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Climate Emergency Working Group Report

Part 2 Identification of risks from climate change and recommendations for reducing severity of risk and adaptation

The natural, social and economic systems of NSW will all be affected by climate change, requiring every sector of society to adapt. NSW councils are key players in adaptation to climate change, having responsibility for a broad range of functions that are likely to be affected, such as public infrastructure, local emergency responses, building regulation and planning, public health and environmental management. Early planning and preparation can minimise long-term economic, social and environmental costs to communities. A number of helpful resources in developing a plan for identification of risks and reducing the severity of the impact of these risks can be found at the NSW government website https://climatechange.environment.nsw.gov.au/Adapting-to-climate-change.

The Department of Planning, Industry and Environment *Guide to Climate Change Risk Assessment for NSW local government* was developed to help councils assess the risks of climate change. It notes that observed changes in the climate of NSW and the rest of the world mean that the assumptions on which cities, towns and regions are planned and run must be reassessed.

The risk assessment *Guide* is focused on assessing the risks to council operations rather than wider community risks. However, it acknowledges that councils should also carry out a process to consider these broader risks, in consultation with the community.

Recommendation of this report

- **that Armidale Regional Council completes a *Climate Change Risk Assessment* for the LGA, in conjunction with the community. This Assessment should also assess broader community risks that are already being experienced or are likely to occur in the area. This should be done to reduce the severity of the consequences of climate change in our region.**

Armidale Regional LGA has its own unique set of geographical, environmental, economic and social circumstances, hence there is a need to identify effects and risks of climate change that are specific to the area. Regional information provided at the Adapt website can help to identify how the expected impacts of climate change may affect local communities, and identify opportunities to respond (see Western Enabling Regional Adaptation New England North West Report). Figure 17 in the *WEA NENW Report* identifies ´climate impact chains´ for the New England North West region. Information from this Figure has been used to show the detailed impacts of climate change on the Armidale Regional LGA and is shown at Table x below and in Appendix x. . as a basis for further development of impact chains specific to the Armidale Regional LGA region and is shown in included as additional tables in Appendix ...

The Regional Vulnerability Assessment (IRVA) for Climate Change (https://climatechange.environment.nsw.gov.au/Adapting-to-climate-change/Regional-vulnerability-and-assessment) provides a process to help to identify and understand regional climate vulnerabilities. Local knowledge is important in identification of potential threats and response options and in helping communities prepare for climate change..

Vulnerability is seen as the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes (IPCC 2001). Vulnerability is viewed as the state of susceptibility to harm from exposure and sensitivity to stresses associated with environmental and social change and from the absence of capacity to adapt.

Adaptation is defined as actions taken to reduce or moderate or adjust to the expected or actual negative effects of climate change and take advantage of new opportunities.

Resilience is the ability of communities and settlements not to collapse in the face of crises such as adverse climatic conditions and water, food and energy shortages and their ability to respond to disturbance with adaptation. It may involve being more prepared for a leaner future.

Projected changes for the New England North West Region (https://climatechange.environment.nsw.gov.au/Climate-projections-for-NSW/Climate-projections-for-your-region/New-England-North-West-Climate-Change-Downloads)

Projected change	Near future (2020-2039)	Far future (2060-2079)
Maximum temperature increase[1]	0.4-1.0ºC	1.9-2.7ºC
Minimum temperature increase	0.5-1.0ºC	1.6-2.7ºC

Number of hot days	Increase
Number of cold nights	Increase

Rainfall	increase in autumn	decrease in winter
Average fire weather	increase in summer, spring and winter	
Severe fire weather days	increase in summer and spring	

Note that there is uncertainty in these predictions due to difficulties in separating the effects of short-term, local weather from long-term changes in climate and in predicting future climate at local scale.

Predicted alterations to ocean and climate systems due to climate change
Recent research provides evidence that the incidence of two of the major climate drivers contributing to severe and prolonged drought in Australia are likely to increase.
Positive Indian Ocean Dipole
The 2019 drought occurred at a time where the Indian Ocean Dipole was at a record positive level. Extreme positive IOD events have been strongly linked to drought in Australia. Indian Ocean Dipole events have become stronger and more frequent since the 1960s. This may be occurring because climate change is causing the Indian Ocean off Africa on the western side of the Indian Ocean to warm more rapidly than in the the eastern Indian Ocean adjactent to Australia. It is predicted that Australia will experience twice as many drought-causing extreme positive IOD events if temperatures warm by 1.5 degrees Celsius.[2] Recent climate model projections indicate that extreme positive Indian Ocean Dipole events, associated with severe drought and bushfire, will occur three times more often this century than last if high greenhouse gas emissions continue. This will make severe drought, as experienced in SE Australia in 2019, more common.
More frequent El-Nino phase of the Southern Oscillation climate driver
New research, based on 33 historical El Niño events from 1901 to 2017, show climate change effects have shifted the El Niño onset location from the eastern Pacific to the western Pacific and caused more frequent extreme El Niño events since the 1970's. Continued warming over the western Pacific warm pool, driven by anthropogenic climate change, promises conditions that will trigger more extreme drought events in the future.[3]

Key areas identified in Armidale Regional Council´s Planning documents including the Community Strategic Plan 2017-2027 and Greenprint for a Sustainable Future are jeopardised by climate change.
These include environment and infrastructure, growth, prosperity and economic development, community, living, air, water, transport, resilience, future, biodiversity.
The potential for severe consequences of climate change is illustrated in the following excerpt from the Australian Government's Climate Change Impacts & Risk Management A Guide for Business and Government 2006 (https://www.environment.gov.au/system/files/resources/21c04298-db93-47a6-a6b0-eaaaae9ef8e4/files/risk-management.pdf)

[redacted]

Example of severe consequence rating, from the Australian Greenhouse Office guide (AGO 2006)

Consequence Rating	Criteria				
	Public safety	**Local economy and growth**	**Community and lifestyle**	**Environment and sustainability**	**Public administration**
Catastrophic	Large numbers of serious injuries or loss of lives.	Regional decline leading to widespread business failure, loss of employment and hardship	The region would be seen as very unattractive, moribund and unable to support its community	Major widespread loss of environmental amenity and progressive irrecoverable environmental damage	Public administration would fall into decay and cease to be effective

If the unprecedented drought and water shortage of 2019 had continued to the degree that Armidale ran out of water, the identified catastrophic outcomes could all have eventuated. Similarly, the scale of the 2019-2020 bushfires had the potential to result in such catastrophic outcomes.
In comparison, national and international responses to the 2020 coronavirus pandemic has potentially severe consequences for public safety and local economy and growth but does not directly threaten environment and sustainability which underpin food production and biodiversity. A co-operative national and global response, such as has occurred in response to the potential consequences of the Coronavirus Pandemic, has the potential to reduce the risk of severe consequences from climate change, which become greater the longer that action is delayed.
The introduction to Armidale Regional Council 2020-21 Budget notes that the 2019/20 financial year was highly unusual with the combined impacts of drought, fire, flood and pandemic in one financial year. Predicted climate change impacts mean that these impacts, identified as unprecedented and unusual, are highly likely to become more frequent and severe into the future. From a budgetary perspective in 2019/2020, the severe drought conditions negatively impacted Council's Water Fund by almost $6million. This included around $3.2 million in net costs associated with drought response communications, rebate programs and bore drilling and around a $2.5 million reduction in revenue from water usage charges resulting from decreased water usage. The risk posed by climate change impacts to council's financial security as well as the community's water security is clearly demonstrated.

Change in climate already underway or predicted for New England North West Region

- **Sequential annual increase in average maximum and minimum temperature** and **seasonal shift** with later onset of cold conditions and earlier onset of warm conditions, ground remaining warmer for longer, extended growing season and later frosts in spring (already evident from weather records, reversible only through reduction of atmospheric carbon / reversal of climate change)
- **Changes in seasonal rainfall patterns** - decreased winter rainfall, increased summer rainfall and changing water cycles
- **Increased hot days, heat waves**, episodes of prolonged and excessive heat (less frequent occurrence than at lower altitude due to cold climate but increasing impact with increasing warming particularly when associated with drought and water shortage).
- **Prolonged drought and water shortage**, low rainfall combined with high evaporation, dust, dust storms
- **Increased incidence, intensity and severity of storm events** and associated weather events such as high velocity winds, heavy rain, hail and flooding
- Decreased snowfalls and changed incidence of frosts including potential for **increased severity of frosts occurring later in the season** and during the growing season
- **Increased duration of period of increased fire risk with increased frequency, intensity and severity of fire events** and reduced ability to reduce hazard and to manage fire effectively to protect life and property.

Effective global action to reduce greenhouse gas emissions and draw down atmospheric carbon is the only pathway to reduce the severity of predicted and unfolding changes identified above and return to a safe climate.

However, the above climate change outcomes have predicted and observable flow on impacts which are complex and which affect a broad range of human impacts such as the natural environment, landscape, food production, livelihood and human health. Some of these flow on impacts are presented in tables ..no.. (see Appendix ..). There are many interventions that have the potential to increase community resilience and reduce the severity of these flow on impacts. Some possible interventions are included below; however the complexity of possible options is beyond the scope of this report.

- **It is recommended that Armidale Regional Council, potentially in conjunction with the Zero30 project and relevant community representatives, holds workshops to inform the community regarding climate change risks and flow on impacts. These could be followed by focussed workshops for community members with expertise in different areas such as agricultural production, native species and ecosystem conservation, water management and human health and wellbeing to enable identification of a diversity of possible interventions by Council and the community.**

Impacts on water availability are highlighted as having the potential for the most severe consequences for the Armidale Regional Local Government Area.

Interventions to reduce adverse climate change impacts

2.1 Natural Environment

2.1.1 Water availability and water security

2.1.1.1 Council

- Complete 30-year Integrated Water Cycle Management (IWCM) Strategy and Secure Yield Model long-term assessment of the Armidale region's water infrastructure, supply needs and community expectations. Ensure that investigation is not weighted towards increase of storage capacity at Malpas Dam without proper assessment of alternative options including options for decreasing usage. Plan for further grant applications to enable detailed planning, design and construction works to improve the region's water security.
- Identify and implement measures such as stock exclusion and revegetation to protect water catchments. This needs to be assessed in the context of increased blue-green algal contamination of domestic water storage due to increased temperatures and increased nutrient runoff due to livestock manure.[4] Further revegetation of Malpas and Dumaresq Dam catchments is consistent with the goal of carbon sequestration.
- Identify and implement measures to decrease evaporation from domestic water storage. Installation of floating solar panels on Malpas Dam has potential in this regard.

2.1.1.2 Council and community

- Engage with and inform community regarding environmentally sound options for optimising water security. Inform community regarding opportunities and potential barriers to security of domestic water supply in the face of predicted and unfolding changes to climate. For example, a costly elevation of Malpas Dam wall will not improve water security if there is insufficient rain or runoff to fill the increased capacity.
- Continue incentives for residential use of grey water and water storage in rainwater tanks.
- Council build on engagement started in 2019 with residents, businesses and institutions, in particular high water users, to bring about behaviour change and technical modifications to decrease water consumption and enhance efficient use of water.
- Work with UNE researchers to investigate potential for decreasing water usage particularly in the food production sector. For example, reduced stocking levels, rotational grazing and regenerative agriculture practices can help with water percolation and moisture retention in soils and water. Also, consumption by sheep is significantly less than that of cattle (see https://www.agric.wa.gov.au/small-landholders-western-australia/livestock-water-requirements-and-water-budgeting-south-west) hence there is potential for producers to re-evaluate their operations to retain farm dam supplies for longer periods.

[redacted]

- Continue to work with intensive horticultural operations to reduce their water usage. Tomato production at Guyra has incorporated water efficient design in more recent greenhouse construction. However, sufficient rainfall and/or underground water is still required in order to meet the design needs and expansion of intensive horticultural operations may need to be limited to ensure that domestic and underground water supplies are not depleted in the face of climate changes
- such as the unprecedented drought and water shortage of 2019.
- In planned joint workshops with agricultural producers

2.1.1.3 Council and State Government

- Council work with the NSW Natural Resources Access Regulator (https://www.industry.nsw.gov.au/natural-resources-access-regulator to ensure that, in the face of predicted changes to climate, cumulative extraction of underground water will not exceed the overall capacity for underground aquifers to be replenished and will not reduce inflow into domestic water storage. The potential for reduced inflow into Malpas Dam due to depletion of aquifers from irrigation by bores, hence diminished flow from springs into waterways that feed domestic water storage must be carefully assessed.
- Council lobby state government to expand options for re-use of greywater and increase flexibility of laws relating to greywater reuse.

2.1.2 Native fauna and flora / protection of threatened species and communities.

Local governments can help protect at risk flora and fauna species and communities by working with local experts and interested community groups, encouraging collaborative citizens' science projects, providing community education and through sensitive planning, policy development and project design. These help to engage the community and bring about an integrated response as well as avoiding impacts on nationally protected matters and minimising the need for Australian Government regulation of local projects.[5]
Opportunities for measures to protect two threatened fauna species are provided below as examples of steps that Council and the community can take to reduce climate change risks to fauna and flora.

2.1.2.1 Koalas

In April 2012, the Australian Government declared the Koala as ‘Vulnerable” under the Federal EPBC Act in New South Wales, the ACT and Queensland. Koalas are in serious decline suffering from the effects of habitat destruction, domestic dog attacks, bushfires and road accidents. Recent research indicates that the koala population in Armidale is relatively healthy. This is significant in the context of substantial eucalypt die off in the area of Mt Duval (an important koala habitat area) during the 2019 drought and extensive death of koalas in south eastern Australia during the 2019-2020 bushfires.
Koalas are regularly seen in the vicinity of Armidale. A Council pamphlet entitled 'The survival of the koala is in our hands' lists the locations of koala sightings in the area[6]. It states that around Armidale, fragmentation of woodland on the urban rural fringe (peri-urban area) and the wider landscape, makes it harder for young koalas to find new home ranges and adult koalas to find mating partners.
Climate change has been clearly identified as a threat to koalas. The June 2020 New South Wales parliamentary inquiry of the Legislative Council into Koala populations and habitat in New South Wales[7] states that at every hearing, the committee received evidence that climate change was having an extremely detrimental effect on koala populations and that the International Union for Conservation of Nature recognises the koala as one of ten species most likely to be adversely impacted by climate change.
The Parliamentary Inquiry made a number of recommendations for action by the NSW Government that are relevant to koalas in the Armidale area. These are listed with their recommendation numbers as follows:

- Urgently prioritise the protection of koala habitat and corridors in the planning and implementation stages of urban growth areas.

[redacted]

- Fund and support local councils to conserve koala habitat, including by identifying pockets of urban bushland to include in the State's protected area network.
- Provide additional funding and support to community groups, so that they can plant trees and regenerate bushland along koala and wildlife corridors and explore mechanisms to protect these corridors in-perpetuity.
- Ensure that in planning for future bushfires, conservation values and the protection of koala habitat is given greater priority.
- Increase funding to local councils to support the implementation of local koala conservation initiatives.
- In finalising the State Environmental Planning Policy (Koala Habitat Protection) 2019 framework, strengthen the ability of consent authorities to protect koala habitat.
- Require all councils with koala populations to develop comprehensive koala plans of management in a timely manner.
- Publish the final State Environmental Planning Policy (Koala Habitat Protection) Guideline as soon as practicable.
- Increase resources to local councils to support them in conducting mapping required for comprehensive koala plans of management.
- Work with willing landholders to identify koala habitat that is of outstanding biodiversity value under the Biodiversity Conservation Act 2016 in order to facilitate more koala habitat on private land being protected.
- Ensure that the NSW Koala Strategy: Bushfire Recovery Plan contains as its key focus, the protection of koala habitat.

Mapping, such as where koalas have been recorded and their habitat, is a critical component for local councils to develop comprehensive koala management plans.
Koala conservation must take priority over land clearing, regardless of the demand for that land. That principle might seem simple, but so far it's proved agonisingly difficult.
It is recommended that Armidale Regional Council develops a comprehensive koala plan of management and lobbies the NSW government to implement these recommendations, in particular increasing funding to local councils to support the implementation of local koala conservation initiatives and increasing resources to local councils to support them in conducting mapping.
https://www.parliament.nsw.gov.au/lcdocs/inquiries/2536/Koala%20populations%20and%20habitat%20in%20New%20South%20Wales%20-%20Report%203.pdf

2.1.2.2 Grey-headed Flying-fox Pteropus poliocephalus

Anecdotal evidence from a local orchardist stated that flying foxes were common in the region in the past and that landowners used to seek out their roosts and shoot them.
https://www.armidaleregional.nsw.gov.au/news/news-2019/black-gully-weeds-cleared-for-flying-fox-plan A colony of grey-headed and little red flying foxes started forming at Black Gully in Armidale in October 2017 and reached a peak population of between 40,000 and 50,000 in December that year. Both species are protected under biodiversity protection laws. Neighbouring residents were concerned regarding noise, smell, droppings and damage to vegetation, raising issues on how to manage the site.
The colony left the city in early 2018 and Stage 1 works that year removed selected trees to create a buffer between flying fox habitat trees and neighbouring homes. A management plan for the flying-fox camp at Black Gully was adopted by Council at the Ordinary Council Meeting held on Wednesday 25 July 2018[8], allowing Council to take action to reduce the impact on residents if flying foxes return.
The Grey-headed Flying-fox is currently listed as vulnerable under the Environment Protection and Biodiversity Conservation Act.
A 2009 Draft Recovery plan for the species[9] states that climate change in the coming decades has the potential to affect food availability and heat related mortality in Grey-headed Flying-foxes.Exposure to high temperatures results in mortality in Grey-headed Flying-foxes (Parry-Jones 2000, Eby et al. unpublished,

[redacted]

Welbergen et al. 2007). Mortality rates are low at ambient temperatures of 41 to 43.5º C but increase rapidly at temperatures > 43.5ºC, particularly affecting flightless young. Climate change is also predicted to affect nectar food supplies as many eucalypts have a narrow range of tolerance to temperature and rainfall, and the predicted levels of change are expected to impact distribution and reproduction (Hughes et al. 1996, Hughes 2003).

It is possible that the cooler Armidale climate may enable flying foxes to persist for longer in the Armidale region than in hotter regions. Retained willows and native vegetation planted alongside Dumaresq Creek in 2011 are currently (June/July 2020) providing habitat for a small population of Grey-headed Flying-foxes. Expansion and maturation of plantings in the area could provide additional habitat, particularly along riparian areas, while at the same time avoiding adverse impacts on residential areas.

Climate Change Impacts on Natural Environment for Armidale Guyra Area

Predicted and unfolding climate change outcomes	**Impacts on natural environment that are already being experienced or are predicted to occur as a result of climate change**						
	Surface water creeks and wetlands Dams	**Ground water**	**Soil**	**Native Vegetation (significant areas on rural land)**	**Fauna (Rural land important in supporting and enabling dispersal of many native fauna species)**	**Human modified natural landscape**	**Air Quality**
Increase in average maximum and minimum temperature and seasonal shift. **Changed seasonal rainfall patterns - decreased winter and increased summer rainfall** **Changing water cycles**	Threat multiplier in association with other threats listed below	Threat multiplier in association with other threats listed below	Threat multiplier in association with other threats listed below	Change in times of flowering and fruiting. Potentially out of sync with fertilising insects and breeding cycles of fauna. Disruption of connections between plants or plants and insects or plants and animals.	Cold adapted species unable to move to higher altitudes / become locally vulnerable to extinction or extinct Threat multiplier in association with other threats listed below	Autumn trees retain leaves longer Deciduous trees come into leaf / blossom earlier in season. Vulnerable to frost damage.	Minimal impact in the short term
Increased hot days, heat waves, episodes of prolonged and excessive heat **Increased hot days, heat waves, episodes of prolonged and excessive heat**	Increased evaporation. Water bodies store less oxygen. Stagnation and algal growth. Increased water usage by humans and animals. Depletion of natural and man made water storage.	Increased extraction of ground water for domestic, agricultural and commercial use. Water table depletion	Potential for soil loss increasing with extent of bare soil and wind intensity	Cold adapted species such as snow gums adversely affected if heat exceeds their tolerance levels. Local extinctions	Sensitive animals such as flying foxes heat stressed with potential for widespread mortality. Reduced health of animal species due to poor water quality / decreased availability. Change in aquatic fauna due to hotter water temperatures.	Deciduous trees lose leaves early Landscape less attractive, extensive areas of dead grass or bare ground and vegetation Increased wildfire risk with potential for catastrophic fire risk.	Increased dust levels in air from dusty roads
Prolonged drought and water shortage **Low rainfall combined with high evaporation** **Dust** **Dust storms**	Progressive reduction and drying out of water storage (waterholes and dams) that supply wildlife. Wetlands dry out. Water shortage. Decreased water quality - increased algae and bacterial contamination, potential for dead animals contaminating water. Sequential loss /adverse impact on aquatic species with repeated events. Increased competition	Decreased rainfall replenishing groundwater supplies. Increased extraction of ground water for domestic, agricultural and commercial use. Decreased water infiltration and increased groundwater extraction causing depletion of aquifers, including those that feed into springs and water storages	Progressive decrease in soil moisture. Expanding areas of bare ground / loss of ground cover. Ground hardens and cracks. Soil biota dies or moves deeper in soil. Soil less fertile and less able to store carbon. Exposure of soil to wind erosion, soil loss. Bare soil vulnerable to water erosion during storm	Prolonged drying, death and dessication of ground cover and / or of shrubs and trees. Decreased pollination. Reduced breeding success and recruitment of new plants. Adverse ecosystem impacts due to failure of parts of connected systems eg flowering of plants no longer co-inciding with breeding of associated fauna. Decreased habitat for	Insufficient water in leaves for foliage dependent animals such as koalas Competition with domestic animals for water resources Insufficient food impacting on survival and breeding success, multiplication of threat for endangered species. Disruption of ecosystem connections. Loss of habitat / refuge. Increased susceptibility to predation and disease. Longer travel distance between water sources. Biodiversity loss.	Deciduous trees lose leaves early. Die back of non-native trees Landscape and parks and gardens unattractive Increased wildfire risk with potential for catastrophic fire risk.	Dust storms, dust pollution of air

Predicted and unfolding climate change outcomes	**Impacts on natural environment that are already being experienced or are predicted to occur as a result of climate change**						
	Surface water creeks and wetlands Dams	**Ground water**	**Soil**	**Native Vegetation (significant areas on rural land)**	**Fauna (Rural land important in supporting and enabling dispersal of many native fauna species)**	**Human modified natural landscape**	**Air Quality**
	between human land use and ecosystem needs for water Changes in stream morphology		events	waterbirds. Local extinctions / biodiversity loss			
Increased incidence, intensity and severity of storm events and associated weather events such as high velocity winds, heavy rain, hail and flooding	Pollution from effluent and garbage associated with flooding, dead animals and harmful chemicals washed into waterways.	Replenishment of some aquifers where flood water is stored and is able to seep into groundwater.	Erosion, damage to creek banks and waterways	Mechanical damage to vegetation. Death of vegetation arising from prolonged immersion. Tree fall in storms, hail damage, defoliation from hail	Drowning of animals. Interruption to life cycles. Death, injury or illness of wildlife arising from hail impact, loss of shelter, flooding, subsequent exposure to cold or predators	Mature trees lost from extensive swathes of land due to windstorms. Loss of stored carbon to atmosphere	
Fire - increased duration of fire season, earlier onset, later cessation. Increased intensity, spread, extent and destruction of fires.	Less water available for fire suppression in times of drought. Pollution of natural vegetation and waterways from use of fire retardants	Unknown	Baking of soil and destruction of soil biota relative to heat penetration of soil. Erosion of exposed soil in follow up storm events.	Destruction of flora with variable potential for recovery dependent on cumulative impacts.[10] Decreased potential for population recruitment where fires are extensive. Local extinctions Damage to vegetation through use of fire retardants	Injury and substantially increased mortality where fires are severe or catastrophic and extensive.[11] Decreased potential for population recruitment where fires are extensive.	Destruction of landscape elements by fire. Landscape unattractive for visitors.	Particulate pollution of air from smoke with adverse health effects for animals and humans. Extensive loss of stored carbon to atmosphere
Potential interventions to reduce severity of risk	More frequent c						

[redacted]

Climate Change Impacts on Food production for Armidale Guyra Area

Predicted and unfolding climate change outcomes	Impacts on food production that are already being experienced or are predicted to occur as a result of climate change						
	Surface water and stored water Ground water - bores and springs	**Soil / Landscape / Land tenure**	**Rural vegetation Crops and pasture, fodder production and availability**	**Effects on livestock, rural animals**	**Energy supply Communi-cations Transport and connect-ivity**	**Technical resources Productivity and business profitability Markets Local economy**	**Human resources Livelihood**
Increase in average maximum and minimum temperature and seasonal shift. Changed seasonal rainfall patterns - decreased winter and increased summer rainfall Changing water cycles	Threat multiplier in association with other threats listed below	Threat multiplier in association with other threats listed below	Invasive species able to move to higher altitudes, extend range and populations; greater resources required for control. Crop and pasture flowering potentially asynchronous with fertilising insects. Potential for increased range and productivity of some crops and pasture species due to extended seasons but only if sufficient water available.	Potential for increased livestock productivity if sufficient water available.	Threat multiplier in association with other threats listed below	Potential for productivity increase and increase in farm income and viability due to longer growing season if occurring in the absence of other threat multiplier effects listed below and if agricultural producers change their production to reflect change in climate. Increased probablity of combined impacts listed below may negate potential increases in productivity.	Threat multiplier in association with other threats listed below
Increased hot days, heat waves, episodes of prolonged and excessive heat	Increased evaporation and drying out of water storage for stock. Increased water consumption by livestock.	Soil dry, compacted. Increased vulnerability of soil to wind and water erosion.	Decreased growth / die off of ground cover and pasture and crop species during prolonged or excessive heat. Leaf fall from trees (especially introduced trees such as willows).	Heat stress and decreased weight gain in livestock.	Increased energy demand to service water supply and cooling devices. Potential Interruption to supply due to overload.	Reduced farm income and reduced viability and profitability af agricultural enterprises. Less money available to spend locally on farm equipment, education and other services	Less energy for outside work. Challenge to maintain conditions cool enough for horticultural workers in glasshouses. Smaller and less efficient landholders forced out reducing rural population diversity,
Prolonged drought and water shortage Low rainfall combined with high evaporation Dust	Decrease in water quality due to algal and bacterial growth and potentially animals dying in water	Soil dry, compacted, progressive loss of groundcover. Decreased soil nutrients due to impoverished	Changes in fertiliser usage Increased crop and pasture disease and stress, reduced crop yield, crop	Need to purchase feed increased costs. Decreased animal health and weight loss due to reduced		Productivity substantially reduced or absent. Increased commodity prices. Loss of farm income and reduced viability. Greater workload on farms. All resources directed to survival rather than	Increased stress and anxiety Human health and wellbeing impaired / increased mortality Challenge to keep outdoor

Predicted and unfolding climate change outcomes	**Impacts on food production that are already being experienced or are predicted to occur as a result of climate change**						
	Surface water and stored water Ground water - bores and springs	**Soil / Landscape / Land tenure**	**Rural vegetation Crops and pasture, fodder production and availability**	**Effects on livestock, rural animals**	**Energy supply Communi-cations Transport and connect-ivity**	**Technical resources Productivity and business profitability Markets Local economy**	**Human resources Livelihood**
Dust storms	reserves. Progressive reduction and drying out of water storage (waterholes and dams) for stock. Need to purchase water increases costs. Reliance on ground water where available. Decreased water infiltration and increased groundwater extraction causing depletion of aquifers, including those that feed into springs.	soil biota and decreased ability of soil to store humus. Stored carbon released to atmosphere. Increased vulnerability of soil to wind and water erosion. Progressive land degradation consistent with intensity and duration of drought. Increased sell off of rural land.	failure. Previously viable agricultural production no longer possible for extended periods. Trees and shrubs die off. Decreased shelter for stock as well as wildlife.	availability and quality of feed and water. Death of or need to cull livestock due to shortage of water and or feed. Health issues arising from disposal of carcasses. Increased vulnerability of livestock to disease. Potential loss of breeding stock, increased cost of restocking following drought. Livestock carrying capacity reduced. Previously viable livestock production no longer possible for extended periods.		productivity. Productivity drops or absent. Decreased rural employment/unemployment in agricultural sector. Decreased spending in region Decreased demand for manufacturing services	workers cool. Less energy for outside work. Increased demand for medical services Adverse impacts on local community (including community cohesion and cooperation in times of emergency) Reduced volunteers available for emergency services such as firefighting. Increased vector borne disease such as Ross River fever. Increased demand for medical services
Increased incidence, intensity and severity of storm events and associated weather events such as high velocity winds, heavy rain, hail and flooding		Property damage. Temporary relocation of residents Increased demand for building and repair services Access to markets interrupted	Damaged or failed crops Food spoilage	Injury or death of livestock from exposure. Drowning of livestock Feed shortage for livestock Need to purchase fodder - increased costs	Blackouts / interruption to energy supply Communications limited or blacked out Damage to vehicles, roads, railway lines Interrupted / limited transport/ flights	Loss of farm income and reduced viability. Property and infrastructure damage and associated costs. Destruction of glasshouses. Resources directed to rebuild and recovery rather than productivity. Increased insurance claims and costs. Increased demand for building and repair services (may stimulate economy) Produce not able to be harvested or late to market. Repair and maintenance costs Council costs Interruption to service provision	Increased stress and anxiety Human injury and increased mortality. Increased demand for emergency services Emergency response times slower. Loss of life from drownings Human exposure to effluent, chemical hazard, pollution in floodwater Community disruption Stress on

Predicted and unfolding climate change outcomes	**Impacts on food production that are already being experienced or are predicted to occur as a result of climate change**						
	Surface water and stored water Ground water - bores and springs	**Soil / Landscape / Land tenure**	**Rural vegetation Crops and pasture, fodder production and availability**	**Effects on livestock, rural animals**	**Energy supply Communi-cations Transport and connect-ivity**	**Technical resources Productivity and business profitability Markets Local economy**	**Human resources Livelihood**
							vulnerable people
Fire - increased duration of fire season, earlier onset, later cessation. Increased intensity, spread, extent and destruction of fires.	Likely to coincide with times of water shortage. Redirection of water usage to fire fighting, further depletion of water storage. Damage to water storage infrastructure such as melting of plastic tanks during bushfire. Water unavailable to people in burnt out areas	Soil baked and left bare in intense fire conditions. Soil fauna destroyed to depth of heat penetration. Soil exposed to erosion from wind or rain following fire.	Damaged crops. Productivity drops or at a standstill.	Injury or death of livestock. Loss of fences to contain livestock. Destruction of pasture. Need to buy in fodder at a time when costs likely to be high. Resources directed away from productivity to repair and rebuild	Blackouts / interruption to energy supply Communications limited or blacked out. People unable to access electronic funds to purchase essentials Damage to vehicles, roads, railway lines Interrupted / limited transport/ flights	Property and infrastructure damage. Productivity reduced or at a standstill. Loss of income due to livestock losses and cost and time needed to rebuild Extensive insurance claims and increased costs. Property values drop	Human injury or death directly from fire or indirectly from smoke inhalation and associated illness. Loss of home and means of livelihood in short or long term. Increased demand for medical and volunteer services Volunteer fatigue Decreased activity levels Social isolation Crisis can bring communities together as well as challenge them
Combined / cumulative impacts overall	Progressive depletion of surface and underground water storage. Water allocation conflict. Withdrawal rather than expansion of water hungry industries such as intensive horticulture. Decreasing ability of area to sustain agricultural production and rural population.	Progressive soil erosion and land degradation Property values drop. Increased sell off of rural land. Potential for purchase by corporate or international buyers with minimal connection to local community environment or economy	Decreased crop and pasture production capability in area	Decreased livestock production capability in area	Short term failure of road maintenance - pothole developmentslowing transport. Long term disruption to transport due to road slips, washouts and damaged bridges not being repaired. Potential for connectivity and technical issues to further isolate rural communities, particularly with regard to health care and education.		
Interventions that may help to reduce severity of	Water restrictions. Changed attitudes and	Reduction of water usage by horticultural					

Predicted and unfolding climate change outcomes	**Impacts on food production that are already being experienced or are predicted to occur as a result of climate change**						
	Surface water and stored water Ground water - bores and springs	**Soil / Landscape / Land tenure**	**Rural vegetation Crops and pasture, fodder production and availability**	**Effects on livestock, rural animals**	**Energy supply Communi-cations Transport and connect-ivity**	**Technical resources Productivity and business profitability Markets Local economy**	**Human resources Livelihood**
impacts	behaviours substantially decrease water usage Policy and regulation changes	industries to a level that is able to be sustained.					

Predicted and unfolding climate change outcomes	**Climate Change Impacts on human community, built environment, health and wellbeing**						
	Food production, distribution and availability Water availability	**Built environment housing and effects on home environs**	**Business Livelihood Economy**	**Energy supply Communi-cations Transport and connectivity**	**Emergency response Governance and Service delivery**	**Community cohesion Education Childcare**	**Health and wellbeing**
Increase in average maximum and minimum temperature and seasonal shift. **Increased hot days, heat waves, episodes of prolonged and excessive heat** **Changed seasonal rainfall patterns - decreased winter and increased summer rainfall** **Changing water cycles**	Food production compromised, particularly if heat waves are associated with periods of low rainfall and high evaporation.	Potential for expanded range of garden species with extended warmer seasons. Heat waves cause leaf fall and potential loss of shade trees from gardens, parks and recreational areas especially when combined with drought and fire. People seek shade in surrounding environs during hot periods whereas previous priority has been warmth from sun during cool seasons.	Less tourism during hot periods	Increased use of air conditioners Increased energy demand Potential for interruption to energy supply due to overload. Potential impact on rail services due to warping of train lines by heat or out of area impacts Reduced use of air services due to decrease in tourism.	Flow on effects from impacts on other sectors eg increased need for shade, potential interruption to energy supply, increased need for invasive species control	School absenteeism during heat waves. Locals take holidays during hot periods hence reduced demand for goods and services. Reduced options for people to move away to cooler regions as local area is identified as a cooler region.	Heat waves cause adverse human health effects and increased mortality. Increased demand for health care services. Challenge to keep outdoor workers cool. Too hot to exercise Increased vector borne disease due to extension of warm weather seasons and decreased cold.
Prolonged drought and water shortage **Low rainfall combined with high evaporation** **Dust** **Dust storms**	Food production reduced or severely compromised along with ability to grow food locally in the context that most food for the region is distributed by and purchased from three major supermarkets (triopoly control of food). Water restrictions greatly limit capacity for locals to grow food as well as jeopardising availability of domestic water. Increased demand for food causes increased food cost depending on degree to which drought and bushfire impact on food supply from outside sources. Risk that available food will be preferentially distributed within urban areas. Risk that	Water restrictions impact on peoples' enjoyment of their environs and recreational gardening. People unable to sell houses due to perception of area as undesirable to move to. Reduction in real estate values.	Loss of income and reduced viability of local businesses that require a lot of water (eg intensive horticulture, farms, school institutions, car wash) or are reliant on scenic nature of landscape (tourism). Greater workload for domestic water supplier (council) and for some businesses in managing water usage. Productivity drops Some businesses need to buy water increasing costs. Unemployment in vulnerable sectors eg tourism. Increased commodity	Increased use of air conditioners Increased energy demand. Potential for interruption to energy supply due to overload.	Water restrictions Changed attitudes to water use Water allocation conflict Policy and regulation changes Greater infrastructure costs Increased costs passed on to users Increased maintenance requirements for sporting fields and or reduced quality and appeal.	Reduced enrolments at private schools due to flow on of economic impacts. Increased enrolments at public schools. School absenteeism Family members move away from area to seek employment. Pressure to close valuable services enhancing social cohesion such as swimming pools. Social friction due to increased constraints and competition for water resources Locals take holidays	Increased stress and anxiety Adverse impacts on mental health - sadness and grief arising from adverse impact on environs, loss of income. Increased demand for medical services Adverse health effects due to increased dust. Sporting injuries due to compacted surfaces leading to reduced participation and reduced fitness.

Predicted and unfolding climate change outcomes	Climate Change Impacts on human community, built environment, health and wellbeing						
	Food production, distribution and availability Water availability	**Built environment housing and effects on home environs**	**Business Livelihood Economy**	**Energy supply Communi-cations Transport and connectivity**	**Emergency response Governance and Service delivery**	**Community cohesion Education Childcare**	**Health and wellbeing**
	previously viable livestock or agricultural production no longer possible in the area due to increased frequency of adverse events. Extension of invasive species.		prices Decreased spending hence flow on effect to other businesses			during hot periods	
Increased incidence, intensity and severity of storm events and associated weather events such as high velocity winds, tornado, heavy rain, hail and flooding	Local food sources damaged or lost in impacted areas. crops. Injury or death of livestock from exposure. Access to markets interrupted. Water availability interrupted during power outages due to pumping stations not operational. Drinking water contaminated from contaminants in floodwater such as fuels, chemicals and sewage.	Property and infrastructure damage eg damage to buildings especially roofs and windows and vehicles from hail, wind, treefall; road damage from flooding. Destruction of glasshouses Increased demand for building and repair services Produce late to market.	Loss of farm income and reduced viability. Business interrupted Increased insurance claims and costs	Blackouts / interruption to energy supply Communications limited or blacked out Damage to vehicles, roads, railway lines Interrupted / limited transport/ flights	Increased demand for emergency services Emergency response times slower. Increased repair and maintenance costs and other council costs Access to services cut. Generation of large volumes of green waste and building waste overwhelming existing waste disposal facilities.	Interrupted School absenteeism	Increased stress and anxiety Human injury and increased mortality Human exposure to effluent, chemical hazard and pollution particularly during flood events. People displaced from their homes and communities. Decreased social cohesion and increased anti-social behaviours. Exacerbation and increased incidence of mental illness. Homelessness.
Fire - increased duration of fire season, earlier onset, later cessation. Increased intensity, spread, extent and destruction of fires.	Damaged crops. Injury or death of livestock. Feed shortage for livestock Damaged or failed crops Food spoilage Increased food costs. Potential disruption to water supply through, for example, melted water plastic water storage tanks, fittings and troughs. Available water further depleted due to use in fire fighting and property protection.	Property damage - loss of homes, businesses and other infrastructure Increased demand for building and repair services. Building materials potentially more expensive or not available following large scale events.	Productivity drops or at a standstill. Long time frame for recovery where resources and labour are directed away from productivity towards rebuilding of housing and infrastructure such as fences and business premises, sheds and water storage. Source of income may be lost and employees may be stood down for extensive periods and Extensive insurance claims and subsequent increases in	Blackouts / interruption to energy supply with potential impacts on ability of people to access electronic funds to pay for water, food and petrol plus impact on essential services such as water supply, sewerage. Communications limited or blacked out Damage to vehicles, roads, railway lines Interrupted or limited transport/ flights available	Potential short term acute shortage of water and food. Increased demand for emergency services Emergency response times slower Insufficient capacity to respond to the extent of the crisis and to meet goals of protecting life and property Volunteer fatigue.	All efforts in community directed towards safety, protection of human life and property during fire events hence not available for other activities such as generating income. Extensive short term and potentially long term displacement of people from their homes, communities and places of work. School absenteeism Cancelled events that promote	Human injury or death directly from fire or indirectly from smoke inhalation and associated illness. Human exposure to effluent, chemical hazard and pollution from damage to infrastructure causing release of pollutants Increased demand for medical services Volunteer fatigue Decreased activity levels Social isolation

Predicted and unfolding climate change outcomes	**Climate Change Impacts on human community, built environment, health and wellbeing**						
	Food production, distribution and availability Water availability	**Built environment housing and effects on home environs**	**Business Livelihood Economy**	**Energy supply Communi-cations Transport and connectivity**	**Emergency response Governance and Service delivery**	**Community cohesion Education Childcare**	**Health and wellbeing**
			insurance costs			community cohesion Social friction and seeking to attach blame	
Combined / cumulative / overall impacts	Decreased agricultural productivity Change in crop selection	Decreased resilience and capacity to recover from adverse events occurring with greater frequency, intensity and longer duration. Property values drop. Greater infrastructure costs. Increased incidence of property damage not able to be repaired due to decreased economic resilience. Temporary relocation of residents Increased demand for building and repair services	Regional economy diminished Region less attractive to visitors or people wishing to relocate. Decreased diversity and prosperity of businesses and institutions resulting in Increased regional unemployment. Increased insurance costs and increased conditions of insurance . Delayed payouts. Increased income support/ welfare claims	Interruption to energy supply / blackouts. Interruption to flights communications Damage to transport routes Interrupted / limited transport/ flights	Emergency response time slower Increased demand for volunteers Volunteer fatigue Less productive workforce Cumulative increase in cost of clean up and maintenance	Decreased community resilience and cohesion. People move away from area	Decreased overall level of health and wellbeing in community. Increased mortality. Loss of life from drownings Human exposure to effluent, chemical hazard, pollution Community disruption. Vulnerable people particularly susceptible to adverse impacts as decrease in stability of environs and community detracts from wellbeing. from impacts. Increased demand for medical services Increased stress on hospitals Hospital staff work longer hours Demographic changes Regional decline Aging population

	Food production, distribution and availability Water availability	**Built environment housing and effects on home environs**	**Business Livelihood Economy**	**Energy supply Communi-cations Transport and connectivity**	**Emergency response Governance and Service delivery**	**Community cohesion Education Childcare**	**Health and wellbeing**
Interventions that may help to reduce severity of impacts	Regenerative agriculture / increase in soil organic matter to increase soil percolation of water. Behaviour change and technical modifications to decrease water consumption and enhance efficient use of water and recycling of waste water. Measures to protect water catchments, decrease evaporation from water storage and decrease leakage from supply lines. Investigate potential for increased size of community water storage to enhance water security. Proper assessment of cumulative impact of groundwater extraction to enable well informed water allocation. Improved planning relating to water storage and improved efficiency of water use. Policy and regulation changes.	Construction of new homes in fire prone areas built to current Australian Standards in order to improve the buildings resistance to bushfire attack. Protective measures as recommended by RFS to reduce bushfire risk around homes. Planting of drought resilient shade trees in urban areas / parks / along walking or cycling tracks. Retrofit insulation and other measures to reduce heat retention in summer as well as heat loss in winter and reduce need for energy inputs. Provision of air conditioned central areas such as libraries where people can gather to shelter in times of heat waves. Construction of flood resilient buildings in flood prone areas (such as prototype built on pontoon / floatable base). Relocation of buildings outside flood zone.	Provision of spaces with internet capability and that would enable businesses to continue or to access some of their operations while awaiting repair of business centres.	Solar or petrol powered generators power People using CB radios to communicate in locations where connectivity is poor or power failure cuts internet connectivity. Satellite phones. Central locations with internet connectivity where people can charge phones during emergency situations. Alternative routes for transport connectivity identified in case of road closures. People learn how to use chainsaws and clear fallen trees from roads eg by joining SES.	Improved awareness raising and preparedness in relation to intense weather events such as cyclone and flood and bushfire events. People taking responsibility early, preparing themselves (grab and go kits, personal protective equipment, places organised for pets and domestic animals) and their homes, evacuating early if necessary (before dark and while roads are still open and not congested) to locations chosen by them (reducing need for evacuation centres), following safety instructions such as avoiding driving through floodwaters.	Early re-establishment of opportunities for education and of childcare establishments following emergencies / disruption.	Provision of temporary housing, eg caravan on existing house block while repairs are underway. Mental health support available.