improved capacity for emergency services in the region	As a result of the Royal Commission into the 2009 Victorian bushfires, the State Government has ordered a major reorganisation of the CFA, re-organising professional and volunteer fire fighters in some areas with the launch of Fire Rescue Victoria (FRV) (a new combined station is in Ballarat). There is also a major increase in funding underway. https://www.vic.gov.au/fire-services-reform Nonetheless, the most recent Volunteerism Strategy from the CFA (2015) maintains an exclusive focus on the volunteer basis of the organisation.
Local and municipal disaster plans	Horsham Rural City Council Ararat City Council City of Ballarat Golden Plains Shire Hepburn Shire Council Hindmarsh Shire Northern Grampians Shire Moorabool Shire Council Yarriambiack Shire Council Ballarat West Wimmera
Improved health provision for rural/ remote communities	**Major health infrastructure:** this remains the preserve of Department of Health, and there are proposals for investment in Ballarat, as well as a general commitment to telehealth and other service provision models in rural Victoria **Community service organisations:** while there are a range of suggestions for improving the response capacity and resilience of regional CSOs in the face of climate change (such as increasing *Resources*, focussing on *Preparedness*, building *Resilience* to direct impacts and *Sharing risks* through insurance and collaboration), the most pressing is also the most obvious – funding increases (Mallon et al, 2013). This will pose a funding challenge for local councils in the region.
Promotion of telehealth options across the region	There are some examples of telehealth approaches within the region, such as that provided by Ballarat Health Services: https://www.bhs.org.au/for-patients-families-friends/telehealth/ and the Peter Macallum Cancer Centre (through partnership with the Wimmera Southern Mallee Health Alliance): https://www.petermac.org/telehealth Similarly, the Rural Workforce Agency (RWAV) (a not-for-profit government funded organisation improving health care for rural, regional and Aboriginal communities in Victoria) have implemented a telehealth approach for GPs and specialists (as a result of the Covid19 lockdowns and emerging approaches to local delivery): https://www.rwav.com.au/outreach-update-telehealth/ However, while there is recognition from DHHS that Covid19 has made telehealth an important healthcare delivery option (https://www.dhhs.vic.gov.au/telehealth-coronavirus-covid-19) the most recent climate change Adaptation Plan from the Department of Health and Human Services makes no mention at all of telehealth options, which is surprising (DHHS, 2019)

7.6 Examples of adaptations from other places

The *Draft Grampians Region Climate Adaptation Strategy* highlights a need for improved community understanding of climate change and health impacts involving health practitioner communities in the region (DELWP, 2021a). This is consistent with findings from Sustainability

Victoria, which noted that while health practitioners are overall aware and concerned about the impacts of climate change on health, there remain gaps in public understanding – particularly in relation to healthy home temperatures (SV 2020).

Many Victorians "do not spontaneously link health impacts to climate change. When prompted, the connection is readily accepted with over half (58 per cent) recognising health as one of the main ways they are likely to be affected by climate change" (SV 2020, p.7). Trusted sources of information on the health impacts of climate change are "emergency services organisations, health professionals, General Practitioners and climate scientists" (SV 2020, p.13). There is a potential opportunity to emphasise capacity building and a component of a health and adaptation response in the Grampians region.

Capacity building involving direct health service providers is highlighted in the case studies below with a focus on social care and community organisation, and highlighted local heat health and other interventions, and an emphasis on the relationship of climate change to health and wellbeing. The Community Climate Change Adaptation (3CA) funded program (see first case study below) investigated awareness, organisational cultures, and adaptive capacity through interviews with service practitioners, to understand their needs for climate change adaptation. This research fed into the design and delivery of sector-relevant workshops and resources to support practitioners and organisations in climate change adaptation. This program has been furthered through the Building Adaptive Communities work (see second case study below) with an emphasis on organisational adaptation and building the capacity of community service organisations and councils to support at-risk communities and articulate support needs to contribute to regional adaptation planning processes.

This 'train the trainer' approach, whereby local and trusted service providers was also utilised in the Glenelg Saves program (Table 7.3). Community support workers were trained in household energy efficiency to not only assess and make improvements or adjustments in their own homes, but also on the homes of their clients. Similarly, the utilisation of a local trusted network (such as local governments) may present opportunities for home upgrades which improve the thermal comfort of householders, as with the Solar Savers program.

Table 7.3 Examples of relevant adaptations in other places

Project/ example name	Where from; Lead Agency	Why this is worthy of note	Link
Glenelg Saves	Glenelg; Glenelg Shire Council, Federation University and Southern Grampians Glenelg Primary Care Partnership, funding from the Australian Government	• This project utilised a participatory training approach to develop the skills of Home and Community Care workers to undertake home energy assessments in their own home, and the homes of their clients. • The aims were to improve the skills of Home and Community Care staff in home energy efficiency, as well as improve the home energy efficiency for clients in receipt of Home and Community Care.	Southern Grampians Glenelg Primary Care Partnership: https://sggpcp.com/projects/glenelg-saves/

Solar Savers	Victoria; EAGA as lead, in partnership with NAGA, CVGA, and participating councils.	• This is an energy project – but in the initial phase of this project, was designed to help pensioners purchase solar by overcoming upfront cost barriers to solar through providing a loan through the council rates system. • This can help improve thermal comfort for low-income households. • However, a key learning from the project is that in subsequent trials there was high uptake of the program, either utilising a bank loan or paying for a system upfront. • Barriers then are not necessarily financial, but trust in council as institution was frequently cited as an enabler for households to participate in the program (see for example project testimonials). • While delivered as a regional project, this program has operated in partnership with the CVGA with participating councils from the Grampians region.	Solar Savers (2019): https://solarsavers.org.au/
Building Vulnerability Assessment	Pilots in Whitehorse City Council, City of Hume, City of Whittlesea, and Maroondah City Council; EAGA. NAGA. & Arup Further work is being completed through the Port Phillip regional Adaptation Strategy to look at scaling and amending vulnerability assessments for council infrastructure; DELWP. EAGA. SECA	• The structure of the building vulnerability assessment allows for an understanding of who is using community facilities, how they are using those facilities, and an examination of the physical characteristic of assets (for example, thermal comfort and accessibility). • Combined with an assessment of usage patterns, and other criteria to determine priority assets (for example, centres utilised to deliver critical care services or emergency relief centres) this could allow for a prioritisation of works.	Northern Alliance for Greenhouse Action (N.D.): https://www.naga.org.au/building-vulnerability-assessment.html
Barwon South West Enhancing Care Coordination	Barwon South West; 25 organisations from across the BSW region signed on to participate in workshops by the Studer Group, focussing on accountability,	• Enhancing the integration of primary care could see more effective use of resourcing across the region. • More effective primary care reduces strain on components of the health sector through improved health outcomes (Machinko et al. 2003). • The enhancing care coordination project undertook workshops to enhance the understanding of barriers specific to care coordination for participating organisations,	Southern Grampians Glenelg Primary Care Partnership: http://sggpcp.com/projects/barwon-south-west-enhancing-care-coordination/ and http://sggpcp.com/wp-content/uploads/2014

	leadership and process for improving care coordination practice.	including a needs assessment to identify priority themes. • The project also engaged in capacity building for participants, in the context of understanding best practice for care co-ordination. • This method demonstrates an incorporation of responses cognisant of both participating agencies needs and care coordination best practice.	/09/2014-January-BSW-Enhancing-Care-Coordination-Project-Background.pdf
DPV Health telehealth services	18 locations across Northern Melbourne (the Cities Whittlesea, Hume, Mitchell, Melton and Banyule including Broadmeadows, Craigieburn, Epping, Meadow Heights, Roxburgh Park, Mill Park, South Morang and Whittlesea Township).	• Flexible health provision can overcome barriers for some individuals and families related to increasing pressures which may be experienced by health services. • Flexibility in service provision is also an important consideration for continuity of care when movement may be restricted – for example as a result of heat impacts.	DPV Health (N.D.): https://www.dpvhealth.org.au/all-services/telehealth-video-phone-appointments/?gclid=Cj0KCQiA962BBhCzARIsAIpWEL0DqrcuFj72lOice8_FUp8TxtriS-jUI90LyHHEehL35a462PPLemAaAn08EALw_wcB

Case Study: Community Climate Change Adaptation for Social Care and Community Organisations Climate Change Exchange (2020a)

Location: Greater Melbourne

Partners: DELWP 3CA Grant, implemented through Jesuit Social Services partnering with the Victorian Council of Social Services and the Climate change Exchange.

- There is a need to understand the ways in which organisations can collaboratively and most effectively address climate change adaptation.
- This will likely see shared services models, pooling resources, and economies of scale.
- Understanding needs in a cross-sector way allows for a deepened awareness and understanding of existing action, gaps, and needs.
- This project brought together community and social care organisations, to help build an understanding and awareness of climate change adaptation, while also generating new insights about risks, challenges, and opportunities for participating organisations, and their role within a more integrated network of care.
- This approach can also be responsive to regional and local needs, through adopting a place-based approach.

Project link

https://climatechangeexchange.org.au/projects/climate-justice-on-the-frontline-the-role-of-community-service-organisations-in-adapting-to-climate-change/

Case Study: Building Adaptive Communities (Northern Alliance for Greenhouse Action, 2021)

Location: South East Melbourne

Partners: DELWP Port Phillip regional adaptation team; NAGA; Enliven

- These workshops build on and complement the capacity building project outlined above for social care and community organisations.
- The workshops are intended to help CSOs and councils to:
- "Build their own organisational capacity to cope with and adapt to climate impacts and risks
- Support at-risk communities experiencing climate impacts
- Articulate their support needs and contribute to regional adaptation planning processes and thinking on government policy
- While there are a range of outcomes intended for the workshops, the workshops aim to build capacity "Identifying and addressing impacts on the communities you work in," and "choosing strategies to address organisational and community needs" (NAGA 2021).

Project link

https://events.humanitix.com/building-adaptive-communities-workshop-1

8 Adaptation Focus – Water

8.1 Introduction

The region's waterways, water supplies and rivers and lakes are vital to urban communities, as habitat and to a number of agricultural industries in the Grampians region. Existing vulnerabilities associated with over-allocation and degraded catchments. The region's boundaries do not align with these catchments, and their health is significant in areas beyond the region, including metropolitan Melbourne and the Northern Irrigation region of Victoria. Observed and projected climate change impacts are associated with changes to seasonal rainfall reliability, particularly the prevalence of drought, but also flood events. These expose vulnerabilities to communities and industry sectors, but also present risks to waterway health and the habitat it provides, as discussed below.

8.2 Existing vulnerabilities and adaptive capacities

8.2.1 Existing vulnerabilities around water

- **Vulnerable water supply.** The region's water supply is classified as Vulnerable because, although Grampians Wimmera Mallee Water uses some groundwater, the region is highly dependent on reliable cool season rainfall and runoff to maintain flow in waterways (DELWP, 2016a). Some of the lakes included in the Victoria water grid (Figure 7.1) as water sources for the region, such as Lake Hindmarsh, are often not full.
- **Very poor river/waterway health:** Decreased environmental flows and a range of historical and contemporary uses (DELWP, 2016b; DDWCAC, 2014) have placed serious pressure on waterways in the region. For example, rivers in the Glenelg Hopkins catchment are impacted by nutrient loads from surrounding agriculture (Morris and Nicholson 2015). As a result, waterway health is rated as low across the Grampians region, with rivers rated as healthy for only 0-10% of their length (DELWP 2016b, p50).

8.2.2 Existing adaptive capacities around water

- **Infrastructure investment:** The development of the Victorian water grid (Figure 8.1) to reduce water losses and enable water to be moved between areas more easily have helped improve the reliability of water supplies, particularly to urban areas. Projects such as the Wimmera Mallee Pipeline and other water modernisation projects have improved reliability in the agricultural sector. There is now a proposal to extend the Wimmera Mallee Pipeline to cover a further 530,000 ha of farmland in the Grampians region (the East Grampians Water Supply Project https://www.water.vic.gov.au/water-grid-and-markets/the-grid).
- **Responses to previous droughts:** examples include the upgrade of emergency water supply points and their use to service industrial water needs (https://www.water.vic.gov.au/groundwater/emergency-water-supply-points) and localised approaches to water reuse such as the Ararat wineries recycled water scheme (https://www.bestswines.com/blog/Sustainability-initiatives-at-Best-s-Wines). These offer potential for continued improvements to water security, although water reuse is dependent on volumes of residential and commercial wastewater, which are likely to fall during droughts as the Millennium Drought demonstrated. A further example is the Goldfields superpipe constructed by Colian Water during the Millennium Drought, which enables the corporation to move water to Ballarat when needed (https://www.water.vic.gov.au/water-grid-and-markets/the-grid).
- **Longstanding waterway health strategies:** Regional catchment strategies, on ground works on waterways and landholder-led projects have established catchment

management practices across the region over several decades offering learnings and lessons for adaptive practices.

- **Existing organisational and community networks**: The regional networks of CMAs, Landcare groups and water utilities offer experience and expertise in policy, research and the mobilisation of on-ground works in catchment management.

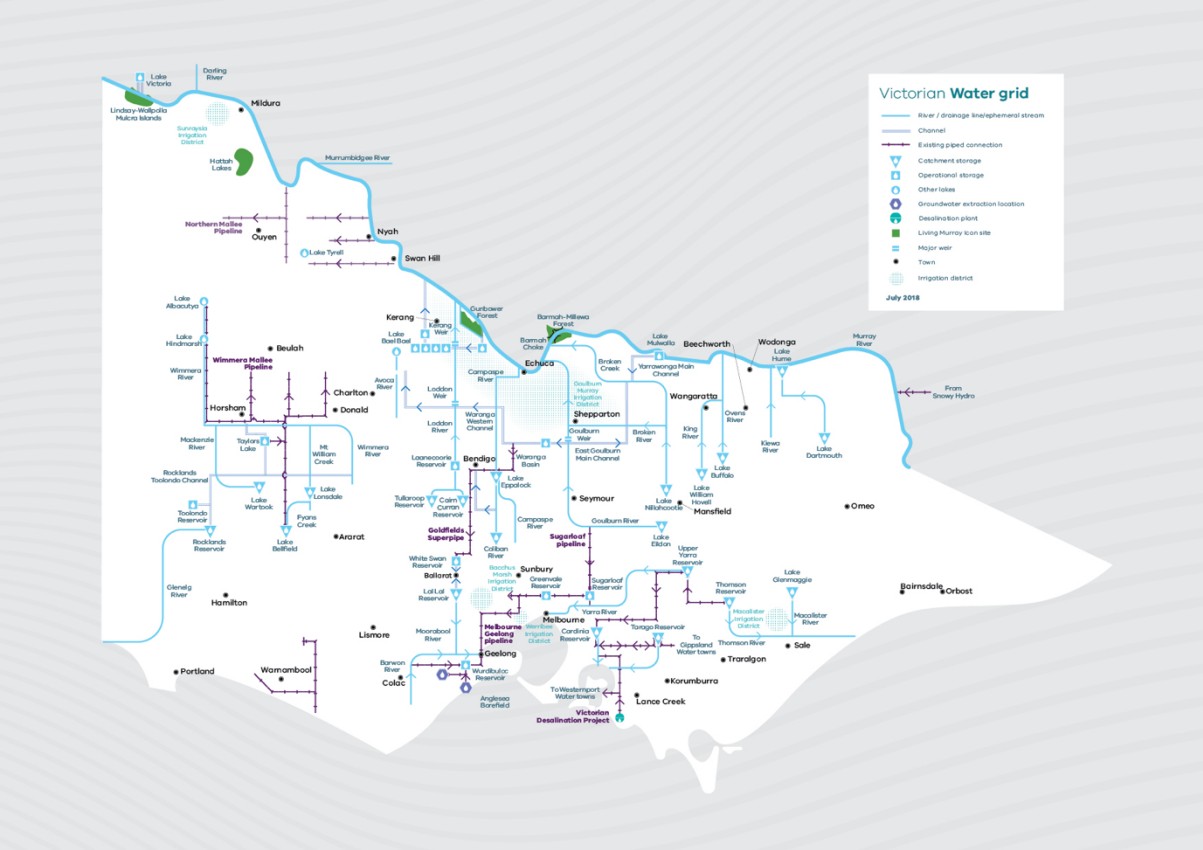

Figure 8.1 Victoria's water grid (https://www.water.vic.gov.au/__data/assets/image/0032/393359/DELWP0079.3_Water_Grid_Statement_v25_pg15.jpg)

8.3 Major climate change risks around water in the Grampians region

Combined with existing vulnerabilities and adaptive capacities, projected and observed climate change means that the major risks posed by climate change to water are:

1. **Reduced quantity, quality and reliability of supply:** water supplies in the region are highly vulnerable due to their existing high dependence on rainfall combined with the decreased magnitude and altered timing of precipitation and runoff under climate change.

   Flow on effects include negative impacts on ecosystems (Nugent *et al*, 2013); reduced affordability and equity; safety, health and wellbeing issues; possible social or political conflict over use; and the possibility of stranded assets or business relocation/closure (such as businesses reliant on security and quality of supply).

2. **Increased water demand:** this is driven by both ongoing trends such as population growth (in certain areas of the region) and changing agricultural land use and by short term spikes such as heatwaves or fires.

Flow on effects include increased water costs for stakeholders; and possible shortfalls (particularly during spikes) leading to negative effects on the region's economy, health and wellbeing, agriculture and environmental management.

3. **Worsened waterway health:** given the low base of existing waterway health in the Grampians region (see above), the interacting effects of climate change will worsen this situation unless existing pressures on waterways are removed.

   Flow on effects include ecosystem stress (Morris and Nicholson, 2015; Nugent *et al*, 2013; DELWP, 2016b); and decreased opportunities for recreational, economic, agricultural and Indigenous cultural use of the region's waterways (DDWCAC, 2014; DELWP, 2016b).

4. **Flood damage:** While rainfall as a whole is predicted to fall across the region, the incidence of extreme rainfall events, in many cases leading to localised or even extensive flooding, is not (DELWP, 2020: 40; DELWP, 2019a). Widespread flooding, like the September 2016 floods (Australian Disaster Resilience Knowledge Hub, N.D.) remain a risk in the region and can cause significant direct impacts to the regional economy, to water, and to energy.

   Flow on effects include negative impacts on the social determinants of health such as clean drinking water, sanitation, stable housing, and employment. At the same time the standing water left by floods, coupled to increasing heat, increases the risk of tropical mosquito borne diseases (Hennessy et al, 2007; DHHS, 2019b). For example, 'between October 2016 and April 2017, there were 1,974 human cases of Ross River virus reported in Victoria, which was nearly 10 times greater than the historical mean of 204 cases per year.' (DHHS 2019b, p29). There is also a tendency to gully erosion by water runoff on soils with little vegetation cover, such as in the area around Nhill. Erosion poses a significant threat to as well as to Indigenous cultural sites (DELWP, 2018a; 2018b)

8.4 Key adaptation needs

Given the above vulnerabilities and adaptive capacities around water in the Grampians, there are some clear adaptation needs and opportunities (Table 8.1).

Table 8.1 Identified climate change risks around water for the Grampians region and related adaptation needs and opportunities

IDENTIFIED RISKS	KEY ADAPTION NEEDS AND OPPORTUNITIES
Reduced quantity, quality and reliability of supply	**Increase alternative water supplies**: This can include such examples as urban and agricultural water reuse, or rainwater capture (Tapsuwan *et al*, 2018). The latter is more likely to occur at a larger organisational scale (i.e. councils and municipalities) while the former can be implemented at more modular/local level. As with reducing water demand (below) there is a clear connection between residents' awareness of water vulnerabilities, and willingness to install rainwater tanks (Tapsuwan *et al*, 2018). Finally, there is a need to better streamline policy to allow more flexibility in the approval of recycled water supply projects (VicWater, 2020)
	Increase access to seasonal forecasts: to enable industrial, residential, agricultural and environmental water users to adjust demand to supply (Prosser, 2011). A 'paradox' (Prosser, 2011) of Australia's variable seasonal rainfall is that it can be predicted months in advance (due to the importance of trends like *El Nino/La Nina*) by relevant organisations like the BoM.

	Increase flexibility in water allocations: Water, particularly in a region reliant on rainfall and runoff, is inherently unpredictable, with many stakeholders (such as farmers) unable to easily predict future needs or supply (Prosser, 2011). There is also a need to expand water allocations to other regional stakeholders, including Indigenous owners and community organisations.
	Increase modularity of water reserves or infrastructure: (at smaller scales than municipalities or water corporations). Such modularity can provide more resilience for smaller scale stakeholders/concerns (Arcari *et al*, 2012). Note: smaller scale (modular) water infrastructure is reliant on uninterrupted supplies of Energy (power) to maintain functioning (Arcari *et al*, 2012). As well, as outlined above there is a clear connection between residents' awareness of water vulnerabilities, and willingness to install more modular water infrastructure such rainwater tanks (Albrecht *et al*, 2010; Tapsuwan *et al*, 2018).
	Managing uncertainty of water supplies: Climate change, considered alongside climate variability, creates challenges for dry inland areas when considering future water supplies (DSE 2011). As noted in the Victorian Water and Climate Initiative, there is significant uncertainty in rainfall and runoff projections (DELWP, 2020) requiring users to "identify the assets and operations in their system that are influenced by climate; be able to define how the performance of the system is measured; be able to identify climate-related risks to their assets and adaptations that are possible under different broad changes in the climate" (DELWP, 2020: 85).
Increased water demand	**Public education to reduce water demand:** This can be focussed on residential, commercial or agriculture users – for example, household water saving measures or incentives for farmers to switch to more drought tolerant varieties. Note: the more aware stakeholders are of the risks to water supply, the more likely they are to respond positively (and act accordingly) (Albrecht *et al*, 2010; Mahler & Barber, 2015). At the same time, there is evidence from Sydney (Turner *et al*, 2005) and the US (Mahler & Barber, 2015) that this is an effective and cost-effective approach for helping reduce water usage and thus demand.
	Use water pricing to disincentivise overuse: Although this has clear and negative implications for vulnerable cohorts, such as the unemployed/financially constrained, the elderly, and those facing geographical disadvantage with regard to affordable water access.
	Planning regulations to mandate reductions in residential or commercial water consumption: Possible approaches include the strategic reuse of urban water in new developments, and (as indicated in the recent Victorian Strategic Agricultural Lands Review*)* the potential to allocate this to peri-urban horticulture, including within the Grampians region (e.g., Bacchus Marsh).
Worsened waterway health	**Increase environmental water flows into 'at-risk' waterways:** This involves state-level regulation to better manage conflicting stakeholder interest in waterways (DELWP, 2016b; 2016c; 2018b; Ehsan *et al*, 2020; Prosser, 2011). It also involves more localised projects and policies that increase or protect environmental water flows.
	Improve integrated catchment water management: This includes improved stakeholder engagement and more effective regulatory oversight. The current understanding is that this is best achieved through an Integrated Catchment Management (ICM) approach which uses catchments (place-based adaptation) as one of the 'logical ways to plan and manage the landscape in an integrated way. This approach recognises that land, water and biodiversity are all part of connected systems, from the top of the catchment, down through receiving waters and landscapes, to the coast and marine environments. It emphasises the value of joined-up planning and management.' (DELWP, 2019b, p7)
	Identify and redress main non-climatic drivers of declines in waterway health: Examples include pollution and run-off from industry, agriculture and urbanised areas (Prosser, 2011; WCMA 2006), including from areas previously mined for gold (Abraham et al. 2018a, Lawrence and Davies 2020); excessive extraction and management for other uses (Prosser, 2011); and (in the northwest of the region) declines in waterway health due to:

	• Altered drainage and flow regimes • Changed channel form. • Deficient floodplain management (WCMA 2006, p3)
Flood impact	**Resourcing data and capacity for local flood plans throughout the region:** Including spatial data and observation/monitoring in line with Victorian Floodplain Management Strategy's systematic approach (DELWP, 2016c).
	Flood mitigation infrastructure and activities (DELWP, 2016c).
	Land use planning to mitigate future increased flood risks (DELWP, 2016c).

8.5 Existing adaptation actions

Existing adaptation actions in the region are strongly characterised by infrastructure investments, although some are relatively low impact, such as examples of water sensitive urban design (WSUD) in Stawell. Lessons from the 2000s drought also indicate a willingness in communities to radically alter use patterns and expectations of water supplies, although this has implications for other adaptation strategies (such as urban greening).

Table 8.2 Example existing adaptations around water in the Grampians region

KEY ADAPTION NEEDS	EXAMPLE ADAPTATIONS FROM THE REGION
Increase alternative water supplies	**Urban and agricultural water reuse** 1. **The Stawell Stormwater Alternative Natural Solutions project** uses stormwater to drought-proof community assets. The project saves over 74 megalitres per year through a series of water quality treatment ponds, storage dams and transfer infrastructure – reclaimed water from this infrastructure is used to irrigate sporting facilities, gardens and public open spaces. 2. In 2020, **recycled water regulations were streamlined** as part of a recycled water guidelines review undertaken by VicWater. These include streamlined audit obligations, fewer and more risk-based scheme approvals and reduced red tape (VicWater, 2020)
Increase access to seasonal forecasts	The BoM and the CSIRO have jointly developed and launched **Weather Together**, which is a forecasting service offering both spatially and temporally variable forecasting, tailored to agricultural stakeholders: https://www.csiro.au/en/Research/AF/Areas/Digital-agriculture/New-opportunities/Weather-Together?ref=/CSIRO/Website/Research/Drought-resilience/Forecasting-and-monitoring/Weather-Together This can be extremely fine-grain (down to the individual property scale) and at a range of temporal scales (from daily to yearly) and is available on monthly subscription.
Increase flexibility in water allocations	Both the *Water Act 1989* and the recent *Water for Victoria Plan* include 'flexibility' as a key component of the overall approach to water allocation in Victoria (DELWP, 2016b). While this is positive, it does not remove competition between stakeholders, including between states, as demonstrated most clearly at a national scale by the deficiencies of the Murray-Darling Plain process.
Increase modularity of water reserves	1. While rural and municipal water corporations are required to provide irrigation, drainage and storage services, and are responsible for the diversion of water from waterways and groundwater extraction, this is at a municipal/ regional scale. There is no statutory obligation for all rural properties to have access to a water supply and this

or infrastructure	lack of regulation at the local/property *scale* represents a possible vulnerability. (DELWP 2016b). 2. The Wimmera Mallee Pipeline is a closed pipe system replacing a leaky, earthen channel system. This has resulted in significantly increased security of water supply (RMCG, 2012).
Public education to reduce water demand	Central Highlands Water - https://www.chw.net.au/education-sustainability GWM Water https://www.gwmwater.org.au/conserving-water/water-restrictions/permanent-water-saving-rules
Increase environmental water flows into 'at-risk' waterways	**Regulatory improvement** 1. The recent State Environment Protection Policy (SEPP) (Water) is a State regulatory framework to address competing waterway uses and prioritise the environmental health of waterways. It is designed to confirm the beneficial uses of Victorian groundwater and surface water, and where these uses apply: • set water quality indicators and objectives to protect beneficial uses • establish a modern, risk-based framework to manage unlicensed point and diffuse pollution sources in rural and urban areas • develop regional target settings and plans to improve water quality • ensure water quality offsets can be used within catchments to maintain regulatory compliance within waterways. 2. Ehsan *et al* (2020) in their discussion of the Mackenzie River, argue that **the conflict between 'consumptive' and 'ecological' flows in this river is, to some extent, a false dichotomy**: 'This study showed that the volume of allocated water for the Mackenzie River as environmental flows did not meet the ecological requirements, particularly in the lower reaches. However, good ecological condition can be achieved if consumptive flows are also released in a manner that benefits the ecology of the River… **Indeed, there are clear benefits that would accrue from integrating environmental flows and consumptive flow operations.** This would be achieved by respective operators exchanging flow release plans and for this to be coordinated between water agencies (GWM Water, WCMA and DELWP). The agencies have this as a planning goal and so the way is paved for more effective use of all water releases' (p195) **Local programs** 1. *Dja Dja Wurrung/ North Central Catchment Management Authority/ Trust for Nature – Putting the swamp back into Long Swamp* (1 of 11 pilot projects around Victoria – immediately to the north of the Grampians region boundary) (DELWP 2018b, p5) 2. Wimmera Catchment Management Authority - Northern Dunmunkle Creek restoration plan (as above) (DELWP 2018b, p5)
Identify and redress main non-climatic drivers of declines in waterway health	1. As above – the SEPP (water) 2. A number of waterways and catchments in the region (including Wimmera and Campaspe River Catchment) earmarked for significant Victorian Government funding
Improve Integrated Catchment Management (ICM)	The ongoing implementation of the *Our Catchments Our Communities* plan (DELWP, 2019b) aims to implement a clear Integrated Catchment Management approach. The goal is to involve regional partners and community networks in its implementation, along with DELWP and CMAs.

Municipal flood plans for local governments throughout the region	These plans have been developed, however, resources for monitoring and observation of flood behaviour for later analysis and future planning can be limited (NGSC & VICSES, 2014; CGS & VICSES, 2019). This is a crucial shortcoming, as 'local knowledge' is a vital component of the overall strategic approach to flood management (DELWP 2016c, p13).
Flood mitigation infrastructure and activities	Within the Grampians region flood mitigation includes examples such as streamside management, linking waterways and wetlands and specific flood mitigation infrastructure projects from CMAs, local government and water authorities.
Land use planning to mitigate future increased flood risks	While there are high level policy statements concerning flood risk and climate change in the Victoria Planning Provisions, the Design Flood Event (i.e. the 1 in 100 year flood event) coverage utilised in local planning schemes is drawn from historical data, and not future projections, with resources to model robust projected flood level data required.

Case study: Sustainable Irrigation Future Initiative - Agriculture Victoria irrigation extension services

Location: Victoria

- Extension services are delivered to farming communities across Victoria's irrigation district.
- This includes tailored advice, as well as workshops, field days and discussion groups
- This includes a broader suite of advice, but incorporates advice about weather, climate, and forecasting.
- Helps land managers manage uncertainty about the quantity and timing of rain and the availability of other water sources

Agency: Agriculture Victoria. See also DELWP (2020d)

Project link

https://www.water.vic.gov.au/planning/environmental-contributions/fourth-tranche-of-the-environmental-contribution/sustainable-irrigation-program

8.6 Examples of adaptation from other places

Whole of Victoria adaptations and examples from other regions point to additional ways the Grampians may reduce negative flood risks.

Table 8.3 Examples of relevant adaptation actions in other places

Project/ example name	Where from	Why this is worthy of note	Link
Victorian Water Market	Various – see links	• A key overarching lesson from the evaluation of Victoria's water markets is that market participant input is key for facilitating participation and understanding.	Effectiveness of Victoria's Water Markets (AITHER, 2018) https://waterregister.vic.gov.au/images/documents/Effecti

		• The evaluation found for example that across all markets, water markets contribute to the efficient distribution of water across social, cultural, economic and environmental uses, but that, "improved information on and for Traditional Owner (and other potential new market participants) participation in the market is needed to better recognise cultural and social values" (AITHER 2018, p.vii). • This suggests that mechanisms outside of water entitlements exist to improve participation in, and improvement of Victoria's water markets (for example, engagement). • Both the Victorian Government water market transparency reforms, and the Australian Competition and Consumer Commission (ACCC) review of markets for tradeable water rights across the Murray-Darling Basin should provide further insights into mechanisms for improving Victorian water markets.	veness%20of%20Victorias%20water%20markets_final%20report.pdf ACCC review (ACCC, N.D.) https://www.accc.gov.au/focus-areas/inquiries-ongoing/murray-darling-basin-water-markets-inquiry/final-report Victorian Government water market transparency reforms (DELWP, 2019f) https://s3.ap-southeast-2.amazonaws.com/hdp.au.prod.app.vic-engage.files/9015/6939/2970/Options_paper-_Water_market_transparency.pdf
Assessing the value of rainwater tanks in Perth	Perth; CRC for Water Sensitive Cities	• Research in Perth suggests that while subsidies are a popular mechanism for encouraging uptake of water tanks amongst home owners, it is an ineffective mechanism for doing so. • This is borne out by ABS data in which only 5% of respondents identified a rebate as the reason for installing a water tank. • Zhang et al. (2014) suggest that information provision may be a more effective mechanism for facilitating the uptake of rainwater tanks, utilising a framework for analysing the distribution of public costs and public benefits. • This suggests there could be opportunities to utilise different mechanisms (i.e. than subsidies) to encourage the uptake of rainwater tanks and other modular water reserves and infrastructure, and that evaluation of the effectiveness of such measures will be an important learning (Zhang et al. 2014).	CRC for Water Sensitive Cities (2015) https://watersensitivecities.org.au/content/assessing-value-rainwater-tanks-perth/
Melbourne Flood Strategy Refresh	Port Phillip & Westernport Catchment	• There is an opportunity for local and state governments, emergency services, and water authorities to work collaboratively in considering the changed risk profile for the region in a changing climate. • The Melbourne Flood Strategy Refresh is an example of collaborative efforts to bring together decision-makers with flood	Melbourne Water (2021) https://www.melbournewater.com.au/about/strategies-and-reports/flood-management-strategy-port-phillip-and-westernport#:~:text=The%20Flood%20Management%20Strategy%20for,flood%20ma

		management responsibilities, as well as a range of other stakeholders to identify local priorities and actions. • This was completed through a number of avenues, including a series of workshops through the Inner Melbourne Climate Adaptation Network, bringing together researchers and practitioners throughout the course of the year to contribute to the Flood Strategy Refresh, while building capacity and understanding of the region profile.	nagement%20in%20the%20region.&text=The%20strategy%20is%20being%20refreshed,open%20until%2021%20March%202021.

Flood Risk Assessment, Planning Evaluation and Scheme Amendment	Toowoomba	• Taking an integrated approach, incorporating hydraulic risk, vulnerability, and tolerability to determine planning and development controls.
		• The vulnerability assessment incorporated
		  ○ Land use type (hospital/residential/park/aged care)
		  ○ Isolation (low/high island)
		  ○ Infrastructure (rising road access, flood free evacuation)
		  ○ Evacuation infrastructure (suitable evacuation centres)
		  ○ Socio-demographic analysis
		• The tolerability assessment was informed through extensive community consultation, incorporating aspects of awareness, education, and experience.
		• Council worked closely with a range of stakeholders and the community to balance competing preferences, values, and risk tolerance within land-use planning controls.
			Planning Award (Planning Institute of Australia, 2019)
			https://www.planning.org.au/awards/toowoomba-region-flood-management---safer-stronger-more-resilient-region
			Presentation, Floodplain Conference (2017)
			https://floodplainconference.com/papers2017/Ian-Ryan.pdf

Collaboration between local Planning Scheme development and Ffloodplain managers situated in CMAs	NA	• CMAs must incorporate projections into their floodplain modelling. • There is an opportunity to utilise this data for inland flood modelling. • While some overlays are beginning to incorporate future flood risk within their LSIO (for example, Bass Coast Shire, City of Greater Geelong), inland (i.e. not only coastal) flooding poses significant risk. • Examples from other jurisdictions demonstrate methods which could be utilised - for example as above with Toowoomba – extensive community consultation to understand tolerability	City of Greater Geelong (C394) (City of Greater Geelong, 2020) https://www.geelongaustralia.com.au/amendments/item/8d6fe3cb76c04fa.aspx Bass Coast Shire (C82) https://www.basscoast.vic.gov.au/building-planning/planning-scheme/planning-scheme-amendments

		could be combined with flood modelling and climate projections.	

Having reviewed the five core sectors for the Grampians, we now turn to examine the four main climate change hazards they are exposed to.

9 Hazard - Heat

9.1 Climate change projections

9.1.1 Higher maximum and minimum temperatures

According to the recent Victorian Climate Projections 2019 (VCP19), in the Central Highlands temperatures are projected to increase by a median of 1.6°C by 2050 under the medium emissions scenario, while under the high emissions scenario the maximum temperature increase is projected to be 1.3°C by the 2030s and 2.1°C by 2050. The projections are similar for the Wimmera Southern Mallee, with a slightly higher projected increase to 2.2°C by 2050 under the high emission scenario.

Increasing minimum temperatures is one of the main manifestations of global warming and reduces the ability for heat to dissipate, leading to heat accumulating in the environment and bodies and so increasing the risk of heat stress. In both the Central Highlands and Wimmera Southern Mallee, under the high emissions scenario, minimum temperatures are projected to increase by 0.8°C by the 2030s, while by the middle of the century an increase of 1.4°C is projected for the former and 1.5°C for the latter. By the 2050s under high emissions, it is projected that in the Central Highlands the 1-in-20-year coldest winter daily minimum temperature will be around 0.8°C warmer, and around 0.6°C warmer in the Wimmera Southern Mallee. Overall, the west of the Grampians region is facing the largest projected increases in temperature.[1]

Although increasing minimum temperatures are projected to reduce frost risk over time, studies suggest that frost risk has increased in south-eastern Australia since 1960 due to clearer skies and this elevated risk will persist until approximately 2030 (Crimp et al. 2016).

9.1.2 Increased severity of extreme heatwaves

Heatwaves are projected to become longer and more severe. Under the medium emissions scenario, by 2050 the predicted temperatures of a '1-in-20-year hottest summer day' is also predicted to increase by 1.5°C in both the Central Highlands and Wimmera Southern Mallee, while under the high emissions scenario an increase of 2.7°C °C is projected for the former and 2.3°C for the latter.

9.2 Regional hazard vulnerability

The impacts of heat are especially acute for cohorts, elements and activities with pre-existing heat sensitivity. For the Grampians region, these include:

- Vulnerable human groups – notably the elderly, those with pre-existing health problems and those who work outdoors, especially if it involves physical exertion. All of these groups are of particular relevance to the Grampians. Tourists are also potentially vulnerable to the extent they are outdoors and physically active.
- Physically exposed and nature-dependent industries – notably agriculture, natural resource, water and tourist sectors. Plants and animals, particularly those outside, are exposed and often sensitive to accumulative and extreme heat. The Grampians current reliance on agriculture increases the vulnerability of the region to heat.
- Built environment – poorly insulated housing and other building stock (McMichael *et al*, 2006; DHHS, 2017), and poorly shaded gardens, pedestrian routes and playing fields, are all especially exposed and sensitive to heat. These are all issues in the Grampians region. In particular, many houses in the region are not well insulated.

Urban areas in the region face the additional pressure of the heat island effect (Bosomworth *et al*, 2013; Beer *et al*, 2013). (McMichael *et al*. 2006; Norton *et al*, 2013; Bosomworth *et al*, 2013; DHHS, 2017; Guilding *et al*, 2013).

9.3 Observed impacts of increased heat in the Grampians region

Changes in temperature (both average maximum/minimum temperatures and the increasing severity and extent of heatwaves) are already being recognised across the region. One example that demonstrates the already changing climate was the January 2009 Victorian heatwave. This event clearly demonstrated the direct and flow on impacts of a severe heat wave (DHHS, 2009). Much of the state broke records both for high day and night time temperatures as well as for the duration of extreme heat. Over the five days from the 27th to 31st January 2009, maximum temperatures were 12–15°C above normal. This event led to spikes in heat-related injuries, illness, hospital admissions, ambulance callouts, and death, primarily amongst older Victorians. The clear lesson from this event is that it was both well within the recorded parameters of climate change at the time and represented an event that is predicted to become much more severe in the future (Environmental Health Unit, 2009).

9.4 Projected impacts of increased heat in the region:

9.4.1 Direct impacts

- Impacts on water (see *Theme: Water*):
    - Reduced supply
    - Reduced water quality – warmer water increases risk of water quality issues such as algal blooms
- Impacts on electrical equipment and energy and transport infrastructure (see *Theme: Economy*)
    - Physical impacts on electrical equipment including computers, due to their inherent thermal limits (Madonna et al. 2019, Rickards and Oppermann 2018).
    - Physical impacts on transport infrastructure, such as road asphalt melting and train tracks warping.
    - Physical impacts on energy infrastructure such as peak electricity pressures and consequent supply risks, as well as risks of supply relating to specific events such as fire.
- Impacts on health and wellbeing (see *Theme: Health and wellbeing*):
    - A rise in heat stress and other heat-related illnesses (heat cramps, heat exhaustion or heat stroke) which can be fatal for those with intrinsic vulnerabilities (such as the elderly or young children).
    - Increased accidents
    - Anger and violence
    - Increased risk of gastroenteritis, in connection with poor food handling – compounded by possible failures of the electricity grid (DHHS, 2019)
    - Certain residents within the region are particularly at risk from heat (Environmental Health Unit 2009, p3; DHHS 2019, p19), including:

        - People with 'intrinsic' risks, such as: the elderly; children under five years old; pregnant or nursing mothers; people with a pre-existing medical condition or a disability; those living alone with little social contact; problematic alcohol or other drug use
        - People with 'circumstantial' risks, such homeless people; low income earners; those with limited access to transport; people who are outdoors for any reason; and linguistically diverse backgrounds who cannot access health services or information.
- Impacts on environmental management (see *Theme: Natural Resource Management*):
    - There will be increased stress on ecosystems, especially as water supplies are impacted (Hughes et al, 2010),
    - Decreasing biodiversity as ecosystems face changing environmental parameters within which they must adapt (DELWP, 2017)
    - Increasing impact of invasive species (Morton et al, 2014; DELWP, 2017; Steffen, 2009).
- Impacts on agriculture (see *Theme: Agriculture*):
    - Heat stress in livestock and plants, such as heat stress on wine grapes
    - Animal welfare on grazing enterprises
    - Longer term shifts in the climatic zones suitable for existing agriculture (Faggian et al, 2014; Beer et al, 2013)
- Economic impacts (see *Theme: Economy*):
    - Reductions in the productivity of those working outside

9.4.2 Indirect effects

- Indirect impacts on water (see *Theme: Water*):
    - Increased water demand due to heat increasing water requirements and evaporation, exacerbating reductions in water supply.
- Indirect impacts on transport
    - Disrupted traffic flows and congestion due to physical impacts of heat on transport infrastructure.
- Indirect impacts on energy
    - Increased risk of power blackouts or brownouts across the region due to impacts of heat on electricity grid and increased demand to run air conditioning units (DHHS, 2019)
- Indirect impacts on health and wellbeing (see *Theme: Health and wellbeing*):
    - increased burdens on health and other emergency service providers due to health clinics, hospitals and ambulance services having to deal with increase in heat-related illnesses and their flow-on effects (OCHO, 2009)
    - Increased risk of drowning as more people engage in water-based recreational activities (DHHS, 2019).

    - Impacts on elderly and others reliant on public transport if the latter is disrupted (DHHS, 2019).

- Economic impacts (see *Theme: Economy*):
- Disruptions to the functioning the local economy due to power disruptions (blackouts or brownouts) that shut down EFTPOS and ATMs (NCCARF, 2018).Cascading effects
- Direct impacts and increased demand can lead to electricity blackouts. Failures of electricity supply can disrupt, in turn, other service infrastructure such as telecommunications and water supplies (Department of Health, 2019). Power disruptions especially pose risks for those already vulnerable to heat stress (such as the elderly or outdoor workers) who rely on electricity for fans, air-conditioning, ice and refrigerated drinks. Workers that are outside repairing electricity infrastructure (which is often dangerously hot itself) to help overcome disruptions to the grid are themselves at risk of adverse health impacts and are themselves reliant on electricity to help manage heat illnesses (DHHS, 2019; Rickards and Opperman 2018). Although many reviews (e.g., Habibi et al., 2021) of occupational heat strain in outdoor workers recommend adapting by reorganising work programs so that the tasks that pose the greatest heat risk are performed in cooler parts of the season or day, such an adaptation is not possible for those involved in emergency work.

9.5 Interactions with other hazards

It is important to note that heat does not act in isolation, and its effects are often amplified by the complex interactions it has with both other hazards and environmental, economic, social and physical conditions. For example:

- Heat is a crucial determinant of fire risk (see *Hazard: Fire*), whether directly or through the cascading effects it has upon aridity in the landscape (see *Hazard: Drought*), which drives fuel combustibility. Furthermore, the interactions of atmospheric heat and low humidity drives dry thunderstorm activity (see *Hazard: Flood*), which also accentuates fire risk due to the likelihood of dry lightning strikes and increased wind speeds.
- An increase in both maximum/minimum temperatures, and in the severity of extreme heatwaves, combined with falls in rainfall across the region leads to higher evaporation and reduced soil moisture, and poorer water quality, reducing available water (see *Hazard: Drought*). When combined with declining rainfall and increased wind, heat can increase water demand and so negatively impact waterflows across the region, leading to lower waterway health and possible water shortages (see *Hazard: Drought*).

9.6 Cross-sectoral adaptation needs

- Municipal heat/heatwave, flood and emergency plans for each shire or municipality
- Education campaigns about how to avoid heat stress and other heat illnesses
- Education campaigns and energy efficiency programs to reduce commercial and domestic electricity use during heatwaves
- Increasing the modularity of the electricity supply to contain blackouts
- Climate change-focussed risk assessments for the road and rail networks which inform network maintenance (NCCARF, 2018; Balston *et al*, 2013).

10 Hazard - Drought

10.1 Climate change projections

10.1.1 Decreasing rainfall

The Grampians region includes areas of high and low rainfall relative to Victorian averages, as the region extends from the semi-arid Mallee to the relatively high rainfall Central Highlands. The recent Victorian Climate Projections 2019 (VCP19) (DELWP, 2019c; 2019d), which are based upon two plausible future greenhouse gas emissions scenarios: medium emissions (RCP4.5) and high emissions (RCP8.5), are projecting declining rainfall until the end of this century. The likelihood of either scenario occurring is dependent upon the mitigation effects (primarily reductions in greenhouse emissions) undertaken across that period.

It is predicted that the ongoing trend of decreasing rainfall will accelerate, with a greater decrease expected in terms of cooler season (particularly spring) rainfall (DELWP, 2019c). By the end of this century, and under the high emissions scenario, the Central Highlands is predicted to see a median 24% decrease in annual rainfall totals, with a larger 31% decrease in spring. The Wimmera Southern Mallee (under the same scenario and timeframe) is predicted to experience a median 24% decrease in annual rainfall totals, with a 34% decrease in spring.

Decreasing average rainfall across the region as a whole is projected. However, there will also be seasonal variation, with a greater decrease expected in cooler season (most importantly spring) rainfall (DELWP, 019c). This has serious implications for agricultural production, given the importance of spring rainfalls for crop viability. At the same time the historic variability of rainfall, which has always been evident across the region, will also increase, with a resultant increase in the likelihood of extreme rainfall events leading to the possibility of flooding.

10.1.2 Increasing evaporation and less water available, increased demand for water

Drought conditions, along with a lack of rainfall and more heat, are projected to increase evaporation from water bodies and evapotranspiration from plants, with the greatest increases predicted for spring and summer (Clark *et al*, 2019), reducing water storage and increasing demand to maintain yields. Water quality is also projected to decrease under drought as smaller, hotter water bodies increase the risk of eutrophication and algal blooms.

10.1.3 The likelihood of increased drought conditions

Even allowing for the historic variability of rainfall, which has always been evident across the region and which is predicted to also increase, an increased incidence and severity of drought is forecast (DELWP, 2019c; 2019d).

10.2 Regional hazard vulnerability

Drought vulnerability in the region has consequences for urban and rural communities, and the region's varied habitats. In the Grampians region this includes:

- Rural towns where recent drought events have revealed limits to urban water supply and security.

- In smaller and larger urban centres with more reliable, networked water systems, the quality of community assets such as sports grounds, local waterways and street trees remain at risk under severe water restrictions, presenting socio-cultural and economic implications in addition to health impacts.
- The significant impacts on agricultural economies in dryland farming areas, and irrigation dependent regions
- Impacts on waterway health riverine and littoral habitat stress.

10.3 Observed impacts

While rainfall variability and resultant drought has always been a feature of the region, there is clear evidence that overall rainfall has been decreasing across the region since at least the 1960's (DELWP, 2015). The Millenium Drought (from 1996 to 2010) provides a clear example of this observable trend. Observed impacts include:

- Western Victoria experienced a prolonged drying period, placing unprecedented strain on water supplies and waterways (DELWP 2018e). Communities in the region experienced "prolonged and severe water restrictions," "[t]here was not enough water to run the Wimmera Mallee delivery system," reliability for domestic users and stock was challenged with water carting sometimes the only way to supply water (DELWP 2018e, p.16).
- While the early completion of the Wimmera Mallee Pipeline in 2010 alleviated some impacts in the region (DSE 2011; DELWP 2018e), this served to expose the water security challenges for inland areas.
- Lessons from the Millennium Drought "were that the region's water supplies need to be reliable, that users need to use water efficiently and that everyone needs to be able to adapt to prolonged, dry conditions as well as very wet periods" (DELWP 2018e, p.16).

10.4 Projected impacts in the region

10.4.1 Direct impacts

- Impacts on water (see *Theme: Water*):
    - Reduced rainfall across the region will lead to reduced flow in rivers and creeks, which will further reduce their already low health.
    - Pan evaporation from open irrigation channels and rivers/creeks will only make the drought worse.
    - Restrictions on water use will be imposed on stakeholders (whether residential, commercial or agricultural) across the region.
    - Reduced opportunities for water-based recreational activities (swimming, boating, and fishing) and for sporting activities (golf, football, cricket) that rely upon grassed playing fields.
- Impacts on health and wellbeing (see *Theme: Health and wellbeing*):
    - Water restrictions will lead to both financial (increased costs for bottled water and for water-dependent businesses) and emotional (stress and anxiety) hardship for residents - particularly those with intrinsic vulnerabilities (such as

the elderly, young children, or those unable to afford the extra costs imposed by drought).

- Increased risk of heat stroke, particularly among the elderly, children, or people with underlying health issues.
- Possible conflicts within communities over perceived inequities in both access to water and its use.

- Impacts on environmental management (see *Theme: Natural Resource Management*):
  - There will be increased stress on ecosystems, especially as water supplies are impacted (Hughes et al, 2010).
  - There is a risk of reductions in biodiversity as ecosystems, and the species within them, face changing environmental parameters within which they must adapt (DELWP, 2017).
- Impacts on agriculture (see *Theme: Agriculture*):
  - Both irrigated and rainfall dependent agriculture will be directly affected (depending on the severity and duration of any drought) with reductions to yield and income.
  - Increases in direct costs for inputs; water and feed.
- Economic impacts (see *Theme: Economy*):
  - Direct costs to agricultural producers due to livestock death or crop destruction.

10.4.2 Indirect effects

- Impacts on agriculture (see *Theme: Agriculture*):
  - Long term drought recovery (stock, finances and other factors) which then has negative flow on effects into the local area's economy over a longer period.
- Impacts on health and wellbeing (see *Theme: Health and wellbeing*):
  - declining incomes and returns to investment (whether for agricultural producers or the businesses dependent upon them), coupled with likely increases in debt, can lead to increased mental health prevalence and presentations (Roughead, 2014).
- Economic impacts (see *Theme: Economy*):
  - Structural changes to community and commercial activities and viability in smaller towns, including business closures, employment loss and population decline (Askew et al., 2014)
  - Economic consequences of challenges to health and wellbeing.

10.5 Interactions with other hazards

The cause of drought is connected to, and amplified by, other hazards such as heat. At the same time, the effects of drought are often amplified by the complex interactions they have with both other hazards and environmental, economic, social and physical conditions. For example:

- Heat (see *Hazard: Heat*) is a driver of both increased pan evaporation and aridity in the landscape, which in turn makes it a primary cause of drought.
- Together with heat, the aridity caused by drought, along with the reduced access to water which it implies, drives fuel combustibility and increases the Forest Fire Danger Index (see *Hazard: Fire* and *Hazard: Heat*). The risk of dry lightning strikes is another interconnected risk (see *Hazard: Flood*).
- The natural (and increasing) rainfall variation across the region means that periods of extended drought may be followed by periods of extreme rainfall (as with the arrival of *La Niña* weather conditions in 2010 that broke the Millennium Drought) (see *Hazard: Flood*).

10.6 Cross-sectoral adaptation needs

- Increased access to seasonal forecasts to enable business and household water users to adjust demand to supply.
- Increased flexibility in water allocations.
- Increase modularity of water reserves or infrastructure.
- Public education to reduce water demand.
- Use of water pricing to disincentivise overuse.
- Planning regulations to mandate reductions in residential or commercial water consumption.
- Increased environmental water flows into ‘at-risk’ waterways.
- Improvements in integrated catchment management.

11 Hazard - Fire

11.1 Climate change projections

The recent Victorian Climate Projections 2019 (VCP19) (DELWP, 2019c; 2019d) are based upon two plausible future greenhouse gas emissions scenarios: medium emissions (RCP4.5) and high emissions (RCP8.5) projected until the end of this century. The likelihood of either scenario occurring is dependent upon the mitigation effects (primarily reductions in greenhouse emissions) undertaken across that period.

Fire seasons are already becoming longer and starting earlier in the year, and under these climate change projections the observed increases in the Forest Fire Danger Index are likely to continue. For example, under a high emissions scenario there is high confidence that the number of fire days in Horsham where the Forest Fire Danger Index is greater than the 95th percentile for 1986–2005 will increase by a median value of 8.7 days per year by the 2050s. This is a 48% increase. For Ballarat the predicted increase over the same period is even more severe; a 68% increase (or a median value of 12.4 days per year by the 2050s).

11.2 Regional hazard vulnerability

Specific regional hazard vulnerability relates to varied nature of fire events and communities in the Grampians region. In some areas, high proportions of visitor or part time populations present specific vulnerabilities. Often even low-level fire on the fringe of new urban development affects large populations, typically unused to fire planning, although this can also occur in peri-urban and bushland housing development. In some areas, population decline presents a significant challenge to the reliance on local volunteering capacity.

11.3 Observed impacts

The Grampians region has seen major fire events in recent years that demonstrate the shifting fire regime and its far-reaching impacts. For example:

- In 2006, a major bushfire burnt half of the Grampians National Park, with significant impacts for the region (Victorian Government 2006).
- The Black Saturday Bushfires in 2009 resulted in significant loss of life and property damage, with a significant fire at Horsham (AIDR undated).
- Subsequent bushfires in 2013 and 2014 saw the area burnt in the Grampians National Park close 90 per cent over the previous decade (White et al. 2016).
- The Grampians region was also impacted by the 2019/20 Black Summer bushfires. Across Victoria, these bushfires caused the loss of five lives, with the destruction of over 300 homes, and 6,632 head of stock lost (AIDR undated). There have been significant impacts on forests, parks, catchments, and habitat. Bushfire smoke from these bushfires in Victoria is associated with 120 excess deaths, and 1300 other poor health outcomes such as emergency room presentations.
- In addition, the most severe thunderstorms occur between October and April (over the warmer months of the year). The most active month is January, followed by December and then November (Vic SES, 2020), and in Victoria generally "*results suggest an increase in the favourable conditions for thunderstorm formation under global warming."* (Clarke *et al* 2019, p64) raising issues for lightning strike and remote fires.

11.4 Projected impacts

11.4.1 Direct impacts

- Impacts on water (see *Theme: Water*):
    - There is a clear risk of damage to residential, commercial or ecological water supplies due to pollution from ash or and other debris washing into waterways and reservoirs, particularly in areas of the Grampians region that were previously mined for gold (Abraham et al 2018a, 2018b, Lawrence and Davies 2020).
- Impacts on energy and transport infrastructure
    - Fires can destroy energy and transport infrastructure such as the electricity grid or transport (road and rail) networks (Beer *et al*, 2013).
- Impacts on health and wellbeing (see *Theme: Health and wellbeing*):
    - Increased risks of serious injury and death amongst people in affected areas.
    - The danger of respiratory problems due to smoke, particularly among those most at risk such as the elderly, or people with existing respiratory problems (DHHS, 2019a; Steffen et al, 2015).
    - Increased stress on health and emergency services during such emergency events (DHHS, 2019a; 2019b; OCHO, 2009).
- Impacts on environmental management (see *Theme: Natural Resource Management*):
    - Direct habitat and wildlife loss (DELWP, 2020c).
- Impacts on agriculture (see *Theme: Agriculture*):
    - Loss of crops and stock, and farming infrastructure such as fences and farm buildings, as well as family homes and gardens.
- Economic impacts (see *Theme: Economy*):
    - Severe financial impacts on businesses and families who experience a loss of assets and income capacity.
    - Disruption to economic activity during and after a bushfire event
    - The direct costs of recovery – including infrastructure and building repair or replacement (Steffen *et al*, 2015; Bosomworth *et al*, 2013; Norton *et al*, 2013; Balston *et al*, 2013).

11.4.2 Indirect effects

- Impacts on water (see *Theme: Water*):
    - Fire can lead to loss of riparian vegetation and increased turbidity and nutrient richness of water bodies, reducing water quality. Water treatment plants can be strained by having to remove large amounts of ash and debris, and irrigation equipment can be damaged. Post-fire tree regrowth can temporarily reduce the amount of water available as young trees grow.
- Impacts on agriculture (see *Theme: Agriculture*)
    - Weeds, pests and diseases can increase after fires due to lack of competition, low water quality, and stressed animals and vegetation. This can create problems for cropping and livestock production.

    - Soil can be damaged by fire and subsequent water or wind erosion, leading to long-term soil degradation.

- Impacts on health and wellbeing (see *Theme: Health and wellbeing*):
    - Disruptions to transport networks can lead to possible shortages of essential goods such as water, food or liquid fuels, with clear effects on the health of residents (Mallon et al, 2013).
    - Transport (particularly road) disruptions also make it difficult for both emergency services to access and respond to large bushfire events, and for residents and visitors to evacuate these same affected areas.
    - Power disruptions pose risks for those already vulnerable to heat stress (such as the elderly) because they won't be able to access air-conditioning.
    - There are ongoing social, personal and economic effects on the social determinants of health, including: the loss of business and economic infrastructure, homelessness and unemployment, and a loss of social capital in badly affected communities (the physical destruction of a town by fire is also the destruction of the social relationships within that town). All of these effects can be secondary causes of ongoing emotional or physical distress and ill health.
- Impacts on environmental management (see *Theme: Natural Resource Management*):
    - An increased risk of affected ecosystems losing adaptive capacity due to bushfire effects changing the environmental parameters to such an extent that they cannot recover (DELWP, 2017; Steffen, 2009; DELWP, 2020c), For example, fires may cause the loss of herbivorous species that reduce fuel load within the environment - only accentuating future fire risks (Hayward et al, 2016).
    - Fires can mobilise legacy pollutants such as mercury and other heavy metals from unrehabilitated gold mining landscapes, releasing them into air, soil, plants and water and triggering long-term consequences (Abraham et al. 2018b).
- Impacts on agriculture (see *Theme: Agriculture*):
    - The direct economic effects of fires may lead to the failure of agricultural producers (they may not recover from a particular fire) which then has negative flow on effects on the local area's economy.
- Economic impacts (see *Theme: Economy*):
    - Any power disruptions (blackouts or brownouts) caused by fires will also shut down EFTPOS and ATMs across the region, causing disruption to the functioning of the local economy (NCCARF, 2018).
    - As above: fires may lead to the failure of local businesses or agricultural producers, which then negatively impacts the local economy.
    - The possible risk of increased insurance premiums for affected residents and businesses.

11.5 Interactions with other hazards

While fire within the region is a clear hazard in and of itself, the *cause* of fire events is connected to, and amplified by, other hazards. At the same time, the *effects* of fire events are often amplified by the complex interactions they have with both other hazards and environmental, economic, social and physical conditions. For example:

- In terms of fire causation, there are clear connections to the hazards of heat and drought. Heat and drought are both drivers of aridity in the landscape, which drives fuel combustibility and increases the Forest Fire Danger Index (see *Hazard: Drought* and *Hazard: Heat*).
- Dry summer thunderstorms with less precipitation also accentuate fire risk, and increase the severity of existing fires, due to the likelihood of dry lightning strikes and increased wind speeds (and the potential formation of *Pyro-cumulonimbus* clouds and storms).
- Fires are often followed by heavy precipitation. The lack of vegetation can increase runoff and cause flash floods, landscape erosion, and ash, sediment, organic matter and nutrient 'slugs' to flow into waterways, reducing water quality and usability (Alexandra and Finlayson 2020).

11.6 Cross-sectoral adaptation needs

- Municipal fire and emergency plans for each shire or municipality
- Modularity of electricity supply (Newell *et al*, 2011; Newman, 2010)
- Climate change-focussed risk assessments for the road and rail networks which inform network maintenance (NCCARF, 2018; Balston *et al*, 2013)
- Modularity or redundancy of local liquid fuel supplies (Frank *et al,* 2014; Blackburn, 2013;2014)
- Improved capacity for emergency services in the region
- Policy decisions regarding environmental management are science based and account for the effects of climate change (Prosser, 2011; DELWP, 2017).

12 Hazard - Flood

12.1 Climate change projections

The recent Victorian Climate Projections 2019 (VCP19) (DELWP, 2019c; 2019d) project that the ongoing trend of decreasing rainfall will accelerate, with a greater decrease expected in terms of cooler season (particularly spring) rainfall (DELWP, 2019c), reducing it during the typical agricultural growing season.

Rainfall variability and intensity are projected to increase, adding uncertainty to the timing, characteristics and consequences of rain events. The Victorian Climate Projections 2019 Technical Report argues:

> *The new VCP19 downscaling results support the previous projections for a likely increase in daily rainfall extremes under a high or medium emissions scenario, despite decreases in average rainfall (Figure 43) and with a range of changes possible.* (Clarke et al 2019, p59)

More intense rain increases the risk of flash flooding. The effects of climate change on the risk of riverine flooding is more unclear because of complex interactions between a greater intensity of rain over short time frames (eg one hour) and decreased volumes over longer time frames (e.g one year), plus declining amounts of soil moisture (Clarke et al. 2019).

12.2 Regional hazard vulnerability

Within the region, vulnerability varies according to location (e.g. proximity to rivers or creeks) and other factors. Halls Gap is especially vulnerable to flash flooding, for example, because of its location in a river valley (Wimmera CMA 2017). Vulnerability varies within communities too, not only because of the uneven distribution of generic adaptive capacities such as financial capital but because of highly localised physical factors (e.g. location and height of house, escape routes) and social factors (e.g. knowledge of flood risk, boating or swimming capability). For example, within Halls Gap, many tourists are especially vulnerable to the extent they have little understanding of the area's flood risk or appropriate responses. Age, disability and other factors also influence individuals' capacity to manage flood events.

12.3 Observed impacts

The Grampians region has always been prone to flooding, and the warning/lead time for such events is often quite limited. Recent flood events and their impacts include:

- the 2011 floods, which highlighted the overall vulnerability of the region, with roads (including several arterial roads) blocked for extended periods, flash flooding in a number of towns, damage to critical services and infrastructure, private and public property, natural assets, and flow-on implications for the health and wellbeing of social systems and the people in the region (CeCC 2014).
- the 2016 Victorian floods which also significantly affected the region - the Wimmera River flooded at several locations, and damage was recorded at the Grampians National Park including road closures, debris on roads and carparks, and the closure of popular visitor sites (Parks Victoria, 2016)
- flash flooding events in locations such as Halls Gap (WCMA, 2017) that has particular challenges relating due to topography and its temporary, seasonal and tourism-driven

population. Increased storm frequency and rainfall variability are forecast as climate change impacts in the region.

- Before the period 2009-2010 the region experienced an average of one large storm event (with over 80 Requests for Assistance (RFAs) for that storm) each year. Since that period the frequency of storm events has almost quadrupled (to nearly four events a year). At the same time their intensity has also increased, with around 1,000 RFAs per year (averaging 250 RFAs per storm) (Vic SES, 2020).

12.4 Projected impacts

12.4.1 Direct impacts

- Impacts on water (see *Theme: Water*):
    - Damage to municipal or private (household) sanitation systems.
    - Pollution of water storages (such as dams or reservoirs) by runoff full of organic matter, sediment, debris, sewerage, or animal remains, leading to increased turbidity, nutrients, algae and pathogens, reducing the quality of the water and creating possible shortages of clean drinking water.
- Impacts on health and wellbeing (see *Theme: Health and wellbeing*):
    - Increased risk of drowning in affected areas, or of entrapment in flooded vehicles.
- Impacts on environmental management (see *Theme: Natural Resource Management*):
    - Destruction of wildlife habitats by high velocity water flows or by inundation.
    - Pollution of waterways by contaminated floodwater.
    - Destruction of riverbanks and natural levées.
- Impacts on agriculture (see *Theme: Agriculture*):
    - Damage to agricultural infrastructure (buildings and fences) as well as the possible loss of crops (through initial flow or silt and sediment deposits) and/or livestock.
- Economic impacts (see *Theme: Economy*):
    - Damage to businesses, infrastructure, housing and vehicles.
    - Loss of access to businesses and tourism attractions.

12.4.2 Indirect effects

- Impacts on water and agriculture (see *Theme: Water* and *Theme: Agriculture*):
    - Extended periods of drought may be followed by periods of extreme rainfall and even flooding (as happened at the end of the Millennium Drought). This then leads to a range of effects linked to floods.
- Impacts on health and wellbeing (see *Theme: Health and wellbeing*):
    - Disruptions to transport and energy networks may lead to shortages of food, water, fuel and electricity, with flow on effects on community health.

  - Transport (particularly road) disruptions also make it difficult for both emergency services to access and respond to flooding, and for residents and visitors to evacuate these same affected areas.
  - A loss of income and/or employment (whether for agricultural producers or the businesses dependent upon them), coupled with probable increases in debt, can lead to increased levels of stress, anxiety and depression.
  - There are ongoing social, personal and economic effects on the social determinants of health, including: the loss of business and economic infrastructure, homelessness and unemployment, and a loss of social capital in badly affected communities (the physical destruction of a town by flooding is also the destruction of the social relationships within that town). All of these effects can be secondary causes of ongoing emotional or physical distress and ill health.
- Economic impacts (see *Theme: Economy*):
  - Reduced economic activity caused by disruptions to transport (road and rail) networks.
  - Power disruptions (blackouts or brownouts) caused by flooding will also shut down EFTPOS and ATMs across the region, causing disruption to the functioning of the local economy (NCCARF, 2018).
  - The economic effects of a flood (decreased income, crop or livestock losses, homelessness, and personal hardship) may lead to agricultural producers leaving the land. This then affects both the economic viability of local businesses and towns, and their population levels.
  - The possible risk of increased insurance premiums for affected residents and businesses.

12.5 Interactions with other hazards

While flooding within the region is a clear hazard in and of itself, it is connected to, and amplified by, the complex interactions floods have with both other hazards and environmental, economic, social and physical conditions. For example:

- Flooding is often connected to the passage of storms which can be responsible for damaging extreme rainfall within short timeframes, causing water erosion.
- The standing water left by floods, coupled with increasing heat (see *Hazard: Heat*), means that floods pose serious risks to the health of residents in the region due to the possibility of waterborne or mosquito borne diseases, or gastrointestinal diseases caused by the breakdown of sewage and sanitation systems (Hennessy et al, 2007; Department of Health 2019) (see *Theme: Health and Wellbeing*).
- When flooding occurs in an area where vegetation has been reduced by prior climatic pressures *(Hazards: Drought, Fire),* runoff can be especially rapid and destructive, causing widespread erosion and impacting water quality.

12.6 Cross-sectoral adaptation needs

- Municipal flood and emergency plans for each local government developed with CMAs.

- Climate change-focussed risk assessments for the road and rail networks which inform network maintenance (NCCARF, 2018; Balston *et al*, 2013).
- Continual improvements in integrated catchment management (ICM) including reduction in sources of pollution and other non-climatic pressures on water catchment health.
- Flood mitigation infrastructure and activities (DELWP, 2016c).
- Spatial data for land use planning to mitigate future increased flood risks (DELWP, 2016c).

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