CORANGAMITE CMA

# Corangamite Natural Resource Management Plan for Climate Change

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Front cover photograph: Raffs Beach, Ocean Grove. Photo: Rick Knowles. All others by Corangamite Catchment Management Authority unless indicated.

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*The Corangamite Catchment Management Authority acknowledges the traditional custodians of the land and waters where we work, and pay our respects to the Elders past and present.*

Australian Government

CORANGAMITE CMA

**This project is supported by the Corangamite Catchment Management Authority, through funding from the Australian Government**.

# Chairperson's foreword

The Corangamite NRM Plan for Climate Change aims to provide support for the region to incorporate climate change mitigation and adaptation into NRM planning. It also aims to provide a blueprint for managing the region's natural assets under a changing climate.

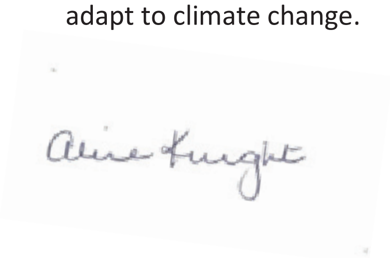
The Corangamite region's climate is changing. Projections for our region show a rise in average temperatures, with more hot days and warm spells and the region will generally have less rainfall. It is also projected that there will be an increase in the intensity of extreme rainfall events and the sea level will continue to rise. These changes may also lead to more extreme events such as more frequent and intense bushfires and floods. There is clearly a need to manage for these changes to the climate now.

This plan identifies the need to encourage the community to address climate change at the paddock, catchment and regional scale. A key to achieving success is growing and nurturing a range of partnerships. The Corangamite Catchment Management Authority recognises the role the Australian, Victorian and local governments play, along with community groups, Aboriginal people and the region's industries.

In developing this plan, we have sought feedback from our regional stakeholders.

As a result, this plan highlights the need to identify and work together in adapting our natural assets to climate change, identify carbon mitigation options and build more resilient landscapes.

We are inextricably linked to our catchment and we have a shared responsibility to act to ensure our community can adapt to climate change. It is hoped that future generations can enjoy the benefits we believe this plan can deliver and continue to help manage our region's natural assets as they adapt to climate change.



Alice Knight, OAM

Chairperson

Corangamite Catchment Management Authority

# Executive summary

The Corangamite Catchment Management Authority (Corangamite CMA) has worked in consultation with a wide range of stakeholders to develop the Corangamite Natural Resource Management (NRM) Plan for Climate Change. The plan is an enabling document with a key target audience being the region's NRM planners and those working directing with the region's NRM groups.

To achieve this, the plan:

- Provides regional information on the projected changes in climate and its likely impact on the region's natural assets
- Provides guidance to the Corangamite CMA and other regional NRM agencies in developing adaptation and mitigation actions to address the impact of climate change on our region's natural ecosystems
- Identifies priority landscapes for carbon plantings and other carbon sequestration methods, as well as strategies to build landscape integrity
- Provides guidance for regional decision-making, community engagement and research needs to improve understanding of the impact of climate change, and how we can manage those impacts.

The plan also includes a web portal that can be accessed at www.swclimatechange.com.au. The portal incorporates all relevant climate change data and information, with the ability to include new information as it becomes available. More information on the portal can be found on page 12.

The plan was developed through funding provided by the Australian Government through the Department of the Environment. This program funded similar approaches for all 53 NRM regions across Australia. In developing the plan, the Corangamite CMA was required by the Australian Government to address the following three principles:

**Principle 1 – Identify priority landscapes for carbon plantings and strategies to build landscape integrity and guide adaptation and mitigation actions to address climate change impacts on natural ecosystems.**

The plan identifies and prioritises areas for a variety of carbon sequestration types. Vulnerable areas of the region's natural assets have been identified and appropriate adaptation and mitigation actions have been developed at a regional scale. These actions set the foundation for ensuring the region's landscapes will be more resilient and adaptive to climate change into the future.

**Principle 2 – The planning process is logical, comprehensive and transparent.**

The process for developing this plan considered previous documents including the Corangamite RCS and its sub strategies, as well as relevant national and state policies, agreements and strategies. The web portal component is designed to be dynamic to enable regular information updates, ensuring the plan promotes an adaptive and agile approach to climate change.

The planning process has been comprehensive with information from international (IPCC), national (CSIRO) and state (DELWP) sources combined with regional and local information. This provides a solid basis for guiding informed decisions on the region's natural assets under a changing climate.

This plan has been developed, in cooperation with other CMAs, state and federal governments and key regional stakeholders.

**Principle 3 – Use best available information to develop actions in collaboration with government, community and other stakeholders.**

The Corangamite CMA worked collaboratively with other CMAs in developing this plan. Examples included establishing the Victorian CMA NRM Planning Forum, developing a state-wide web portal showcasing CMA climate change adaptation and mitigation projects and research partnership projects relating to climate change mitigation (i.e. blue carbon) and adaptation (i.e. spatial vulnerability assessment).

A Community and Stakeholder Engagement Plan was developed, endorsed and implemented as a key component of this project.

Engagement undertaken in developing the RCS was utilised, as was the region's community and land use profiling study. This process enabled a better understanding of community aspirations at a landscape zone, particularly around carbon sequestration and climate change. The plan's spatial vulnerability assessment component has also provided integrated and current climate change information. The assessment included overlays of socio-economic data as well as biophysical data to enable management decisions to be made at appropriate scales.

A complete list of stakeholders involved in the collaboration with the Corangamite CMA is provided in the appendices.

***Freshwater Wetland, Deans Marsh. Photo: Rick Knowles***

# Important terms and definitions

**Exposure:** Relates to the influences or stimuli that impact on a system. Exposure is a measure of the projected changes in the climate for the future scenario assessed. It includes both direct stressors, such as increased temperature, and indirect stressors or related events, such as increased frequency of wildfire.

**Sensitivity:** Reflects the responsiveness of a system to climatic stressors or influences, and the degree to which changes in climate might affect that system in its current form. Sensitive systems are highly responsive to climate and can be significantly affected by small climate changes.

**Vulnerability**: The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity. This plan is focused on the vulnerability of natural assets to climate change.

**Resilience:** The ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change (IPCC, 2012).

**Adaptation:** The IPCC refers to adaptation as 'the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects' (IPCC, 2014).

**Adaptive capacity:** Is the ability of a system to adjust to climate change, including climate variability and extremes, to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (IPCC, 2014b). The adaptive capacity of a system or society describes its ability to modify its characteristics or behaviour, to cope better with changes in external conditions. The more adaptive a system, the less vulnerable it is. For the purposes of this plan, adaptive capacity will be assigned in terms of the ability of an asset to adjust to climate stressors based on its current state, which may vary from pristine to degraded.

**Mitigation:** The term mitigation refers to making a condition or consequence less severe. By definition, mitigation is an adaptation response to climate change, aiming to reduce hazards and exposure to potential impacts. In the context of climate change and this plan, mitigation is about taking action to reduce human-induced climate change.

**Representative Concentration Pathways:** Are used to describe greenhouse gas concentration trajectories. The pathways are used for climate modelling and research. They describe four possible climate futures, all of which are considered possible depending on how much greenhouse gases are emitted in the future. According to the IPCC, the highest RCP (RCP 8.5) assumes a concentration of 1313 ppm CO2-e by 2100. Projected global mean temperatures associated with this scenario range from 2.6-4.8°C above current temperatures. A mid-range scenario assumes 538 ppm CO2-e (RCP 4.5), projected increases range from 1.0-2.6°C by 2090 (IPCC, 2013). Currently, global emissions have consistently tracked at or above the highest emissions scenario (RCP 8.5).

# How was the plan developed?

The Corangamite NRM Plan for Climate Change has been developed to complement the Corangamite Regional Catchment Strategy (RCS) 2013 – 2019. To learn more how this plan complements the region's current RCS please refer to Section 2.3.

Funding to develop the plan was provided by the Australian Government's NRM Planning for Climate Change program, delivered by the Department of the Environment (Biodiversity Conservation Division) and came in two streams.

Stream 1 came directly to the Corangamite CMA to develop the plan. Stream 2 was delivered through the Southern Slopes Climate Change Adaptation Research Partnership (SCARP), a collaborative partnership between the Department of Economic Development, Jobs, Transport and Resources (DEDJTR), RMIT University, University of Tasmania (UTS) and Monash University.

The SCARP project worked closely with Corangamite CMA, as well as other CMA/NRM regions within the Southern Slopes Cluster (SSC), to translate current climate change information from the CSIRO and other sources, into formats that could be readily applied to develop climate change adaptation plans. A map of the SSC is provided below. More information on SCARP can be found at www.climatechangeinaustralia.gov.au/en/impacts-and-adaptation/southern-slopes/

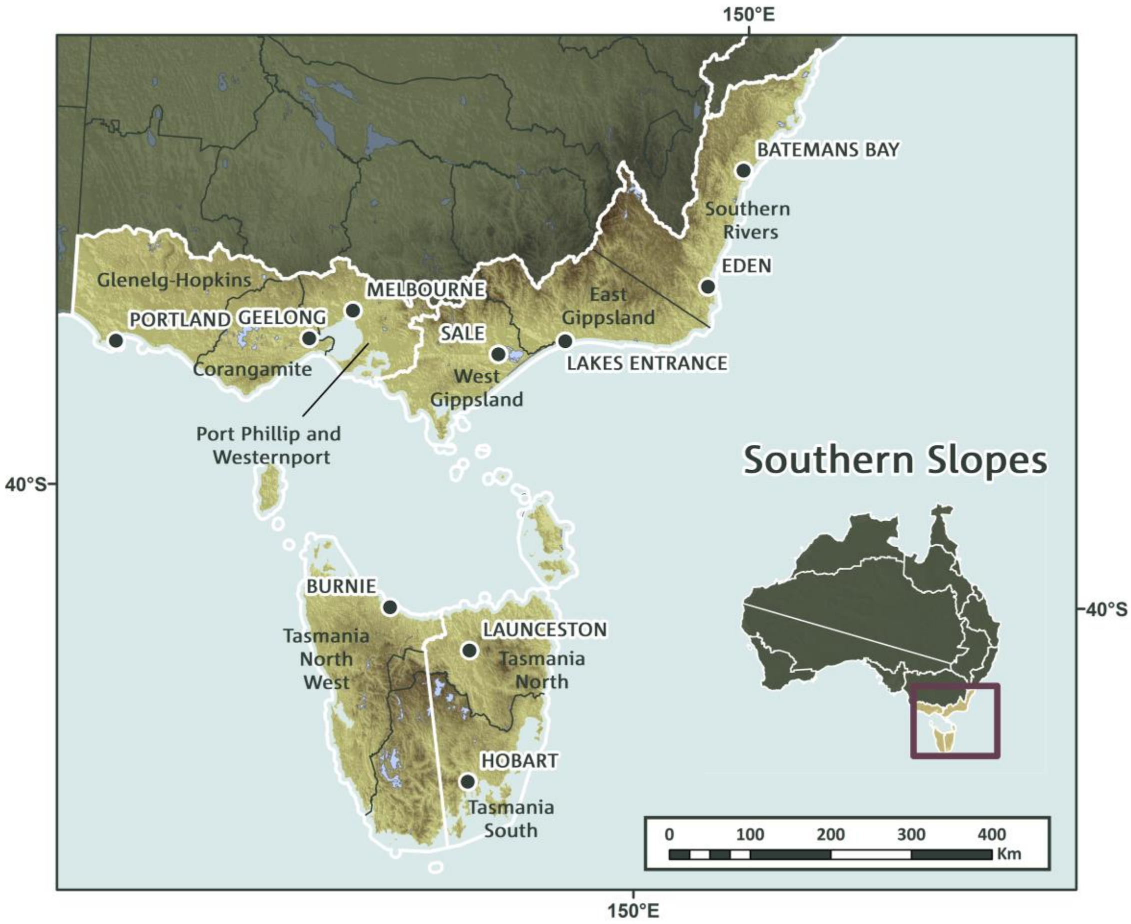
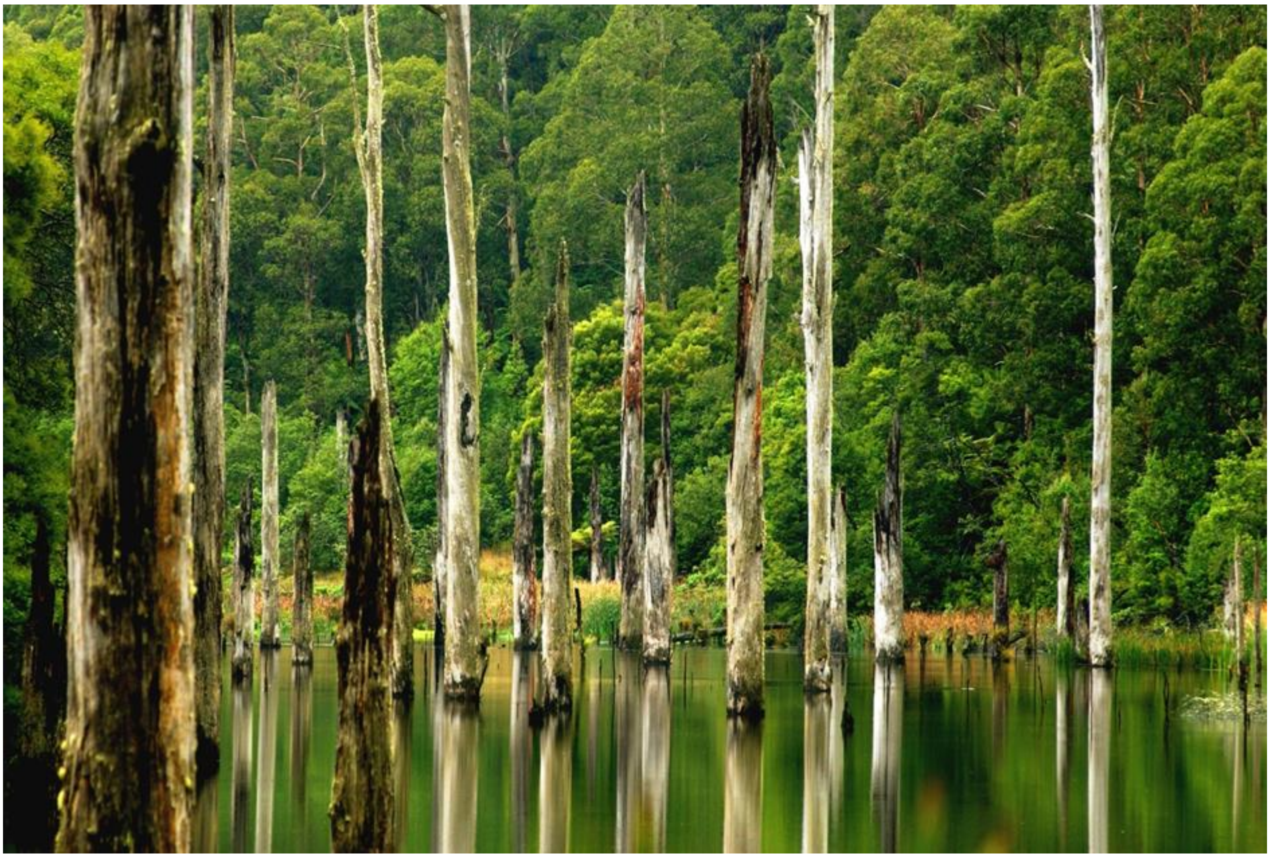



Figure 1: Southern Slopes Climate Change Adaptation Research Partnership

Stakeholder engagement was also used to inform the region's directions in NRM management under a changing climate. This engagement included a series of seven workshops with regional experts under the following natural assets themes; native vegetation, waterways, wetlands, estuaries, coasts and marine, soil, and flora and fauna species. The workshops:

- Provided feedback on the regional vulnerability modelling
- Helped develop objectives that addressed climate change, for each of the natural assets
- Assisted in developing 'adaptation pathways' case studies for each asset
- Provided recommendations on knowledge gaps and NRM decision tools for application in climate change decision making.

Broader community feedback was also sought in the latter stages of the plan's development with a four-week consultation period that included the plan being made available on the Corangamite CMA website for feedback.



***Lake Elizabeth. Photo: Alison Pouliot***

# How to use this plan

This plan will be used by a broad range of stakeholders for a wide variety of reasons. The plan provides guidance for adapting the region's natural assets to a changing climate and is based on science, current policy and the knowledge of the region's NRM stakeholders and broader community. The plan is presented in nine parts:

**Part 1: Planning for uncertainty and change** – provides an overview of the region's natural assets and the expected climate change impact. This section also looks at adapting and mitigating concepts to manage this impact.

**Part 2: Understanding the policy context** - provides a brief insight into the current climate change policies at a national and state level, as well as exploring how the plan can inform the next Regional Catchment Strategy and other future NRM plans.

**Part 3: Knowing the climate science** – presents the latest climate change trends and projections and provides explanations of the science behind climate change as well as the components of climate change.

**Part 4: Vulnerability assessment – How might our natural assets be impacted by climate change?** – looks at each of the region's seven natural assets and their expected responses to climate change. It also sets the regional strategic direction for managing weeds under climate change.

**Part 5: Determining carbon sequestration options for the Corangamite region** – explores opportunities for mitigating climate change through carbon sequestration and provides priority areas for implementing these options.

**Part 6: Regional opportunities, challenges and strategic linkages** – looks at the many projects and programs that are already contributing to improving the adaptation potential of natural assets and mitigating the impacts of climate change in the region. It also introduces the adaptation pathways process.

**Part 7: A plan for action – addressing climate change in the Corangamite region** – arguably the most important section of the plan, which lists regional and catchment scale actions that will enable future regional strategies and plans to more comprehensively consider climate change and climate change impacts.

**Part 8: Monitoring, evaluation, reporting and improvement** - sets a framework for implementing, monitoring and reviewing the plan and is based on a MERI framework.

**Part 9: Appendices** - includes the plan's glossary, list of references and other sections of supporting information of the plan.

Table 1 provides a summary guide to how to use this plan. Links to the relevant sections of the South West Climate Change Portal are also provided.

**Table 1: Summary guide to plan**

| Information | Key users | Key sections in plan |
|---|---|---|
| Impacts of climate change on the region's natural assets | NRM Planners, Land Managers, Community | Parts 1 and 4 |
| Links to current climate change policy and RCS | NRM Planners | Part 2 |
| Regional climate change projection data (trends and projections) | NRM Planners, Land Managers, Community | Part 3 |
| Background and science behind climate change | NRM Planners, Land Managers | Part 3 |
| Regional carbon sequestration priorities | NRM Planners, Land Managers | Part 5 |
| Current projects addressing climate change (adaptation and mitigation) | NRM Planners, Land Managers | Part 6 |
| Adaptation pathways – background to and regional approach | NRM Planners, Community | Part 6 |
| Priority actions – regional and catchment scale | NRM Planners, Land Managers, Community | Part 7 |
| Monitoring, evaluation, reporting and improvement | NRM Planners | Part 8 |

## South West Climate Change Portal

It is important to note that due to limitations in data and information, setting regional directions for how we, as a region, manage our natural assets under climate change, is done with a level of uncertainty.

To help address this need for updated information, the South West Climate Change Portal was developed. This project was a collaboration between the councils of the Great South Coast (under the Climate Resilient Communities of the Barwon South West project) and the Corangamite and Glenelg Hopkins CMAs, in partnership with the Centre for eResearch and Digital Innovation (CeRDI).

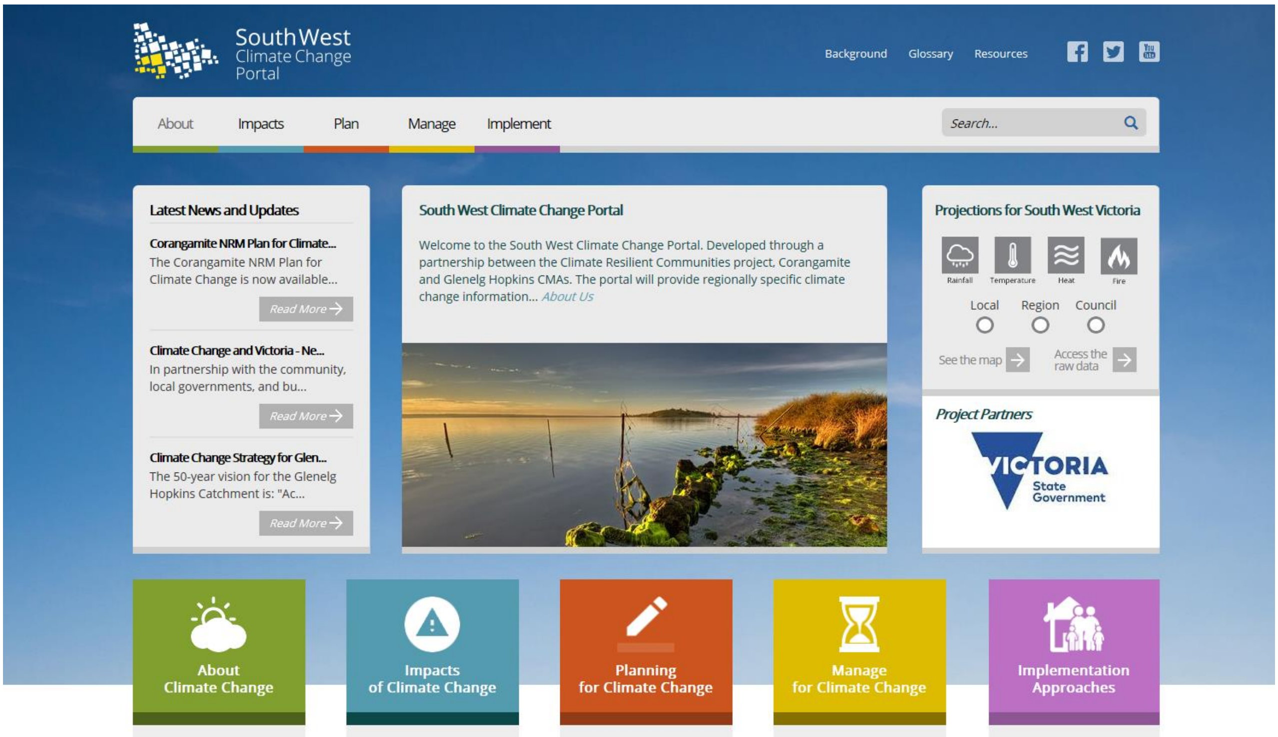
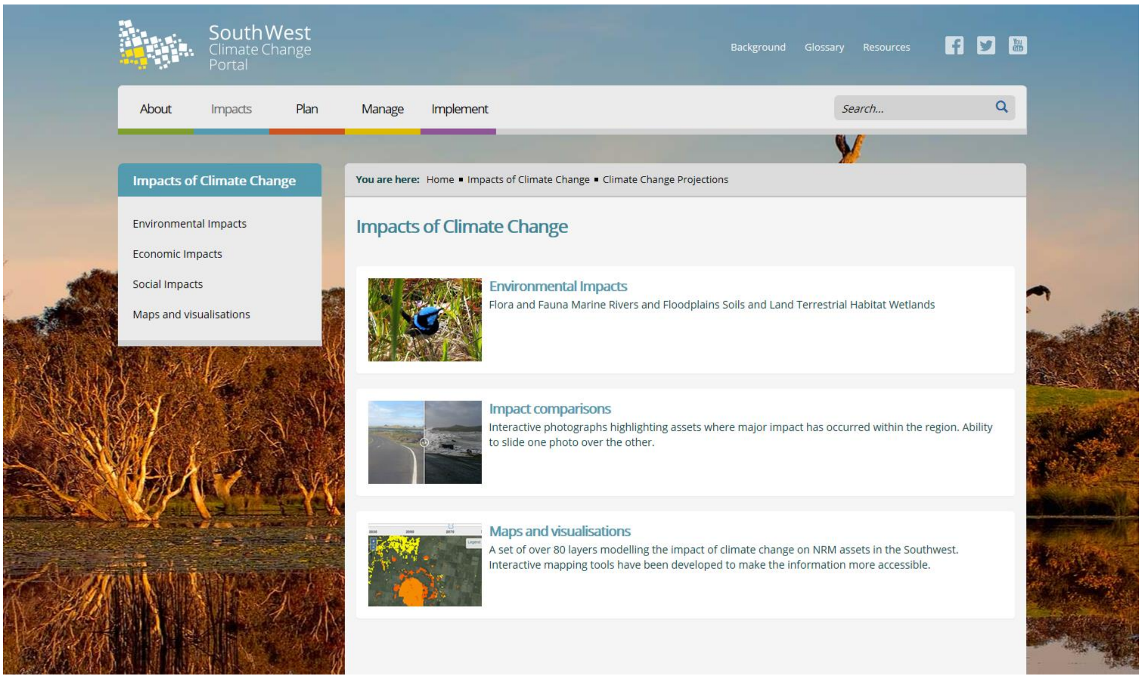



**Figure 2: South West Climate Change Portal**

The portal incorporates all relevant climate change data and information, with the ability to include new information as it becomes available. Community groups and regional stakeholders can use the portal for planning and developing on-ground projects, can build on this information through adaptive learnings and are able to search for relevant information by either location and/or topic.

The portal will promote the sharing of knowledge and information throughout the south-west in the hope that all climate change projects, data and information that relates to NRM in the south-west will be added to the portal over time.

The South West Climate Change Portal can be found at www.swclimatechange.com.au.



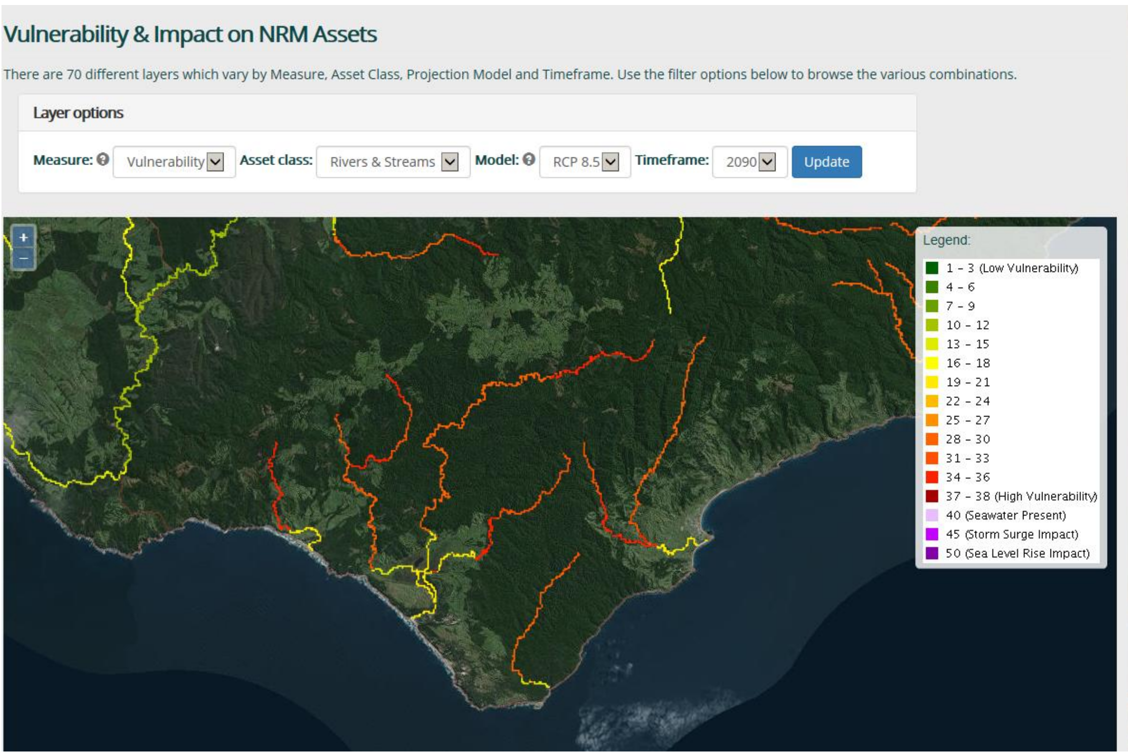




**Figure 3: South West Climate Change Portal**

# 1. Planning for uncertainty and change

***Lochard Gorge. Photo: Lachlan Manly***

Section one provides an overview of the region as well as its natural assets, namely native vegetation, rivers and streams, estuaries, wetlands, coasts, soil and flora and fauna. It also includes a brief summary of how each will be impacted by climate change.

This section also introduces the terms of adaptation and mitigation, which are key concepts in determining how to address the impacts of climate change and are key themes throughout the plan.

**Key Messages**

- The majority of natural assets within the Corangamite region will be impacted by climate change
- Adapting the region's natural assets and targeting mitigation efforts are key ways to address the impacts of climate change

## 1.1 The Corangamite region – overview of natural assets

The Corangamite region comprises 1.3 million hectares of south-western Victoria, including 175 kilometres of coastline. It includes the shires of Colac Otway, Golden Plains, Surf Coast and the Borough of Queenscliffe. Also included are most of the cities of Ballarat and Greater Geelong, and parts of the shires of Corangamite, Moorabool and Moyne (Figure 4).

The Victorian Volcanic Plain slopes west to east through the centre of the region and is flanked by the Otway Ranges to the south and the Central Highlands to the north.

The volcanic hills that emerge from the plains in the west provide a backdrop to large lakes set within an otherwise flat landscape. These Western District lakes are of international ecological significance for migratory birds and are home to iconic fauna such as the Corangamite Water Skink.

The region's climate is described as temperate Mediterranean, with rainfall dominant in winter and spring, and with hot and dry weather in summer and autumn. Rainfall is highest in the Otway Ranges (1500 – 1900 mm) and the Western Uplands in the north (1000 – 1100 mm) while the central Victorian Volcanic Plain experiences much lower rainfall (500 – 600 mm). The future climate of the region is expected to be hotter and drier than today with a higher frequency of extreme weather events such as bushfires and floods.

More than 75% of the region's land is in private ownership. Primary production is important in the region with major industries including grazing, cropping, dairy, plantation forestry and horticulture.

***Mountain Ash Forest. Photo: Corangamite CMA***

The Corangamite region consists of four drainage basins that reflect the geology and landscape evolution of the region. These basins are the Barwon River, Lake Corangamite, Moorabool River and Otway Coast. The major population centres of Ballarat and Geelong are becoming increasingly urbanised, encroaching on surrounding agricultural areas. The spatial distribution of the population is changing, with significant expansion in the coastal areas including Armstrong Creek, Torquay and the Bellarine Peninsula, as well as the Ballarat to Greater Geelong corridor centred on Bannockburn.


**Figure 4: Overview of Corangamite region**

The region has a number of natural assets, many of which are unique to the region.

**Native Vegetation –** Since European settlement, the region has lost almost 75% of its original vegetation cover. Today, losses of native vegetation may be attributed to declines in condition (80%) with 20% being removed through clearing (VEAC, 2011). From the cool temperate rainforests and lowland forests in the south, to the dry foothill forests to the north and the scattered grassy woodland and grassland communities that lie between; of the original vegetation that remains, approximately half is now restricted to areas of private land.

As well as changes to the extent of native vegetation, the quality of native vegetation has also declined, due to a history of introduced pest plants and animals, changes to flooding and fire regimes, as well as other human induced practices.

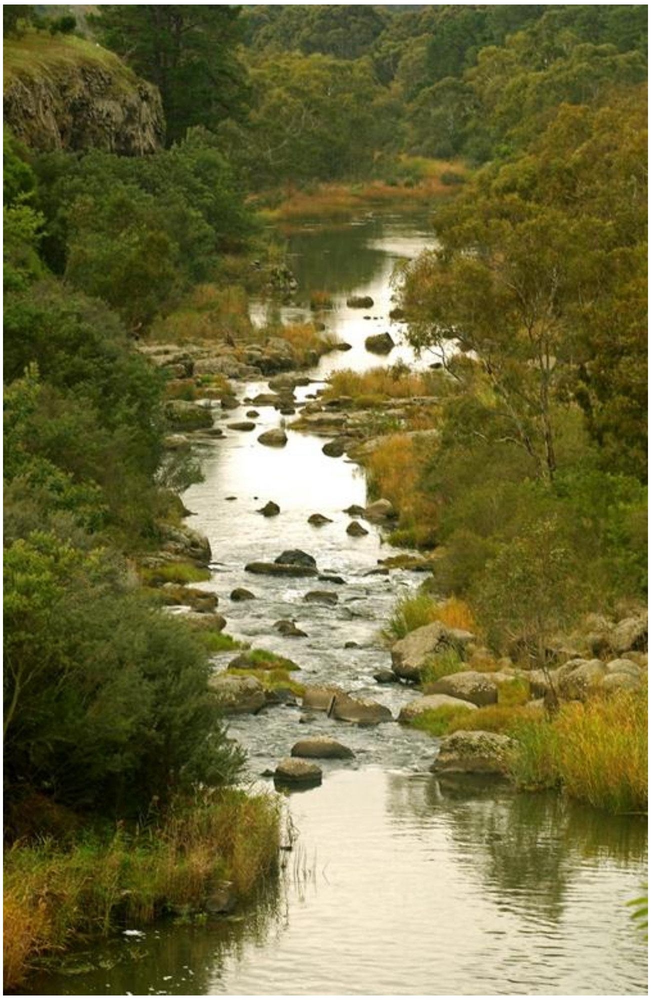
More information on the region's native vegetation can be found in VEAC's state-wide investigation into remnant native vegetation at:

www.veac.vic.gov.au/investigation/remnant-native-vegetation-investigation/reports

*It is expected that climate change will impact the region's native vegetation through modifications to vegetation communities, such as loss of particular plant species and changes to community structure, as a result of higher temperature and lower rainfall, changes to natural fire and flooding regimes and climatic conditions favouring new and established weed species.*

*Native vegetation will play an important role in climate change mitigation, mainly through its role in carbon sequestration.*

**Rivers and streams –** The region's waterways are spread across four major drainage basins.



***Barwon River. Photo: Alison Pouliot***

These basins are shown in Figure 5 and include the:

- Moorabool Basin - includes the Moorabool River which is the major river system flowing through the region's east and Hovells Creek, a small creek system rising in the southern foothills of the You Yangs and flowing into Corio Bay.
- Barwon Basin - includes the Barwon River which rises in the northern slopes of the Otway Range, and the Leigh River which begins in the central Victorian uplands around Ballarat, joining the Barwon River at Inverleigh.
- Lake Corangamite Basin - a landlocked system that includes the Woady Yaloak River and a number of small ephemeral creeks feeding Lake Corangamite as well other significant lakes and wetlands.
- Otway Coast Basin - includes the Curdies River in the west, the Gellibrand, Aire and numerous small coastal streams in the central Otways and the Erskine River, Spring and Thompson creeks which flow through the eastern section.

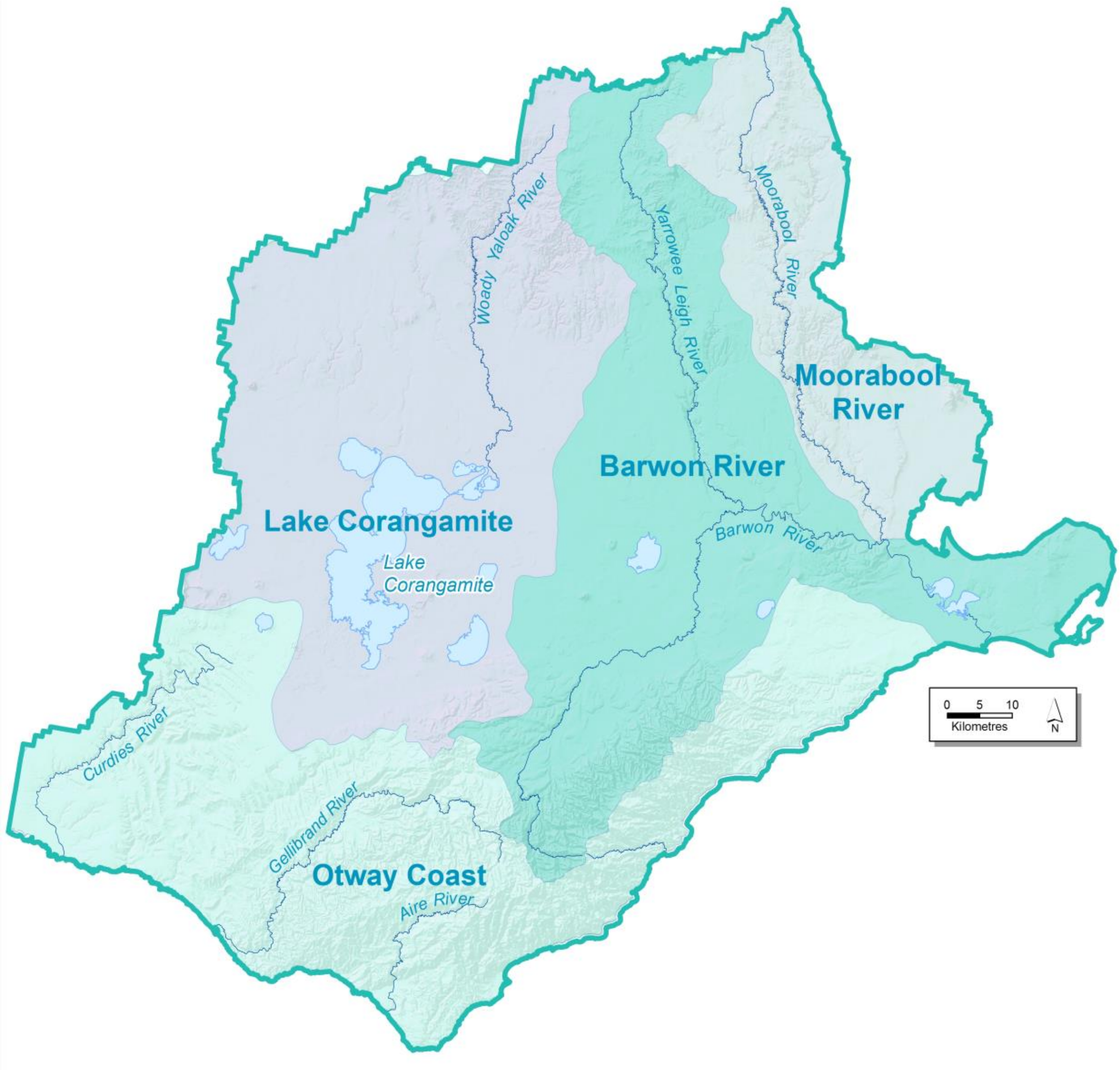



**Figure 5: Main basins and rivers of the Corangamite region**

The condition of waterways varies across the region. The majority of stream length in good and excellent condition is in heavily forested areas within the Otway Coast Basin. In contrast, there were no streams in good or excellent condition in the highly modified Moorabool basin. The majority of stream lengths in the Barwon, Moorabool, and Corangamite basins were in moderate or poor condition (Corangamite CMA, 2014).

More information on the region's waterways can be found in the Corangamite Waterway Strategy at [www.ccma.vic.gov.au](http://www.ccma.vic.gov.au)

***Lake Corangamite. Photo: Corangamite CMA***

**Wetlands –** The region contains more than 1,500 wetlands, totalling an area of 65,000 ha. The region's wetlands are dynamic in character and type and support many nationally important fauna. Coastal swamps, shallow seasonal meadows and marshes, stony-rise lowlands and large permanent saline lakes are examples of the region's diversity of wetlands.

Impacts on the region's wetlands are wide and varied; however, drainage is largely responsible for the decline. Up to 75% of the region's wetland area occurs on public land; however, this reflects just 25% of the wetland number with many of the region's smaller, more vulnerable wetlands (less than 10 ha in area) occurring on private land, including the most vulnerable and depleted wetland types.

*Climate change will impact both the region's extent and quality of wetlands through a reduction in the frequency and duration of rainfall events combined with an increase in the duration of drier periods leading to the drying of shallow wetlands, drainage of existing freshwater wetlands due to changes in land management practices (i.e. from grazing to cropping) and changes to salinity levels due to higher evaporation rates. Wetlands that are dependent on groundwater will also be largely impacted by climate change though reduced inflows.*

More information on the region's wetlands can be found in the Corangamite Waterway Strategy at www.ccma.vic.gov.au

**Estuaries** – The region also supports many important estuaries, ranging in size from those being fed by small streams along the Otway coast, through to large, wide river-ocean interfaces like the Barwon River estuary. Estuaries play an important role as a spawning nursery for many fish species and as rich food and breeding habitats for birds. They play a major role in nutrient cycling and provide an important buffer between catchments and the marine environment.

The condition of most estuaries (61%) within the region are classified as being in moderate to excellent condition (CWS, 2014). Current main threats include urbanisation, unpermitted estuary openings, acidification, changes in water regimes and high levels of sediment and/or nutrients.

*Projected sea level rise, temperature increase, reduction in rainfall and an increase in extreme natural events (i.e. flooding) are all expected to impact the ecology and dynamics of the region's estuaries. Existing threats, such as acidification, changes to natural estuary openings and nutrient levels may also be exaggerated by the indirect impacts of climate change.*

More information on the region's estuaries can be found in the Corangamite Waterway Strategy (2014) at www.ccma.vic.gov.au

***Barwon River Estuary. Photo: Corangamite CMA***

**Coasts** – The Corangamite region includes 175 kilometres of Victoria's coastal fringe and approximately 450 square kilometres of in-shore coastal waters (Corangamite CMA, 2009). The region's coastal extremities are Point Wilson on the north-west shores of Port Phillip Bay and Peterborough in the south west.

The Corangamite region has a diverse range of natural assets that are features of the area's coastline. The marine and coastal environments of the region include rocky reefs, pelagic waters, sand beaches, intertidal mudflats and coastal wetlands (with a connection to the sea). Equally diverse habitats include kelp forests on shallow rocky reefs, seagrass communities and mangroves.

The condition of the region's coastal environment is generally healthy due to low levels of nutrients, turbidity and bio-contaminants. Some larger areas of coastline within public land have been actively managed for conservation purposes over many years and are considered to be nearly intact. Threats to the region's coasts are largely attributed to activities in adjacent landscapes and catchments.

*Sea level rise will impact the region's coastline through increasing inundation and erosion as well as direct impacts on coastal habitats and biodiversity, such as higher water temperatures on specific marine species and communities. Projected increases in storm surges will also directly impact the majority of the region's coastal assets. Coastal habitats such as seagrass meadows and mangrove communities also play a major role in carbon sequestration.*

More information on the region's coastal assets can be found in the Corangamite Marine and Coastal Biodiversity Strategy (2009) at www.ccma.vic.gov.au

***12 Apostles. Photo: Lachlan Manly***

**Soil** – Soil is important to the region for its important environmental and economic roles and as a result is a fundamental base for all life. Soil acts as medium for the region's native plants and farming crops, it recycles nutrients and organic wastes, it acts as a filter to improve water quality and is habitat for many important organisms that, in turn, play important roles in both natural and farming ecosystems.

Soil types in the Corangamite region reflect the great diversity of their geological origins, landforms, climate, age and degree of weathering. Over 200 soil-landform types in the region have been identified and mapped (Clarkson, 2007).

Threats to the region's soil health, in priority order (as listed in the Corangamite Soil Health Strategy), include landslides, water erosion (including sheet/rill and gully/tunnel), acid sulphate soils, soil structure decline, waterlogging, nutrient decline, soil acidification and wind erosion.

*Higher temperatures and a drier climate will change the unique relationships that soil organisms have with plants. The loss of plants – within both natural and agricultural system, will most likely increase the impact and extent of the soil threats listed above. Indirect impacts of climate change such as bushfires and flooding will also have direct erosion impacts.*

More information on the region's coastal assets can be found in the Corangamite CMA's Soil Health Knowledgebase at www.ccma.vic.gov.au/soilhealth/

**Flora and Fauna** – The Corangamite region is home to flora and fauna species that are unique to the area, many of which are dependent on the natural assets mentioned above such as native vegetation, waterways and wetlands. Unfortunately, the region has more than 300 species classified as 'threatened' in Victoria, with 53 listed as 'threatened' at a national scale (Corangamite CMA, 2012).

The threats to the region's flora and fauna are wide and varied, with clearing and fragmenting of existing habitat (e.g. native vegetation), draining of wetlands, changes to environmental flows, environmental weeds and introduced animals, all considered to be highly threatening processes.

*Many species have evolved over thousands of years and may not have the ability to adapt to what will be a rapidly changing climate. A climate that is hotter and drier will lead to other indirect impacts such as changes to natural fire and flooding regimes. An increase in these events may have direct impacts on small, localised populations. The actions in this plan will help flora and fauna populations adapt to climate change, as well as create more resilient landscapes.*

## 1.2 Adaptation – encouraging our natural assets to adapt to climate change

'Adaptation' is not a new concept in natural systems however it is a fundamental requirement if systems are to exist under a changing climate. Adaptation in NRM is an adjustment in response to actual or expected climatic change or its effects, which minimises detrimental impacts or encourages beneficial opportunities.

Climate change is likely to have many and varied impacts on the region's natural systems. There are three main types of adaptation and these will underpin the types of adaptation methods, adopted in this plan, to ensure the region's natural assets can adapt to an environment influenced by climate change.

- **Resilience** – the magnitude of change is small and predictable. Adaptation can occur in the form of incremental changes to current management of natural assets, e.g. fencing wetlands on the Victorian Volcanic Plain to protect them from stock and to allow them to build on their own adaptive methods to climate change.

- **Transition** – the magnitude of change is larger and less predictable. Change to current management of natural assets needs increased modification and new management measures, e.g. changing the amount of environmental flows in the Moorabool River to allow vulnerable fish species to adapt to projected lower stream flows.

- **Transformation** – change is large and the level of uncertainty requires fundamental changes to the management of natural assets, e.g. relocation of fish populations in small creeks to larger permanent waterways to ensure populations are maintained.

***Lake Connewarre. Photo: Rick Knowles***

The region's natural assets, by definition, are adaptive as they have persisted through much climate change in the past. However, this adaptive capacity has now been compromised by environmental changes such as fragmentation, competition for water use and the introduction of foreign plants and animals. The best way we can help our natural assets adapt to climate change will be largely reflected in how we manage our catchments and landscapes into the future.

It is important to note that the potential scale, timing and significance of a changing climate may mean our efforts to build the resilience of natural assets may not be enough. We may have to change or transform what we do and how we manage now, because the assets themselves may need to change dramatically. Having an adaptive and agile approach to managing our natural assets is the basis of this plan.

## 1.3 Mitigation – implementing actions to minimise the impacts of climate change

By definition, 'mitigation' is an adaptation response to climate change. Mitigation aims to reduce hazards and exposure to potential impacts to climate change by making a condition or consequence less severe. The most common forms of climate change mitigation include reducing fossil fuel usage, changing human activities to reduce greenhouse gas production, and removing carbon from the atmosphere by actively increasing carbon sequestration.

Undertaking carbon sequestration activities can have varied positive NRM outcomes. Therefore, the protection, enhancement and creation of high quality, long-term carbon sequestration areas will be the main focus for addressing climate change mitigation in this plan.

Examples of positive joint carbon sequestration and NRM outcomes include implementing a strategic revegetation program that addresses carbon sequestration, habitat resilience and creating linkages for native fauna to move to more suitable habitats as existing habitats become unsuitable due to climate change.

# 2. Understanding the policy context

***Lake Victoria. Photo: Lachlan Manly***

This section explores the different policies, at both a national and state level, that are relevant to addressing climate change impacts on the region's natural assets.

Government climate legislation and programs continue to be amended as climate change policy shifts. As such, the currency of information in this section may be only short lived. Readers are encouraged to refer to the links of relevant websites that have been provided to access the most up-to-date policy information.

Information on how the plan will influence future regional NRM planning, including the next Regional Catchment Strategy, is also provided in this section.

**Key Messages**

- Australia has a commitment to reduce greenhouse gas emissions to 5 per cent below 2000 levels by 2020
- Victoria is developing a Climate Change Adaptation Plan, has reviewed the state's Climate Change Act 2010 and is developing an emission reduction target
- This plan will be incorporated into all future NRM planning, including the RCS

## 2.1 National policy context

The Australian Government has a commitment to reducing Australia's greenhouse gas emissions to five per cent below 2000 levels by 2020. The Government aims to reach its emissions reduction target through its 'Direct Action Plan' to source low cost emissions reductions and improve Australia's environment. The Australian Government commenced implementation of the Direct Action Plan on July 1, 2014 through an Emissions Reduction Fund.

The **Emissions Reduction Fund** (ERF) aims to implement a long-term framework for climate change policy. The Carbon Farming Initiative has been amended to include the ERF. The ERF builds on the Carbon Farming Initiative (CFI), expanding coverage to encourage emissions reductions across the economy. The ERF has three elements:

- Crediting emissions reductions that have been certified by the Clean Energy Regulator, based on methods approved by an independent assurance body
- Purchasing credited reductions by the regulator through auctions where the lowest bids from proponents are bought first and payment under the contract tied to delivery of reductions
- Safeguarding public money spent on reductions by setting emissions baselines for large facilities. This arrangement will be determined in close consultation with affected parties and will begin a year after the crediting and purchasing arrangements are in place.

Projects can reduce salinity and erosion, improve water quality and protect biodiversity. ERF project proponents also need to confirm their projects are consistent with 'Regional NRM Plans' such as this plan. More information, including how the Emissions Reduction Fund works, can be found at www.environment.gov.au/emissions-reduction-fund.

The government is committed to maintaining adaptation research capacity in Australia through its renewed funding of the **National Climate Change Adaptation Research Facility** (NCCARF). NCCARF has a national focus across Australia to build resilience to climate change in government, NGOs and the private sector. NCCARF works to support decision makers through synthesising the best available adaptation research and producing practical, hands-on tools and information for local decision-makers as they prepare for and manage the risks of climate change and sea-level rise. More information on NCCARF can be found at www.nccarf.edu.au

The Australian Government has a national goal to plant 20 million trees by 2020, to re-establish green corridors and urban forests. The **20 Million Trees Programme** is part of the national stream of the National Landcare Program and has four strategic objectives:

- 20 million trees – 20 million trees and associated understorey planted by 2020.
- Environmental conservation – support local environmental outcomes by improving the extent, connectivity and condition of native vegetation that supports native species
- Community engagement – work cooperatively with the community
- Carbon reduction – contribute to Australia reducing its greenhouse gas emissions.

The Australian Government has committed $50 million over four years to the 20 Million Trees Program with funding from 2014-15. The programme will involve competitive grants, delivered by individuals and organisations. More information on the 20 Million Trees Programme can be found at www.nrm.gov.au/national/20-million-trees

For more information on the Australian Government's role in other climate change programs, please refer to www.environment.gov.au/climate-change

## 2.2 State policy context

The **Victorian Government's Climate Change Act 2010** is the primary legislative framework for climate change action in Victoria. An independent review of the Act occurred in 2015 and was tabled in Parliament by the Minister in February 2016.

The Victorian Government is also developing a **whole of government climate change framework** that will be released in 2016. The Framework is being developed through community consultation and will set out the priorities of the Victorian Government in adaptation and mitigation. The Framework will include the second **Victorian Climate Change Adaptation Plan**. The development of the Adaptation Plan will involve:

- a re-assessment of climate change threats to Victoria;
- engagement across the Victorian Government and with communities, business and local government; and,
- an assessment of the strategic responses government will focus on.

The development of the Adaptation Plan will also enable cross government collaboration to work towards improving the resilience of Victorian Government assets, including natural assets, and decision making.

The Climate Change Act requires the Adaptation Plan to include a summary of observed changes and the best available climate science information for Victoria. A climate science update for Victoria was released in January 2016 to inform the development of the plan; as a tool for engagement available across the Victorian Government; and as a means to progress community understanding and conversations about climate change. Refer to http://www.climatechange.vic.gov.au/understand for further information.

The Adaptation Plan will be informed by the outcomes of the Climate Change Act review. Alignment will be sought with other climate change policy pieces and relevant work across government and will be informed by climate change partnership between state and local government. The Plan is due for completion in 2016.

The **Inter-jurisdictional Climate Change Adaptation Working Group**, chaired by Victoria, includes representatives from all Australian states and territories (except the Northern Territory). The Group fosters best practice approaches to adaptation and enables jurisdictions to collaborate and consult on priority matters of common interest.

The Victorian Government has committed to review legislation and programs to commit to an achievable **emissions reduction target**. This work is being led by the Department of Environment, Land, Water and Planning, in conjunction with other Victorian departments and agencies.

**Sustainability Victoria's** purpose is to support the use of resources more sustainably and to take practical action on climate change. This will be done by engaging the community to understand their aspirations, needs and priorities; to inspire action; to broaden community support for action; and deliver initiatives that support mitigation to climate change.

## 2.3 Linking the plan to the Corangamite Regional Catchment Strategy

The Corangamite RCS has been prepared under the provisions of the *Catchment and Land Protection Act* 1994 (Vic.) as well as in accordance with the requirements of Commonwealth and State legislation and policies relating to biodiversity, land and water resources.

The process to develop the RCS involved considerable community engagement. The RCS provides the foundation for investment decisions to achieve improved outcomes for the region's natural resources. The approach begins by determining the high value natural resources which are a priority for protection, restoration and enhancement, and identifies desired outcomes at a regional scale.

**Vision of the RCS**

A healthy Corangamite catchment valued by engaged communities.

The RCS is built on four identified foundations for change: increasing participation, increasing investment and developing joint priorities, improving integration and coordination, and increasing and sharing knowledge. Each foundation has defined objectives and a suite of actions to achieve those objectives. Ultimately, the achievement of foundation objectives and natural resource management objectives is required to achieve the vision and goal of this RCS.

Climate change was identified as both a key challenge and opportunity for the RCS. The RCS states 'As knowledge about the impacts of climate change develops, objectives and actions to protect natural resources may need to be revised'.

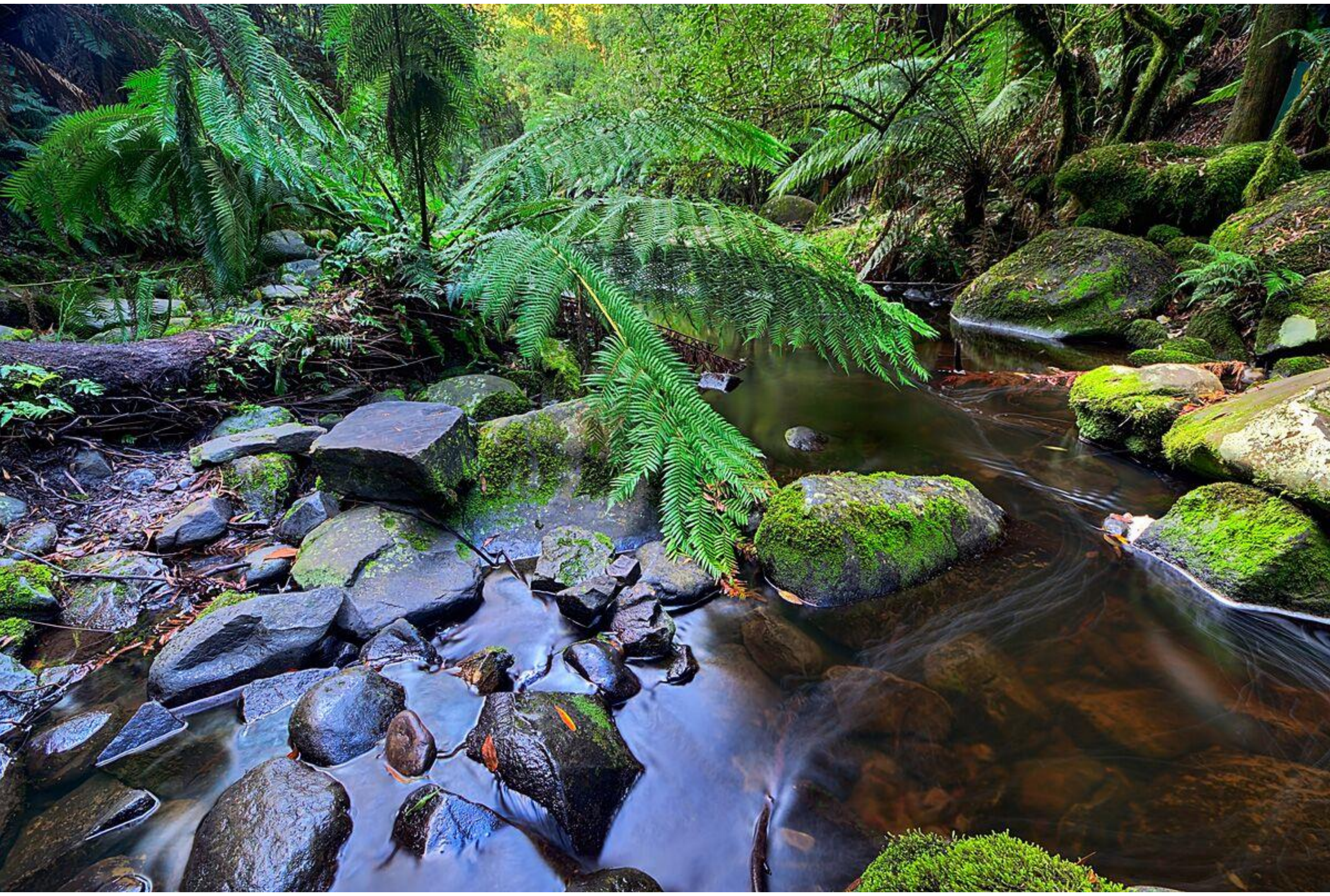
**Goal of the RCS**

Increase the protection, enhancement and restoration of valuable natural resources to improve the health and sustainable productivity of the Corangamite catchment.

The main objective of the NRM Plan for Climate Change is to provide support for the region to incorporate climate change mitigation and adaptation into the region's next RCS and other existing regional NRM plans, as well as to build on the region's already increasing knowledge on the impacts of climate change on natural assets. It is hoped that this information will be used as a reference document (the plan) and tool (the web portal) for all regional NRM planning and project development.

To ensure that this plan achieves its primary objective of incorporating climate change planning into the region's future NRM planning, appropriate monitoring, evaluation, reporting and improvement (MERI), has been developed. This is explained in more detail in Section 8.

# 3. Knowing the climate science



***Erskine River. Photo: Rick Knowles***

Knowing the climate science can improve interpretation and understanding of the role of climate change projections in NRM planning. This section explores the key definitions used in understanding climate change and describes the climate trends in Victoria as well as the climate change projections at a regional scale.

For the Southern Slopes Cluster, CSIRO and the Bureau of Meteorology produced a technical climate report (Grose et al., 2015), available at:

www.climatechangeinaustralia.gov.au/en/publications-library/cluster-reports

Information for this section has also been sourced from *Southern Slopes Information Portal Report: Climate change adaptation information for natural resource planning and implementation* developed by SCARP. The full report can be found at: www.climatechangeinaustralia.gov.au/en/impacts-and-adaptation/southern-slopes

**Key Messages**

- Climate change is largely attributed to human activity altering the earth's atmosphere
- Climate change projections are scientific statements, based on climate models, about future changes in climate
- Victoria's climate projections are for a hotter, drier climate

## 3.1 Global climate system

In order to understand how climate change affects us at local, catchment and/or regional scale, we need to first understand what climate change is and how it is affecting NRM at a global scale.

### What is Climate Change?

Climate change is often described as the change in the average weather over a long period of time, usually over a period of 30 years. Climate change can occur due to a combination of natural and human causes. The United Nations Framework Convention on Climate Change (UNFCCC, 1992) describes climate change as:

> *...a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.*

Over geological timescales, even rapid climatic change occurred much slower than the current rate of change. For example, it took centuries for the ice from the last glaciation to decline (about 10,000 years ago). By comparison, in the last century the global climate has changed rapidly, with an increase of around 0.74 °C (1906-2005). Most of this change occurred during the second half of the last century. In Australia, there has been a warming of 0.9 °C each year since 1910 (CSIRO and Australian Bureau of Meteorology, 2014).

Atmospheric concentrations of greenhouse gases (carbon dioxide, methane and nitrous oxide) are now at the highest level they have been for at least the last 800,000 years (CSIRO and Australian Bureau of Meteorology, 2014). Concentrations of carbon dioxide have increased by 40% since pre-industrial times, due mainly to emissions from fossil fuels and changes to land use. In its latest report, the IPCC states:

> *It is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century.*

#### What is climate variability?

Climate variability is defined as,

> *Variations in the mean state of the climate and other statistics (such as standard deviations and the occurrence of extremes) across temporal and spatial scales beyond that of individual weather events* (IPCC, 200b).

It is important for climate 'variability' not to be confused with climate 'change'. Typically, climate variability relates to shorter periods of time than climate change.

Weather is usually associated with day-by-day atmospheric change, whereas climate refers to changes occurring over decades or centuries. For example, intense and heavy rainfall causing consecutive years of flood events can be described as climate variability, whereas an increase in rainfall over several decades is referred to as climate change. A single heavy rainfall event is part of daily weather.

**Why is climate variability important for adaptation?**

Climate variability can result in extreme weather events, such as droughts, heavy rainfall, fire weather, heat waves, hail storms and flooding. These extreme weather events can occur in increased frequency and intensity over a period of several weeks, months or years. They have strong and immediate impact on human lives, assets and natural resources.

***12 Apostles. Photo: Lachlan Manly***

Climate variability, especially extremes, is a key short to medium term consideration for climate change adaptation. For example, the region's farmers may consider climate variability in their planning to manage seasonal climate differences – maximising profit in good seasons and managing through poor seasons. However, climate change adaptation can be more strategic and encourages a long-term approach. Long-term change such as decreasing average rainfall or increased summer temperatures are taken into account. Farmers may think strategically about shifting some of their practices and sources of revenue to accommodate any medium and long term changes to the climate, or diversify their livelihoods to be less reliant on rainfall that experience and projections might indicate is becoming less reliable.

**What are climate change projections?**

Climate change projections are scientific statements, based on the output of global or regional climate models, about changes in aspects of the future climate. At a global scale, there are substantial uncertainties regarding what the actual climate change projections will be. These uncertainties are represented in climate models as emissions scenarios. These essentially simplify assumptions about climate diplomacy, technological change and development trajectories into scenarios of atmospheric models associated with greenhouse gas concentrations (measure in parts per million [ppm] of carbon dioxide equivalents).

Scenarios are referred to by the IPCC (2013) as Representative Concentration Pathways (RCPs). The highest RCP (RCP 8.5) assumes a concentration of 1313 ppm $CO_2$-e by 2100. Projected increases in global mean surface temperatures for 2081 – 2100 relative to 1986 - 2005 associated with this scenario range from 2.6 °C - 4.8 °C. A mid-range scenario assumes 538 ppm $CO_2$-e (RCP 4.5), and projected increases in global mean surface temperature from 1.1 °C - 2.6 °C by 2100. Currently, global emissions have consistently tracked at or above the highest emissions scenario (RCP 8.5). The projections for the Southern Slopes Region state:

> *For the near future (2030), the projected increase of mean annual temperature is around 0.4 to 1.1 °C above the climate of 1986–2005, with only minor differences between RCPs. For late in the century (2090), there is a large difference between scenarios, with projected warming of 1.1 to 2.0 °C for RCP4.5 and 2.5 to 4.0 °C for RCP8.5. (Grose et al., 2015)*

Climate projections are dependent on a set of influential conditions; such as changes in atmospheric greenhouse gases. Because of these dependencies on external conditions, projections are not predictions of the future, but are an expression of a conditional expectation. That is, they model the changes in atmospheric and oceanic circulation and conditions given differing fundamental conditions such as greenhouse gas concentrations, particles (aerosols) in the atmosphere, or changes in solar activity.

It is not possible to project the future climate, because of the uncertainty around future emissions, the uncertainty represented by the range in climate models and the natural variability of the climate system. The intention of simulating future climate is therefore not to make accurate projections regarding the future state of the climate system at any given point in time. Rather it is to provide model-derived descriptions of possible future climates under a given set of scenarios of climate models (IPCC, 2007a).

The effect of climate change on key climate variables across south-eastern Australia is relatively well understood in general terms. Differences in the direction and magnitude of change are increasingly being resolved at the regional level. In contrast, the regional impacts associated with these changes are less well known. Table 2 provides an overview of potential impacts of changes to the region's natural assets based on the key climate variables.

**Table 2: Climatic variables and their impact across the region's natural asset types**

| Key Climate Variable | Associated Indices | Native Vegetation | Waterways | Estuaries | Wetlands | Coastal Wetlands | Flora & Fauna | Soil |
|---|---|---|---|---|---|---|---|---|
| Air Temperature | Average Annual Temperature | | | | | | | |
| | Minimum Daily Air Temperature | | | | | | | |
| | Maximum Daily Air Temperature | | | | | | | |
| | Heatwave | | | | | | | |
| | Seasonal Temperature Regimes | | | | | | | |
| | Frost | | | | | | | |
| | Snow Cover | | | | | | | |
| | Sea Surface Temperature | | | | | | | |
| | Marine Heat Waves | | | | | | | |
| | Drought/Extended Dry Spells | | | | | | | |
| Rainfall | Seasonal Rainfall (decrease) | | | | | | | |
| | Regional Runoff (decrease) | | | | | | | |
| | Seasonal Runoff (decrease) | | | | | | | |
| | Riverflow (decrease) | | | | | | | |
| | Intense Rainfall (increase) | | | | | | | |
| | Bushfire Intensity (increase) | | | | | | | |
| | Bushfire Frequency (increase) | | | | | | | |

| Key Climate Variable | Associated Indices | Native Vegetation | Waterways | Estuaries | Wetlands | Coastal Wetlands | Flora & Fauna | Soil |
|---|---|---|---|---|---|---|---|---|
| Sea Level | Incremental SLR | yellow | yellow | red | yellow | red | orange | yellow |
| | Extreme sea-level/ storm surges/tide | yellow | yellow | red | yellow | red | orange | yellow |
| Atmospheric CO2 Concentrations | Atmospheric CO2 | yellow | yellow | yellow | yellow | yellow | yellow | yellow |
| | Ocean acidification | yellow | yellow | orange | yellow | red | yellow | yellow |
| Wind & Extreme Wind Events | Annual Average Wind Speed & Direction | yellow | yellow | yellow | yellow | yellow | yellow | orange |
| | Extreme Wind | yellow | yellow | yellow | yellow | yellow | yellow | orange |
| | Total Cloud Cover | orange | yellow | yellow | yellow | yellow | yellow | yellow |
| Radiation & Evaporation | Average Annual Radiation | orange | orange | yellow | orange | yellow | orange | orange |
| | Evaporation | orange | orange | yellow | red | yellow | orange | orange |
| Humidity | Annual Average Relative Humidity | orange | yellow | yellow | orange | yellow | orange | orange |

***Key: (red = high impact; orange = medium impact; yellow = low impact)***

## 3.2 Climate trends in Victoria

The Victorian Government's 'State of the Environment' Report, released in 2013, provides an overview of both the current condition of Victoria's climate and trends based on past climatic data. It is important in planning for the future that we learn from the past and the report provides an excellent basis for this. The report states that:

- Average temperatures in Victoria have risen by approximately 0.8°C since the 1950s
- The severity, duration and frequency of heatwaves have increased
- Between 1997 and 2009, Victoria experienced a record-breaking 13-year drought, the longest recorded period of rainfall deficits on record
- Over the past two decades, there has been a large decline in autumn rainfall, a small decline in winter and spring rainfall, a small increase in summer rainfall, and reduced frequency of very wet years
- Victoria experienced its highest summer rainfall on record in 2010–11. The record rainfall led to major flooding that affected a third of Victoria
- Since 1993, Victoria's sea level rise has been similar to global averages of 3 mm per year
- Annual sea-surface temperatures in south-eastern Australia increased at approximately four times the global average.

Figure 6 illustrates that Victoria's climate is steadily getting warmer with the state's mean temperature anomaly increasing since the 1950's.

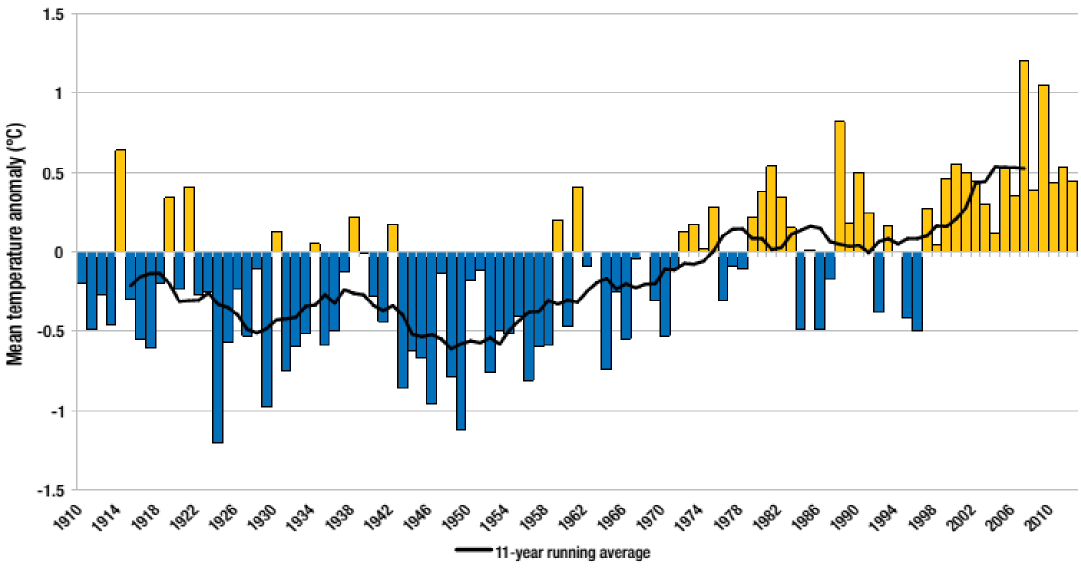



**Figure 6: Victorian Mean Temperature Anomaly 1910 – 2012 (Source: BoM)**

Over the past two decades the average autumn rainfall has dropped significantly and when combined with declines in both winter and spring rainfalls, as well as reduced frequency of very wet years, it points towards a definite need to change how water is managed, especially when combined with projected further declines in annual rainfall and increasing temperatures (Section 3.4).

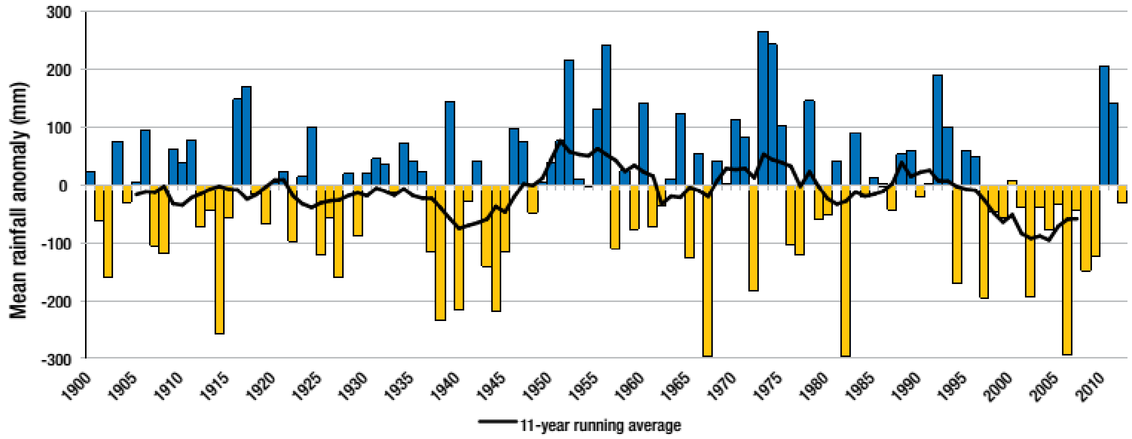



**Figure 7: Victorian Annual Rainfall Anomaly 1910 – 2012 (Source: BoM)**

Monitoring of sea levels at a global scale has been conducted since 1870. Since the 1900s the sea had been rising at around 1.7 millimetres annually. However, since 1993, records are showing that this annual rise has climbed to 3.1 millimetres a year and is largely attributable to recent increases in ocean warming, expansion and the melting of land-based ice (CES, 2013).

Sea levels around Australia, and indeed Victoria, are not rising equally due to factors such as prevailing winds and changes to ocean currents. For example, monitoring stations at Lorne and Stony Point in Victoria have recorded rises of 2.8 millimetres per year and 2.4 millimetres per year respectively since 1991 (CES, 2013).

## 3.3 Regional projections for the Corangamite Region

The Corangamite region's natural assets are unique – but what will they look like in the future under a changing climate? It is projected that temperatures will continue to increase in all seasons, including more hot days. There is also likely to be less rainfall, but with more intense rainfall events. Sea levels are expected to rise and there is expected to be an increase in extreme natural events such as bush fires and floods.

This section details the changes in climate that are projected by CSIRO, for the Corangamite region, over the next 75 years.

The level of confidence by CSIRO in this information is also summarised in Table 3.

For further and update projected information on climate change projections for our region, visit www.climatechangeinaustralia.gov.au/en/impacts-and-adaptation/southern-slopes

**Table 3: Summary of Climatic Projections for the Corangamite Region**

| Climatic projections for the Corangamite region | Level of confidence (CSIRO) |
|---|---|
| Less rainfall in winter and spring | High confidence |
| Average temperatures to continue to increase in all seasons | Very high confidence |
| More hot days and warm spells | Very high confidence |
| Fewer frost days | High confidence |
| Increased intensity of extreme rainfall events | High confidence |
| Time spent in drought to increase | Medium confidence |
| Sea level to continue to increase | Very high confidence |
| Harsher fire-weather climate | High confidence |
| Evapotranspiration is projected to increase | High confidence |
| Increase in solar radiation and decrease in relative humidity | High confidence |

**Rainfall**

Generally, for the Corangamite region, less rainfall in the cool season is projected. Changes to summer and autumn rainfall are possible but less clear. For the near future, natural variability is projected to dominate any projected changes.

The region experienced wet and dry decades through the 20th century, and has shown a drying trend in rainfall since 1960, especially in autumn. The wet decades of the 1950s and 1970s were followed by a very significant period of drought, known as the Millennium Drought (1996 to 2009).

In the near future (2030) natural variability is projected to dominate trends due to greenhouse gas emissions. Understanding of climate drivers and associated rainfall processes (e.g. southward shift of winter storm systems), supported by climate model results, indicate rainfall decreases for winter and spring.

The projected decreases in rainfall are up to 25 per cent in winter, and up to 45 per cent in spring by 2090 under high emissions. By the middle of the century, under high emissions, winter and spring changes are projected to be evident against natural variability. Changes to summer and autumn rainfall are possible but not clear, although there is a tendency for a decrease in western Victoria in autumn.

It is important to note that in Victoria, current models used to project future rainfall are considerably underestimating the actual rainfall decline trends.

**Temperature**

Average temperatures will continue to increase in all seasons. Temperatures have increased over the past century, with the rate of warming higher since 1960. There are projections of continued substantial increases in mean, maximum and minimum temperatures in line with the understanding of the effect of further increases in greenhouse gas concentrations.

For the near future (2030), the annually averaged warming across all emission scenarios is projected to be around 0.4 to 1.1 °C above the climate of 1986–2005. By late in the century (2090), for a high emission scenario (RCP8.5), the projected range of warming is 2.4 to 3.8 °C. Under an intermediate scenario (RCP4.5) the projected warming is 1.1 to 1.9 °C.

**Extreme temperature**

More hot days and warm spells are projected with very high confidence. Fewer frosts are projected. Extreme temperatures are projected to increase at a similar rate to mean temperature, with a substantial increase in the temperature reached on hot days, the frequency of hot days and the duration of warm spells.

Frost-risk days (minimum temperatures under 2 °C) are expected to decrease across the south-west of Victoria.

**Extreme rainfall and drought**

Increased intensity of extreme rainfall events is projected. Even though annual mean rainfall is projected to decrease, understanding of the physical processes that cause extreme rainfall, coupled with modelled projections indicate a future increase in the intensity of extreme rainfall events. However, the magnitude of the increases cannot be confidently projected.

Time spent in drought is projected to increase over the course of the century.

**Marine and coast**

Mean sea level will continue to rise and height of extreme sea-level events will also increase.

For 1966 to 2009, the average rate of relative sea-level rise for Australia, from observations along the coast, was 1.4 mm/year.  By 2030 the projected range of sea-level rise for the region’s coastline is 0.08 to 0.18 m above the 1986 – 2005 level, with only minor differences between emission scenarios.

As the century progresses, projections are sensitive to concentration pathways. At Portland (141.613E, 38.343S) by 2090, the intermediate emissions case (RCP4.5) is associated with a rise of 0.29 to 0.64 m and the high case (RCP8.5) a rise of 0.39 to 0.84 m. Under certain circumstances, sea-level rises higher than these may occur.

Late in the century warming of the Southern Slopes coastal waters poses a significant threat to the marine environment through biological changes in marine species, including local abundance, community structure and enhanced coral bleaching risk.

Sea surface temperature is projected to increase in the range of 1.6 to 3.4 °C by 2090 under high emissions (RCP8.5). The sea will also become more acidic with acidification proportional to emissions growth.

### Other

There is high confidence that climate change will result in a harsher fire-weather climate in the future. However, there is low confidence in the magnitude of the change to fire weather. This depends on the rainfall projection and its seasonal variation.

Potential evapotranspiration is projected to increase in all seasons as warming progresses.

An increase in solar radiation and a decrease in relative humidity are projected in the cool season through the century. This will be influenced by changes in rainfall (and associated changes to cloudiness) and temperature. Changes in summer and autumn are less clear.

DELWP have developed the Barwon South West Fact Sheet that looks at climate change projections for the region. It also provides a snapshot to how climate change will have an impact on agriculture, infrastructure, tourism, health and the environment.

The fact sheet can be downloaded at http://www.climatechange.vic.gov.au/__data/assets/pdf_file/0005/323456/Barwon-South-West.pdf

# 4. Vulnerability assessment – How might our natural assets be impacted by climate change?

***Gateway Sanctuary. Photo: Lachlan Manly***

In 2014, seven CMAs collaborated to develop a comprehensive spatial climate change impact assessment across most of Victoria.

The aim was to help determine how vulnerable natural assets were to projected changes to the climate, as well as help identify priority locations within the landscape for adaptation and mitigation activities. Spatial Vision and Natural Decisions were engaged to undertake the assessment.

The following section provides an overview of the vulnerability assessment, as well as a brief summary of results for each of the six natural assets – native vegetation, waterways, estuaries, wetlands, soil and coastal wetlands.

For a more detailed background of the assessment, including how the assessment was undertaken, the datasets that were used and for additional mapping, please refer to the South West Climate Change Portal (www.swclimatechange.com.au).

**Key Messages**

- The region's native vegetation, waterways, wetlands and soil are vulnerable to a hotter, drier climate
- The region's estuaries and coastal wetlands are vulnerable to sea level rise
- The vulnerability assessment will be used to improve the region's knowledge in climate change adaptation

## 4.1 Spatial vulnerability assessment project

The aim of this project was to spatially depict the potential impacts of climate change for natural assets within the Corangamite region to assist in NRM planning.

The project reviewed existing knowledge regarding the potential impact and vulnerabilities of the region's natural assets to anticipated climate change. It then collated the best available data to assess and identify which natural assets were most likely to be impacted by climate change.

Information and data for climate change planning is constantly being updated and refined. The framework of the assessment can be readily added to as new information becomes available.

The work was delivered by a project team consisting of consultants and a representative from the Corangamite CMA on behalf of all participating CMAs. In addition, an 'expert panel' was formed to review the draft project outputs from a conceptual and methodological viewpoint. The expert panel included Victoria University, University of Tasmania, Charles Sturt University representatives and other experts.

The climate change impact assessment incorporated two climate change projection scenarios (RCP 4.5 and RCP 8.5) and up to two different 'end points' (2030 – 2090). The assessment framework used to assess the potential climate change impact and vulnerability is presented in Figure 8.

A natural asset vulnerability assessment based on an **impact** and **adaptive capacity** assessment process was undertaken for each of the natural asset types described in this plan. The process involved identifying the **sensitivity** of an asset to two different climatic factors (temperature, rainfall, sea level rise, etc.). This information was then used to determine **potential impacts**. When combined with the natural asset's adaptive capacity, this process provided a **vulnerability** rating.

The vulnerability assessment describes how impact can be modified based on an asset's intrinsic ability to cope with the adverse effects of climate change or in other words - its adaptive capacity. Only state-wide data was used in the process. This method allows regional refinement of a vulnerability rating as local information and knowledge concerning the adaptive capacity of an asset can be incorporated into the method to recalculate the assigned vulnerability ratings.

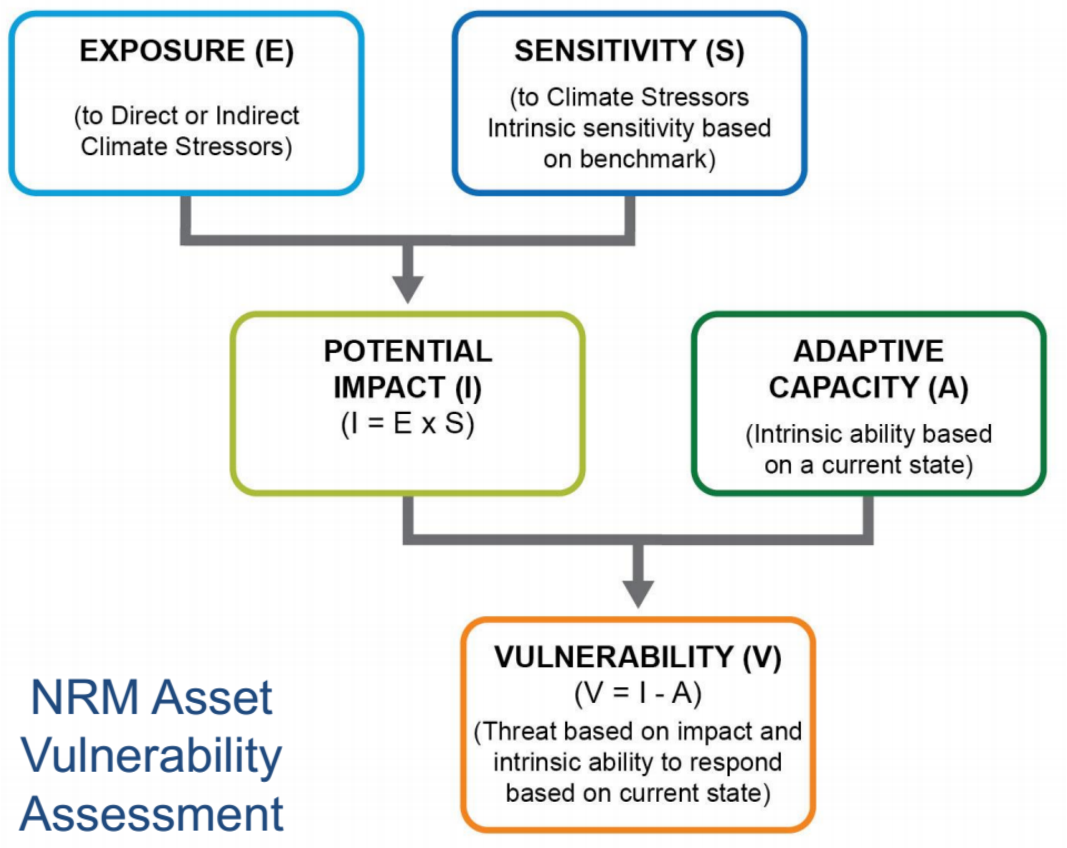



**Figure 8. Climate change impact and vulnerability assessment framework (Spatial Vision and Natural Decisions, 2014)**

Indicators and trends that are associated with socio-economic data have also been developed to complement the spatial vulnerability assessment. These datasets will be used to assist in determining the vulnerability and adaptive capacity of social and economic systems in relation to addressing climate change in different areas of the region. For many of the region's more vulnerable natural assets, the impacts of climate change may be strongly moderated by future socio-economic and technological developments. Socio-economic needs will be used to complement future assessment to assist in the decision-making for planning works, as well as for developing appropriate community engagement strategies.

The key socio-economic parameters for the region that are likely to be relevant for NRM planning and decision making include:

- Population trends,
- Changes in ownership of rural land,
- Trends in reasons for people owning rural land,
- Relative importance of agriculture as a source of employment and wealth,
- Price of rural land in $ per hectare,
- Profitability of major agricultural enterprises.

The following modelled vulnerability maps are a general assessment of the vulnerability of the region's natural assets under a RCP of 8.5 and a timeframe of 75 years. They cannot be seen as definitive predictions of what may happen to each of our natural assets under a changing climate. However, they give us a very reasonable sense of what is 'likely' to happen under the depicted scenarios and can therefore be used both as a tool for exploring better adaptation options for our natural assets and as a medium for engaging with land managers on climate change. For different timeframes and/or a more moderate scenario (RCP 4.5), please view additional maps that are provided at www.swclimatechange.com.au.

Recommendations for improving the vulnerability assessment are also provided. These were derived from each REP Workshop where regional experts provided the Corangamite CMA with constructive feedback on each of the vulnerability assessments. Detail regarding this feedback is provided in Tables 4 – 10.

Additional information on how the spatial vulnerability assessment was developed and implemented can be found in the appendices, (pages 155 – 167).

***Hopetoun Falls. Photo: Lachlan Manly***

### The following should be noted regarding the mapping

- The resulting maps depict asset impact and vulnerability based on 100 meter grid cells across the landscape. The corresponding scale of these maps should be around 1:100,000 resulting in data that should be viewed as state wide to regional in nature. This means that the mapping should be used for overall context of impact and vulnerability or in preliminary assessments for natural resource planning.
- Sensitivity and adaptive capacity is subjectively applied by expert opinion
- Other secondary exposures that were not included such as fire and wind may play a significant role in overall impacts
- Coastal marine assets were not fully assessed because the sensitivities and adaptive capacities were not well understood
- The vulnerability modelling approach is based on the use of data representing assets where there is:
  - A great range in the scale of assets with a particular asset type
  - Often ambiguity in the way that assets are categorized
  - Aggregation of assets at different levels
  - Newer data available since the modelling was undertaken, e.g. Index of Estuary Condition

For more specific information at a landscape scale, such as displayed in Figure 9 below, please refer to the modelling provided on the South West Climate Change Portal at www.swclimatechange.com.au

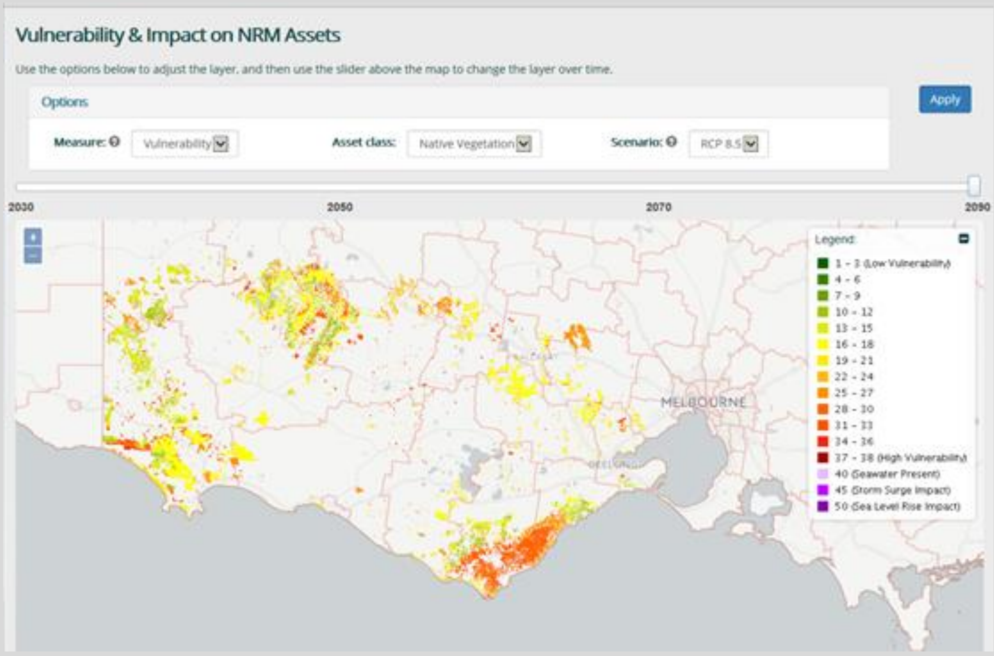



**Figure 9: Vulnerability assessment modelling on South West Climate Change Portal**

### Important Disclaimer

*This mapping been prepared for use by the Corangamite CMA by A.S.Miner Geotechnical and has been compiled by using the consultant's expert knowledge, due care and professional expertise. A.S.Miner Geotechnical does not guarantee that the publication is without flaw of any kind or is wholly appropriate for every purpose for which it may be used. No reliance or actions must therefore be made on the information contained within this report without seeking prior expert professional, scientific and technical advice. To the extent permitted by law, A.S.Miner Geotechnical (including its employees and consultants) excludes all liability to any person for any consequences, including but not limited to all losses, damages, costs, expenses and any other compensation, arising directly or indirectly from using this publication (in part or in whole) and any information or material contained in it.*

## 4.2 Native vegetation

Figure 10 shows the potential vulnerabilities of vegetation communities within the Corangamite region under a changing climate by 2090 under a RCP8.5 scenario. Under this scenario, communities that currently rely on wet climates with consistently high levels of rainfall are most vulnerable. Examples include the rainforests and wet forests of the Otway Ranges.

Other vegetation communities vulnerable to this scenario of climate change will be the riparian communities of the region, especially those found along the smaller tributaries that feed into the larger river systems. These vegetation communities are dependent on regular flooding or at least periods of inundation from heavy rainfall events. Examples include the riparian forests and woodlands found in the upper catchments.

Not all vegetation communities are highly vulnerable to this scenario of climate change. Communities such as Coastal Scrubs, Salt Tolerant Shrublands and Heathy Woodlands are all quite resilient to hotter and drier conditions. Should such conditions eventuate, these communities are likely to have greater capacities to cope with change in both temperature and reduced rainfall because they occur naturally in such conditions today.

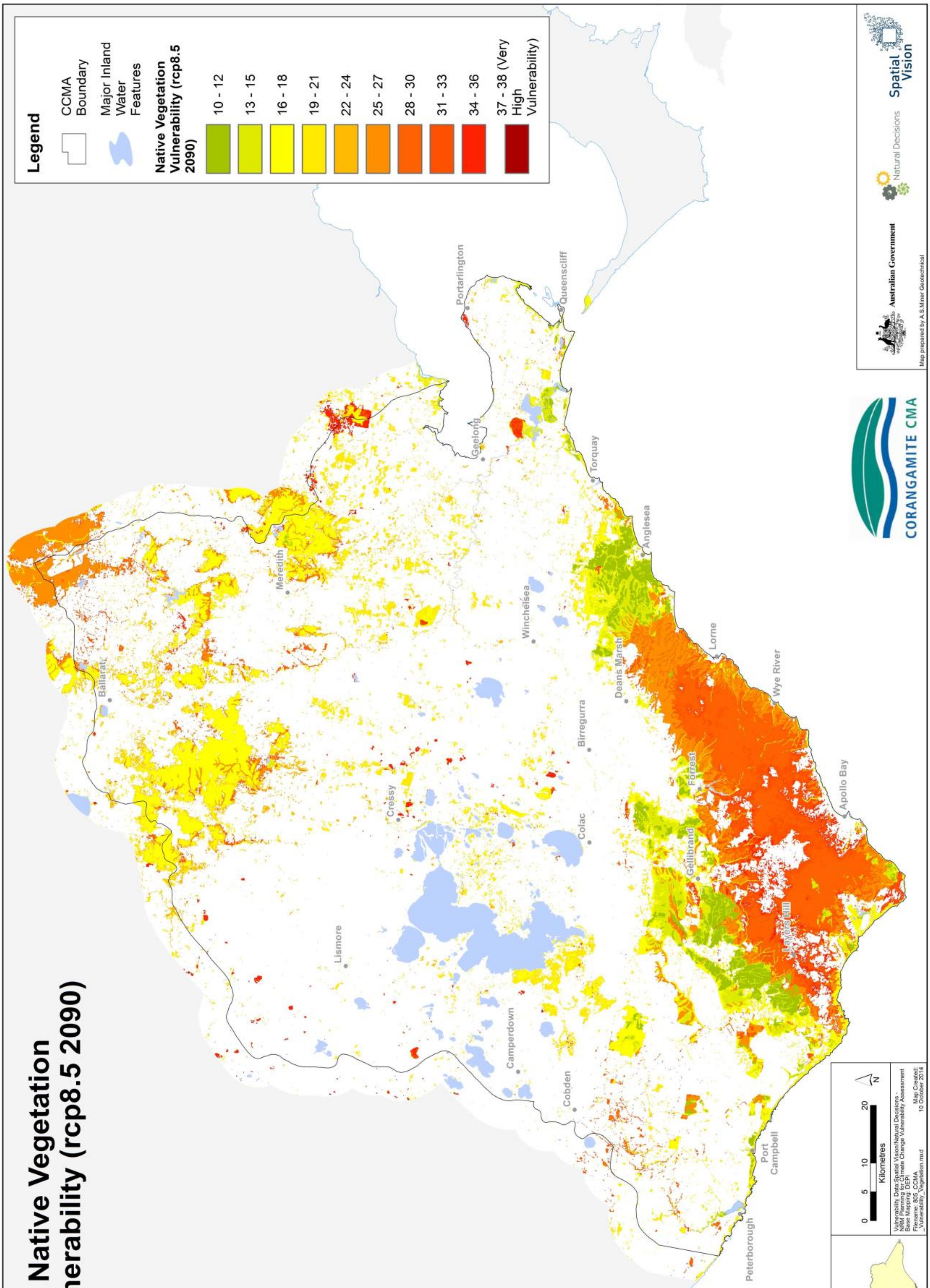
However, climate change can have other - perhaps greater- impacts on native vegetation. One important driver is through changes to existing fire regimes, with more frequent and intense bushfires projected alongside smaller windows of opportunity for prescribed burning (whether ecological or fuel reduction focused).

***Native Grassland at Rokewood. Photo: Kurtis Noyce***

This has potentially serious ramifications for vegetation communities already restricted in extent; either naturally or through fragmentation e.g. native grasslands. All vegetation communities will respond to climate change. Some may be able to adapt, for example by altering their floristic compositions and/or structures, or changing their reproductive processes. However, some species may not be able to adapt and so we will see changes in community composition or even replacement of one community type by others more resilient to altered ecological processes. We are also likely to see establishment of new vegetation communities.

**Table 4: Recommendations from the Regional Expert Panel Workshop (Native Vegetation) to improve vulnerability assessment**

| Recommendation | Why is this needed? |
|---|---|
| Finer scale modelling would allow for more specific and localised NRM planning. | Expect to see greatest level of change in areas where two EVCs adjoin – the transition point where EVCs meet will also be the best point to monitor for changes. Current modelling does not differentiate this due to scale and grouping of EVCs. |
| Add other ratings, including invasive species and likelihood of species loss, to current sensitivity ratings to further refine spatial vulnerability assessment for native vegetation. | EVCs are sensitive to temperature and rainfall but also sensitive to other factors such as weeds. Some are also specific in their threats e.g. Coastal Saltmarsh and sea level rise, and these also need to be included. |
| More vulnerability assessment work is needed on key plant species within vegetation communities as indicators of climate change. | Easy to determine on species basis, it's either present or not.<br><br>EVCs will take much longer to change as species will change within the vegetation community. |
| Model should also be based on raw data, not just modelled data. | The region has a wealth of ground-truthed data that could be used to complement the existing modelled data to improve accuracy. |
| Other spatial data should be used to complement existing/improved vulnerability assessment. | The region has a wealth of other data that could be used to complement the existing modelled data to improve accuracy. |


Native Vegetation Vulnerability (rcp8.5 2090)
Legend
CCMA Boundary
Major Inland Water Features
Native Vegetation Vulnerability (rcp8.5 2090)
10 - 12
13 - 15
16 - 18
19 - 21
22 - 24
25 - 27
28 - 30
31 - 33
34 - 36
37 - 38 (Very High Vulnerability)
Ballarat
Meredith
Geelong
Portarlington
Queenscliff
Torquay
Anglesea
Winchelsea
Lorne
Deans Marsh
Wye River
Birregurra
Forrest
Apollo Bay
Cressy
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Gellibrand
Lavers Hill
Lismore
Camperdown
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CORANGAMITE CMA
Australian Government
Natural Decisions
Spatial Vision
Map prepared by A.S.Miner Geotechnical
Map Created: 10 October 2014

## Shifts in the region's Cool Temperate Rainforest

The following case study is taken from AdaptNRM's '*Helping Biodiversity Adapt: Supporting climate-adaptation planning using a community-level modelling approach'*, available at: www.AdaptNRM.org

The Corangamite region contains remnants of a Cool Temperate Rainforest that are unique, stretching southwest from Lorne through Great Otway National Park (see (a) in Figure 11 below). These remnants have high value, not just for biodiversity but also for tourism as their important role in ensuring the health of designated water catchments in the Otway Ranges are maintained.

CSIRO has carried out modelling to map the distribution of Cool Temperate Rainforest under projected changes in the region's climate. CSIRO's modelling suggests that Cool Temperate Rainforest is likely to become even more restricted by 2050, and would virtually disappear from the region under a RCP 8.5 scenario.

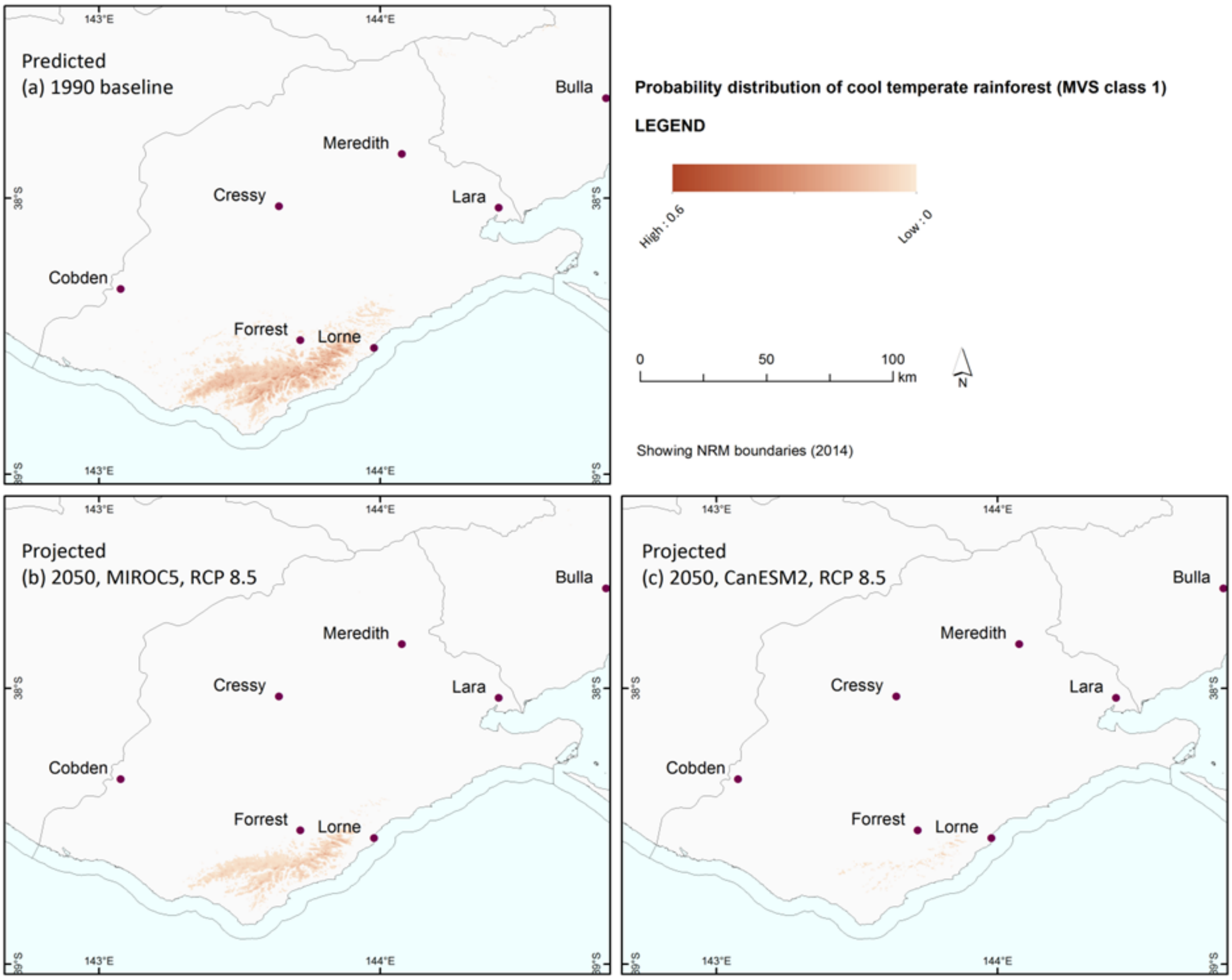



**Figure 11: Projected probability of Cool Temperate Rainforest occurrence for the baseline (1990)climate (a) and projected occurrence for 2050 under the high emissions' mild MIROC5 (b) and hot CanESM2 (c) climate scenarios.**

A variety of measures can be used to provide a more holistic picture of the shifts that climate change could produce. Maps of potential future vegetation types, suggest that Eucalypt forest may dominate, with either a tree-fern or a grassy understory. They also suggest, particularly under a hot climate scenario (RCP 8.5), the new vegetation type will continue to be unique in the region, showing stronger affinities with parts of eastern Victoria than the rest of the Corangamite region.

Exploration of CSIRO's measures indicate the overall potential degree of ecological change in the region is not exceptionally high and that these vegetation communities are not likely to disappear from a continental perspective, and that the vegetation communities that exist in the future will not necessarily be novel (refer to Appendices, page 169). While Cool Temperate Rainforest may be lost from the region, this may occur through a change of the species present. Although the newly assembling vegetation type may not be unique from a continental perspective, it may still retain a unique character in the Corangamite region.

Regional experts have discussed and provided opinions on this modelling through a series of workshops and follow-up consultation. This consultation has resulted in a need to acknowledge other factors when interpreting climate change modelling that may also impact of the distribution of Cool Temperate Rainforest in the future.

Changes to the surrounding fire regimes of fire-dependent vegetation communities may have a greater impact on the distribution and species composition, for example, from a tree-fern to a grassy dominated understorey of Cool Temperate Rainforest. This may also act to accelerate the changes to the distribution of Cool Temperate Rainforest as projected by CSIRO's modelling.

Regional opinion also recommended that the best adaptive practice to enable Cool Temperate Rainforest to persist under climate change, is to allow the forest in the watershed to grow old under a regime of minimal disturbance as this will increase catchment water yield, increase under canopy humidity and impede the passage of fire.

The options available to manage these projected changes to the distribution of Cool Temperate Rainforest will depend on new principles and strategic goals for biodiversity conservation that land managers may choose to adopt. These include:

**Optimise ecological processes** – If this is a core principle, one goal could be to help nature take its course by minimising other stressors and maintaining connectivity in the areas currently supporting Cool Temperate Rainforest.

**Maintain regional character** – If this is a core principle, analysis suggests these areas are likely to retain unique regional values. Therefore, one goal could simply be to promote the assembly of the new vegetation type with native species, focusing on monitoring and management of potential transformer species that might threaten that unique character.

**Promote cross-sectoral adaptation planning** – If this is a core principle, one goal could be to ensure that any changes to adjacent land uses do not further contribute to changed fire regimes that may accelerate loss of Cool Temperate Rainforest.

## 4.3 Rivers and streams

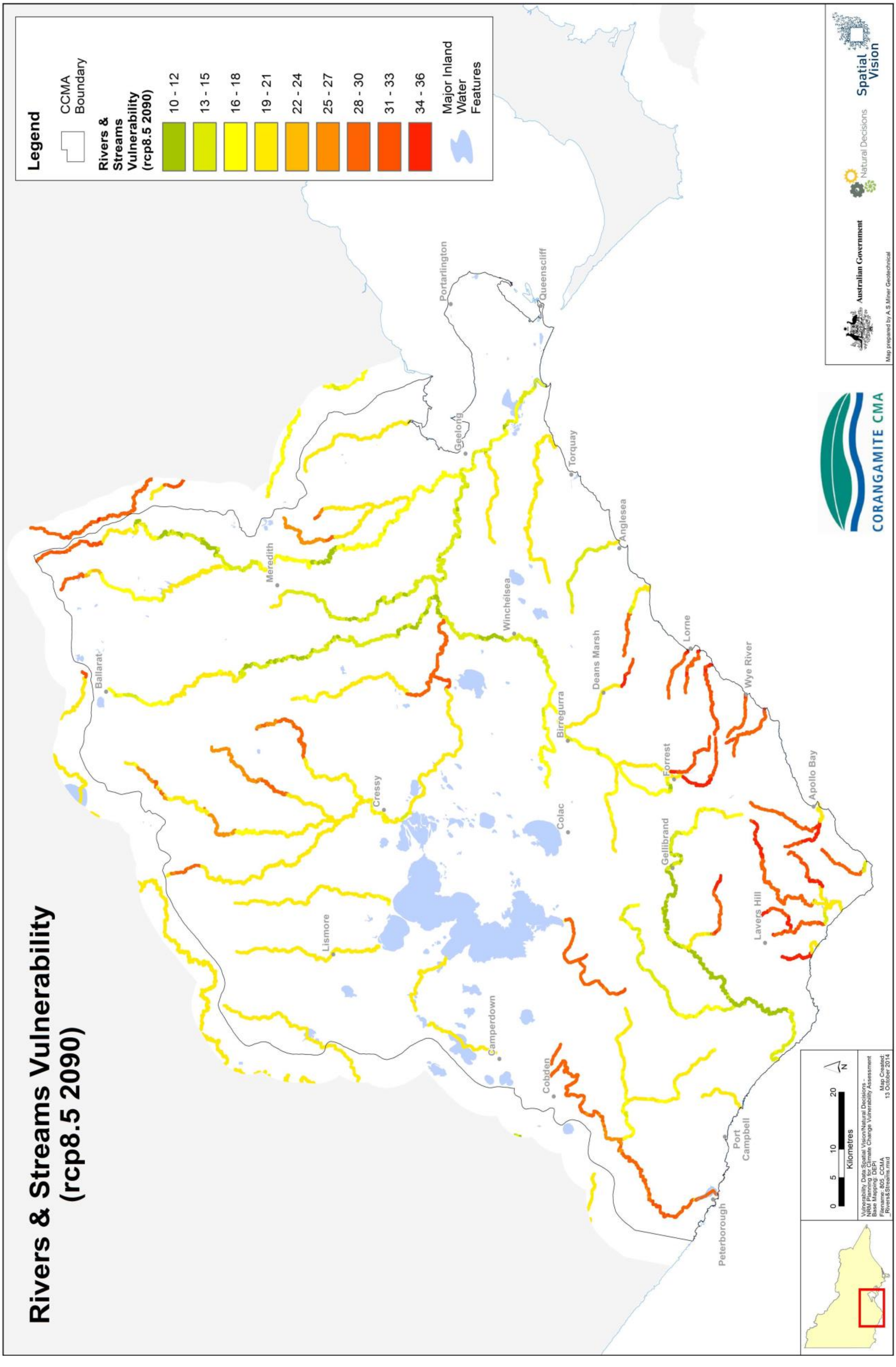
Figure 12 is a vulnerability assessment of the region's rivers and streams to climate change (RCP 8.5 2090). The most vulnerable waterways in the region are those in the Otway Ranges, especially those flowing southwards into the Southern Ocean. These waterways have small, confined catchments, are unregulated, rely on high levels of rainfall and are relatively short in length. Reduced runoff into these rivers and streams will have a detrimental impact on these systems. One adaptive approach that was suggested during one of the Regional Expert Panel Workshops is to allow the forest in the watershed of these catchments to grow old under a regime of minimal disturbance as this may increase catchment water yield.

Many tributaries of the upper catchments to the north of the region will also be highly vulnerable to climate change. This is largely attributed to reduced runoff as well as high levels of modifications that have been made to these systems since European settlement, usually in the form of reservoirs, weirs and similar infrastructure. Rethinking how this infrastructure can be managed may lead to rivers and streams becoming more resilient to what will be a warmer climate with less rainfall.

The vulnerability assessment also shows that some rivers and streams will be more resilient to climate change. These include reaches of the Gellibrand, Leigh, Moorabool and Barwon rivers and this high resilience can be attributed to these specific reaches being highly regulated flows and/or already highly degraded. As a result, there is limited scope for these reaches to be degraded further by climate change, mainly due to their already reduced flows.

**Table 5: Recommendations from the Regional Expert Panel Workshop (Rivers and Streams) to improve vulnerability assessment**

| Recommendation | Why is this needed? |
|---|---|
| Add other ratings, including invasive species and likelihood of species loss, to current sensitivity ratings to further refine spatial vulnerability assessment for rivers and streams. | Knowledge about sensitivity to rivers and streams can be greatly improved in the Corangamite region due to improved modelling and data available regionally when compared to state-wide data. |
| Create a regulation status layer to improve an understanding of the adaptation capacity of the region's waterways. | Addition of this data will assist environmental flow planning and help determine other adaptation measures that are required. As an example, this has been done for Cundare Pool by the Corangamite CMA. This specific mapping could be done to coincide with regional drainage scheme mapping. |
| Liaise with other waterway management data providers e.g. Barwon Water to improve on current vulnerability assessment data. | Information and modelling currently residing with other waterway managers can assist the spatial vulnerability assessment through refining sensitivity ratings and/or complementing other modelling and water management information. |
| Use current vulnerability assessment data for site-specific projects. | NRM planners/waterway managers might want to focus on collecting and processing data at a local scale. The scale of information required to assess an entire region is problematic. |


Rivers & Streams Vulnerability
(rcp8.5 2090)
Legend
CCMA Boundary
Rivers & Streams Vulnerability (rcp8.5 2090)
10 - 12
13 - 15
16 - 18
19 - 21
22 - 24
25 - 27
28 - 30
31 - 33
34 - 36
Major Inland Water Features
Portarlington
Queenscliff
Geelong
Torquay
Anglesea
Meredith
Winchelsea
Lorne
Deans Marsh
Wye River
Ballarat
Birregurra
Forrest
Apollo Bay
Cressy
Colac
Gellibrand
Lavers Hill
Lismore
Camperdown
Cobden
Port Campbell
Peterborough
0 5 10 20
Kilometres
Vulnerability Data Spatial Vision/Natural Decisions - NRM Planning for Climate Change Vulnerability Assessment
Base Mapping: DEPI
Filename: 805_CCMA_Rivers&Streams.mxd
Map Created: 13 October 2014
CORANGAMITE CMA
Australian Government
Natural Decisions
Spatial Vision
Map prepared by A.S.Miner Geotechnical

## 4.4 Estuaries

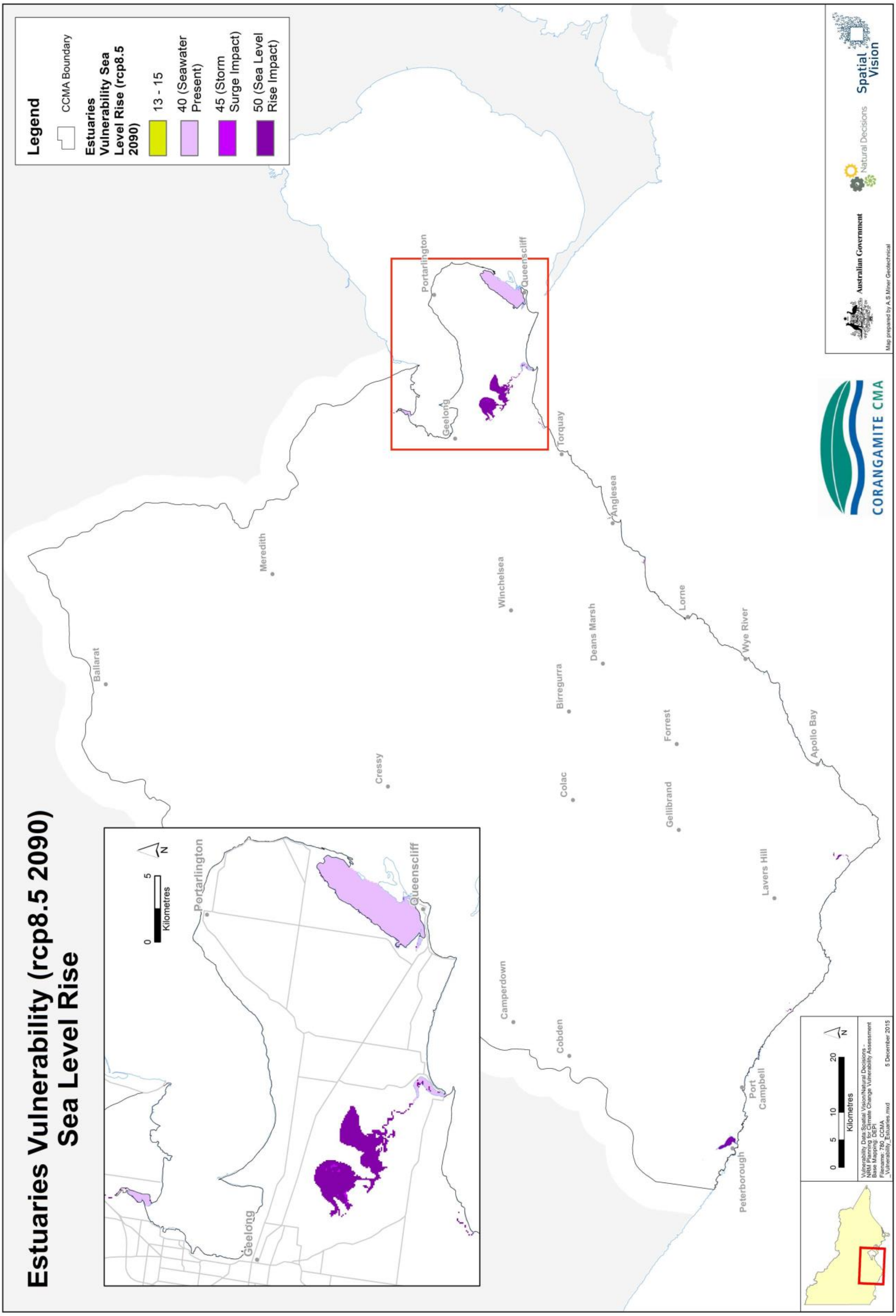
The region's estuaries are normally quite resilient to coastal processes such as tidal exchanges, shoreline recession and natural estuary openings. However, with sea levels projected to rise on average by 0.8–1.1 metres by 2100, combined with an increase in storm surge events and reduced inflows, climate change is expected to greatly impact all estuaries in the region, as Figure 13 illustrates.

Climate change impact is expected to be higher in the estuaries of the Curdies, Gellibrand, Aire and Anglesea rivers. It is also expected to have a major impact on the Barwon River estuary, especially in the upper reaches of the estuary into Lake Connewarre.

It is expected sea level rise will have less of an impact on the Hovells Creek estuary. This estuary is located in Corio Bay and is not as exposed to the increase in projected storm surge events expected in the more exposed areas of the region's coastline.

**Table 6: Recommendations from the Regional Expert Panel Workshop (Estuaries) to improve vulnerability assessment**

| Recommendation | Why is this needed? |
|---|---|
| Add other ratings, including Index of Estuary Condition (IEC), frequency of estuary openings, connectivity, annual rainfall (opposed to November-April) and runoff estimate data to current sensitivity ratings to further refine spatial vulnerability assessment for estuaries. | IEC data was not available at the time when original vulnerability assessment was done (expected to be made available in mid-2016). IEC data would be a major addition for use at both a local and regional scale. Some estuaries have a connectivity factor that will impact on species and their ability to adapt. Run off and flow variability due to rainfall may be better aligned with annual rainfall data - rather than rainfall levels between November and April. Runoff estimate data (estuaries and rivers), developed by the South East Australia Climate Institute could be used as another climate induced stressor, rather than just rainfall. |
| Determine if likelihood of acid sulphate soil exposure is both a) a threat under conditions brought about by climate change and b) if this can be added as a stressor to the vulnerability assessment. | It is projected that more frequent acid events are likely to occur in estuaries under climate change. Dry spells create decreases in water level and increases in acid sulphate soils and when there is a drop in the upper catchment this is compounded. It is projected that coastal acid sulphate soils will be covered under sea level rise but this may cause an increase in acid sulphate soils upstream. |


Estuaries Vulnerability (rcp8.5 2090)
Sea Level Rise
Legend
CCMA Boundary
Estuaries Vulnerability Sea Level Rise (rcp8.5 2090)
13 - 15
40 (Seawater Present)
45 (Storm Surge Impact)
50 (Sea Level Rise Impact)
Portarlington
Queenscliff
Geelong
Torquay
Anglesea
Meredith
Winchelsea
Lorne
Wye River
Deans Marsh
Ballarat
Birregurra
Forrest
Apollo Bay
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Lavers Hill
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Peterborough
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Vulnerability Data: Spatial Vision/Natural Decisions - NRM Planning for Climate Change Vulnerability Assessment
Base Mapping: DEPI
Filename: 780_CCMA_Vulnerability_Estuaries.mxd
5 December 2015
CORANGAMITE CMA
Australian Government
Natural Decisions
Spatial Vision
Map prepared by A.S.Miner Geotechnical

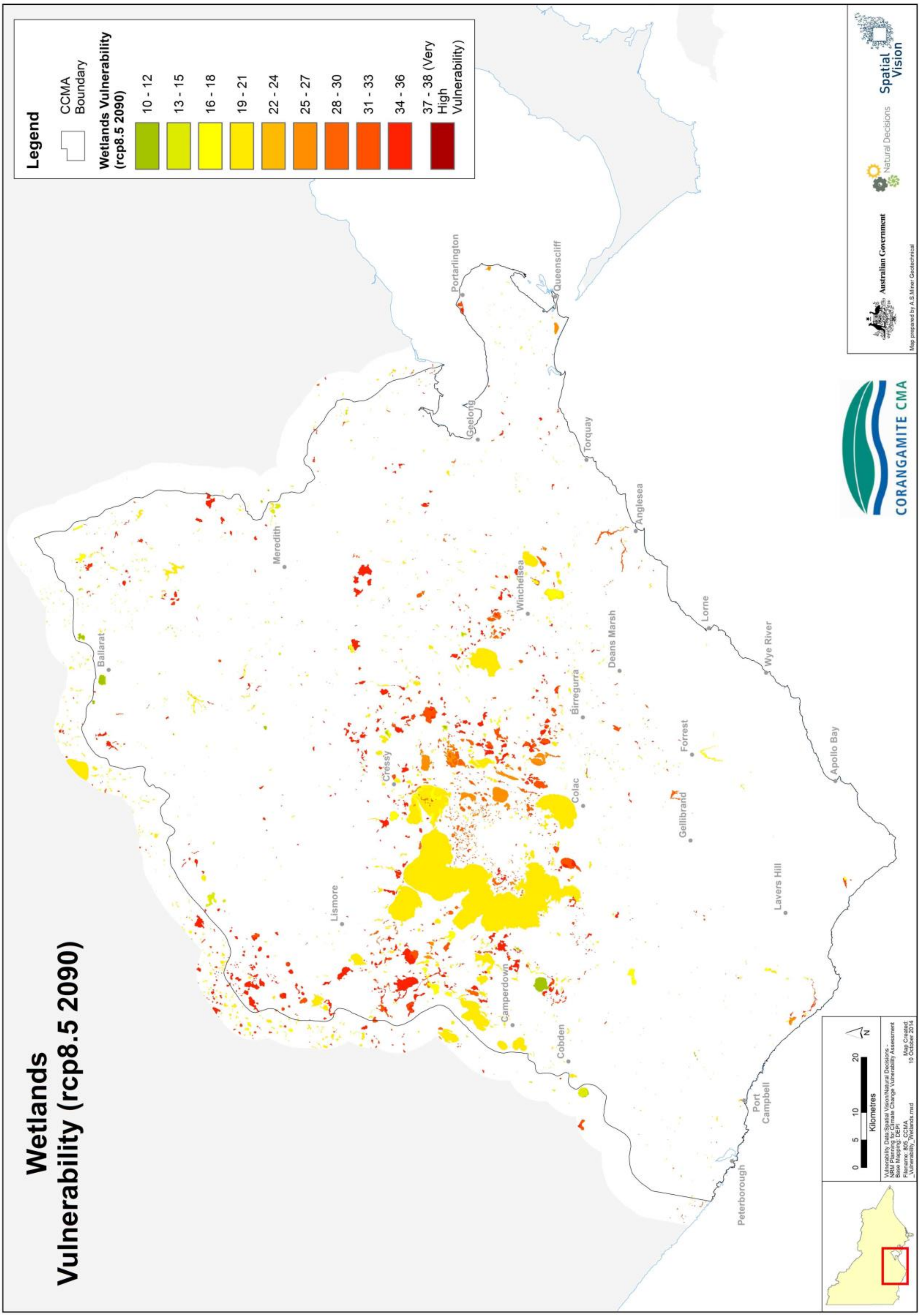
## 4.5 Wetlands

Figure 14 illustrates that climate change will greatly impact the region's wetlands. A reduction in rainfall and runoff will cause some temporary wetlands to dry up permanently, while a reduction in water inflow may also cause an increase in salinity of some wetlands and changes in the types of vegetation communities they can support. These changes may lead to other impacts such as a loss of critical habitat for migratory and other bird species. There will also be an impact on some wetlands reliant on groundwater or springs.

Those most vulnerable wetlands include freshwater meadows and marshes, as well as wetlands that are currently ephemeral in nature, both freshwater and saline. Iconic wetlands in this category include Lake Gherang, Lake Beeac and Lake Victoria, and many of the wetlands on the Victorian Volcanic Plain. Wetlands that will be more resilient to climate change include those that are deeper and/or larger in size such as Lake Purrumbete.

**Table 7: Recommendations from the Regional Expert Panel Workshop (Wetlands) to improve vulnerability assessment**

| Recommendation | Why is this needed? |
|---|---|
| Add other ratings, such as sedimentation and connectivity to existing waterways to current sensitivity ratings to further refine spatial vulnerability assessment for wetlands. | Sedimentation impact on wetlands is a factor that needs to be considered. This data could be gathered in the form of a percentage of disturbed catchment, based on soil type, slope and other factors. The use of erosion susceptibility modelling could also be considered. |
| Develop spatial mapping that shows temporal aspects of the region's wetlands to provide a true baseline for setting strategic climate change adaptation management actions. | Mapping would provide for a more realistic representation of the 2030 – 2090 scenarios with current vulnerability compared to projected vulnerability. Many wetlands are already vulnerable and this needs to be shown as a starting point since the maps give a false sense of vulnerability e.g. low vulnerability rating for many of our wetlands in 2030. |
| Create a regulation status layer (i.e. diversions and other man-made structures) impacting the region's wetlands. | This layer would be used to improve adaptation planning and develop appropriate adaptation measures. |
| Create a groundwater dependent wetland layer to improve adaptation planning and appropriate adaptation measures. | This layer would be used to improve adaptation planning and develop appropriate adaptation measures. |


Wetlands
Vulnerability (rcp8.5 2090)
Legend
CCMA Boundary
Wetlands Vulnerability (rcp8.5 2090)
10 - 12
13 - 15
16 - 18
19 - 21
22 - 24
25 - 27
28 - 30
31 - 33
34 - 36
37 - 38 (Very High Vulnerability)
Portarlington
Queenscliff
Geelong
Torquay
Anglesea
Meredith
Winchelsea
Lorne
Deans Marsh
Wye River
Ballarat
Birregurra
Forrest
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Port Campbell
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Australian Government
Natural Decisions
Spatial Vision
CORANGAMITE CMA
Map prepared by A.S.Miner Geotechnical

## 4.6 Soils

Figure 15 provides a regional impact assessment of soils under RCP 8.5 (worst case scenario) and a timeframe of 2090.

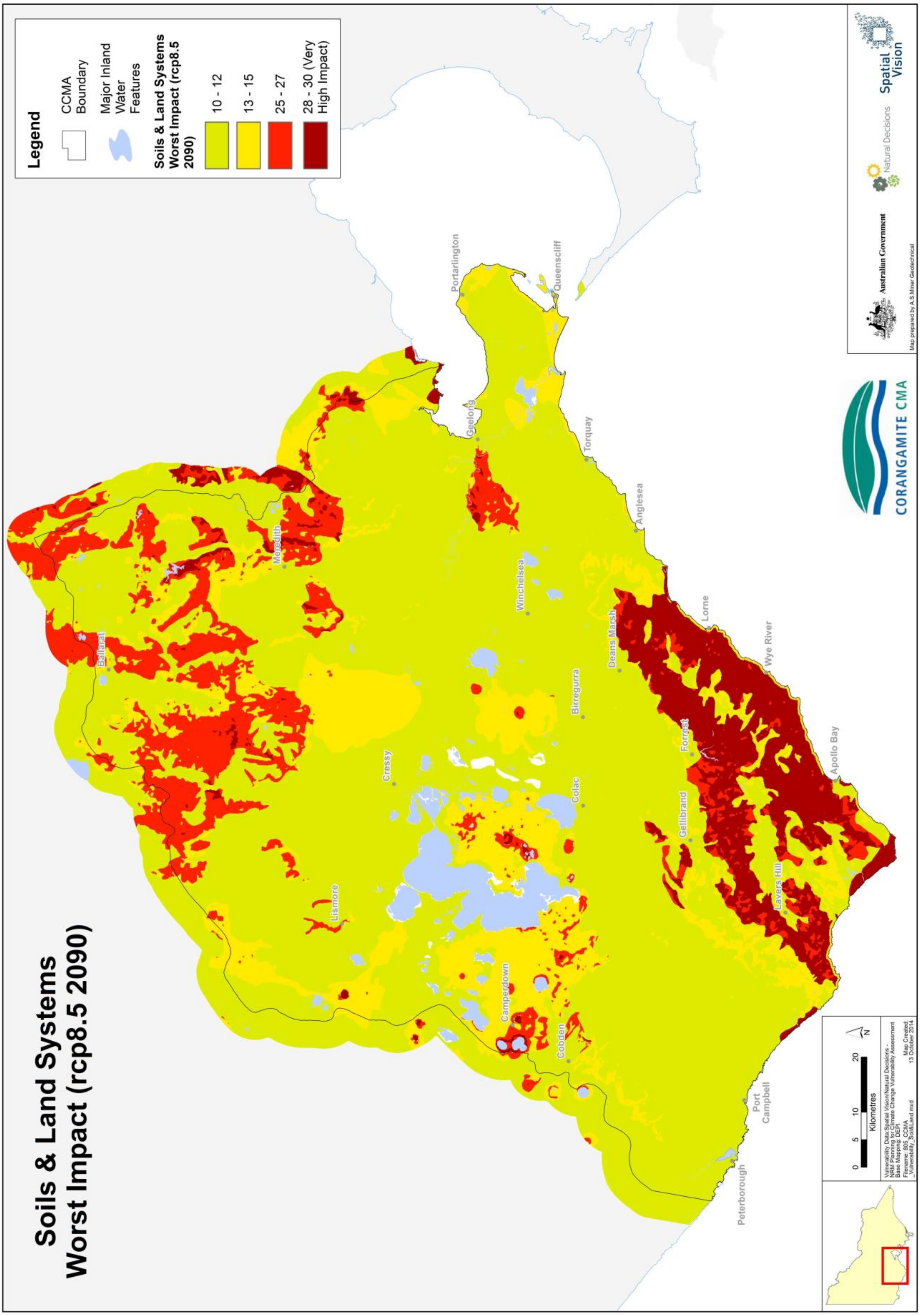
A natural asset's adaptive capacity is one of the crucial components for determining its vulnerability to climate change (refer page 35). The REP Workshop for Soils identified that modelling how land is managed, is ineffective in determining its adaptive capacity, as there are too many variables in how this has evolved since European settlement. However, sensitivity and exposure - and therefore impact of climate change on the region's soils - can be used as an effective means of communication to land managers about climate change threats to soil.

The impact assessment therefore provides an opportunity for dialogue with land managers on the adaptive strategies, and developing appropriate actions for the site. For example, determining the best NRM and business outcome, identifying the key decisions to reach these outcomes e.g. through adaptation pathways, identifying data and/or knowledge gaps and applying the most appropriate actions.

The Corangamite region has a wide range of information and data, and therefore knowledge, to complement work done to assess the climate change impacts on the region's soils. It is envisaged this previous work will be used to improve climate change impacts to soil during the next two to three years.

**Table 8: Recommendations from the Regional Expert Panel Workshop (Soils) to improve vulnerability assessment**

| Recommendation | Why is this needed? |
|---|---|
| Replace vulnerability assessment with impact assessment modelling to better represent the impact of climate change to the region's soils. | Vulnerability mapping can only represent approximately 35% of the region covered by remnant vegetation. This is because the current adaptive capacity values use native vegetation cover and site condition as the only factors and do not consider cleared managed land. |
| Add other ratings, such as susceptibility to erosion (all types) to current sensitivity ratings to further refine spatial vulnerability assessment for soils | Knowledge about sensitivity to the soil asset can be greatly improved in the Corangamite region due to improved mapping available here in comparison to state-wide data. Examples of this improved regional data and mapping includes:<br>• Corangamite Land Resource Assessment (soil groupings and characteristics that are not available in other regions at this scale)<br>• Soil property mapping (many parametersat 25m grid resolution)<br>• Erosion and landslide susceptibility mapping<br>• Waterlogging data<br>• LiDAR modelling including derived terrain data.<br>CSIRO soil carbon data should also be considered. |


Soils & Land Systems
Worst Impact (rcp8.5 2090)
Legend
CCMA Boundary
Major Inland Water Features
Soils & Land Systems Worst Impact (rcp8.5 2090)
10 - 12
13 - 15
25 - 27
28 - 30 (Very High Impact)
Portarlington
Queenscliff
Geelong
Torquay
Anglesea
Lorne
Wye River
Apollo Bay
Lavers Hill
Gellibrand
Forrest
Deans Marsh
Winchelsea
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Base Mapping: DEPI
Filename: 805_CCMA_Vulnerability_Soil&Land.mxd
Map Created: 13 October 2014
Map prepared by A.S.Miner Geotechnical
Australian Government
Natural Decisions
Spatial Vision
CORANGAMITE CMA

## 4.7 Coastal wetlands

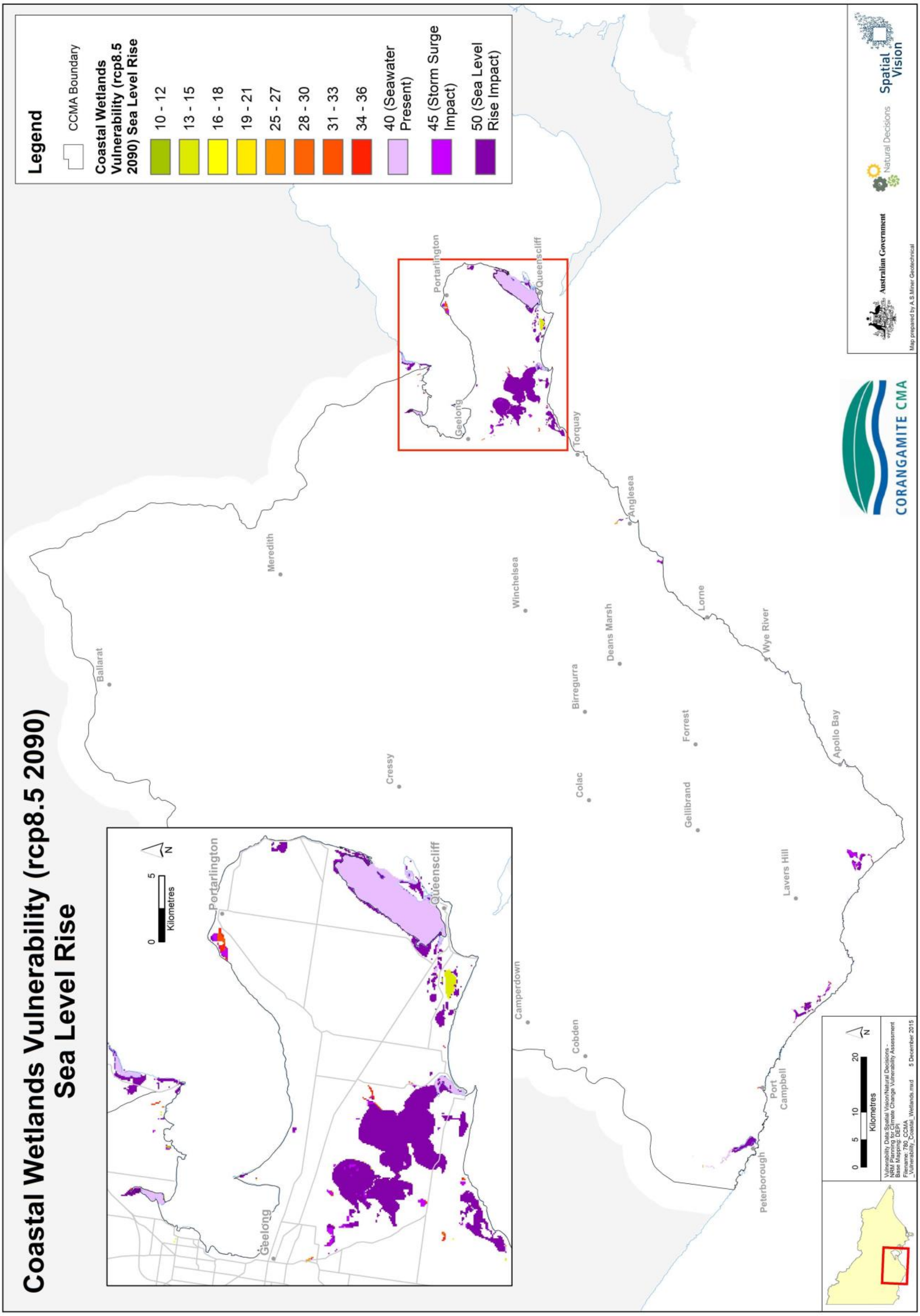
Figure 16 indicates coastal wetlands will be very vulnerable to climate change. Increased drought frequency and intensity, decreases in freshwater inputs, rising sea levels and increases in coastal storm surges may impact these important ecosystems. These conditions may also change the character of coastal wetlands through a reduction in size, conversion to dryland or a shift from one wetland type to another e.g. brackish to saline. Under hotter and drier conditions, as well as reduced inflows, acid sulphate soils in coastal wetlands have increased risk of exposure.

Coastal wetlands highly vulnerable to climate change include those found in the Lower Barwon, Gellibrand and Aire rivers. These wetlands occur in low lying areas and are more susceptible to sea level rise and storm surges.

**Table 9: Recommendations from the Regional Expert Panel Workshop (Coasts and Marine) to improve vulnerability assessment**

| Recommendation | Why is this needed? |
|---|---|
| Add other ratings, such as turbidity, nutrient levels, water temperature, groundwater, etc. to current sensitivity ratings to further refine the spatial vulnerability assessment for coastal wetlands. | Knowledge about sensitivity to the coastal wetlands can be greatly improved in the Corangamite region due to improved mapping and information available here when compared to state-wide data. |
| Use digital elevation models e.g. LiDAR to determine which coastal wetlands may be impacted by sea level rise, including opportunities for migration. | Elevation data will have a major role in understanding impacts at a more refined regional and local level. Some areas will not change e.g. where a cliff exists, and some will, e.g. low lying areas where farmland may become a coastal wetland. |

***Coastal Saltmarsh at Edwards Point. Photo: Corangamite CMA***


Coastal Wetlands Vulnerability (rcp8.5 2090)
Sea Level Rise
Legend
CCMA Boundary
Coastal Wetlands Vulnerability (rcp8.5 2090) Sea Level Rise
10 - 12
13 - 15
16 - 18
19 - 21
25 - 27
28 - 30
31 - 33
34 - 36
40 (Seawater Present)
45 (Storm Surge Impact)
50 (Sea Level Rise Impact)
Kilometres
Portarlington
Queenscliff
Geelong
Torquay
Anglesea
Meredith
Ballarat
Winchelsea
Deans Marsh
Lorne
Wye River
Birregurra
Forrest
Apollo Bay
Cressy
Colac
Gellibrand
Lavers Hill
Camperdown
Cobden
Port Campbell
Peterborough
CORANGAMITE CMA
Australian Government
Natural Decisions
Spatial Vision

## 4.8 Coasts

Figure 17 provides a high level assessment of the potential risks from sea level rise and storm surge at a state-wide to regional scale for 2100. It can be used as an indicative assessment of which areas are likely to be at risk where a more detailed local assessment is not available.

The modelling has been derived from the Victorian Government's Victorian Coastal Inundation Dataset and is intended to be used at a regional scale to assist strategic planning and risk management. It is not intended to be used to inform decisions about individual properties or other structures. The dataset builds on the methodology used in the Australian Government's National Coastal Risk Assessment.

This modelling should be used with the Victorian Coastal Hazard Guide. The Guide is intended to improve the impacts of inundation and erosion of coastal assets, including coastal wetlands, estuaries and inter-tidal areas as well as the effects of climate change on these assets. It also assists decision-making for managing coastal assets and to manage the risks posed by coastal hazards through providing a risk-based approach for incorporating climate change into decision making processes associated with managing coastal areas. The Guide also promotes the use of adaptive management and response options to improve adaptive capacity of assets under climate change.

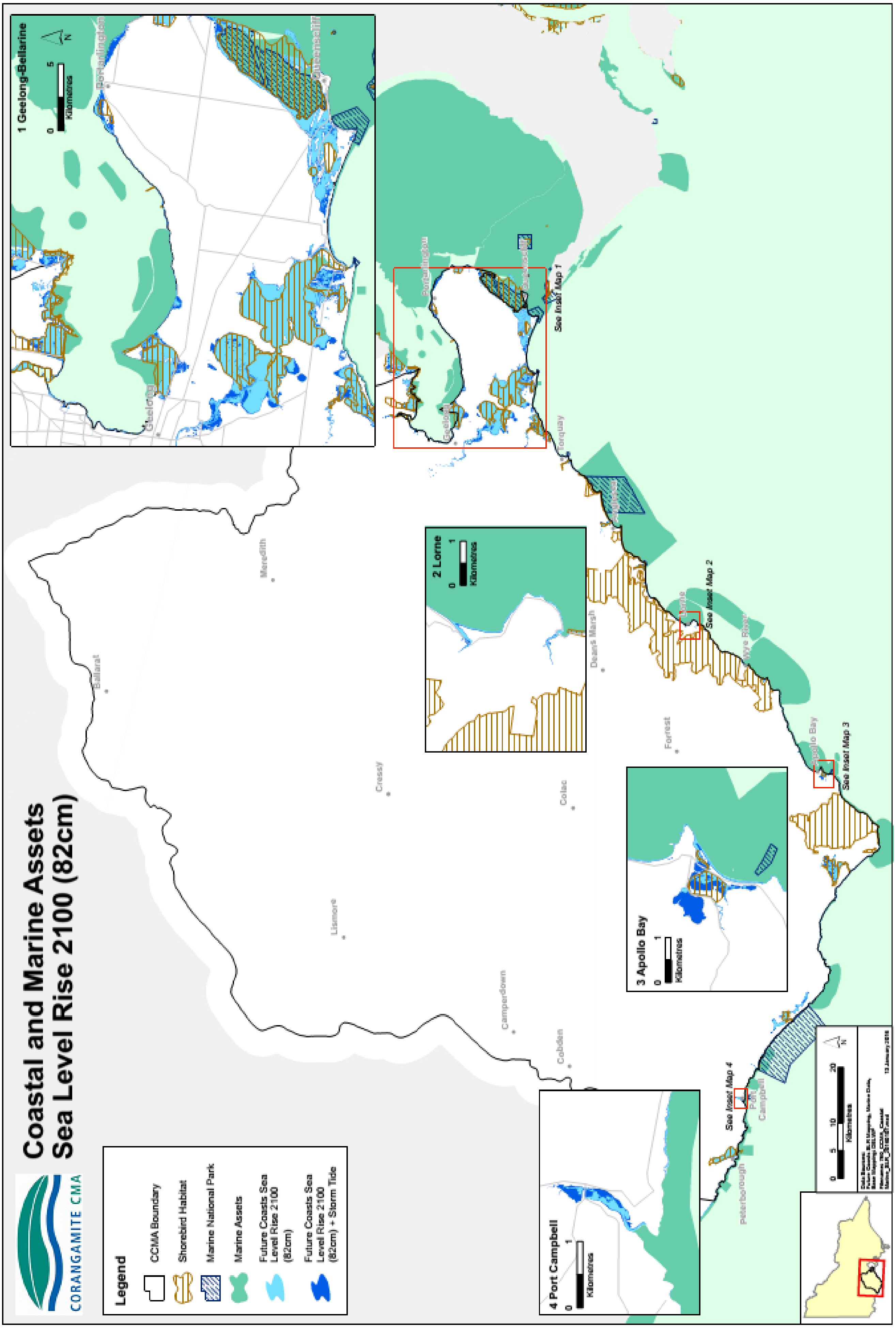
More information on the Victorian Coastal Inundation Dataset and Victorian Coastal Hazard Guide can be found at www.climatechange.vic.gov.au/climate-science-and-data/future-coasts

The Victorian Government, Corangamite CMA and local coastal Committees of Management are working closely with the City of Greater Geelong and Borough of Queenscliffe to undertake more detailed local coastal hazard assessments at several priority locations along the coast on the Bellarine Peninsula and within Corio Bay.

This assessment will test a range of methods to analyse the impacts of sea level rise as well as provide practical information for planners and coastal asset managers to make decisions at a local scale. It is hoped that this work, once completed, will continue to be developed for other areas within the region.

**Table 10: Recommendations from the Regional Expert Panel Workshop (Coasts and Marine) to improve vulnerability assessment**

| Recommendation | Why is this needed? |
|---|---|
| Use digital elevation models e.g. LiDAR to determine which coastal assets may be impacted by sea level rise, including opportunities for migration. | Elevation data will have a major role in understanding impacts at a more refined regional and local level. |


Coastal and Marine Assets
Sea Level Rise 2100 (82cm)
CORANGAMITE CMA
Legend
CCMA Boundary
Shorebird Habitat
Marine National Park
Marine Assets
Future Coasts Sea Level Rise 2100 (82cm)
Future Coasts Sea Level Rise 2100 (82cm) + Storm Tide
1 Geelong-Bellarine
2 Lorne
3 Apollo Bay
4 Port Campbell
See Inset Map 1
See Inset Map 2
See Inset Map 3
See Inset Map 4
Kilometres
Ballarat
Meredith
Cressy
Lismore
Colac
Camperdown
Cobden
Deans Marsh
Forrest
Geelong
Torquay
Portarlington
Queenscliff
Lorne
Apollo Bay
Port Campbell
Peterborough

## 4.9 Flora and fauna species

Flora and fauna species, or biodiversity, were not assessed as part of the vulnerability assessment.

It was considered that critical habitat or species distribution was significantly covered by the vulnerability assessment of the existing natural assets, e.g. native vegetation.

The application of the vulnerability assessment process to a number of indicator species was also initially considered, in addition to consideration of its application to areas of old growth forest.

However, it was decided that critical habitat was best treated like asset value or significance information, and therefore could be used in combination with native vegetation, wetland, or other asset information.

### Future planning for species under a changing climate

Evidence over the past decade has shown that ecological change in response to climate change is unavoidable, that it is happening now and that the impacts will be wide and varied. In some cases, the impacts may be substantial.

To better adapt the region's biodiversity to climate change (and help us adapt with those changes), new shifts in how we plan and manage our flora and fauna need to be assessed, and if deemed appropriate, adopted.

CSIRO, through the AdaptNRM program, has recognised this need and as a consequence has developed a number of climate change adaptation tools and resources for regional NRM bodies and NRM planning in general.

AdaptNRM sets new directions for assessing the magnitude, extent and type of expected changes in biodiversity under climate change through introducing new modelling approaches and these are explained in more detail in the Appendices (pages 168 – 170).

One of the main actions listed in the current RCS is for the Corangamite CMA to develop a Biodiversity Strategy for the region.

This requirement, combined with the Victorian Government release of a state-wide Biodiversity Strategy and Victorian Climate Change Adaptation Plan in 2016, provides an excellent opportunity to plan for biodiversity at a regional scale.

Corangamite CMA will engage with its regional stakeholders and community groups to develop the region's Biodiversity Strategy and will work with both the Victorian Government and CSIRO – in particular AdaptNRM – to incorporate consistent planning and management directions for biodiversity.

Our aim is to ensure that the region's biodiversity managers have the best information available to help them plan to adapt to a changing climate.

More information on AdaptNRM, including modules, can be found at www.AdaptNRM.org.

## 4.10 Existing threats and climate change

Many current threats to the region's natural assets may increase under a changing climate.

One example is weeds. Weeds are a threat to almost all of the region's natural environments and agricultural landscapes. Under a changing climate, the threat of weeds becomes greater and more widespread.

1. The suite of weed species will change under different climatic conditions. Species that are weeds in other parts of Australia due to the current climate there, may become weeds here, once the region's climate shifts
2. Some existing weeds may become more invasive. The rate of response to climate change by weeds is expected to be faster and more efficient than that of native plants and farm crops (Scott *et al*., 2014).

The main drivers for climate change impacts on weeds such as a warmer climate, changes to rainfall, increased carbon dioxide levels and changed land use, will all have an influence on weed distributions and their impacts on natural and agricultural systems.

These need to be addressed alongside current planning for weeds to ensure the impacts of weeds are managed appropriately for a changing climate.

A summary of existing threatening processes and how they may increase their impact under climate change for each natural asset include;

- **Native vegetation:** *A hotter and drier climate may cause existing vegetation communities to change in their composition and structure, with some species being replaced by others. Fire regimes will be modified, most likely with more frequent and intense events. Vegetation communities may be vulnerable to environmental weeds. Some vegetation communities will be more vulnerable than others to the direct impacts of climate change e.g. Riparian Woodland, Cool Temperate Rainforest and Coastal Saltmarsh.*

- **Rivers and streams:** *The rivers and streams of the region will be impacted by climate change mainly through a decline in rainfall (projected to be 30% by 2090), leading to a decrease in runoff. Combined with a climate that is projected to have more intense rainfall events, this means many of the region's waterways that have evolved to their current form over millions of years may be greatly modified. More intense rainfall events may lead to more waterways being susceptible to bank erosion. Streams that are spring-fed and/or dependent on groundwater will also be impacted by climate change through a lack of inflow from already reduced aquifers.*

- **Wetlands:** *Climate change will impact both the region's extent and quality of wetlands. This will be through* a *reduction in the frequency and duration of rainfall events combined with an increase in the duration of drier periods leading to the drying of shallow wetlands; drainage of existing freshwater wetlands due to changes in land management practices, for example from grazing to cropping; and through changes to salinity levels due to higher evaporation rates. Wetlands that are dependent on groundwater will also be largely impacted by climate change though reduced inflows.*

- **Estuaries:** *A sea level rise of between 0.8-1.1 metres by 2100, hotter temperatures, and reduction in rainfall and an increase in extreme natural events e.g. flooding, are all expected to impact the ecology and dynamics of estuaries. Existing threats, such as changes to natural estuary openings and increases in nutrient levels may also be exacerbated by the indirect impacts of climate change, in particular through sea level rise and increases in storm surges. Existing threats, such as acidification, changes to natural estuary openings and nutrient levels may also be exaggerated by the indirect impacts of climate change.*

- **Coasts and coastal wetlands:** *Sea level rise will impact the region's coastline through increasing inundation and erosion as well as direct impacts on specific coastal habitats and biodiversity. Coastal wetlands are very vulnerable to climate change. Increased drought frequency and intensity, decreases in freshwater inputs, rising sea levels and increases in coastal storm surges may all impact these important ecosystems. These conditions may also change the character of coastal wetlands through a reduction in size, conversion to dryland or a shift from one wetland type to another (e.g. brackish to saline). Under hotter and drier conditions and reduced inflows, acid sulphate soils in coastal wetlands will face an increased risk of being exposed. The retention of coastal wetlands will require planning approaches which allow for the migration of wetland communities in order to avoid significant loss in both extent and character.*

- **Soil:** *Climate change will have a direct impact on soil health and in its ability to support specific uses. Prolonged periods of higher temperatures and reduced moisture may lead to more areas being more susceptible to wind erosion. More intense rainfall events may also lead to areas of sheet, rill and gully erosion. Reduced vegetation cover due to climate change will also exacerbate these impacts. More frequent and intense fires may also change the structure and productivity of soils. An increase in dryness and lack of moisture will also impact organic carbon in soil. Agricultural productivity may increase or decrease under a changing climate, depending on where it is located e.g. from grazing to cropping. However, as a general rule, productivity will reduce as total rainfall declines.*

- **Flora and Fauna:** *Many species have evolved over thousands of years and will not have the ability to adapt to what will be a climate that is changing in a relatively short timeframe and as a result, changes to the distribution of species is expected to occur. A climate that is hotter and drier will lead to other indirect impacts such as changes to natural fire and flooding regimes. An increase in these events may have direct impacts on already small, localised populations.*

Corangamite CMA and its regional partners will work with the Victorian Government and its agencies to develop appropriate responses to likely new and emerging threats due to climate change. These responses will underpin any strategic directions that exist at a regional level and will be included in all future NRM plans, including the Regional Catchment Strategy.

# 5. Determining carbon sequestration options for the Corangamite region

***George River Estuary. Photo: Rick Knowles***

One of the main objectives of this plan is to identify and prioritise, areas of the region suitable for a variety of carbon sequestration types. Traditionally, revegetation would be the main carbon sequestration option for the region, however, new and alternative options such as blue carbon and soil carbon present additional opportunities for both protecting and enhancing existing natural assets and as additional income, especially for land managers.

This section explores the carbon sequestration options available to the region. Priority has been given to options addressing other NRM benefits such as habitat protection and connectivity, water quality and soil stabilisation. Modelling for determining carbon sequestration priorities e.g. enhancement and revegetation, has been done by Wimmera CMA, in partnership with a number of other CMAs, including Corangamite. Further information on how the modelling was developed can be found here (www.swclimatechange.com.au).

**Key Messages**

- There are many regional options for carbon sequestration
- Priorities for carbon sequestration using native vegetation will be based on carbon and other NRM outcomes
- Blue carbon habitats have the potential to be the region's best source of carbon sequestration

## 5.1 Natural regeneration

Enhancing native vegetation through natural regeneration is a recognised method for promoting carbon sequestration under the Australian Government's Emissions Reduction Fund (ERF).

It is often the most efficient and cost effective, especially when compared to standard revegetation practices and other carbon sequestration activities. Natural regeneration can be encouraged through reducing current threatening processes such as over grazing and environmental weeds, and/or increasing processes such as additional plantings and restoring natural fire or flooding regimes.

Many of the region's Ecological Vegetation Classes (EVCs) respond well to natural regeneration. Examples include most communities in the Otways, floodplain woodlands along many of the region's waterways and native grasslands on the basalt plains.

Regional priorities for natural regeneration for carbon sequestration purposes will be assessed on a site-by-site basis. Other factors such as the type and/or quality of vegetation community, its conservation status as well as other NRM benefits e.g. river protection, should always be considered when priotising sites for carbon sequestration purposes.

Figure 18 is a map showing regional native vegetation management priorities for carbon sequestration purposes. Areas highlighted in dark green, with a total extent of 267,914 hectares or 20% of the Corangamite region, indicate remnant vegetation and should be used as a guide for areas to promote regeneration.

This map can be accessed from the portal at www.swclimatechange.com.au

## 5.2 Farm forestry

Farm forestry is another form of carbon sequestration activity already being implemented in many parts of the region. In addition, carbon sequestration, farm forestry provides a future source of timber. This places less pressure on existing remnant areas of vegetation on roadsides and private land as firewood sources. For example, indigenous tree species such as Messmate (*Eucalyptus obliqua*), can be incorporated into farm forestry plantings that have the dual benefits of biodiversity and commercial value, e.g. for sawn timber or firewood. Farm forestry can also act as a buffer to fragmented vegetation and a way to broaden the appeal of biodiverse plantations on private land.

Regional priorities for farm forestry should be assessed on a site-by-site basis, with other NRM benefits used to prioritise potential sites. Areas highlighted in light green, with a total extent of 120,751 hectares or 9% of the region, are identified as areas of high carbon sequestration potential, combined with other NRM benefits such as buffering and linking fragmented remnant vegetation, and are provided as a guide for targeted farm forestry.

This map can be accessed from the portal at www.swclimatechange.com.au

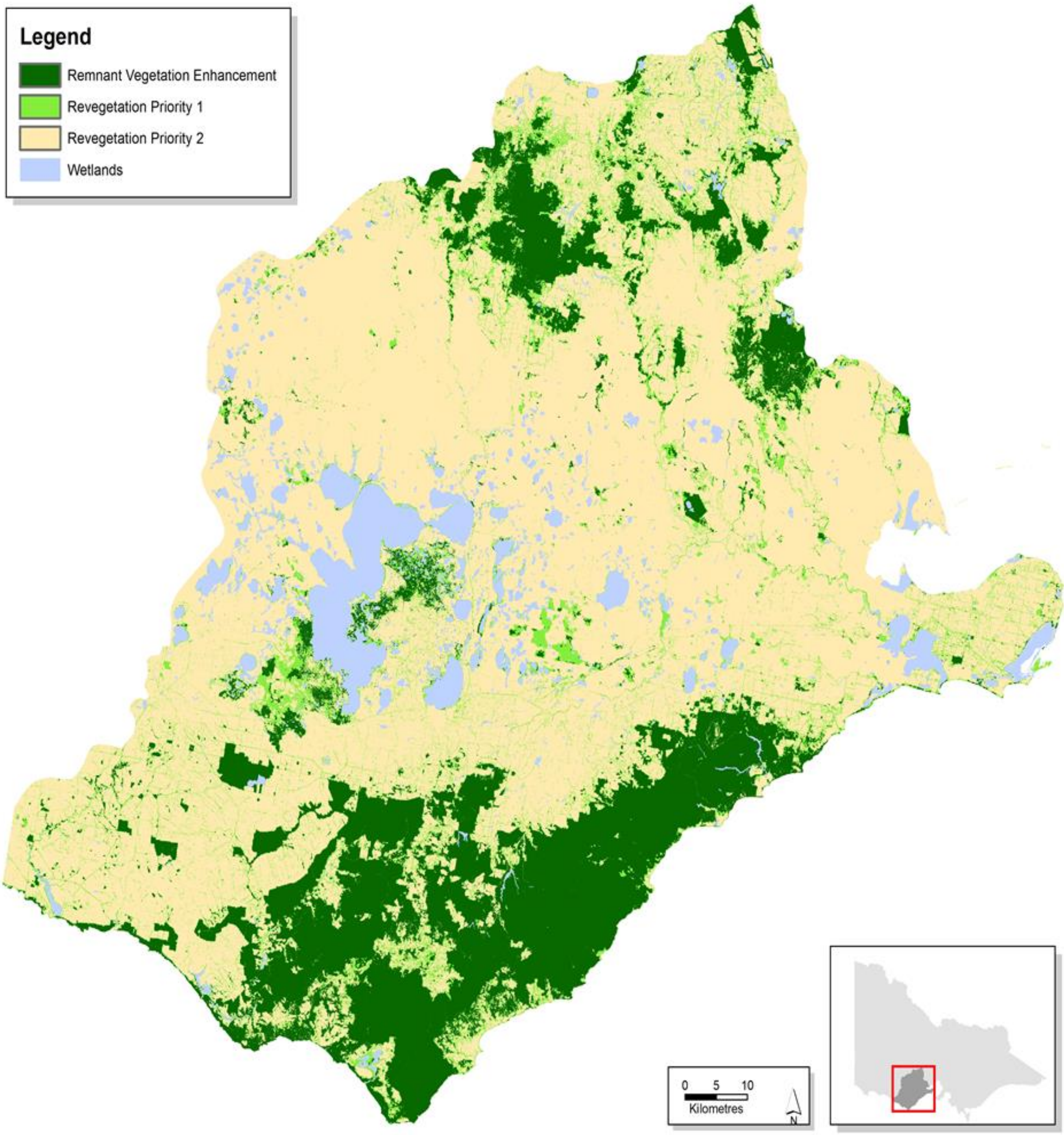



**Figure 18: Terrestrial carbon sequestration priorities**

## 5.3 Revegetation

Revegetation is another recognised method of encouraging carbon sequestration through the Australian Government's ERF.

Revegetation, through biodiverse plantings, has many other NRM benefits, and is one of the most effective ways to make many of the region's landscapes more resilient to climate change. Mainly through buffering existing remnants, protecting riparian areas and reducing existing threatening processes such as soil erosion. Revegetation can also increase connectivity i.e. buffers, corridors, stepping stones, between existing areas of fauna habitat, and create refugia. This will be important as the region's climate changes and some fauna in existing locations need to move to more favourable areas.

Species selection for revegetation programs will reflect what is currently being planted now, i.e. species indigenous to the area. With projected changes to the region's climate, there is an expectation existing plant species will need to be replaced with species that are more suitable to a warmer, drier climate. Feedback from the native vegetation REP workshop discussed this potential need, however, it was determined that EVCs are quite resilient in their own right, and while some may lose certain species, there is no requirement to replace indigenous species with those that may be deemed more appropriate under a changing climate.

Similar to the carbon sequestration methods already mentioned, regional priorities for revegetation for carbon sequestration purposes should also be assessed on a site-by-site basis, with other NRM benefits being used to help prioritise potential sites. Areas highlighted in light green in Figure 18 (revegetation priority one) are areas of high carbon sequestration potential, combined with other NRM benefits such as buffering and linking fragmented remnant vegetation, and should be used as a guide only. The region has an estimated total of 120,751 hectares, or 9% of the region, which can be categorised as high priority areas of potential revegetation for carbon sequestration and which also address other NRM benefits.

This map can be accessed from the portal at [www.swclimatechange.com.au](http://www.swclimatechange.com.au)

**Implementing Emissions Reduction Fund projects within the Corangamite region**

The Australian Government's main funding source for carrying out revegetation projects that seek to address carbon sequestration outcomes is through the Emissions Reduction Fund. The Government sets the elements and funding of the ERF. As well as mitigation outcomes, the ERF draws on complementary measures, such as reducing salinity and erosion, improving water quality and protecting biodiversity to ensure that its 2020 target is met.

ERF project proponents need to confirm that their projects are consistent with 'Regional NRM Plans' such as the Corangamite NRM Plan for Climate Change. To encourage this consistency, the Corangamite CMA recommends the following principles for ERF project proposals that have revegetation components;

- Protect, enhance and restore areas of high biodiversity conservation
- Improve landscape resilience through enhancing existing ecological linkages and increasing functional biolinks
- Increase the resilience of soils
- Prioritise areas of low value agricultural land and degraded landscapes
- Do not impact on existing natural values, i.e. native vegetation communities
- Consider bushfire risks and potential impacts on designated high yield water catchment areas.

Projects should also align to priorities within the RCS as well as refer to other existing regional NRM plans, i.e. the Corangamite Waterway Strategy, when proposing a carbon farming project. It is important to note that key carbon farming activities can support the implementation of the RCS. These should be included in project proposals and include:

- Natural regeneration – to assist carbon stocks associated with existing native habitat
- Environmental plantings – to increase terrestrial carbon stock through revegetation, especially along waterways, and to buffer and connect high value remnant vegetation.
- Other plantings – establish forested areas on land that has not recently supported native forest cover. This may include agroforestry, other forms of farm forestry or long-rotation hardwood plantation, particularly those plantations incorporating indigenous species.
- Grazing system change – to increase soil carbon through implementing management actions such as flexible grazing techniques based on pasture and stock requirements (while ensuring other emissions such as methane and nitrogen are also managed).
- Blue carbon – sequestration through the conservation and restoration of freshwater and estuarine ecosystems such as wetlands, saltmarsh, mangroves and seagrass.

Alignment of projects with these priorities will help ensure carbon farming activities contribute to the vision and goals of the Regional Catchment Strategy. These principles should be considered when applying carbon farming activities from the Australian Government's Emission Reduction Fund, as well as the voluntary market.

In addition, the Corangamite CMA encourages the use of the ERF's "Negative List" for all carbon farming activities within Victoria. This list ensures proposed projects do not impact on natural assets and their associated values and can be found at www.environment.gov.au/climate-change/emissions-reduction-fund/cfi/negative-list

***Mountain Ash Forest. Photo: Alison Pouliot***

## 5.4 Blue carbon

Saltmarsh, mangroves and seagrass meadows are collectively known as "Blue Carbon" habitats. Blue carbon habitats have recently been identified as one of the most effective carbon sinks on the planet. Such habitats can bury carbon at a rate 35-57 times faster than tropical rainforests and can store carbon for thousands of years. These features make vegetated coastal habitats ideal candidates for carbon offset programs and nature-based climate mitigation initiatives (Carnell *et al.* 2015). The main benefits of blue carbon habitats include;

- Their ability to sequester nearly equivalent quantities of organic carbon as their terrestrial counterparts, in spite of their comparatively limited biomass (0.05% of terrestrial plant biomass).
- They can store organic carbon at almost 40 times the rate of terrestrial systems (Fourqurean *et al.* 2012a), largely due to their relatively anaerobic soils preventing organic carbon remineralisation and therefore promoting long-term sequestration (Mateo *et al.* 1997; Pedersen *et al.* 2011).
- Carbon in blue carbon habitats may be stored for centuries to millennia.
- Blue carbon habitats can both produce and store their own carbon, but also trap carbon produced from other locations.
- Their ability to trap particles and suspended sediment means that they may appropriate large quantities of carbon that originates from adjacent habitats, both terrestrial and marine (Gacia and Duarte 2001; Agawin and Duarte 2002; Hendriks *et al.* 2008; Kennedy *et al.* 2010). This is of particular importance in the Corangamite region where a majority of waterways filter through coastal saltmarsh before entering the sea.
- In addition to their important role in carbon sequestration, blue carbon habitats also provide a range of ecosystem services, such as nursery habitat for many fish species and play a critical role in shoreline stabilisation, which is increasingly important with respect to sea-level rise and extreme weather events associated with climate change (i.e. storm surges).

***Barwon River Estuary. Photo: Alison Pouliot***

While blue carbon habitats are excellent at accumulating carbon, degradation and loss of vegetated coastal habitats via mismanagement could shift them from carbon sinks to carbon sources, releasing atmospheric $CO_2$ equivalent to annual damages of US$6 to 42 billion globally (Pendleton *et al.* 2012). Examples of impacts include land clearing, changes to tidal influences and stock grazing.

The region is fortunate in that many of its original areas of blue carbon habitat are secure with a large majority of what remains being managed for conservation purposes, i.e. within a reserve system and/or being managed through incentives by the Corangamite CMA. However, with projected changes in sea level rise and competing use for land development, many of these areas are now vulnerable. The protection, and improvement of, the adaptive capacity of these habitats should, and will be, a priority for the region.

In 2014, the Corangamite CMA identified a lack of information on the distribution and abundance of blue carbon within the catchment. Such information is critical for guiding the spatial prioritisation of conservation efforts. To address this knowledge gap, the Corangamite CMA commissioned researchers from Deakin University to conduct the region's first blue carbon stock assessment, focussing on sedimentary organic carbon. Figure 19 provides a map of where sampling was undertaken.

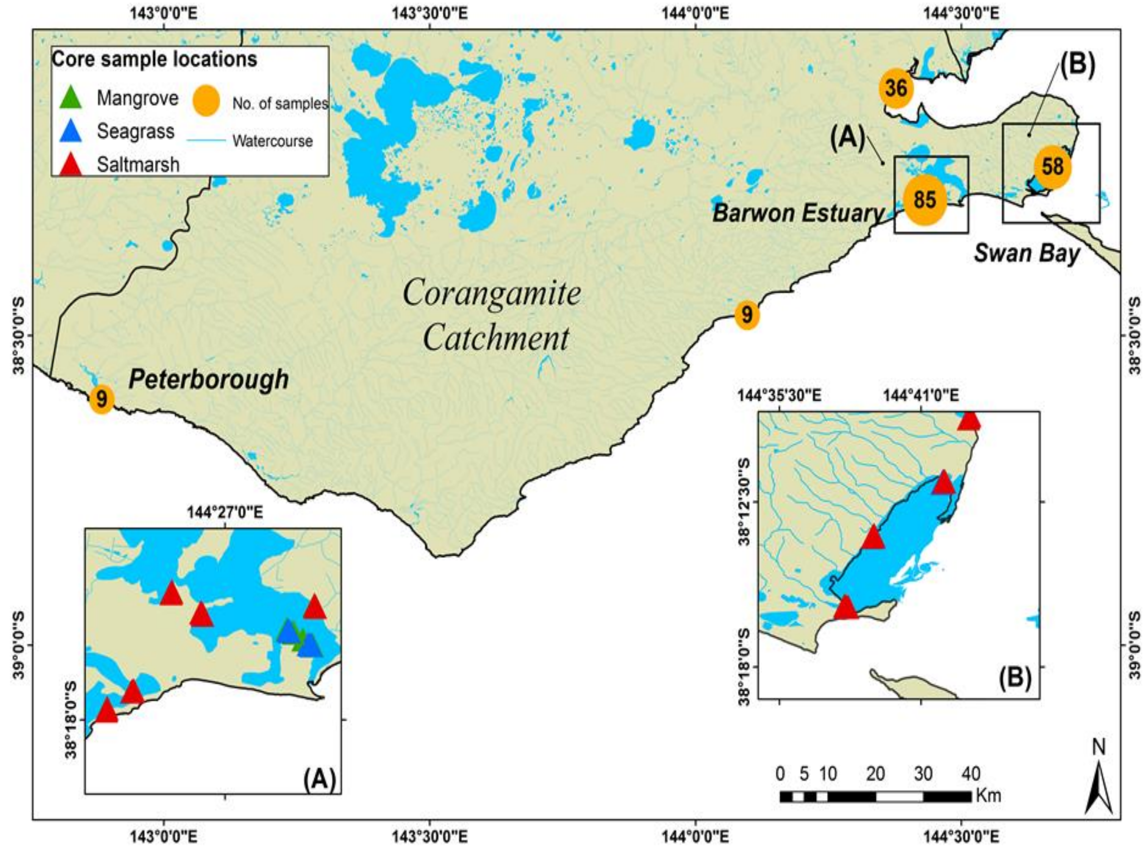



**Figure 19. Blue carbon habitat sampling sites within the Corangamite catchment. The majority of samples were taken from the Barwon River Estuary (Lake Connewarre) (A) and Swan Bay area (B). The number of samples collected in each area are represented by the size of the orange circles on the main map (larger circles equal more samples collected), while blue carbon habitat types are represented in the inset maps by blue triangles (seagrass), red triangles (saltmarsh), and green triangles (mangroves).**

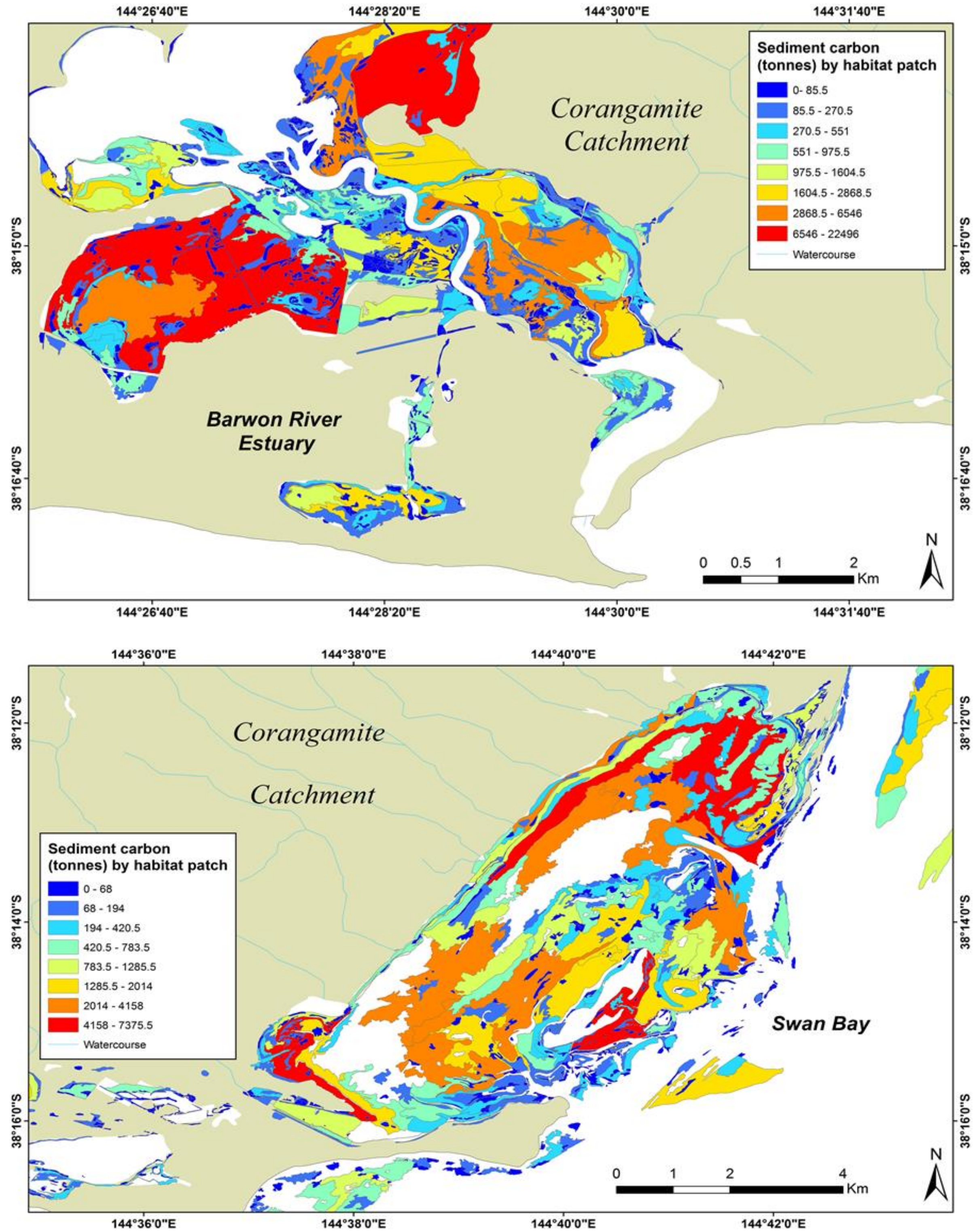



**Figure 20: Carbon heat maps for two regions of blue carbon habitats in Corangamite catchment, Barwon River Estuary (top) and Swan Bay area (bottom). Blue carbon values represent tonnes of organic carbon stored in the top 30cm of the soil in seagrass, mangrove, and saltmarsh habitat areas**.

The major findings of this program were:

- The region has an estimated total blue carbon sediment stock of 431,502.02 tonnes and a total carbon value of $6,472,530 over the top 30 cm of sediment at $15 $Mg^{-1}$ (voluntary market price). It should be noted that because current sampling was confined to the top 30 cm of sediment, the carbon estimates given here are highly conservative. In fact, since organic carbon is stored at depths up to several metres, the true value of these habitats is significantly greater.
- The average soil carbon content is 4.96%, and 64.24 Mg $C_{org}$ $ha^{-1}$ (over the top 30 cm).
- The region's carbon stock is comprised mostly of saltmarsh (62%) and seagrass (37%), with mangroves contributing < 1%, in spite of their high carbon stocks due to their limited distribution.
- Saltmarsh habitats comprised almost half of the vegetated coastal habitat samples in the region and were found to have high carbon stocks, with exceptionally high values recorded at Aireys Inlet, Breamlea, Lake Connewarre, Hospital Swamp, Indented Head and Swan Bay.
- Higher carbon stocks were found in estuaries (or closer to fluvial inputs).

Deakin University identified a number of areas that should be prioritised for conservation because of their notably high carbon stocks (Figure 20). This included areas of saltmarsh in Breamlea, Lake Connewarre and both saltmarsh and seagrass in Swan Bay.

These locations currently represent varying levels of protection for saltmarsh. Further, the trends identified in blue carbon soil stocks and carbon heat maps, provide valuable insight for identifying appropriate locations for revegetation, and potentially, carbon offset programs. These can be implemented through strategic preservation e.g. through additional fencing, or restoration of former blue carbon habitats e.g. bund/dyke wall removals and through management of catchment-level processes to enhance blue carbon sequestration within existing habitats e.g. restore natural hydrology.

Figure 21 is a regional overview of potential blue carbon habitat areas considered worthy of further research for carbon sequestration purposes.

As part of the commitment to exploring blue carbon opportunities for the Corangamite region, the Corangamite CMA, in partnership with Deakin University is sponsoring a PhD scholarship titled 'Mitigating Climate Change with Blue Carbon Ecosystems'.

The three-year project has the following objectives, to:

1. Measure carbon accumulation rates and greenhouse gas fluxes within Corangamite's current and former blue carbon ecosystems
2. Investigate the potential negative impacts of agricultural stressors on the carbon sink capacity of Corangamite's blue carbon habitats
3. Test a range of strategies for reducing carbon losses and maximise carbon gains in the Corangamite catchment.

Information and findings from this research will be made available as the project is delivered through the South West Climate Change Portal (2016 - 2019).

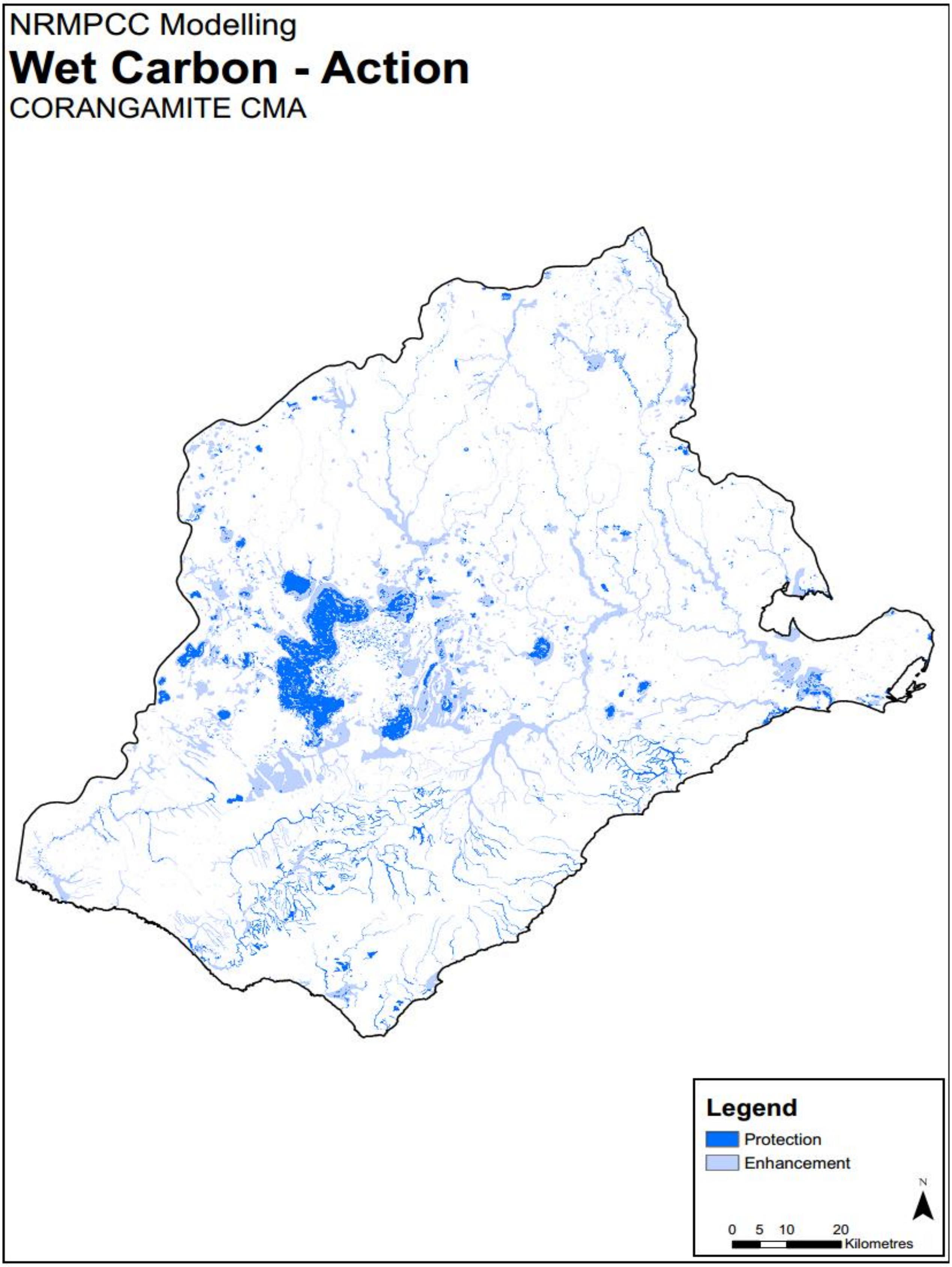



**Figure 21: Potential blue carbon priorities**

## 5.5 Soil carbon

Information for this section has been sourced from *A Review of Carbon Sequestration in Vegetation and Soils: options, opportunities and barriers for the Southern Slopes Cluster NRM organisations* developed by SCARP.

The report can be found at

www.climatechangeinaustralia.gov.au/en/impacts-and-adaptation/southern-slopes

Soil organic carbon (SOC) is essential for soil health. It assists in soil structure and provides food for soil microbes that in turn benefits plants and helps regulate nutrient cycling.

SOC is in a constant state of flux as microbes and other soil fauna decompose and convert carbon into carbon dioxide. SOC can be maintained or increased by increasing organic carbon inputs, or by reducing organic carbon losses. Management strategies aimed at increasing soil carbon may also have negative impacts. For example, changing from annual crops to permanent pastures may increase soil carbon, but it may also lead to an overall increase in total emissions when the additional ruminant livestock production (methane emissions) is taken into account.

The amount of soil carbon varies across the Corangamite region with peat soils in the region's southwest at levels greater than 10%, through to areas with high cultivation histories where the carbon level is typically less than 1%. This variation is a result of many factors, namely:

- Soil and vegetation type, which determines the carbon-holding capacity
- Climate, especially rainfall and temperature which determine the rate of decomposition
- Land management practices, both current and historic.

In general terms, on agricultural land, higher soil organic carbon is likely to be found in areas of higher rainfall where traditionally perennial pastures have been used (i.e. dairy areas), whereas lower rainfall areas with annual cropping rotations have lower soil organic levels.

A recent study by the Woady Yaloak Catchment Group - on 950 soil samples collected over 20 years - indicated the majority of results fell in a band of between 2.0% and 3.5%. They determined that cropping tended to decrease total soil organic carbon while perennial pastures increased the rate. (Woady Yaloak Catchment Group, 2012).

The amount of carbon in soil can be maintained or increased with the rate of loss influenced by the:

- The amount and type of organic matter, both plant and animal, entering the soil
- Management practices which reduce carbon inputs, increase losses and/or increase decomposition rates. Examples include cultivation, stubble removal and overgrazing
- Climate conditions such as rainfall, temperature and sunlight
- Soil properties including the clay, silt or sand content.

The natural perennial vegetation cover that existed prior to European settlement declined as a result of traditional farming practices along with the region's soil organic carbon.

Since the 1990s, the region has made progress in adopting more perennial based grazing systems and encouraged minimal cultivation cropping. Industry groups such as Sustainable Grazing Systems, Evergraze and programs delivered by the state government have led to more land management practices that have minimised carbon losses. An interest in soil carbon sequestration has also led to this shift in land management.

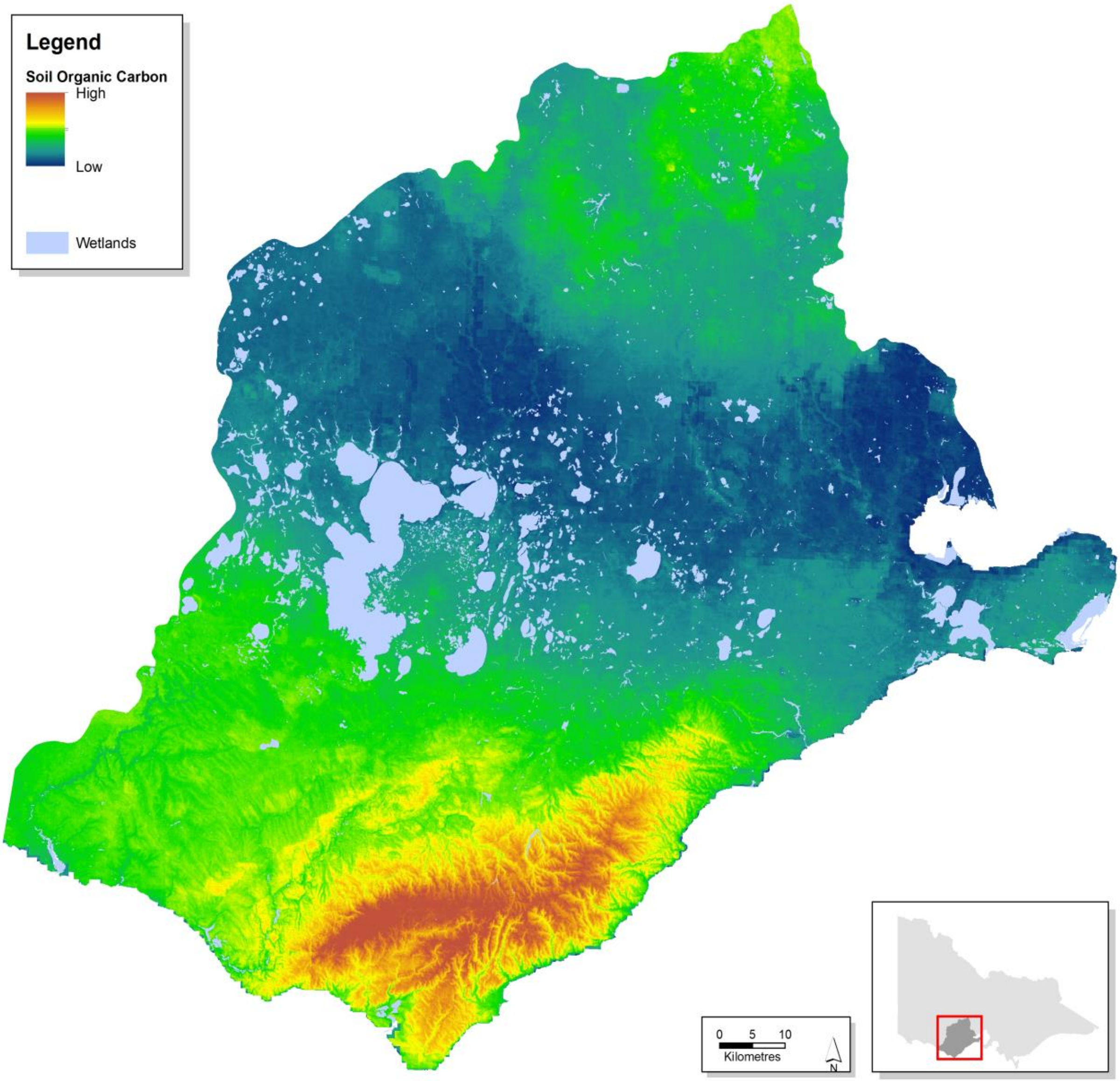



**Figure 22: Regional soil organic carbon potential**

There are three main practices to improve soil carbon in the region's soils. These are:

- Grow pastures, crops and trees to maximise above ground biomass and root production whilst appropriately 'fitting' the farming system.
- Retain as much existing soil carbon as possible.
- Use carbon rich sources or practices that increase soil function (biochar, humates, biological products, biosolids, green manure, high carbon using crops).

Actions to achieve these practices can be found in Section 7.5.

More information on soil organic carbon potential can be found in the "Brown Book", a sustainable agricultural information resource for the Corangamite region. It addresses the needs of farmers to develop simple solutions in effective management of soils to enhance productivity, including soil organic carbon. More information on the Brown Book can be found at www.ccmaknowledgebase.vic.gov.au/soilhealth/brown_book/home

# 6. Regional opportunities, challenges and strategic linkages

***Hay Bales at Ceres. Photo: Lachlan Manly***

This section explores strategic directions to enable the region to embrace a climate ready future.

While cultural shifts are needed at all levels of NRM, there are already approaches being implemented across the region addressing climate change, through the delivery of a wide variety of adaptation and carbon sequestration projects.

The section introduces the use of guiding principles for adaptation and the need to identify and prioritise management options using a proper planning approach called 'adaptation pathways'. Adaptation Pathways can be used to address climate change, at a regional and local scale, and with many stakeholders.

This section also discusses the Corangamite CMA plans to develop a regional adaptation pathways framework and then apply adaptation pathways at a landscape scale to improve adaptation planning across the region.

**Key Messages**

- The region is implementing a range of climate change adaptation and carbon mitigation projects
- Adaptation principles enable NRM managers to include climate change into project planning, design and implementation
- Adaptation pathways are a planning approach that addresses the uncertainty of climate change decision-making

## 6.1 Current regional approaches to managing for climate change

While it is important to set new, innovative directions to manage the region's natural assets under a changing climate, it's also important to acknowledge current management actions and learn from current and past practices. Most current management actions have helped natural assets become more resilient to existing threats, including climate change.

In many cases this will continue to be the most appropriate management approach, however there is a need to look for ways to assist natural assets to adapt to climate change and not just be resilient.

The following section explores how we, as a region, currently promote and implement both adaptation and mitigation approaches to NRM.

### Adaptation

The region has many examples of climate change adaptation projects, with many focusing on making natural assets more resilient to climate change.

Examples include managing environmental flows of some of the region's more stressed waterways, protecting and enhancing vulnerable wetlands on the Victorian Volcanic Plains and dune stabilisation works along the region's coastline to cope to rising sea levels.

There is a need to build on these resilient approaches, while at the same time embracing both transitional and transformational forms of NRM.

Table 11 presents examples of regional NRM projects that are assisting natural assets adapt to climate change. Some of these are concerned with resilience building, and some will enable transitions, and ultimately some transformation.

### Mitigation

The region also has many examples of NRM projects that promote carbon mitigation – usually in the form of carbon sequestration. Most projects have focused on revegetation, however, there is an increasing shift towards non-traditional sequestration practices such as blue carbon.

Many past and current carbon sequestration projects have operated on a trial basis. This, combined with an unclear carbon market, has led to uncertainty for land managers and private landholders. Examples of regional NRM projects that are promoting carbon mitigation are provided in Table 12.

**Table 11: Regional examples of current climate change adaptation projects within the Corangamite region**

| Stakeholder | Name of project | Adaptation type | Location | Objectives | Method | Further Information |
|---|---|---|---|---|---|---|
| Corangamite CMA | The Victorian Volcanic Plains and Western District Lakes Recovery Program | Resilience | Wetlands and vegetation communities within the VVP bioregion | Promote financial incentives combined with community engagement and capacity building programs to deliver conservation outcomes in high priority asset areas. These assets include:<br>• Western District Lakes Ramsar sites<br>• EPBC listed species and EPBC listed ecological communities, including wetlands, woodlands and grasslands. | The project utilises a tender based approach to deliver targeted incentive funding to public and private land managers.<br>Land managers establish their own price for the management services they are prepared to offer to improve their native vegetation. This price forms the basis of their bid which is compared with the bids from all other participating land managers. Successful bids are those that offer the best value for money. | www.ccma.vic.gov.au |
| Corangamite CMA | Coastal Saltmarsh Protection Project | Resilience | Coastal Saltmarsh communities | Promote financial incentives combined with community engagement and capacity building programs to deliver conservation outcomes in high priority asset areas. These assets include:<br>• areas of Coastal Saltmarsh<br>• known habitat sites of the Orange-bellied Parrot | The project utilises a tender based approach to deliver targeted incentive funding to public and private land managers.<br>Land managers establish their own price for the management services they are prepared to offer to improve their coastal saltmarsh. This price forms the basis of their bid which is compared with the bids from all other participating land managers. Successful bids are those that offer the best value for money. | www.ccma.vic.gov.au |
| Heytesbury District Landcare Network | Yellow-bellied Glider Wildlife Corridor Project / Rufous Bristlebird Biolink Project | Transition | Curdies Landscape Zone | Create biolinks between fragmented areas of remnant vegetation in the Curdies River catchment, to improve long-term habitat opportunities for the Yellow-bellied Glider. | Encourage private landholders to protect, and enhance remnant vegetation on their properties, as well as revegetate riparian and gully areas, using indigenous plant species | www.heytesburylandcare.org.au |

| Stakeholder | Name of project | Adaptation type | Location | Objectives | Method | Further Information |
|---|---|---|---|---|---|---|
| City of Greater Geelong/ Borough of Queenscliff | Geelong - Queenscliffe Coastal Adaptation Program | Resilience/ Transition | Coastal zone of Corio Bay and Bellarine Peninsula | The program has three key phases:<br>- Modelling sea level rise<br>- Identifying and assessing risks<br>- Developing adaptation solutions | The project's main aim is to improve the capacity of the two Councils to use climate assessment information in conjunction with coastal hazard data to assess risk.<br>Determining risk will allow NRM planners to formulate appropriate adaptation responses in terms of planning, asset management and conservation of environmentally sensitive areas. | www.geelongaustralia.com.au |
| Corangamite CMA | Moorabool Environmental Water Management Plan<br>(Moorabool River Environmental Entitlement 2010) | Transition | Moorabool River | To improve the Moorabool Rivers flow-dependent ecological values and services through the provision of environmental water. The delivery of environmental water also provides social and cultural values for both current and future generations. | The Corangamite CMA has a statutory role under the Water Act to manage environmental water entitlements to achieve ecological outcomes with the use of environmental water. Annual Seasonal Watering Plans are developed to deliver environmental water and consider seasonal and climatic impacts. | www.ccma.vic.gov.au |
| Corangamite CMA | Barwon River Environmental Entitlement 2011 | Transition | Lake Connewarre<br>(Reedy Lake and Hospital Swamps) | To maintain the ecological character of the lower Barwon Wetlands. | The Corangamite CMA has a statutory role under the Water Act to manage environmental water entitlements to achieve ecological outcomes with the use of environmental water. Annual Seasonal Watering Plans are developed to deliver environmental water and consider seasonal and climatic impacts. | www.ccma.vic.gov.au |
| Wannon Water/ Corangamite CMA | Improving Environmental Flows in the Gellibrand River | Transition | Gellibrand River | Assess a preferred water supply augmentation option and implementation process to improve critical flows in the Gellibrand River through the summer low flow period. | Assess augmentation options to better understand the supply security benefits and the change in demand for water. Quantify the environmental benefits of maintaining summer base flows to levels below the recommendations in the assessment of environmental flow requirements. | www.depi.vic.gov.au/water/governing-water-resources/sustainable-water-strategies/western-region-sustainable-water-strategy |

**Table 12: Regional examples of climate mitigation projects within the Corangamite region**

| Stakeholder | Name of project | Carbon sequestration type | Location | Objectives | Method | Further Information |
|---|---|---|---|---|---|---|
| Corangamite CMA | Corangamite Carbon Capture Recovery Project | Remnant vegetation enhancement/ revegetation | Regional | Prioritise sites based on carbon sequestration potential, landscape context and other NRM benefits | The project utilises a tender based approach to deliver targeted incentive funding to public and private land managers.<br>Land managers establish their own price for the management services they are prepared to offer to undertake works. This price forms the basis of their bid which is compared with the bids from all other participating land managers. Successful bids are those that offer the best value for money.<br>Land managers undertaking revegetation activities in this project also have the opportunity to participate in the Australian Government's Carbon Farming Initiative (CFI). Landholders receive a figure of estimated carbon sequestration in which they can use as a starting point to enter the carbon market. | www.ccma.vic.gov.au |
| City of Greater Geelong | City of Greater Geelong Urban Forest Strategy 2015-2025 | Revegetation | City of Greater Geelong region | 'Green the City' through increased numbers of tree planting<br>'Cool the City' through strategic tree planting.<br>Engage the community and build regional partnerships<br>Promoting 'best practice' urban tree management | 'Green the City' through planting out 45,000 vacant nature strips and planting 500 additional advanced trees per annum<br>'Cool the City' through increasing canopy cover to 25% leading to reduced temperatures, increased shade and reduced energy use<br>'Engage the community and build regional partnerships' through improving community involvement, educating the community and strengthening key tree planting partnerships<br>Promoting 'best practice' urban tree management through improving tree planting consistency across Council, having structurally sound and healthy trees and encouraging appropriate species and age diversity of trees | www.geelongaustralia.com.au |

| Stakeholder | Name of project | Carbon sequestration type | Location | Objectives | Method | Further Information |
|---|---|---|---|---|---|---|
| Victorian State Government | CarbonTender (completed 2006) | Revegetation | Otway Plain & Otway Ranges Bioregions | Purchase "carbon rights" from private landowners by paying landholders to create "greenhouse sinks"<br><br>Prioritise sites based on carbon sequestration potential, landscape context and other NRM benefits | The project utilised a tender based approach to deliver targeted incentive funding to public and private land managers. Contracts were offered to the best value bidders (dollars per tonne of carbon dioxide offset). Sites that linked or buffered remnant vegetation were given highest priority.<br><br>CarbonTender offered the potential for two new income streams to landholders – first through guaranteed establishment payments from the Victorian Government for the first five years, and then through possible income opportunities from carbon trading markets. | www.delwp.vic.gov.au |
| Corangamite CMA | The Distribution and Abundance of 'Blue Carbon' within Corangamite<br><br>(completed 2015) | Blue carbon | Blue carbon habitats (mangroves, seagrass communities, coastal saltmarsh communities) of the region | Determine the distribution and abundance of blue carbon within the region (coastal)<br><br>Prioritise areas of blue carbon for conservation<br><br>Provide regional recommendations for managing areas of blue carbon<br><br>Provide recommendations for further blue carbon research | To quantify and characterise the carbon sequestration capacity of blue carbon habitats across the region, a combination of geospatial analysis and sediment carbon content analyses was done.<br><br>This provided carbon 'hotspot' modelling for the region. | www.ccma.vic.gov.au |

## 6.2 Identifying and prioritising options – using adaptation pathways

Planning for climate change requires a shift from what are usually considered normal and traditional planning approaches with one final outcome, towards another that considers multiple possible outcomes.

Approaches such as 'adaptation pathways' can help us think through and plan for multiple possible futures.

Adaptation pathways is a planning approach addressing the uncertainty and challenges of climate change decision-making. It enables consideration of multiple possible futures and allows analysis/exploration of the robustness and flexibility of various options across those multiple futures.

This section explores the concept of adaptation pathways and is largely based on work developed by SCARP in partnership with NRM regions within the Southern Slopes Cluster (SSC).

More information on this work can be found in 'Adaptation Pathways: a playbook for developing robust options for climate change adaptation in Natural Resource Management' at www.climatechangeinaustralia.gov.au/en/impacts-and-adaptation/southern-slopes

### What is 'adaptation pathways' planning?

NRM planning needs to be able to justify, prioritise and implement actions, whilst at the same time recognise and allow for future changes in climate, environment, values (both social and economic), knowledge, socio-political environment, and climate modelling systems.

Adaptation pathways acknowledge these and allow NRM planners to plan for change and allow for uncertainty. SCARP has come up with a list of advantages of adaptation pathways when compared to other existing NRM planning processes. An adaptation pathways approach allows NRM planners to:

- **Adopt strategic rather than reactive planning:** So rather than being driven by current policies, conditions and issues, adaptation pathways encourage creative forward thinking about potential and desirable futures.
- **Develop an adaptively robust strategy:** This facilitates short-term actions, leaves options open, and provides a guiding framework for monitoring the robustness of specific options across possible futures. Sequencing such actions identifies when, why and how to change course and sets the foundations for a 'living' plan.
- **Use vulnerability assessments for action planning:** This addresses underlying drivers of those vulnerabilities.
- **Adopt a social learning approach to adaptation: Through** co-learning among decision-makers, researchers and other stakeholders, issues and problems can be discussed in order to define a greater array of potential options and actions. Adopting a learning approach to planningaids in greater insights into the current situation and can facilitate identification of more innovative transitional and transformational pathways.
- **Facilitate discussions:** Discussions with and among stakeholders about possible adaptation options and pathways preferences.
- **More readily recognise potential maladaptive actions:** Undesirable outcomes can result from a narrow focus on simple cause-effect relationships or assumptions that individual approaches or policies are 'right'. Using a pathways approach can help identify when an option or pathway may shut-down future options, thus reducing plan robustness.

- **Support best practice in regional NRM**: Existing good practice helps to reduce vulnerabilities to climate change impacts, and using pathway planning allows NRM planners to commit to short-term actions within a larger framework that guides the robustness, including flexibility, of future actions.

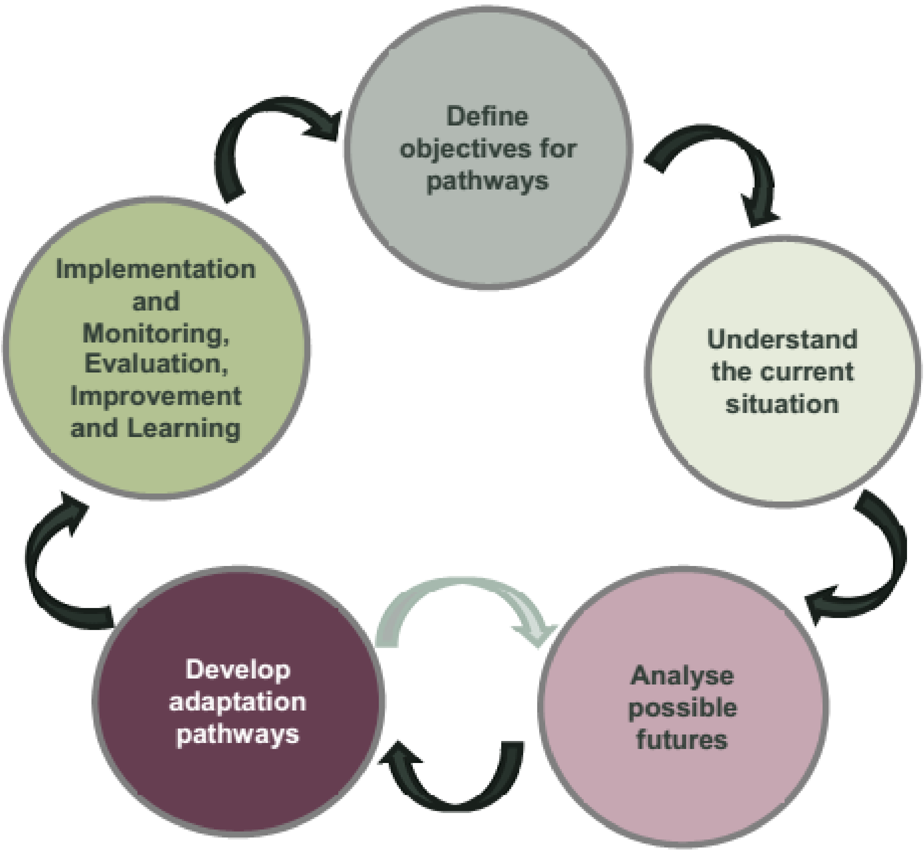



**Figure 23: Five stages of adaptation pathways planning**

Adaptation Pathways consists of five core components (Figure 23 above). As the pathways approach is designed to be adaptive this process can also be flexible. For example, instead of a linear approach that is usually adopted in NRM, a more reflective, adaptive approach is used.

**1. Defining objectives for pathways**

As with most NRM planning processes, defining the objective - determining what you want to achieve - is a crucial initial step. Objectives need to be specific, measureable and time framed, and need to relate to an overall goal. Developing appropriate objectives allows better options for developing and evaluating options, as well as providing a basis for monitoring and evaluating all stages of the adaptation pathways planning approach.

**2. Understanding the current situation**

Knowing as much about the natural asset or landscape that the adaptation pathway is being designed for provides a basis for analysing potential future and developing pathways. It can be done in three steps.

1. Analyse the current situation and with historical information reflect on how the asset has been managed. Use this information to develop potential future management options.
2. Determine management actions that may lead to reducing the vulnerability and/or increase the adaptability opportunities for the asset you are developing a pathway for.
3. Identify evidence-based, robust, 'no regret' options.

Understanding the current situation, while acknowledging the past, helps inform how a pathway approach might be best developed.

There are six main aspects to consider when assessing current situations. These include level of agreement (i.e. what the objectives are amongst stakeholders); degree of scientific certainty; scale; capacity (of the asset manager); urgency and number of stakeholders involved.

When these are considered in collaboration with stakeholders involved in implementing the pathways, current situations can be more clearly understood and future options better developed. It is important to note that decisions about these categories are subjective and set processes and tools are often needed to determine each.

**3. Analysing possible futures**

Stage three involves exploring a number of potential futures, and developing various management responses. It is important to acknowledge at this stage other factors influencing a management response, such as future policies, markets and social values. In any case, the future is always going to be uncertain. By developing a range of scenarios, a range of options can be tested and determined if they are robust, flexible or both.

The choice or relevance of future analysis methods should be determined by the type of 'problem' the current situation presents. There are a range of tools and decision frameworks to help determine potential futures. More information on these can be found in Section 7.4.

**4. Developing adaptation pathways: identifying and prioritising options**

Stage four is the main component of adaptation pathways planning.

It identifies potential adaption options and determines the flexibility and robustness of each. Potential turning, tipping and trigger points are identified, and alternate options that can lead to original objectives are determined. This stage is reliant on work done in stages two and three.

There are six steps in identifying adaptation pathways for a particular objective:

1. Identify options to address existing drivers of vulnerabilities under current conditions
2. Identify tipping points, turning points and trigger points (see Table 13)
3. Identify alternate and additional options to help address objectives under the range of potential futures
4. Sequence and document potential actions into draft pathways
5. Analyse and evaluate the pathways
6. Finalise and document or map pathways.

| |
|---|
| **Tipping points - what is likely to change in the biophysical system?** |
| These are biophysical thresholds where the magnitude of change means the current management strategy will no longer be able to meet the objectives. Identifying these helps to indicate whether and when other options are needed. An example of a tipping point is when an estuarine mangrove community, which cannot retreat because of geological or infrastructure constraints, becomes permanently inundated under sea level rise scenarios. |
| **Turning points - what are the plausible 'game changers' in the socio-economic conditions or rules?** |
| These are situations in which a social–political barrier is reached. This may be due to climate change, or changes in formal policy objectives as well as informal societal preferences, stakes and interests. For example, a policy change relating to the mechanism for pricing carbon can lead to landscape-scale changes in re-afforestation with implications for conservation, livelihoods and rural communities. A social threshold relevant to south-eastern Australia may be the point at which too many regional landholders are 'absentees' to effectively enact community-based NRM. |
| **Trigger points—when do we need to start?** |
| Trigger points mark the necessary lead time for action before reaching a turning point. They are also defined by how long a decision to change takes to be made and implemented. However, this aspect of defining trigger points stems from the next stage of identifying alternate options. They are a crucial part of a pathways approach; enabling plans to be strategic and anticipatory, rather than reactive and ad hoc. |

**Table 13: Tipping, turning and trigger points**

### 5. Implementation and Monitoring, Evaluation, Reporting, Improvement and Learning

A sound monitoring, evaluation, reporting and improvement (MERI) system is fundamental to adaptation to enable both adaptive management and governance. Monitoring of key indicators of systems change (e.g. tipping, turning and trigger points) underpins decision-making about adjustments to strategies, operational plans and implementation practices. MERI can help make successes reproducible. It makes the strengths and weaknesses of different forms of activity, intervention and investment explicit. Learning from MERI is also important and can take many forms. Learning about what worked and didn't through implementation can link back to higher level strategies and policies through good MERI and governance across many scales.

For further information and guidance on how to apply these steps, refer to SCARP's 'Adaptation Pathways: a playbook for developing robust options for climate change adaptation in Natural Resource Management' at

www.climatechangeinaustralia.gov.au/en/impacts-and-adaptation/southern-slopes

## 6.3 Applying adaptation pathways in the Corangamite region

A regional framework for applying adaptation pathways will be provided on the South-West Climate Change Portal (www.swclimatechange.com.au - note still under development).

This framework will be reviewed and improved to provide guidance for developing, implementing and reviewing adaptation pathways at a landscape and asset level.

An adaptation pathway approach can assist land and resource managers understand the link between actions and possible changes in climate to achieve a more resilient landscape.

Providing the information and tools required to develop pathways through the Corangamite NRM Planning Portal (www.ccmaknowledgebase.vic.gov.au/nrmpp/), will enable this process to be readily applied across the region.

Local NRM stakeholders will be the leading contributors to how adaptation pathways are applied at the local level and regional bodies will be the leading contributors at a regional and/or asset level. Learnings from implementing the adaption pathways process may be shared on the NRM Planning Portal to demonstrate how adaptation pathways are applied at the regional, landscape and asset scale.

### Case studies

Case studies for each of the region's natural asset groups have been developed and are provided in this plan in Tables 13-19. They cover:

- Native vegetation (Coastal Saltmarsh)
- Rivers and streams (Moorabool River)
- Estuaries (Aire Estuary)
- Wetlands (Lake Colac)
- Coastal wetlands (Swan Bay)
- Flora and fauna (Corangamite Water Skink) and
- Soil (Woady Yaloak)

These case studies were developed as part of each respective REP workshop and have been refined using current NRM information and projected changes to climate. They have been developed to provide guidance for adaptation pathways when it is applied at a landscape zone scale.

Each management action has been classified as either a 'resilience', 'transitional' or 'transformational' adaptation type, as described on page 23.

Risk assessment ratings are included for the categories of:

- Enablers (level of land managers – quantity and acceptance to undertake action)
- Financial (cost associated to undertake action)
- Socio-political (the amount of acceptance from a political and/or community perspective)
- Perverse outcomes (the likelihood of the action's impact on other natural assets and/or values)

A rating of high, medium and low has been provided for each of these. Risk assessment ratings are included for the categories.

**Table 13: Example Adaptation Pathways Case Study – Moorabool River (Reaches 5 & 6)**

**Objective: Maintain the viability (recruitment and survival) of populations of native fish species as water availability**

| Management Type | Management Action | Information Source | Adaptation Type | 2015 -2020 |
|---|---|---|---|---|
| Advocacy (i.e. policy & legislation) | Encourage farm dams to pass summer flows | REP Workshop - Waterways | Resilience | |
| | Deliver current environmental water entitlements as per Environment Water Management Plan for Moorabool River | CCMA (2015b) | Resilience | |
| | Protect & increase current regulated and unregulated environmental water entitlements | REP Workshop - Waterways | Transitional | |
| Research | Research impacts of adjacent farm dams regarding reaches 5 and 6 | REP Workshop - Waterways | Resilience | |
| | Research the effect on water demand in the Moorabool Catchment in response to the changing climate & water resource constraints | SCARP (2015) | Resilience | |
| | Use LiDAR & ground truthing to identify potential 'shade zones' and 'habitat pools' to increase refugia potential | REP Workshop - Waterways | Resilience | |
| | Identify habitat requirements of platypus in Reach 5, Moorabool River's Flagship Species | REP Workshop - Waterways | Transitional | |
| | Undertake an assessment on instream habitat (large wood) density | CCMA (2015b) | Resilience | |
| Planning | Develop, implement and review Environment Water Management Plan for Moorabool River | REP Workshop - Waterways | Transitional | |
| | Plan for habitat connectivity and refugia requirements of fauna based on appropriate research | REP Workshop - Waterways | Transitional | |
| | Develop appropriate revegetation lists for reaches 5 and 6 based on predicted changes to the climate | REP Workshop - Waterways | Transitional | |
| | Plan for appropriate relocation sites from Sutherlands Creek for Yarra Pygmy Perch based on previous research | REP Workshop - Waterways | Transformational | |
| Social Capacity (i.e. community engagement) | Numerous Government measures within Western Region Sustainable Water Strategy (2011) | DSE (2011) | Transitional | |

**and quality change**

| Timeframe | | | | | Risk (High = red, medium = orange, low = yellow) | | | |
|---|---|---|---|---|---|---|---|---|
| | 2020 - 2030 | 2030 - 2050 | 2050 - 2070 | 2070 - 2090 | Enablers | Financial | Social-Political | Perverse Outcomes |
| | | | | | Red | Red | Red | Yellow |
| | | | | | Orange | Orange | Orange | Yellow |
| | | | | | Orange | Orange | Orange | Yellow |
| | | | | | Red | Orange | Red | Yellow |
| | | | | | Orange | Red | Orange | Yellow |
| | | | | | Yellow | Yellow | Yellow | Yellow |
| | | | | | Yellow | Yellow | Yellow | Yellow |
| | | | | | Yellow | Orange | Yellow | Yellow |
| | | | | | Orange | Orange | Orange | Yellow |
| | | | | | Yellow | Yellow | Yellow | Yellow |
| | | | | | Yellow | Yellow | Yellow | Yellow |
| | | | | | Orange | Orange | Yellow | Yellow |
| | | | | | Orange | Orange | Orange | Yellow |

| Management Type | Management Action | Information Source | Adaptation Type | 2015 -2020 |
|---|---|---|---|---|
| | Develop river management recommendations for reaches 5 and 6 applicable for a river system with 30% less rainfall but with more rainfall intense events | REP Workshop - Waterways | Transitional | |
| Incentives | Develop appropriate incentives for stewardship for private landholders | CCMA (2015b) | Transitional | |
| On-ground Actions | Protect riparian vegetation through fencing | CCMA (2015b) | Resilience | |
| | Maintain fencing | CCMA (2015b) | Resilience | |
| | Undertake woody weed control | CCMA (2015b) | Resilience | |
| | Restore riparian zone using appropriate revegetation | CCMA (2015b) | Transitional | |
| | Maintain revegetation | CCMA (2015b) | Transitional | |
| | Translocation of Yarra Pygmy Perch from Sutherlands Creek | REP Workshop - Waterways | Transformational | |
| | Remove weirs/barriers as determined by regional research | REP Workshop - Waterways | Transitional | |
| Monitoring | Maintain Waterwatch program | CCMA (2015b) | Transitional | |
| | Monitor the effect on water demand in the Moorabool Catchment in response to the changing climate & water resource constraints | SCARP (2015) | Resilience | |
| | Annual evaluation of 'natural' flooding using remotely sensed imagery | SCARP (2015) | Transitional | |

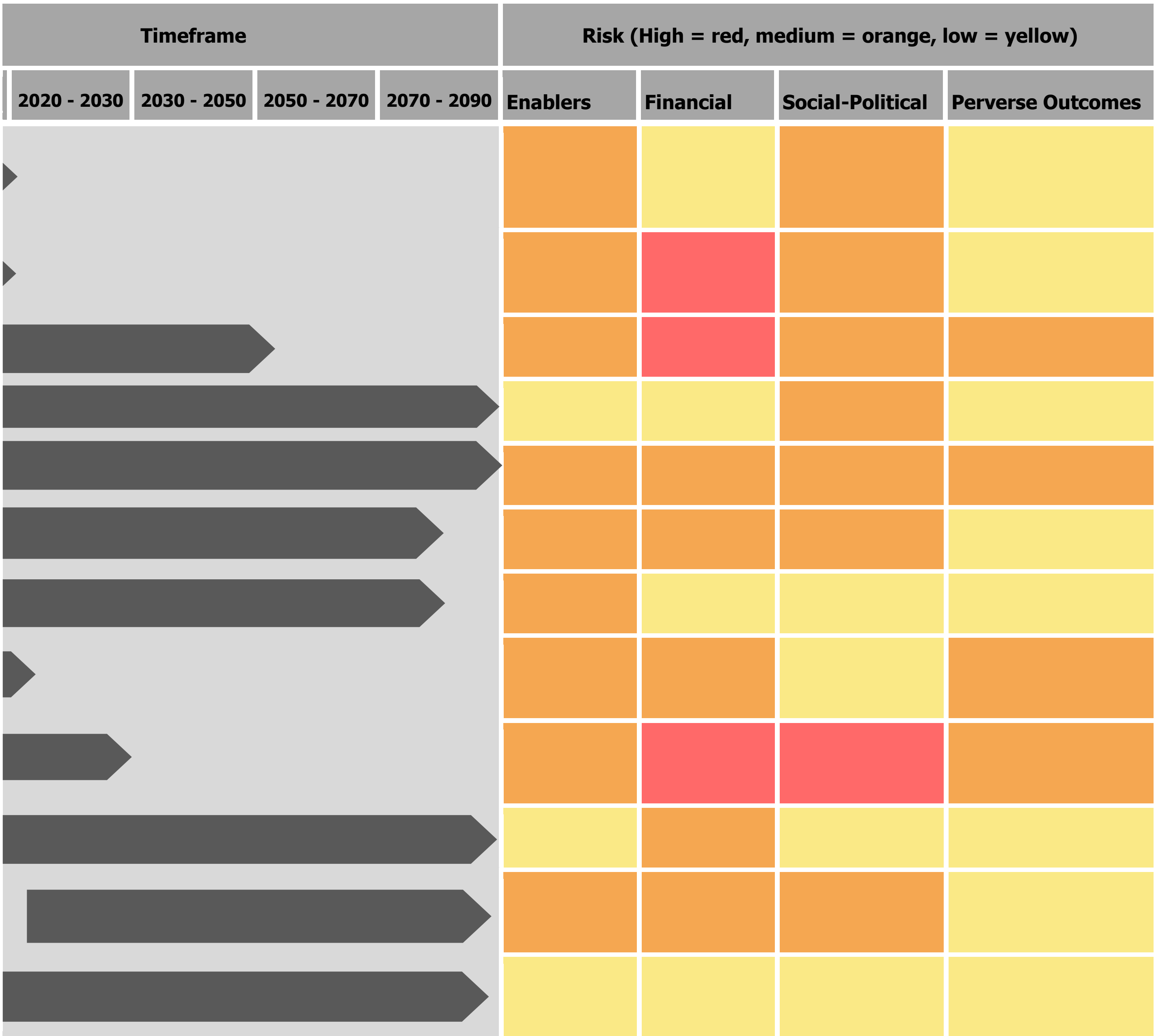
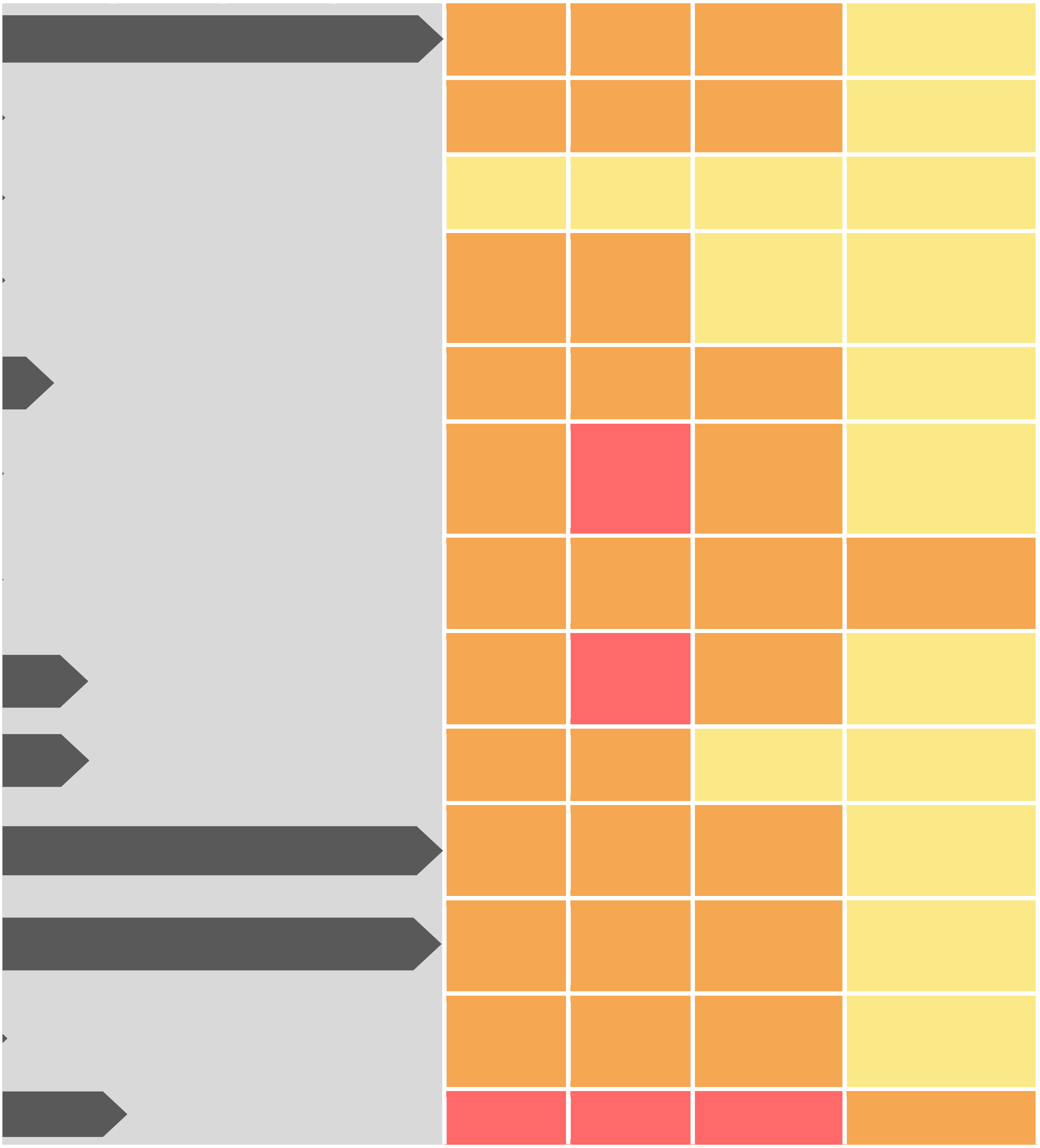

Timeframe
Risk (High = red, medium = orange, low = yellow)
2020 - 2030
2030 - 2050
2050 - 2070
2070 - 2090
Enablers
Financial
Social-Political
Perverse Outcomes

**Table 14: Example Adaptation Pathways Case Study – Aire Estuary**

**Objective: Maintain and improve ecosystem functionality of the Aire Estuary, as type, composition, structure and proc**

| Management Type | Management Action | Information Source | Adaptation Type | 2015 - 2020 |
|---|---|---|---|---|
| Advocacy (i.e. policy & legislation) | Develop a Memorandum of Understanding outlining the roles and responsibilities for artificial openings of the estuary. | CCMA (2015a) | Transitional | |
| | Ensure that the effects of climate change are incorporated into the Colac Otway Shire Planning Scheme by 2020 | REP Workshop - Estuaries | Transitional | |
| Research | Investigate further the blue and green carbon sequestration potential in the Aire Valley floodplain | CCMA (2015a) | Transitional | |
| | Conduct research into the life cycle of Australian Mudfish within the Aire Estuary. Specifically, determine the sequence and timing of events, and what adaptability the fish may have to climate change. | DSE ( | Resilience | |
| | Assess natural freshwater flow regimes into the Aire Estuary catchment and provide recommendations for improved flows. | REP Workshop - Estuaries | Transitional | |
| | Assess the likely impacts of climate change on estuary processes (i.e. tidal exchange, berm position and shoreline recession, entrance openings, water balance, geomorphology, water quality and biodiversity). | REP Workshop - Estuaries | Transitional | |
| Planning | Incorporate key findings of the State-wide Drainage Strategy (currently draft) that contribute to the management of the estuary. | CCMA (2015a) | Transitional | |
| | Investigate opportunities to upgrade infrastructure that becomes inundated with high estuary water levels, with 'green infrastructure'. | CCMA (2015a) | | |
| | Use LiDAR to identify latitudinal and elevational gradients, areas of refugia and opportunities to enhance connectivity. | REP Workshop - Estuaries | Transitional | |
| Social Capacity (i.e. community engagement) | Plan, develop and implement an 'Adaptation Pathways Plan' for the Aire Landscape Zone. | REP Workshop - Estuaries | Transitional | |
| Incentives | Establish management agreements with private landholders within the Aire River estuary to improve resilience of estuarine vegetation to climate change. | CCMA (2015b) | Resilience | |
| | Investigate opportunities for other potential sources of income for stewardship of the floodplain (e.g. carbon credits for land that is inundated). | CCMA (2015a) | Resilience | |
| On-ground Actions | Protect riparian vegetation through fencing | CCMA (2015b) | Resilience | |

| cesses change | | | | | | | |
|---|---|---|---|---|---|---|---|
| Timeframe | | | | Risk (High = red, medium = orange, low = yellow) | | | |
| 2020 - 2030 | 2030 - 2050 | 2050 - 2070 | 2070 - 2090 | Enablers | Financial | Social-Political | Perverse Outcomes |



| Management Type | Management Action | Information Source | Adaptation Type | 2015 - 2020 |
|---|---|---|---|---|
| | Maintain fencing | CCMA (2015b) | Resilience | |
| | Undertake woody weed control | CCMA (2015b) | Resilience | |
| | Restore riparian zone using appropriate revegetation | CCMA (2015b) | Transitional | |
| | Maintain revegetation | CCMA (2015b) | Transitional | |
| Monitoring | Develop an EstuaryWatch group for the Aire River estuary | CCMA (2015a) | Transitional | |
| | Repeat Index of Estuary Condition (IEC) monitoring | CCMA (2015a) | Transitional | |
| | Review flood overlays (LSIO & FO) as significant information on climate change and sea level rise becomes available | CCMA (2015a) | Transitional | |
| | Replacement of current gauge board to the bridge. Move to new pole separate to the bridge | CCMA (2015a) | Transitional | |
| | Investigate opportunities for a permanent data monitoring station within the estuary | CCMA (2015a) | Transitional | |
| | Establish the baseline condition and extent of all EVCS in the Aire Estuary to monitor impacts of sea level rise | REP Workshop - Estuaries | Transitional | |
| | Establish the baseline condition and extent of specific fauna (i.e. estuarine dependent fish species) in the Aire Estuary to monitor impacts of sea level rise. | REP Workshop - Estuaries | Transitional | |


Timeframe
Risk (High = red, medium = orange, low = yellow)
2020 - 2030
2030 - 2050
2050 - 2070
2070 - 2090
Enablers
Financial
Social-Political
Perverse Outcomes

**Table 15: Example Adaptation Pathways Case Study – Lake Colac**

**Objective: Incorporate flora and fauna requirements into the management of Lake Colac as water availability, quality**

| Management Type | Management Action | Information Source | Adaptation Type | | |
|---|---|---|---|---|---|
| | | | | 2015 - 2020 | 2 |
| Research | Research potential of existing feeder waterways as potential water sources for Lake Colac | REP Workshop - Wetlands | Transitional | | |
| | Research potential groundwater sources (both quality and quantity) for Lake Colac | REP Workshop - Wetlands | Transitional | | |
| | Research potential recycled water/stormwater sources from Colac (both quality and quantity), for Lake Colac | REP Workshop - Wetlands | Transitional | | |
| | Research flora and fauna requirements of the littoral zone of Lake Colac in light of predicted changes caused by climate change | REP Workshop - Wetlands | Transitional | | |
| | Research potential translocation sites around Lake Colac for the Corangamite Water Skink from nearby vulnerable sites to climate change | REP Workshop - Wetlands | Transitional | | |
| | Research feasibility of Lake Colac being main climate resistant wetland within the Western District Lakes area | REP Workshop - Wetlands | Transitional | | |
| | Research 'blue carbon' opportunities of Lake Colac | REP Workshop - Wetlands | Transitional | | |
| Planning | Develop a climate adaptation plan for Lake Colac | REP Workshop - Wetlands | Transitional | | |
| | Explore feasibility of developing a 'Western District Adaptation Pathways Plan' | REP Workshop - Wetlands | Transitional | | |
| | Incorporate recommendations from Drainage Scheme Review that apply to Lake Colac | REP Workshop - Wetlands | Transitional | | |
| | Finalise and implement the Colac Integrated Water Cycle Management Plan | REP Workshop - Wetlands | Transitional | | |
| | Undertake an analysis of RAMSAR listed criteria for Lake Colac against predicted climate change impacts and associated management responses | REP Workshop - Wetlands | Transitional | | |
| Social Capacity (i.e. community engagement) | Plan, develop and implement an 'Adaptation Pathways Plan' for the Stony Rises Landscape Zone | REP Workshop - Wetlands | Transitional | | |
| Incentives | Establish management agreements with private landholders around Lake Colac to improve resilience of vegetation to climate change | CCMA (2015b) | Resilience | | |

| y and temperature change | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Timeframe | | | | | Risk (High = red, medium = orange, low = yellow) | | | |
| | 2020 - 2030 | 2030 - 2050 | 2050 - 2070 | 2070 - 2090 | Enablers | Financial | Social-Political | Perverse Outcomes |
| → | | | | | orange | orange | orange | yellow |
| → | | | | | red | red | red | yellow |
| → | | | | | orange | orange | orange | yellow |
| → | | | | | orange | orange | yellow | yellow |
| → | | | | | orange | orange | yellow | yellow |
| → | → | | | | orange | orange | orange | yellow |
| | | | | | yellow | yellow | yellow | yellow |
| → | → | | | | orange | orange | orange | orange |
| | | | | | orange | orange | orange | orange |
| | | | | | orange | orange | red | yellow |
| | | | | | orange | orange | orange | yellow |
| | | | | | orange | orange | orange | yellow |
| → | → | → | → | → | orange | orange | orange | yellow |
| | → | → | → | → | orange | orange | orange | yellow |

| Management Type | Management Action | Information Source | Adaptation Type | |
|---|---|---|---|---|
| | | | | 2015 - 2020 |
| | Investigate opportunities for other potential sources of income for stewardship of the lake's margins (e.g. carbon credits for land that is inundated) | REP Workshop - Wetlands | Resilience | |
| On-ground Actions | Protect vegetation around Lake Colac through fencing | CCMA (2015b) | Resilience | |
| | Maintain fencing | CCMA (2015b) | Resilience | |
| | Undertake woody weed control | CCMA (2015b) | Resilience | |
| | Restore land around Lake Colac using appropriate revegetation | CCMA (2015b) | Transitional | |
| Monitoring | Maintain Waterwatch groups collecting baseline data on condition of Lake Colac | CCMA (2015b) | Transitional | |

| Timeframe | | | | Risk (High = red, medium = orange, low = yellow) | | | |
|---|---|---|---|---|---|---|---|
| 2020 - 2030 | 2030 - 2050 | 2050 - 2070 | 2070 - 2090 | Enablers | Financial | Social-Political | Perverse Outcomes |
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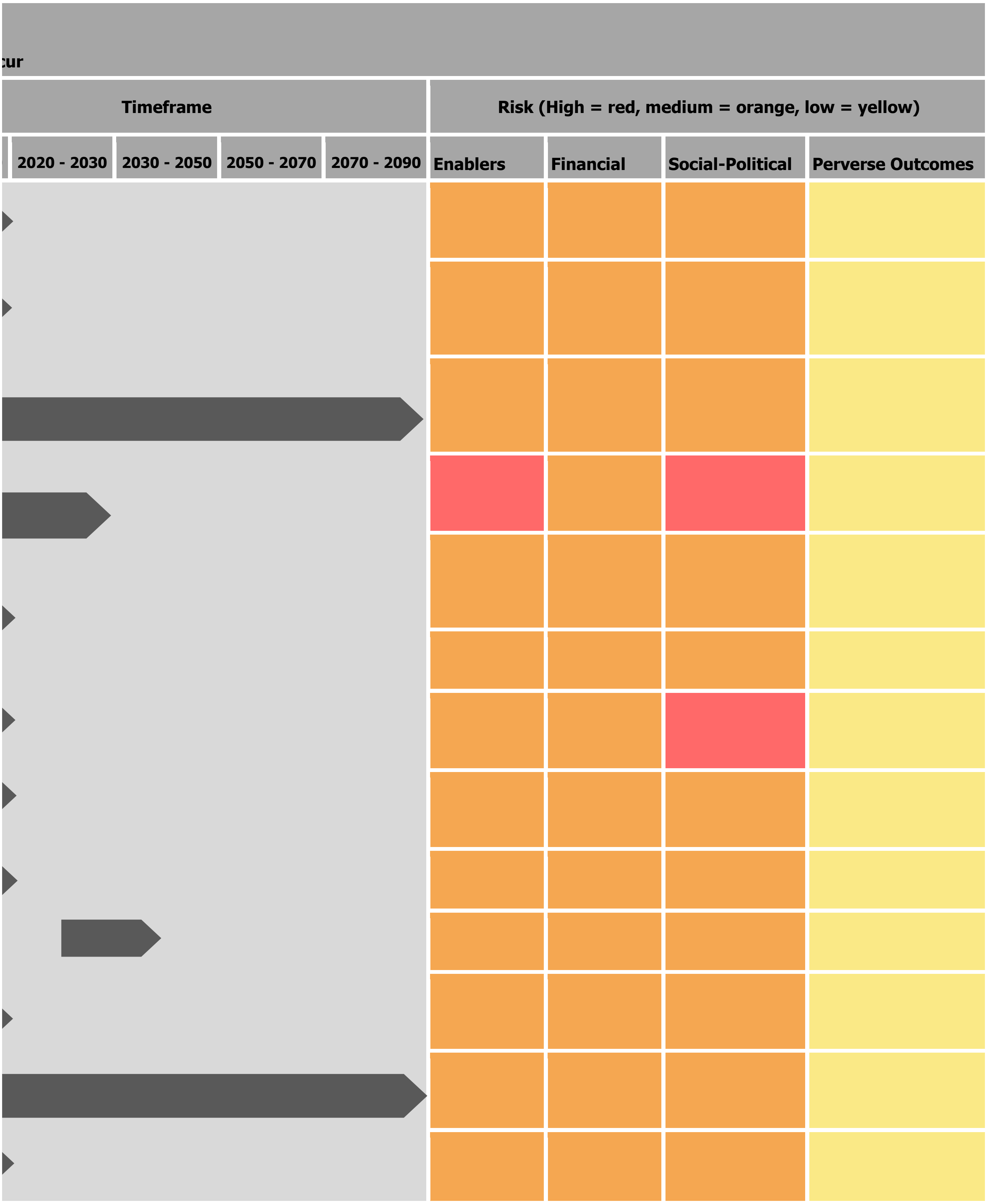
**Table 16: Example Adaptation Pathways Case Study – Corangamite Water Skink**

**Objective: Maintain and improve habitat as land/water use change and other indirect impacts of climate change occu**

| Management Type | Management Action | Information Source | Adaptation Type | 2015 - 2020 |
|---|---|---|---|---|
| Advocacy (i.e. policy & legislation) | Establish and implement appropriate management arrangements and guidelines for reserves containing the Corangamite Water Skink | DSEWPC (2011) | Resilience | |
| | Liaise with grassland/wetland managers to establish and implement interim management guidelines for landholders responsible for non-reserve land which contains Corangamite Water Skink and/or its habitat | DSEWPC (2011) | Resilience | |
| | Periodically review guidelines for the management of Corangamite Water Skink habitat, as new information on the biology of the subspecies, and on threats and their amelioration, becomes available. | DSEWPC (2011) | Transitional | |
| | Include Corangamite Water Skink habitat in local government Environmental Significance Overlays to provide additional legislative protection | DSEWPC (2011) | Resilience | |
| Research | Determine the habitat requirements of Corangamite Water Skink especially vegetation structure and floristics of grasslands/wetlands, relationship between the rock size, structure and aggregation pattern and waterbody characteristics. | DSEWPC (2011) | Resilience | |
| | Determine movements, seasonality and habitat use of the Corangamite Water Skink | DSEWPC (2011) | Transitional | |
| | Investigate ground water/surface water interactions and the implications of ground water irrigation on the Corangamite Water Skink habitat | DSEWPC (2011) | Resilience | |
| | Define the need for and role of a captive population of Corangamite Water Skink and set objectives for captive management. | DSEWPC (2011) | Transitional | |
| | Source animals for captive maintenance, considering genetics and ensuring that wild populations are not compromised | DSEWPC (2011) | Transitional | |
| | Maintain a captive population and use in biological studies as appropriate. | DSEWPC (2011) | Transitional | |
| | Undertake population viability analysis of Corangamite Water Skink populations and use results to prioritise management activities. | DSEWPC (2011) | Transitional | |
| | Research potential translocation sites around Lake Colac for the Corangamite Water Skink from nearby vulnerable sites to climate change | REP workshop - wetlands | Transformational | |
| | Determine key ecological parameters of the life history of the Corangamite Water Skink | Peterson, pers. comm (2015) | Transitional | |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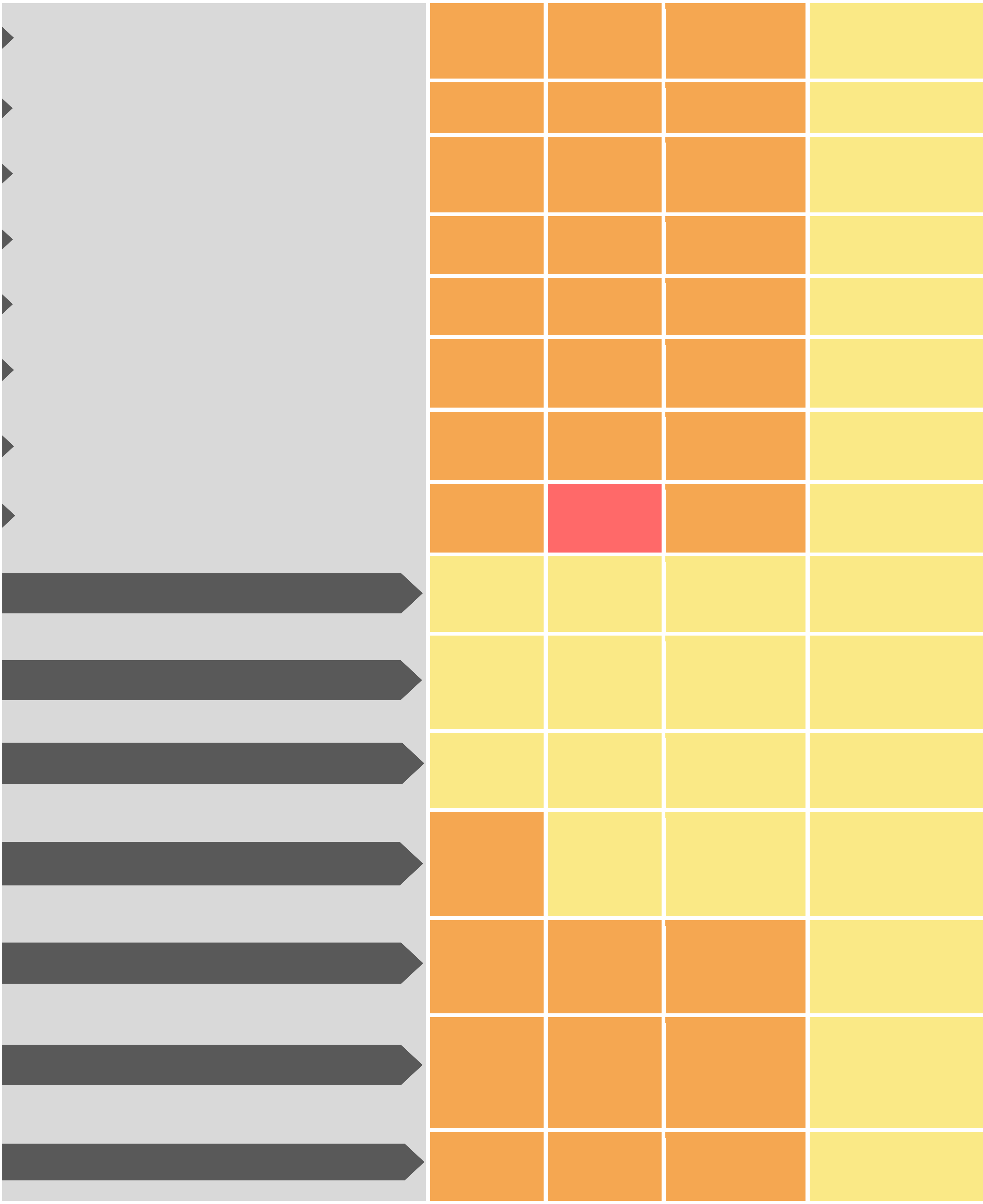
Timeframe
Risk (High = red, medium = orange, low = yellow)
2020 - 2030
2030 - 2050
2050 - 2070
2070 - 2090
Enablers
Financial
Social-Political
Perverse Outcomes

| Management Type | Management Action | Information Source | Adaptation Type | 2015 - 2020 |
|---|---|---|---|---|
| | Undertake population modelling and viability analysis using demographic data collected over the past 20 years to assess extinction risks | Peterson, pers. comm (2015) | Transitional | |
| Planning | Determine the location and conditions for a captive population. | DSEWPC (2011) | Transformational | |
| | Determine the circumstances under which Corangamite Water Skink may be salvaged from doomed sites, and develop agreed protocols. | DSEWPC (2011) | Transformational | |
| | Determine the potential objectives, feasibility and appropriateness of translocation. | DSEWPC (2011) | Transformational | |
| | Determine the circumstances under which Corangamite Water Skink may be translocated, and develop agreed protocols. | DSEWPC (2011) | Transformational | |
| | Explore feasibility of developing a 'Western District Adaptation Pathways Plan' | REP Workshop - Wetlands | Transitional | |
| | Plan, develop and implement an 'Adaptation Pathways Plan' for the Stony Rises Landscape Zone | REP Workshop - Wetlands | Transitional | |
| | Identify areas of land to purchase for translocation of vulnerable populations | REP workshop – Flora and Fauna | Transformational | |
| Social Capacity (i.e. community engagement) | Encourage broader community involvements in projects directed at the conservation of Corangamite Water Skink and native grasslands/wetlands, especially on public land | DSEWPC (2011) | Resilience | |
| | Produce information material on volcanic plain grasslands and wetlands, and Corangamite Water Skink conservation and management, for access by community groups, landholders, and private and government organisations. | DSEWPC (2011) | Resilience | |
| | Publicise in various media and at forums the conservation status of Corangamite Water Skink, up-dates and progress on its recovery and encourage the reporting of any sightings | DSEWPC (2011) | Resilience | |
| | Encourage voluntary buffer zones around known Corangamite Water Skink populations to assist in protection from agricultural insecticide control | REP Workshop – Flora and Fauna | Resilience | |
| Incentives | Identify and approach specific landholders with Corangamite Water Skink habitat on their land to participate in conservation management of the taxon, providing support such as land management incentives. | DSEWPC (2011) | Resilience | |
| | Ensure long-term sympathetic management of Corangamite Water Skink and its habitat on non-reserve land, by developing conservation management agreements with landholders controlling Corangamite Water Skink habitat across the range of the taxon. | DSEWPC (2011) | Resilience | |
| On-ground Actions | Predator control, including but not limited to feral cat and fox baiting, and eradication | REP Workshop – Flora and Fauna | Resilience | |

| Timeframe | | | | Risk (High = red, medium = orange, low = yellow) | | | |
|---|---|---|---|---|---|---|---|
| 2020 - 2030 | 2030 - 2050 | 2050 - 2070 | 2070 - 2090 | Enablers | Financial | Social-Political | Perverse Outcomes |



| **Management Type** | **Management Action** | **Information Source** | **Adaptation Type** | **2015 - 2020** |
|---|---|---|---|---|
| | Establish new habitat at wetland sites | REP Workshop – Flora and Fauna | Transitional | |
| | Enhance habitat by fencing off habitat to exclude or regulate stock access allow regeneration of vegetation. | Peterson, pers. comm (2015) | Resilience | |
| | Manage weed invasion at Corangamite Water Skink sites to prevent biomass accumulation, particularly Phalaris | Peterson, pers. comm (2015) | Resilience | |
| | Manage environmental flows at 10 sites which include impacts from surface flows and groundwater extraction | Peterson, pers. comm (2015) | Resilience | |
| Monitoring | Undertake periodic threat assessments at all Corangamite Water Skink sites, determine the severity of these threats and implement remedial action | DSEWPC (2011) | Transitional | |
| | Conduct annual monitoring on 14 representative sites (at least 1 site per population) between October and May, to identify population trends of Corangamite Water Skink. | DSEWPC (2011) | Transitional | |

| Timeframe | | | | Risk (High = red, medium = orange, low = yellow) | | | |
|---|---|---|---|---|---|---|---|
| 2020 - 2030 | 2030 - 2050 | 2050 - 2070 | 2070 - 2090 | Enablers | Financial | Social-Political | Perverse Outcomes |
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**Table 17: Example Adaptation Pathways Case Study – Swan Bay**

**Objective: Maintain and enhance the quality and functionality of Swan Bay as type, composition, structure and functi**

| Management Type | Management Action | Information Source | Adaptation Type | 2015 - 2020 |
|---|---|---|---|---|
| Advocacy (i.e. policy & legislation) | Develop and implement planning controls for land adjacent to Swan Bay to ensure that future land use and development does not significantly impact on locations needed for sea level rise due to climate change | REP Workshop – Coastal Wetlands | Transitional | |
| | Ensure municipal strategic statements and local planning schemes recognise and protect important wetlands and migratory shorebird values in the Ramsar site, including requirements due to climate change, and also take account of the complementary values of wetlands outside the Ramsar site | DSE (2003) | Transitional | |
| Research | Further refine carbon sequestration modelling for Swan Bay with a focus on revegetation of blue carbon habitats and wetlands. | REP Workshop – Coastal Wetlands | Transitional | |
| | Research flora and fauna requirements of the littoral zone of Swan Bay in light of predicted changes caused by climate change | REP Workshop – Coastal Wetlands | Transitional | |
| | Undertake an analysis of RAMSAR listed criteria for Swan Bay against predicted climate change impacts and associated management responses | REP Workshop – Coastal Wetlands | Transitional | |
| Planning | Plan future habitats for internationally important migratory waders, particularly FFG, JAMBA, CAMBA and Bonn-listed species, and ensure important new high tide roosting sites, that occur as a result of sea level rise, are adequately protected | DSE (2003) | Transitional | |
| | Implement and continually review activities and outcomes of elements of the Orange-bellied Parrot Recovery Plan that apply to adapting the species to climate change impacts within Swan Bay | DSE (2003) | Transitional | |
| | Plan, develop and implement an 'Adaptation Pathways Plan' for Swan Bay | REP Workshop – Coastal Wetlands | Transitional | |
| | Develop modelling and plan for the migration of coastal saltmarsh (i.e. amend planning schemes to reflect migration options) and other similar vegetation communities in Swan Bay due to sea level rise | REP Workshop – Coastal Wetlands | Transitional | |
| | Incorporate recommendations from the Geelong-Queenscliffe Coastal Adaptation Program to assist in modelling sea level rise, identifying and assessing risks and developing adaptation responses | REP Workshop – Coastal Wetlands | Transitional | |
| Social Capacity (i.e. community engagement) | Plan, develop and implement an 'Adaptation Pathways Plan' for the Bellarine Landscape Zone | REP Workshop – Coastal Wetlands | Transitional | |

ion of natural values change

| Timeframe | | | | Risk (High = red, medium = orange, low = yellow) | | | |
|---|---|---|---|---|---|---|---|
| 2020 - 2030 | 2030 - 2050 | 2050 - 2070 | 2070 - 2090 | Enablers | Financial | Social-Political | Perverse Outcomes |
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| Management Type | Management Action | Information Source | Adaptation Type | 2015 - 2020 |
|---|---|---|---|---|
| Incentives | Develop appropriate incentives for stewardship for private landholders that are adjacent to and/or have waterways that flow into Swan Bay | REP Workshop – Coastal Wetlands | Transitional | |
| | Establish management agreements with private landholders adjacent to Swan Bay to improve resilience to climate change | REP Workshop – Coastal Wetlands | Transitional | |
| | Investigate opportunities for other potential sources of income for stewardship of land managed for migration of coastal saltmarsh (e.g. carbon credits for land that is inundated) | REP Workshop – Coastal Wetlands | Transitional | |
| On-ground Actions | Plan and implement appropriate predator control, including but not limited to feral cat and fox baiting, and eradication | REP Workshop – Coastal Wetlands | Resilience | |
| | Establish new habitat at wetland sites, prioritising areas based on adaptation and mitigation outcomes | REP Workshop – Coastal Wetlands | Transitional | |
| | Enhance habitat by fencing off habitat to exclude or regulate stock access allow regeneration of vegetation, with a focus on priority locations for coastal vegetation migration | REP Workshop – Coastal Wetlands | Resilience | |
| | Protect all existing saltmarsh and mangrove habitats and, where practicable, rehabilitate areas subject to degradation. | DSE (2003) | Resilience | |
| | Encourage riparian enhancement projects in the upper catchment to minimise nutrient and sediment input entering Swan Bay | REP Workshop – Coastal Wetlands | Resilience | |
| Monitoring | Establish a regular seagrass monitoring program for Swan Bay, that includes biotic and abiotic parameters of the community, as a basis for determining the effectiveness of management and as an indicator of the impacts of climate change | REP Workshop – Coastal Wetlands | Transitional | |
| | Develop trigger points, rather than tipping points, for monitoring impacts of sea level rise | REP Workshop – Coastal Wetlands | Transitional | |
| | Monitor coastal erosion and sediment movement and the extent and health of seagrass beds in Swan Bay | DSE (2003) | Transitional | |
| | Develop and maintain standardised mapping of seagrass beds at appropriate temporal and spatial scales | REP Workshop – Coastal Wetlands | Transitional | |
| | Maintain Swan Bay Catchment Waterwatch Program | REP Workshop – Coastal Wetlands | Transitional | |
| | Explore opportunities to establish a SeagrassWatch Program for Swan Bay | REP Workshop – Coastal Wetlands | Transitional | |
| | Establish the baseline condition and extent of all EVCS in and adjacent to Swan Bay to monitor impacts of sea level rise | REP Workshop – Coastal Wetlands | Transitional | |
| | Establish the baseline condition and extent of specific fauna (i.e. migratory bird and fish species) in Swan Bay to monitor impacts of sea level rise | REP Workshop – Coastal Wetlands | Transitional | |

| Timeframe | | | | Risk (High = red, medium = orange, low = yellow) | | | |
|---|---|---|---|---|---|---|---|
| 2020 - 2030 | 2030 - 2050 | 2050 - 2070 | 2070 - 2090 | Enablers | Financial | Social-Political | Perverse Outcomes |
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**Table 18: Example Adaptation Pathways Case Study – Coastal Saltmarsh**

**Objective: Avoid species extinction, improve ecosystem services and maintain genetic diversity as type, composition,**

| Management Type | Management Action | Information Source | Adaptation Type | 2015 - 2020 |
|---|---|---|---|---|
| Advocacy (i.e. policy & legislation) | Develop and implement planning controls for land adjacent to Swan Bay to ensure that future land use and development does not significantly impact on locations needed for sea level rise due to climate change | REP Workshop – Coastal Wetlands | Transitional | |
| Research | Further refine carbon sequestration modelling for coastal saltmarsh with a focus on revegetation | REP Workshop – Coastal Wetlands | Transitional | |
| | Research flora and fauna requirements of coastal saltmarsh in light of predicted changes caused by climate change | REP Workshops – Coastal Wetlands/Native Vegetation | Transitional | |
| Planning | Map areas of coastal saltmarsh that have the imposition of infrastructure that are impacting on the natural hydrology and can be restored to improve their resilience to climate change | Saintilan and Rogers (2009) | Resilience | |
| | Implement and continually review activities and outcomes of elements of the Orange-bellied Parrot Recovery Plan that apply to coastal saltmarsh | DSE (2003) | Transitional | |
| | Use LiDAR to plan for the migration of coastal saltmarsh (i.e. amend planning schemes to reflect migration options) due to sea level rise | REP Workshops – Coastal Wetlands/Native Vegetation | Transitional | |
| | Incorporate recommendations from the Geelong-Queenscliffe Coastal Adaptation Program to assist in modelling sea level rise, identifying and assessing risks to coastal saltmarsh as well as developing adaptation responses | REP Workshops – Coastal Wetlands/Native Vegetation | Transitional | |
| Social Capacity (i.e. community engagement) | Encourage voluntary buffer zones around areas of coastal saltmarsh to assist in future migration due to sea level rise | REP Workshops – Coastal Wetlands/Native Vegetation | Transitional | |
| Incentives | Continue appropriate incentives for stewardship for private landholders that have coastal saltmarsh, e.g. CoastalTender | REP Workshop – Native Vegetation | Resilience | |
| | Establish management agreements with private landholders with coastal saltmarsh to improve resilience to climate change | REP Workshop – Native Vegetation | Resilience | |

| structure and function of vegetation communities adapt to climate change | | | | | | | |
|---|---|---|---|---|---|---|---|
| Timeframe | | | | Risk (High = red, medium = orange, low = yellow) | | | |
| 2020 - 2030 | 2030 - 2050 | 2050 - 2070 | 2070 - 2090 | Enablers | Financial | Social-Political | Perverse Outcomes |

| Management Type | Management Action | Information Source | Adaptation Type | 2015 - 2020 |
|---|---|---|---|---|
| | Investigate opportunities for other potential sources of income for stewardship of land managed for migration of coastal saltmarsh (e.g. carbon credits for land that is inundated) | REP Workshop – Native Vegetation | Transitional | |
| On-ground Actions | Establish coastal saltmarsh, prioritising areas based on adaptation and mitigation outcomes | REP Workshops – Coastal Wetlands/Native Vegetation | Transitional | |
| | Enhance habitat by fencing off habitat to exclude or regulate stock access allow regeneration of coastal saltmarsh, with a focus on priority locations for coastal saltmarsh migration | REP Workshops – Coastal Wetlands/Native Vegetation | Resilience | |
| Monitoring | As coastal saltmarsh floristic diversity increases with increasing latitude, ensure floristics of coastal saltmarsh are benchmarked and monitored to measure impact of projected rise in the region's temperature | Saintilan and Rogers (2009) | Transitional | |
| | Develop trigger points, rather than tipping points, for monitoring impacts of sea level rise on coastal saltmarsh | REP Workshop – Native Vegetation | Transitional | |
| | Establish the baseline condition and extent of coastal saltmarsh to monitor impacts of sea level rise | REP Workshop – Native Vegetation | Transitional | |

| Timeframe | | | | Risk (High = red, medium = orange, low = yellow) | | | |
|---|---|---|---|---|---|---|---|
| 2020 - 2030 | 2030 - 2050 | 2050 - 2070 | 2070 - 2090 | Enablers | Financial | Social-Political | Perverse Outcomes |
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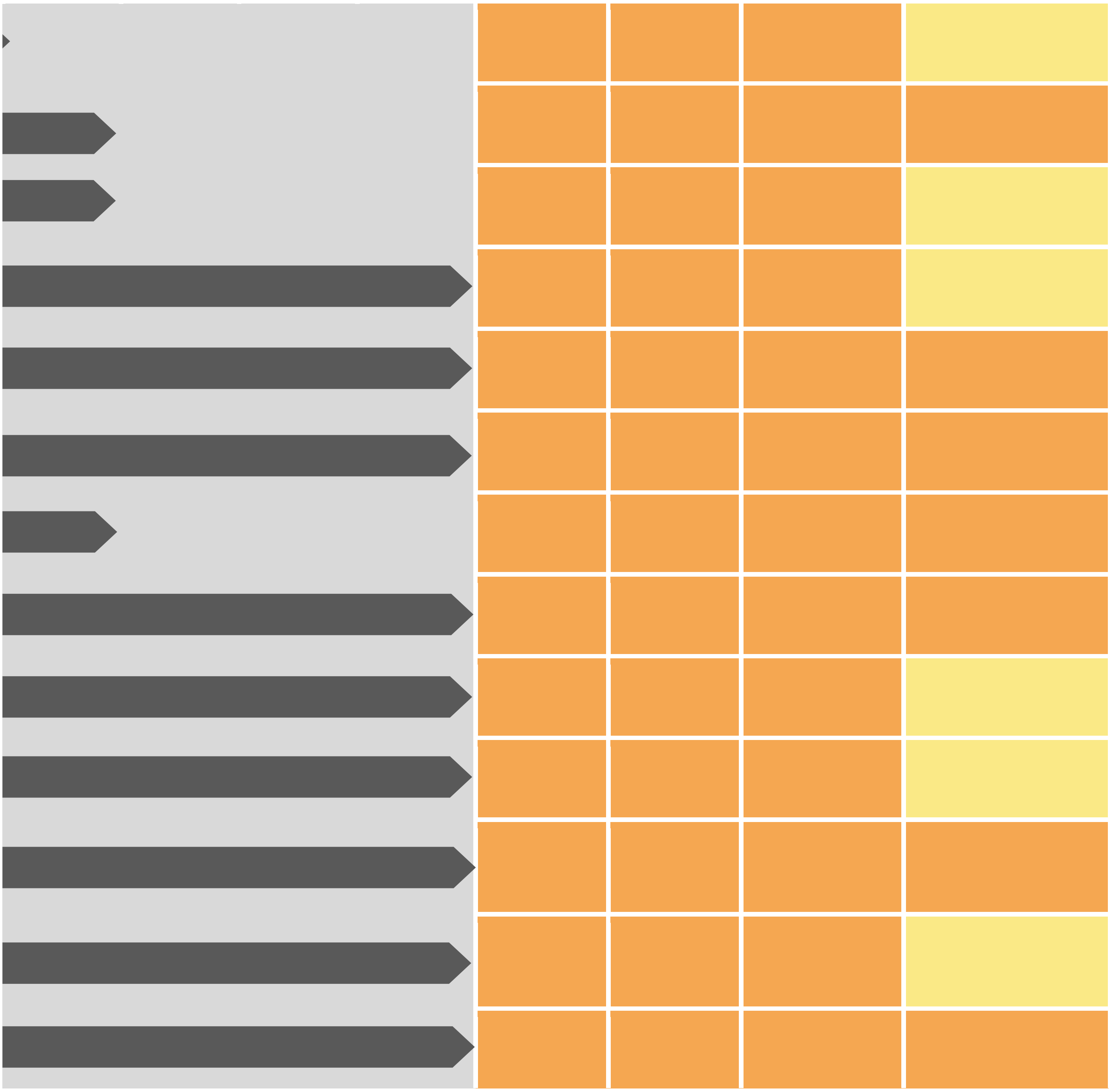
**Table 19: Example Adaptation Pathways Case Study – Soils within lower Woady Yaloak catchment**

**Objective: Maintain or enhance soil condition for continued environmental benefits and sustainable agricultural produ**

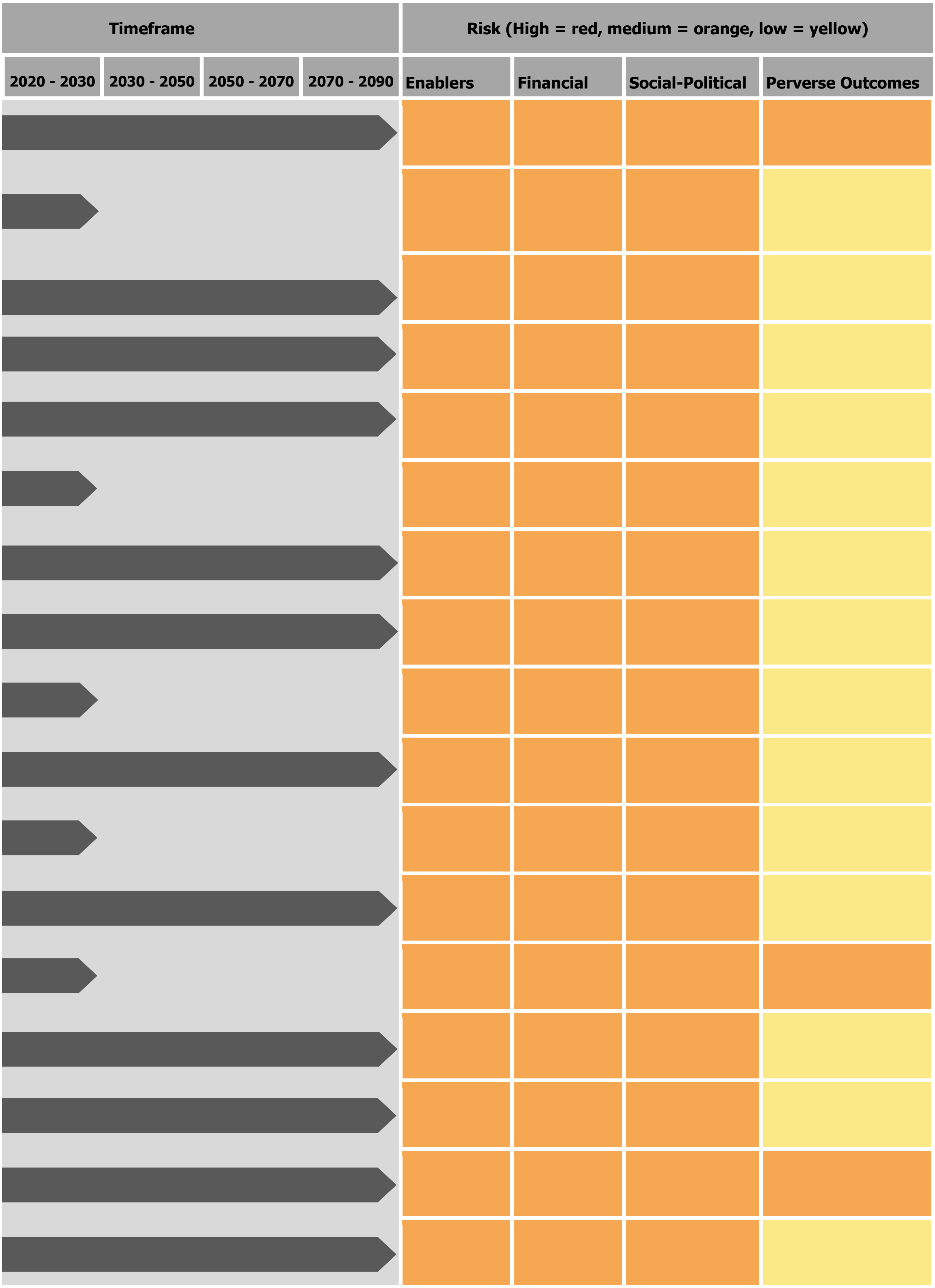
| Management Type | Management Action | Information Source | Adaptation Type | 2015 - 2020 |
|---|---|---|---|---|
| Reduce wind erosion | Increase shelterbelts from <1% to >10% | REP Workshop - Soils | Transitional | |
| Maintain/improve groundcover | Reduce burning stubble from greater than 50% to less than 30% | REP Workshop - Soils | Transitional | |
| | Establish stock containment areas | REP Workshop - Soils | Transitional | |
| | Improve grazing management | REP Workshop - Soils | Transitional | |
| | Match pasture species to climate requirements (annual and perennial) | REP Workshop - Soils | Transitional | |
| | Retain stubble | REP Workshop - Soils | Resilience | |
| | Establish land class fencing | REP Workshop - Soils | Resilience | |
| | Establish strategic water point allocation | REP Workshop - Soils | Transitional | |
| | Improve cover cropping, i.e. manure application | REP Workshop - Soils | Transitional | |
| | Improve weed management | REP Workshop - Soils | Transitional | |
| | Pasture cropping | REP Workshop - Soils | Transitional | |
| | Establish spring sowing winter crops (% land managers) (<1% - 2050; 30% 2070; 50% 2090) | REP Workshop - Soils | Transitional | |
| | Establish Tree/shrubs crops | REP Workshop - Soils | Transformational | |

**uction under a changing climate and land uses**

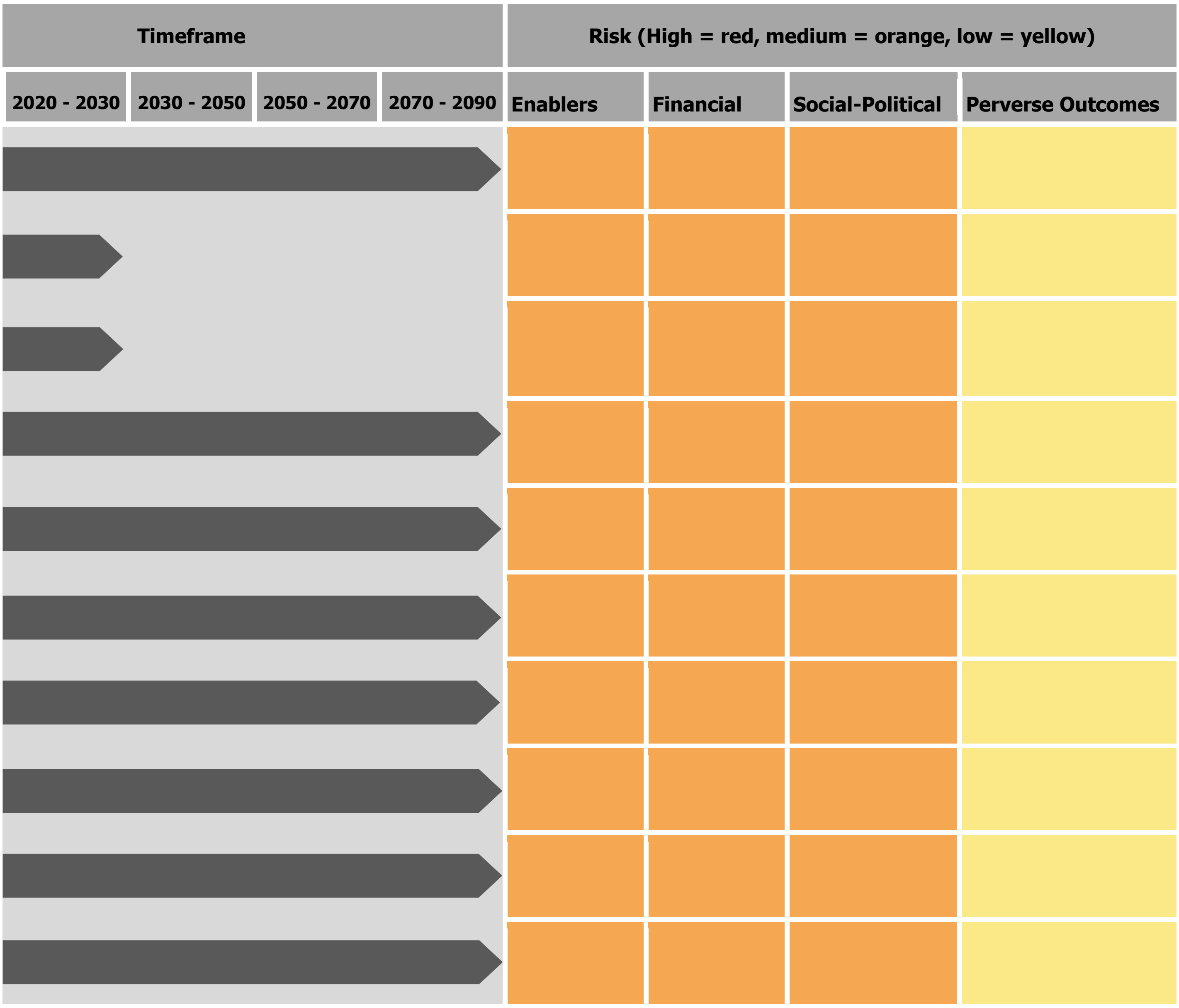
| Timeframe | | | | Risk (High = red, medium = orange, low = yellow) | | | |
|---|---|---|---|---|---|---|---|
| 2020 - 2030 | 2030 - 2050 | 2050 - 2070 | 2070 - 2090 | Enablers | Financial | Social-Political | Perverse Outcomes |



| Management Type | Management Action | Information Source | Adaptation Type | 2015 - 2020 |
|---|---|---|---|---|
| | Manage grazing pressure from pest animals | REP Workshop - Soils | Resilience | |
| Maintain/increase soil organic matter | Reduced strategic tillage to reduce size, number and duration of bare patches and fallow ground to increase soil carbon and reduce soil erosion | REP Workshop - Soils | Transitional | |
| | Increase soil organic carbon input and other nutrients to balance carbon and nitrogen ratios that maintain and improve productivity | REP Workshop - Soils | Transitional | |
| | Increase biochar input | REP Workshop - Soils | Transformational | |
| | Increase soil biota | REP Workshop - Soils | Transitional | |
| | Introduce biological ripping - deep rooted plant species | REP Workshop - Soils | Transformational | |
| | Improve subsoil modification | REP Workshop - Soils | Transitional | |
| | Address imbalance of nutrients | REP Workshop - Soils | Resilience | |
| | Increase testing of nutrient loads/constraints | REP Workshop - Soils | Resilience | |
| | Increase use of legumes | REP Workshop - Soils | Resilience | |
| | Inoculation – to current mycorrhiza species to other species as conditions change (i.e. soil moisture content) | REP Workshop - Soils | Transitional | |
| Reduce water erosion | Refer above (maintain/improve groundcover) | REP Workshop - Soils | Transitional | |
| Reduce impact of waterlogging | Improve surface and subsoil drainage | REP Workshop - Soils | Resilience | |
| | Increase stock containment areas | REP Workshop - Soils | Resilience | |
| | Improve grazing management | REP Workshop - Soils | Resilience | |
| | Raise bed cropping | REP Workshop - Soils | Transitional | |
| | Dewatering through pasture species selection (i.e. lucerne) | REP Workshop - Soils | Transitional | |


Timeframe
Risk (High = red, medium = orange, low = yellow)
2020 - 2030
2030 - 2050
2050 - 2070
2070 - 2090
Enablers
Financial
Social-Political
Perverse Outcomes

| Management Type | Management Action | Information Source | Adaptation Type | 2015 - 2020 |
|---|---|---|---|---|
| | Subsoil modification | REP Workshop - Soils | Transitional | |
| Reduce structure decline | Reduced strategic tillage | REP Workshop - Soils | Transitional | |
| | Improve controlled traffic | REP Workshop - Soils | Resilience | |
| | Avoid compaction (stock & machinery) during wet periods | REP Workshop - Soils | Resilience | |
| | Increasing carbon input - soil organic input (break down into different categories) | REP Workshop - Soils | Transitional | |
| | Increasing biochar input on appropriate soil and production system types | REP Workshop - Soils | Transformational | |
| | Increasing soil biota | REP Workshop - Soils | Transitional | |
| | Biological ripping through planting deep rooted plant species | REP Workshop - Soils | Transformational | |
| | Gypsum application | REP Workshop - Soils | Resilience | |
| | Increase subsoil modification | REP Workshop - Soils | Transitional | |


Timeframe
Risk (High = red, medium = orange, low = yellow)
2020 - 2030
2030 - 2050
2050 - 2070
2070 - 2090
Enablers
Financial
Social-Political
Perverse Outcomes

# 7. A plan for action – addressing climate change in the Corangamite region

***Erskine Falls. Photo: Lachlan Manly***

Previous sections have discussed and highlighted the reasons for changing how the region manages its natural assets and the need to ensure that they are resilient and able to adapt to a changing climate.

This section builds on this need through introducing the concept of adaptation guiding principles and climate ready objectives and providing a series of actions, at a regional scale, to assist the region manage for climate change. It also provides guiding adaptation responses that can be applied at a more local scale.

Information on the roles and responsibilities of regional stakeholders in addressing climate change and information on decision tools and frameworks is also provided.

**Key Messages**

- Guiding adaptation principles can be used to shift current responses to NRM
- Climate ready objectives enable current objectives to acknowledge climate change
- Regional actions ensure the region moves towards a climate ready future

## 7.1 Adaptation guiding principles

Ensuring an appropriate response to a changing climate may mean there is a cultural shift in how NRM is viewed, and how current management practices are carried out. Indeed, climate change adaptation needs to be considered in every natural resource management decision.

One way of achieving this is to promote the use of 'adaptation guiding principles'.

Adaptation guiding principles ensure climate change is incorporated into the thinking of all management decisions relevant to NRM. Adaptation principles also help ensure adverse or perverse actions do not cause an increase in and/or hasten the impacts of climate change on the natural asset that is being targeted to be managed (or others).

Table 21 provides an overview of adaptation principles as well as the core actions and strategies that can be adopted to ensure the principles are adhered to.

They are based on stakeholder consultation, along with from learnings from other regions across Australia and internationally which have set similar climate ready objectives.

**Table 20: Adaptation guiding principles**

| Adaptation guiding principle | Why is this a guiding principle? |
|---|---|
| Planning and management decisions need to be flexible, adaptive and acknowledge multiple possible futures. | Climate change adaptation, in particular for NRM, is continually being updated. Ways to plan that are agile enough to consider a range of futures and desired outcomes are needed to ensure management actions are the most appropriate and that these consider regional knowledge, natural asset responses, as well as longer-term planning cycles. Adaptation pathways enable the uncertainty and challenges of climate change mitigation to be considered. |
| Identify and prepare for likely climatic changes | As actions and information change over time, there is a need to allow for future decision-making. Identifying appropriate triggers, setting appropriate monitoring and pre-planning are all critical to achieve this. Adaptation pathways enable the uncertainty and challenges of climate change to be considered and can also be used as a stakeholder engagement tool. |
| Manage natural assets for transformation and/or resilience | Many of the region's natural assets will need to adapt to a changing climate. Ensuring these natural assets are managed so they can be resilient to climate change helps achieve this. This usually requires the management of threatening processes to protect priority assets, for example, native vegetation and new and emerging environmental weeds. |
| The adaptive capacity of land managers, NRM groups and organisations is improved through regional leadership as well as encouraging local solutions to be developed that address regional issues. | Sharing new and innovative adaptation management information and encouraging regional and landscape scale actions to be developed together, will improve the awareness and capacity of land managers and community groups to manage natural assets and associated ecological processes in a changing climate. |

## 7.2 Climate ready objectives for the Corangamite region

Dunlop et al. (2013) have developed the notion of 'climate-ready conservation objectives' as a means by which to rethink established aspirations around biodiversity conservation and take into account the likely impacts of climate change.

They recommend that existing biodiversity strategies be framed as 'climate-ready' by abandoning static models of conservation (i.e. models that frame as essential the relations between biota and place) and instead use the following adaptation propositions as guidelines:

1. Conservation strategies accommodate large amounts of ecological change and the likelihood of significant climate change-induced loss in biodiversity.
2. Strategies remain relevant and feasible under a range of possible future trajectories of ecological change.
3. Strategies seek to conserve the multiple different dimensions of biodiversity that are experienced and valued by society.

Through a series of workshops around the plan's main natural asset themes, example climate-ready objectives were developed based on existing objectives in the Corangamite Regional Catchment Strategy and the Corangamite Waterway Strategy. These are provided in Tables 22 - 27.

**Table 21: Climate ready objectives - native vegetation**

| Corangamite Regional Catchment Strategy objective | Example climate ready objectives |
|---|---|
| Halt the decline in quality (condition) and extent of high value native vegetation and enhance its connectivity | Avoid species extinction, improve ecosystem services and maintain genetic diversity as type, composition, structure and function of vegetation communities adapt to climate change |
| | Reduce impacts of - and improve resilience to - invasive species |
| | Increase vegetation extent and security as vegetation communities and land use change under climate change |
| | Enhance landscape connectivity as landscape and land use change under climate change |

**Table 22: Climate ready objectives - rivers and streams**

| Corangamite Waterway Strategy objectives | Example climate ready objectives |
|---|---|
| Maintain or improve waterway condition where it supports high social values | Maintain or improve environmental condition of waterways to support significant social values, i.e. Barwon through Geelong, as the availability, quality and temperature of water changes |
| Secure and manage waterways that provide significant economic benefits to the region | Maintain or improve the environmental condition of waterways to support significant economic values, i.e. water supply purposes, as the availability, quality and temperature of water changes |
| Maintain the viability of populations of native fish species | Maintain the viability, including recruitment and survival, of populations of native fish species as habitat and the availability, quality and temperature of water changes |
| Maintain or improve the resilience of other waterway dependent species | Maintain or improve the resilience of other waterway dependent species as habitat and the availability, quality and temperature of water changes |
| Manage water for the environment to improve waterway condition | Optimise water use, i.e. via additional environmental entitlements and restrictions, to maintain or improve waterway condition, as habitat and the availability, quality and temperature of water changes |
| Maintain or improve waterways with formally recognised significance | Maintain or improve waterways with formally recognised significance as habitat and the availability, quality and temperature of water changes |
| Maintain waterways in near natural condition | Monitor and protect waterways in near natural condition as habitat and the availability, quality and temperature of water changes |

**Table 23: Climate ready objective - soil**

| Corangamite Regional Catchment Strategy objective | Example climate ready objectives |
|---|---|
| Maintain or enhance soil condition for continued environmental benefits and sustainable agricultural production | Maintain or enhance soil condition for continued environmental benefits and sustainable agricultural production under a changing climate and land uses |

**Table 24: Climate ready objectives - wetlands**

| Corangamite Waterway Strategy objective | Example climate ready objectives |
|---|---|
| Maintain the extent and condition of other significant wetlands (by type) | Maintain or improve wetlands with formally recognised significance as habitat and the availability, quality and temperature of water changes |
| | Identify, understand and manage wetlands to achieve sufficient representation, as habitat and the availability, quality and temperature of water changes |
| | Protect priority wetlands from disturbance during times of natural drying as water availability changes |
| | Encourage the creation of new wetlands to increase representativeness, habitat extent and ecological values of wetland types as habitat and the availability, quality and temperature of water changes |
| | Incorporate flora and fauna requirements into the management of wetlands as habitat and the availability, quality and temperature of water changes |

**Table 25: Climate ready objectives – coastal assets (including estuaries and coastal wetlands)**

| Corangamite Regional Catchment Strategy objective | Example climate ready objectives |
|---|---|
| Maintain the quality and extent of high value coastal assets | Maintain and/or increase the extent of coastal natural assets as abundance and distributions change |
| | Maintain and enhance the quality and functionality of coastal natural assets as type, composition, structure and function change |
| Retain the ecological function of estuarine floodplains and protect community infrastructure and values | Maintain and improve ecosystem functionality of estuaries, as type, composition, structure and processes change |
| Limit impacts to the marine environment from the catchment such as they are within the bounds of its resilient capacity | Limit impacts to the marine environment from the catchment as land/water uses change |

**Table 26: Climate ready objectives – flora and fauna**

| Corangamite Regional Catchment Strategy objective | Example climate ready objectives |
|---|---|
| Manage the threat of species extinction so that key populations are resilient and secure in the longer-term | Reduce species extinction, as abundance and distribution change |
| | Maintain and improve habitat as type, composition, structure and function change |
| | Maintain and improve habitat as land/water use change and other indirect impacts of climate change occur |
| | Manage threats to species as climate changes |

***Sooty Oystercatcher. Photo: Lachlan Manly***

## 7.3 Roles and Responsibilities

There are many government and community stakeholders (both within and outside of the Corangamite region) who are addressing climate change adaptation projects and activities, however, more are needed.

Addressing threats and opportunities of climate change can be broken down into five main categories – research, planning, community engagement, on-ground action, and MERI (Monitoring, Evaluation, Reporting and Improvement).

**Research – Improving the region's knowledge in climate change adaptation**

Research can be done in two ways:

- Researching the natural assets of the region, in particular, their ability to adapt and/or respond to climate change
- Synthesising the latest climate change data to inform future decision making.

The combination of these two research methods can inform how the region plans for climate change. It will determine what new information needs to be provided to the region's land managers and community, as well as provide better knowledge to manage natural assets under climate change.

Corangamite CMA and DELWP have a role in partnering with universities, NRM/agricultural industry groups and other important stakeholders in coordinating research that will improve the region's knowledge in climate change adaptation.

**Planning – improving the region's capacity to plan for adaptation in a changing climate**

The Australian Government and Victorian Government will provide overarching leadership through their respective agencies.

This is supported through organisations such as CSIRO, AdaptNRM and NCCARF to provide best practice for adaptation planning, and provides the latest information from a national perspective. SCARP - and the partnership that has been formed by NRM regions within the SSC -has a similar role.

From a more local perspective, the Corangamite CMA has a role to work with regional stakeholders who are lead drivers in developing local planning solutions to what are essentially regional and larger scale issues. These stakeholders include local government, NRM groups and coastal boards.

**Community engagement – ensuring the region has the right knowledge, management tools and decision frameworks to address climate change**

Community engagement is led by stakeholders who already engage with our region's community.

These include NRM groups and NRM/agriculture industry groups and is supported by the Corangamite CMA. Local government, public land managers and non-government organisations such as Trust for Nature and Greening Australia also have roles in community engagement.

**On-ground action – encouraging land managers to help contribute to best management practices that maximise opportunities for climate change adaptation**

Similar to community engagement, on-ground action is led by stakeholders within the region. These include landholder and community based groups such as NRM groups, NRM/agriculture industry groups and private landholders. Public land managers such as Parks Victoria, committees of management and local government are also key stakeholders implementing on-ground actions to address climate change adaptation outcomes in the region.

**MERI – ensuring the region is adapting its natural assets to climate change**

MERI is essential to determine the region's progress in adapting its natural assets to climate change.

Both levels of Government (through their respective agencies) and support organisations such as CSIRO, AdaptNRM and NCCARF Stakeholders will be involved in ensuring the MERI framework is rigorous and adaptable. These organisations can provide the best practice for developing MERI, as well as learnings from other regional and local organisations.

While it is important to have a MERI framework that is supported, it is vital that those undertaking the MERI are provided with the same support.

The Corangamite CMA will make relevant information available on the South West Climate Change Portal so it is available to regional stakeholders including NRM groups, private landholders and public land managers.

Table 28 provides an overview of the roles and responsibilities of stakeholders that are involved in improving how the region adapts its natural assets to a changing climate.

***Lake Cundare. Photo: Alison Pouliot***

**Table 27: Overview of the roles and responsibilities of stakeholders involved in climate change adaptation within the Corangamite region**

| Stakeholder | NRM adaptation role within Corangamite region | Research | Planning | Community engagement | Onground action | MERI |
|---|---|---|---|---|---|---|
| Department of the Environment | Has invested in the development of the 'NRM Plan for Climate Change' as well as other NRM projects within the Corangamite region. | Low | Low | Low | Low | Medium |
| Commonwealth Scientific and Industrial Research Organisation (CSIRO) | Research, interpret and provide climate change data to use in regional adaptation planning. | Medium | Low | Low | Low | Low |
| National Climate Change Adaptation Research Facility (NCCARF) | Works with NRM decision makers to prepare for and manage the risks of climate change, in particular sea-level rise. | Medium | Medium | Low | Low | Low |
| AdaptNRM | A national initiative, AdaptNRM works with the CORANGAMITE CMA to improve its role in climate adaptation planning. | Medium | Medium | Low | Low | Low |
| Department of Environment, Land, Water and Planning (DELWP) at a state level | Sets the strategic direction for the management of the state's natural assets and climate change, including the development of the 'Victorian Climate Change Adaptation Plan'. | Medium | Medium | Low | Low | Medium |
| Department of Environment, Land, Water and Planning (DELWP) at a regional level | Manages a number of NRM projects, with a focus on species. Also has role in strategic fire management and statutory planning. | Medium | Medium | Low | Medium | Medium |
| Department of Economic Development, Jobs, Transport and Resources (DEDJTR) | Manages a number of NRM projects, with a focus on agricultural sustainability. | Medium | Low | Low | Low | Medium |
| Victorian Environmental Water Holder | With the CORANGAMITE CMA and water authorities, ensures environmental water entitlements achieve the best environmental outcomes. | Low | Medium | Low | Low | Medium |
| Corangamite CMA | Sets the strategic direction for the management of the region's natural assets, including the development of the 'NRM Plan for Climate Change'. | Low | High | Medium | Medium | High |

| Stakeholder | NRM adaptation role within Corangamite region | Research | Planning | Community engagement | Onground action | MERI |
|---|---|---|---|---|---|---|
| | Also involved in managing numerous climate change adaptation and mitigation projects. | | | | | |
| Local government | Incorporating climate change adaptation into planning (i.e. planning schemes), services and land management. Most Councils in the region are involved in the South West 'Climate Resilient Communities' Project. | Low | High | Medium | Medium | Medium |
| Parks Victoria | Parks Victoria is responsible for managing public land, most of which sits in a broader landscape that is changing. PV is at substantial risk from climate change because the natural assets they manage are vulnerable to climate change and other associated impacts such as bushfire. | Low | High | Medium | Medium | Medium |
| Committees of management (CoMs) | Manage crown land reserves on behalf of the Victorian government. CoMs are at risk from climate change because the natural assets they manage are vulnerable to climate change. They work closely with Coastal Boards. | Low | High | Medium | High | Medium |
| Water authorities | Water authorities are influential in shaping future water use in a context of rapid growth, competing demands for water resources and climate change. They work closely with VEWH and the Corangamite CMA. | Low | High | Medium | Medium | Medium |
| Central and Western Coastal Boards | Oversee the co-ordination, planning and management of the coast and marine environment in the state's western and central coastal regions, a role that is increasingly challenging particularly given the need for adaptation to climate change. | Low | High | Medium | Low | Medium |
| Southern Slopes Cluster (of NRM regions for Climate Change Adaptation) | The exchange of climate change adaptation information between CMAs and NRM regions improves the capacity of the Corangamite CMA to develop regional management approaches to climate change. | Medium | Medium | Low | Low | Medium |
| Southern Slopes Climate Change Adaptation Research Partnership (SCARP) | Supports the development of climate change adaptation in the Southern Slopes Cluster and builds the capacity of the Corangamite CMA to make best use of adaptation research. SCARP works closely with the SSC and CSIRO. | Medium | Medium | Medium | Low | Medium |
| Greening Australia | Provides support to community groups and organisations in conservation planning, seed supply and revegetation works. Regionally, GA is also involved in large-scale native vegetation projects and biochar research, a new area of research showing real benefits to soil carbon. | Medium | Medium | Medium | High | Medium |
| Trust for Nature | Protects remnant vegetation, in cooperation with private landowners, through its conservation covenant and land stewardship programs, making it more resilient to climate change. | Low | Medium | Medium | High | Medium |

| Stakeholder | NRM adaptation role within Corangamite region | Research | Planning | Community engagement | Onground action | MERI |
|---|---|---|---|---|---|---|
| Agriculture industry groups | Agriculture industry groups work directly with private land holders and can have a direct role in encouraging land management practices to acknowledge climate change. | Medium | Medium | High | Medium | Medium |
| Universities | Research is needed to understand problems and develop solutions for managing for climate change. Regionally, Universities are frequently involved in NRM monitoring and capacity building amongst the NRM community. Examples include the SWCCP and blue carbon research. | High | Medium | Low | Low | Medium |
| NRM groups (including Landcare networks and groups) | Have access to local knowledge and influence local landholders and can have a direct role in encouraging land management practices to acknowledge climate change. Collectively, they have the largest membership of community members. | Low | Medium | High | High | Medium |
| Indigenous groups | Indigenous Australians have a deep connection to Country and provide valuable knowledge of the landscape. Traditional Owners have a right and desire to; contribute to Indigenous cultural heritage maintenance and protection, and crown land and water management, all of which also address climate change. | Low | Medium | Medium | Medium | Medium |
| Private Land managers | Private land holders manage at least 70% of the region's catchment and therefore their practices have a great influence on NRM, including the need to adapt to climate change. | Low | Medium | High | High | Medium |
| The regional community | Members of the broader community are significant users of natural resources and can act on pro-environmental policies, including climate change. They participate in community groups taking action to address climate change. | Low | Low | Medium | Low | Low |

## 7.4 Recommended actions – Corangamite region

Actions for improving the way climate change is included in regional planning are provided in this section. Actions have been divided into two themes – regional and catchments (based on existing Landscape Zones).

The recommended actions are aspirational in nature and have been included as a guide only.

### Regional actions

Regional actions, listed in tables 29 - 31, can help the whole region move towards a climate ready future. They have been developed by assessing all available information to develop recommended actions to improve adaptation responses. They have been prepared with guidance from organisations such as CSIRO, AdaptNRM, NCCARF, SCARP, other NRM regions and through consultation with regional experts.

They are designed to be broad and provide guidance for adapting to climate change.

Each action listed has a lead stakeholder and supporting stakeholder/s. The action's capacity to improve a natural asset's adaptation potential is also provided. This will assist the reader to readily identify actions by natural asset. It also provides an overview of what actions will be single focused (i.e. address the adaptation capacity of one natural asset) or those which are multi-focused.

Each action has been prioritised to help focus future strategic directions for adapting the region's natural assets to climate change.

**High** – action is recommended to occur within the next 1-2 years to coincide with the development of adaptation pathways at a landscape scale, the development of the Regional Biodiversity Strategy and the Victorian Government's state-wide Adaptation Plan.

Actions that will form part of the Corangamite CMA and Deakin University's Blue Carbon Research Project are also categorised as high as they will be implemented over the next 1-2 years.

**Medium** – action is recommended to occur within the next 3-4 years to coincide with the review of the Corangamite Waterway Strategy and development of the next Regional Catchment Strategy.

**Low** – action is recommended to occur >5 years from the release of this plan and/or are actions that will be needed with the increasing impact of climate change on the region's natural assets.

**Table 28: Recommended actions - Research**

| Management theme | Recommended management action | Source of management action | Lead stakeholder/ partner stakeholder/s | Natural asset adaptation capacity improvement rating (*** High; ** Medium; *Low) | | | | | | | Priority |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Native Vegetation | Wetlands | Waterways | Estuaries | Coasts | Flora and Fauna | Soil | |
| Research | Determine indicator and keystone species for monitoring impacts of climate change. An indicator species is any species that defines a trait or characteristic of the environment (e.g. Hooded Plover). A keystone species plays a unique and crucial role in the way an ecosystem functions (e.g. Myrtle Beech). | REP Workshop – Flora and Fauna | DELWP (ARI)<br>DELWP (Regional), CCMA, SWIFFT, CEC | ** | ** | ** | ** | * | *** | * | High |
| | Undertake an annual evaluation of 'natural' flooding areas using remotely sensed imagery to assist NRM planners determine where resources should be focused on for future areas of resilience e.g. to flooding events. | REP Workshop – Waterways | CCMA<br>LGA'S | ** | *** | ** | * | * | * | * | Medium |
| | Determine 'tipping points' of wetlands from an ecological perspective based on previous paleosite research to assist NRM planning for wetlands under climate change. | REP Workshop – Wetlands | CCMA<br>FedUni, PV, DELWP (River Health) | * | *** | * | * | * | ** | * | Medium |
| | Investigate the potential 'tipping point' of an EVC where it changes to another EVC (the point where | REP Workshops – Native Vegetation | DELWP (ARI) | | | | | | | | |

| Management theme | Recommended management action | Source of management action | Lead stakeholder/ partner stakeholder/s | Natural asset adaptation capacity improvement rating (*** High; ** Medium; *Low) | | | | | | | Priority |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Native Vegetation | Wetlands | Waterways | Estuaries | Coasts | Flora and Fauna | Soil | |
| | climate change impacts are likely to be best monitored and adaptation measures implemented). | | CCMA, CSIRO, SWIFFT | *** | * | * | * | * | * | * | Medium |
| | Research (and monitor) the effect on water demand in the region through changing land use and agricultural practices in response to a changing climate and water resource constraints. | REP Workshops – Waterways and Wetlands | DEDJTR<br>CCMA, Ag Groups, NRM Groups, VEWH | * | ** | *** | ** | * | ** | * | Medium |
| | Undertake investigations to find credible links between carbon retention and inputs and the business e.g. trials, modelling, case studies, including south west specific information. | REP Workshop - Soils | CCMA<br>DEDJTR, SFS | * | * | * | * | * | * | *** | Medium |
| | Undertake trials that demonstrate the benefits derived from adding carbon rich sources to the farming system. | REP Workshop - Soils | CCMA<br>DEDJTR, SFS | * | * | * | * | * | * | *** | Medium |
| | Many of the region's estuaries are becoming more saline and/or stratified due to reduced freshwater inflows. Catchment flow modelling is needed to address the future impact of stream flow and the impacts of this on estuarine condition. | REP Workshop - Estuaries | CCMA<br>VEWH, RWAs | * | * | ** | *** | ** | ** | * | Medium |
| | Determine likelihood of translocation of fish species due to predicted changes to current environmental flows with priority provided to those populations with limited access to areas of refugia. | REP Workshop - Waterways | DELWP (ARI), CCMA<br>DELWP (Regional), VEWH, RWAs | * | * | ** | * | * | *** | * | Low |

| Management theme | Recommended management action | Source of management action | Lead stakeholder/ partner stakeholder/s | Natural asset adaptation capacity improvement rating (*** High; ** Medium; *Low) | | | | | | | Priority |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Native Vegetation | Wetlands | Waterways | Estuaries | Coasts | Flora and Fauna | Soil | |
| | Research the likelihood of invasive plants changing their distribution in the region, in particular within natural ecosystems through reduction or increase of existing distributions and the emergence of new species. | REP Workshops – Native Vegetation | DELWP, CCMA<br>DEDJTR, NRM Groups, Ag Groups, PV, CoMs, LGAs | *** | ** | ** | ** | ** | ** | * | Low |
| | Identify native flora and fauna species that might fill equivalent ecological roles as existing species move out of an area due to changing climatic conditions; and evaluate whether they should be allowed to persist. | REP Workshops – Native Vegetation | DELWP (ARI)<br>CSIRO, SWIFFT, CCMA, CEC | ** | * | * | * | * | ** | * | Low |
| | Explore research opportunities into ecological burning and carbon abatement in fire-dependent EVCs of the region (e.g. native grasslands). | REP Workshops – Native Vegetation | DELWP (ARI)<br>CFA, PV, CoMs, CCMA, NRM Groups | *** | * | * | * | * | ** | * | Low |
| | Determine the sea level rise impacts on groundwater systems (e.g. Bellarine Peninsula). | REP Workshop - Wetlands | FedUni<br>LGAs, CCMA, PV | * | *** | * | * | ** | ** | * | Low |

**Table 29: Recommended actions - Planning**

| Management theme | Recommended management action | Source of management action | Lead stakeholder/ partner stakeholder/s | Natural asset adaptation capacity improvement rating (*** High; ** Medium; *Low) | | | | | | | Priority |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Native Vegetation | Wetlands | Waterways | Estuaries | Coasts | Flora and Fauna | Soil | |
| Planning | Ensure all future regional NRM plans (i.e. Regional Biodiversity Strategy) incorporate key objectives, management directions and other related information from the NRM Plan for Climate Change. | Requirement of NRM Plan for Climate Change | CCMA | ** | ** | ** | ** | * | ** | * | High |
| | Develop spatial mapping that shows temporal aspects of the region's wetlands to provide a true baseline for setting strategic climate change adaptation management actions.<br>*Mapping would provide a more realistic representation of the 2030 – 2090 scenarios with current vulnerability compared to projected vulnerability. Many wetlands are already vulnerable and this needs to be shown as a starting point since the maps give a false sense of vulnerability.* | REP workshop - Wetlands | CCMA<br>FedUni, PV, DELWP (Regional) | ** | *** | * | *** | * | * | * | High |
| | Create a groundwater dependent wetland layer to improve adaptation planning and appropriate adaptation measures. | REP workshop - Wetlands | CCMA<br>FedUni, PV | ** | * | * | *** | * | * | * | High |

| Management theme | Recommended management action | Source of management action | Lead stakeholder/ partner stakeholder/s | Native Vegetation | Wetlands | Waterways | Estuaries | Coasts | Flora and Fauna | Soil | Priority |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Natural asset adaptation capacity improvement rating (*** High; ** Medium; *Low) | | | | | | | |
| | Explore feasibility of developing Adaptation Pathways Plan for the region's Ramsar listed wetlands | REP workshop - Wetlands | CCMA<br>PV, FedUni, RMIT, NRM Groups | ** | *** | * | *** | * | * | * | High |
| | Develop pilot Landscape Adaptation Plans using adaptation pathways for two of the region's Landscape Zones. | REP Workshops - All | CCMA<br>NRM Groups, RMIT, CeRDI | *** | *** | *** | *** | *** | *** | *** | High |
| | Refine current vulnerability modelling. Regional experts are confident that modelling can be improved through the addition of ground-truthed and other associated data, with a particular focus on native vegetation and soils. | REP Workshops – Native Vegetation/ Soils | CCMA<br>DELWP (ARI), Ag Groups, FedUni, SWIFFT | *** | ** | ** | ** | * | ** | * | High |
| | Use downscale climate change prediction data from CSIRO to refine vulnerability modelling to allow better NRM planning at the regional and landscape scale.<br>*Downscaled data will improve decision making and is expected that this refinement will be required every 5 years as new predictions are determined modelling is improved.* | REP Workshop – All | CCMA<br>CSIRO, DELWP (Biodiversity) | *** | *** | *** | *** | *** | *** | *** | High |
| | Use LiDAR, combined with ground-truthing, to identify latitudinal and elevational gradients and areas of refugia, including areas of shade zones and habitat pools to enhance connectivity and habitat within the region's high priority waterways, as defined in the CWS. Moorabool River to be done in 2016. | REP Workshop - Waterways | CCMA<br>DELWP (River Health), DELWP (ARI) | * | * | *** | ** | * | *** | * | High |

| Management theme | Recommended management action | Source of management action | Lead stakeholder/ partner stakeholder/s | Natural asset adaptation capacity improvement rating (*** High; ** Medium; *Low) | | | | | | | Priority |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Native Vegetation | Wetlands | Waterways | Estuaries | Coasts | Flora and Fauna | Soil | |
| | Develop landscape connectivity modelling based on fauna requirements under a changing climate. | REP Workshop – Flora and Fauna | DELWP (Biodiversity)<br>CCMA, CSIRO, SWIFFT | ** | * | ** | * | * | *** | * | High |
| | Continue to refine regional approach to adaptation pathways for both managing the region's natural assets and as a process for developing landscape scale plans. | REP Workshops - All | CCMA<br>NRM Groups, RMIT, CeRDI | *** | *** | *** | *** | *** | *** | *** | High |
| | Further refine carbon sequestration modelling for the region with a focus on revegetation and blue carbon habitats and wetlands. | REP Workshops – Wetlands and Coastal Wetlands | CCMA<br>Deakin, PV, LGAs, NRM Groups, Ag Groups, GA | ** | ** | ** | ** | * | * | ** | High |
| | Develop a regional or south west baseline species climate adaptation priority matrix acknowledging that some species not may adapt to climate change. | REP Workshop – Flora and Fauna | DELWP (Regional)<br>CCMA, SWIFFT, DELWP (ARI & Biodiversity) | ** | ** | ** | ** | * | *** | * | High |
| | Combine Species Distribution Models, NaturePrint and other state level related datasets, with regional biodiversity datasets and relevant climate change modelling to develop priority landscapes for conservation, as part of the development of the Corangamite Biodiversity Strategy. | REP Workshop – Native Vegetation | DELWP (Biodiversity)<br>CCMA, CSIRO, SWIFFT, PV | ** | ** | ** | ** | * | *** | * | High |

| Management theme | Recommended management action | Source of management action | Lead stakeholder/ partner stakeholder/s | Natural asset adaptation capacity improvement rating (*** High; ** Medium; *Low) | | | | | | | Priority |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Native Vegetation | Wetlands | Waterways | Estuaries | Coasts | Flora and Fauna | Soil | |
| | Develop and maintain standardised mapping of seagrass beds at appropriate temporal and spatial scales | REP Workshop – Coastal Wetlands | Deakin<br>CCMA, PV, CCB, WCB | ** | ** | ** | ** | * | *** | * | High |
| | Develop, implement and review Environment Water Management Plan for Moorabool River. | REP - Waterways | CCMA<br>VEWH, NRM Groups | ** | * | *** | * | * | ** | * | High |
| | Add other ratings, including invasive species and likelihood of species loss, to current sensitivity ratings from the spatial vulnerability assessment, to further refine spatial vulnerability assessment for native vegetation. | REP Workshop – Native Vegetation | CCMA<br>DELWP (Regional), SWIFFT, PV, CoMs | *** | * | ** | ** | * | ** | * | High |
| | Explore opportunities for the potential translocation of Corangamite Water Skink populations based on predicted changes to existing habitat locations | REP Workshops – Wetlands/ Flora and Fauna | DELWP (Regional)<br>DELWP (Biodiversity), PV | * | * | * | * | * | *** | * | High |
| | Update Corangamite RCS, at its mid-term review (due in 2016), to incorporate key objectives, management directions and other related information from the 'NRM Plan for Climate Change' | Requirement of NRM Plan for Climate Change | CCMA | ** | ** | ** | ** | ** | ** | ** | Medium |

| Management theme | Recommended management action | Source of management action | Lead stakeholder/ partner stakeholder/s | Natural asset adaptation capacity improvement rating (*** High; ** Medium; *Low) | | | | | | | Priority |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Native Vegetation | Wetlands | Waterways | Estuaries | Coasts | Flora and Fauna | Soil | |
| | Update Corangamite Waterway Strategy, at its mid-term review (due in 2017), to incorporate key objectives, management directions and other related information from the NRM Plan for Climate Change. | REP workshop - Waterways | CCMA | ** | *** | ** | ** | * | ** | * | Medium |
| | Review ISC 2010 to determine ranking of stressed rivers for sensitivity refinement to improve regional vulnerability assessment of waterways | REP workshop - Waterways | DELWP (River Health)<br>CCMA | ** | *** | ** | ** | * | ** | * | Medium |
| | Develop Landscape Adaptation Plans using adaptation pathways for each of the region's remaining Landscape Zones. | REP Workshops - All | CCMA<br>NRM Groups, RMIT, CeRDI | *** | *** | *** | *** | *** | *** | *** | Medium |
| | Use LiDAR, combined with ground-truthing, to identify latitudinal and elevational gradients and areas of refugia to enhance connectivity and habitat within the region's high priority estuaries, as defined in the CWS. | REP Workshop - Estuaries | CCMA<br>DELWP (River Health & ARI), Deakin | * | * | ** | *** | * | *** | * | Medium |
| | Use state-wide burn strategy datasets to help plan for projected greater impacts caused by more frequent and intense fire events, with a priority on the impact on flora and fauna species to fire from 2015 to 2050. | REP Workshop – Native Vegetation | DELWP (Fire)<br>PV, DELWP (Regional), CoMs | ** | * | * | * | * | ** | * | Medium |
| | Ensure all current landslip susceptible areas, as well as other vulnerable areas identified as high priority under climate change, are included in planning schemes and associated controls | REP Workshop - Soils | LGAs<br>FedUni, CCMA | * | * | * | * | * | * | *** | Medium |

| Management theme | Recommended management action | Source of management action | Lead stakeholder/ partner stakeholder/s | Natural asset adaptation capacity improvement rating (*** High; ** Medium; *Low) | | | | | | | Priority |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Native Vegetation | Wetlands | Waterways | Estuaries | Coasts | Flora and Fauna | Soil | |
| | Undertake finer scale regional EVC mapping based on ground-truthed data. It is predicted the greatest level of change will be in areas where EVCs adjoin one another – current mapping does not allow this. Finer scale mapping will allow for specific and better localised planning. | REP Workshop – Native Vegetation | DELWP (ARI)<br>DELWP (Regional), CCMA, PV, | *** | * | ** | ** | * | ** | * | Medium |
| | Add regional Index of Estuary Condition data to current sensitivity ratings, to further refine spatial vulnerability assessment for estuaries. Also explore estuary openings and runoff estimate data. | REP Workshop - Estuaries | CCMA<br>Deakin, LGAs, PV, DELWP (River Health) | * | * | ** | *** | * | * | * | Medium |
| | Improve region's acid-sulphate soil mapping, with a particular focus on estuarine environments and ephemeral wetlands.<br>*Dry conditions create drops in water level and increase in acid sulphate soils. When there is a drop in the upper catchment this is compounded. Coastal acid sulphate soils will be covered under sea level rise but this may cause an increase in acid-sulphate soils further upstream* | REP Workshop - Estuaries | CCMA<br>DELWP, Monash University | * | * | ** | *** | * | * | ** | Medium |
| | Improve current sensitivity mapping with regional information and data, including CSIRO soil carbon data if applicable, as part of the soil vulnerability assessment, to better represent the impact of climate change. (Adaptive capacity will be developed through land manager requirements). | REP Workshop - Soils | CCMA<br>FedUni, Ag Groups, CSIRO | * | * | * | * | * | * | *** | Medium |

| Management theme | Recommended management action | Source of management action | Lead stakeholder/ partner stakeholder/s | Natural asset adaptation capacity improvement rating (*** High; ** Medium; *Low) | | | | | | | Priority |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Native Vegetation | Wetlands | Waterways | Estuaries | Coasts | Flora and Fauna | Soil | |
| | Develop modelling and plan for the upstream migration of fauna within the region's estuaries due to sea level rise | REP workshop - Estuaries | DELWP (ARI)<br>CCMA, Deakin, DELWP (River Health) | ** | ** | *** | *** | ** | ** | * | Low |
| | Develop modelling and plan for the migration of coastal saltmarsh (i.e. amend planning schemes to reflect migration options) and other similar vegetation communities due to sea level rise. | REP Workshop – Coastal Wetlands | CCMA<br>DELWP, Deakin, LGAs, PV, CoMs | ** | *** | * | ** | ** | * | * | Low |

**Table 30: Regional priority actions - MERI**

| Management theme | Management action | Source of management action | Lead stakeholder/ partner stakeholder/s | Natural asset adaptation capacity improvement rating (*** High; ** Medium; *Low) | | | | | | | Priority |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Native Vegetation | Wetlands | Waterways | Estuaries | Coasts | Flora and Fauna | Soil | |
| MERI | Monitor the condition and extent of all EVCS, based on 2010 benchmark, in the Aire, Anglesea, Curdies and Hovells creek estuaries to detect impacts of sea level rise. | REP Workshop - Estuaries | CCMA<br>DELWP (ARI), PV, CoMs | *** | ** | ** | *** | ** | ** | * | High |
| | During periods of drought, conduct monthly inspections of systems with important surviving populations of endangered fish species (Curdies River, Callahan Creek, Barwon River West Branch, Gosling Creek, Waurn Ponds Creek, Painkalac Creek, Thompsons Creek, Matthews Creek, Pennyroyal Creek, Moorabool River) | (CCMA, 2007) | CCMA<br>DELWP (ARI), NRM Groups | * | * | ** | ** | * | *** | * | High |
| | Explore opportunities to establish a SeagrassWatch Program for Swan Bay | REP Workshop – Coastal Wetlands | CCMA<br>Deakin, NRM Groups, PV | ** | ** | * | ** | ** | ** | * | High |

| Management theme | Management action | Source of management action | Lead stakeholder/ partner stakeholder/s | Natural asset adaptation capacity improvement rating (*** High; ** Medium; *Low) | | | | | | | Priority |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Native Vegetation | Wetlands | Waterways | Estuaries | Coasts | Flora and Fauna | Soil | |
| | Establish the baseline condition and extent of specific fauna (i.e. estuarine dependent fish species) in the Aire, Anglesea, Curdies and Hovells creek estuaries to monitor impacts of sea level rise. | REP Workshop - Estuaries | CCMA<br>DELWP (ARI), PV | * | * | * | *** | ** | *** | * | Medium |
| | Maintain a strategic long-term sea-grass community monitoring program that includes biotic and abiotic parameters of the community. | REP Workshop – Coastal Wetlands | CCMA<br>Deakin, PV, DELWP (Biodiversity), COGG | *** | *** | ** | ** | ** | ** | * | Medium |
| | Establish native vegetation monitoring standards that incorporate indicators such as structure, function and extent, to climate change.<br>*Current native vegetation monitoring and assessment programs do not monitor changes to vegetation communities caused by climate change (i.e. loss of species, changes to structure, new weed species, etc.)* | REP Workshops – Native Vegetation | DELWP (Biodiversity)<br>DELWP (ARI), CCMA, PV, CoMs, SWIFFT | *** | ** | ** | ** | ** | * | * | Medium |
| | Establish a soil carbon monitoring network across the region, over a representative range of the region's farming enterprises, with a minimum sampling period of five years. | REP Workshop - Soils | CCMA<br>DEDJTR, Ag Groups | * | * | * | * | * | * | *** | Medium |

## Catchment actions

The impacts of climate change will vary across the region. For example, in the southern part of the region, a warmer and drier climate could result in a higher frequency and greater intensity of bushfires and as a result, a loss of wetter dominated vegetation communities like Cool Temperate Rainforest. In other areas, such as those to the north of the region, wetlands will be most significantly impacted.

In light of this, 'Guiding Adaptation Principles' have been developed at a 'catchment scale' through interpreting predicted climate change impacts on the region's natural assets and developing the adaptation responses that are needed. They are designed to be broad and provide guidance for adapting to Climate Change in each landscape zone. Figure 24 provides a map of the regions catchments (and associated Landscape Zones) – Barwon River, Lake Corangamite, Moorabool River and the Otway Coast.


**Figure 24: Water basins and landscape zones of the Corangamite region**

Within each catchment, vulnerability ratings have been given to each of the respective catchment's main natural assets. These ratings are based on the regional vulnerability assessment (refer Section 4). Ratings have been adopted from this assessment and are presented in Table 32.

**Table 31: Vulnerability ratings**

| Natural Asset | Low | Moderate | High | Very High |
|---|---|---|---|---|
| Native Vegetation | <15 | 16 – 21 | 22 - 27 | >28 |
| Rivers and Streams | <15 | 16 – 21 | 22 - 27 | >28 |
| Wetlands | <15 | 16 – 21 | 22 - 27 | >28 |
| Coastal Wetlands | <15 | 16 – 21 | 22 - 27 | >28 |
| Estuaries | <15 | 40 (Seawater Present) | 45 (Storm Surge Impact) | 50 (Sea Level Impact) |
| Soils* | 10 -12 | 13 – 15 | 25 - 27 | 28 - 30 |

**(*impact ratings were used for soils, as explained in Section 4.5)**

Key stakeholders within each of the catchments have also been listed as those who may show leadership in ensuring that these guiding adaptation responses are adopted.

For aligning water reach numbers and their location in the landscape, please refer to the Corangamite Waterway Strategy at www.ccma.vic.gov.au

## 7.5 Priority actions – Moorabool River Catchment

**Overview**

The Moorabool River catchment is located north-east of Geelong and includes the Moorabool and Hovells Landscape Zones. The main rivers are the Moorabool River, which is highly regulated and flows into the Barwon River at Fyansford and Hovells Creek, which flows into Corio Bay via Limeburners Lagoon. NRM groups in this catchment include Moorabool Catchment Network and Geelong Landcare Network. Public land managers include Parks Victoria, Barwon Water, Melbourne Water and the City of Greater Geelong. Local municipalities include Golden Plains Shire, Moorabool Shire and the City of Greater Geelong.

**Natural values**

The catchment contains a number of wetlands, including Limeburners Lagoon, which form part of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site.

Wurdi Youang (You Yangs) Regional Park is located in the north of the landscape zone and is of significant environmental, cultural and social importance. The gorges and steep escarpments of the Moorabool River contain areas of remnant vegetation that provide important wildlife corridors throughout the catchment. The significant land use in the landscape zone is agriculture, with dominant types being grazing, horticulture and cropping.

**Potential impacts of climate change**

The already highly stressed waterways of this catchment, notably the Moorabool River and its tributaries, will be further impacted through a predicted decline of 30% rainfall, leading to a decrease in runoff and **reduced environmental flows**. Many of the catchment's waterways are steep and dissected and have not evolved to accommodate annual flooding events which are predicted to increase under a changing climate. As a consequence, **bank erosion** is expected to increase after such events.

The catchment contains large areas of dry forests and woodlands to the north and with a hotter climate and less rainfall, may also be impacted by **more frequent and intense fire events**. The shallow, friable soils of the upper catchments may be more susceptible to erosion due to a higher frequency of fire events and may lead to **increased levels of sedimentation** and events of sand slugs within the catchment's waterways.

The catchment has a number of species which may be impacted by climate change. Examples of flora include the Yarra Gum (*Eucalyptus yarraensis*), Brittle Greenhood (*Pterostylis truncate*) and Spiny Rice-flower (*Pimelea spinescens*). Examples of fauna species include the Orange-bellied Parrot (*Neophema chrysogaster*), Grassland Earless Dragon (*Tympanocryptis pinguicolla*) and Yarra Pygmy Perch (*Nannoperca obscura*).

**Sea level rise** will impact the coastline areas of the Hovells Creek, causing changes to current estuarine processes. **Land use practices may change** to adapt to the drier and warmer climate, as well as further reduced access to water from the Moorabool River and groundwater sources.

**Carbon sequestration opportunities**

The main carbon sequestration opportunities include revegetation through shelterbelts, riparian protection and wildlife corridors. Opportunities for soil carbon may exist but more research is required to determine the best methods and the best locations. There are limited opportunities for blue carbon sequestration within and adjacent to Limeburners Lagoon.

**Table 32: Moorabool catchment priority actions**

| Natural asset | Vulnerability rating* | Climate change threat (direct &/or indirect) | Guiding adaptation responses | Stakeholders |
|---|---|---|---|---|
| Moorabool River (reaches 32-8 and 32-9) | Very High | Higher temperatures and longer periods without rainfall will lead to less flow and reduced areas of refugia for aquatic species. More intense rainfall events may lead to more areas being susceptible to bank erosion. | Prioritise areas within reaches for targeted revegetation to improve shading and habitat as well as alleviate impacts of potential bank erosion. Protect riparian vegetation through fencing. Revegetate priority areas and provide instream habitat. Investigate options for removing artificial fish barriers e.g. weirs. Investigate feasibility of relocating isolated fish populations (Yarra Pygmy Perch). Collaboratively review and optimise water management to increase waterway resilience. Continue to develop, implement and review Environment Water Management Plan for Moorabool River. | CCMA, NRM groups, Moorabool Shire, DELWP (ARI), EWH, Barwon Water, private landholders |
| Moorabool River (reaches 32-5 and 32-7) | High | | | |
| Moorabool River (reaches 32-1, 32-2, 32-3 and 32-6) | Moderate | | | |
| Moorabool River (reaches 32-4, 32-10, 32-11 and 32-12) | Low | | | |
| Hovells Creek | Moderate | Higher temperatures and longer periods without rainfall will lead to less flow and reduced areas of refugia for aquatic species. More intense rainfall events may lead to more areas being susceptible to bank erosion. | Prioritise areas within reaches for targeted revegetation to improve shading and habitat as well as alleviate impacts of potential bank erosion. Protect riparian vegetation through fencing. Revegetate priority areas and provide instream habitat. Investigate options for and management of weir under Old Melbourne Road. | CCMA, NRM groups, COGG, private landholders |
| Hovells Creek Estuary and Limeburners Lagoon | Low | A sea level rise of between 0.8-1.1 metres by 2100, hotter temperatures, a reduction in rainfall and an increase in extreme natural events e.g. flooding are all expected to impact the ecology and dynamics of Limeburners Lagoon. | Assess natural freshwater flow regimes into Limeburners Lagoon and determine options for improved flows. Investigate opportunities to upgrade infrastructure that becomes inundated with high estuary water levels, with 'green infrastructure'. Use LiDar to identify latitudinal and elevational gradients, areas of refugia and opportunities to enhance connectivity. Establish management agreements with private landholders within Limeburners Lagoon to improve resilience of estuarine vegetation to climate change Protect riparian vegetation through fencing Restore riparian zone using appropriate revegetation. Explore opportunities for a modified EstuaryWatch program for Limeburners Lagoon to help monitor changes associated with climate change. | COGG, CCMA, NRM groups, GA, private landholders |

| Natural asset | Vulnerability rating* | Climate change threat (direct &/or indirect) | Guiding adaptation responses | Stakeholders |
|---|---|---|---|---|
| Native Vegetation – Lower Slopes/Hills Woodland and Riparian Woodland/ Forests | Very High | A hotter and drier climate may cause existing vegetation communities to change in their composition and structure, with some species being replaced by others. Fire regimes will be modified, most likely with more frequent and intense events. Vegetation communities may be vulnerable to environmental weeds. Some vegetation communities will be more vulnerable than others to the direct impacts of climate change e.g. Riparian Woodland. | Management should focus on maximising the resilience of communities and maintaining ecosystem function. In many cases this will mean managing native vegetation as we do today. Improving the current condition is likely to be important for the long-term viability of a community, with those in better condition more resilient to change in the short term, and more adaptable in the long term, due to their greater genetic, floristic and structural diversity. | NRM groups, CCMA, PV, LGAs, VicRoads, Trust, private landholders |
| Native Vegetation – Dry Forests | Moderate - High | | | |
| Native Vegetation – Plains Woodland, Lowland Forest and Plains Grassland | Moderate | | | |
| Native Vegetation – Heathy Woodland | Low | | | |
| Wetlands – Coastal Wetlands (i.e. Point Lillias & Point Wilson) | Moderate | Coastal wetlands are very vulnerable to climate change. Increased drought frequency and intensity, decreases in freshwater inputs, rising sea levels and increases in coastal storm surges may impact these important ecosystems. These conditions may also change the character of coastal wetlands through a reduction in size, conversion to dryland or a shift from one wetland type to another e.g. brackish to saline. Under hotter and drier conditions as well as reduced inflows, acid sulphate soils in coastal wetlands may face an increased risk of being exposed. The retention of coastal wetlands will require planning approaches which allow for the migration of wetland communities, in order to avoid significant loss in both extent and character. | Assess the likely impacts of climate change on coastal wetland processes (i.e. tidal exchange, berm position and shoreline recession, entrance openings, water balance, geomorphology, water quality and biodiversity). Monitor sea level rise and associated impacts. Plan areas for marginal terrestrial vegetation e.g. Coastal Saltmarsh, migration due to sea level rise. Prioritise blue carbon habitats and investigate blue carbon opportunities. Investigate opportunities to upgrade infrastructure that becomes inundated with high sea water levels, with 'green infrastructure'. Develop an 'Adaptation Plan for Point Lillias and Point Wilson' including adjacent habitats. Establish the baseline condition and extent of all EVCS within both Point Lillias and Point Wilson to monitor impacts of sea level rise. | PV, COGG, GA, NRM groups, private landholders |
| Wetlands – Lake Serendip and others | Very High - High | Wetlands that are highly vulnerable to a climate that is hotter and drier will reduce in both extent and quality. A reduction in rainfall and runoff could cause some temporary wetlands to dry up permanently. A reduction in water inflow may also cause an increase in the salinity of some wetlands, and changes in the types of vegetation communities that they can support. Wetlands that are reliant on groundwater/spring fed may also be impacted. | Management should focus on maximising the resilience of wetland communities and maintaining ecosystem function. In many cases this will mean managing wetlands as we do today. Improving the current condition is likely to be important for the long-term viability of a wetland, with those in better condition more resilient to change in the short term, and more adaptable in the long term, due to their greater genetic, floristic and structural diversity. Research potential recycled water/stormwater sources from Lara (both quality and quantity), for Lake Serendip. Develop a climate adaptation plan for Lake Serendip. Research 'blue carbon' opportunities of the catchment's wetlands. Research potential groundwater sources (both quality and quantity) for selected wetlands. | PV, NRM groups |

| Natural asset | Vulnerability rating* | Climate change threat (direct &/or indirect) | Guiding adaptation responses | Stakeholders |
|---|---|---|---|---|
| Agricultural Land | Low – Moderate | Climate change will have a direct impact on soil health and the ability of soil to support specific uses. Prolonged periods of higher temperatures and reduced moisture may lead to more areas being more susceptible to wind erosion. More intense rainfall events may also lead to areas of sheet, rill and gully erosion. Reduced vegetation cover due to climate change will also exacerbate these impacts. An increase in dryness and lack of moisture will also impact organic carbon in soil. Agricultural productivity may increase or decrease under a changing climate, depending on where it is located e.g. from grazing to cropping. | Addressing the impacts on soil will need to be assessed, planned and implemented at a site level due to a) the level of impact (often site-specific) and b) the adaptation response of the land manager of that site. A changing climate may mean that a current agricultural enterprise may need to also change to make better use of the climatic conditions, as well as changes to the soil properties that are expected. Research opportunities for soil carbon sequestration within this catchment should also be a priority. | Ag groups, NRM groups, CCMA, private landholders |
| Native Flora | Very High | The rate of climate change is likely to overtake the ability of most flora species to adapt and as a result, changes to the distribution of flora species are expected to occur. Changes in life cycle events e.g. flowering times, are also expected to greatly impact flora populations. There is also potential for greater tree mortality under climate change due to drought and temperature increases. | Management should focus on maximising the resilience of communities and maintaining ecosystem function. In many cases this will mean managing flora populations as we do today. Improving the current condition is likely to be important for the long-term viability of a community, with those in better condition more resilient to change in the short term, and more adaptable in the long term, due to their greater genetic, floristic and structural diversity. Protection and promoting the regeneration of large old paddock trees should be seen as a landscape priority due to their genetic capacity to survive through a significant range of climatic conditions and therefore provide a future seed source. | NRM groups, LGAs, CCMA, PV, DELWP (regional) |
| Native Fauna | Very High | Similar to flora species, the rate of climate change is also likely to overtake the ability of most fauna species to adapt and as a result, changes to the distribution of fauna are expected to be a major response to climate change. More mobile species may find refuge from increasing temperatures by shifting to higher, cooler elevations or cooler, south-facing slopes. Species already restricted to high altitudes without the option of upslope migration are expected to become extinct unless they are able to adapt. Some species will be more vulnerable than others to extinction. Species may not be able to shift to areas with suitable climatic conditions where they are located in fragmented habitats, or because of their limited dispersal ability. Species with small, isolated or fragmented ranges, or those with low genetic variation and specific climatic requirements, will be more vulnerable and local extinctions are likely. | Protect and enhance existing natural populations. Maintain and improve diversity. Accept and accommodate unavoidable loss and facilitate transformation, when possible. Reduce impacts from other impacts of climate change (i.e. invasive species & changes to flooding and fire regimes). Allow and create space for species shifts and movement throughout the landscape. Increase connectivity (i.e. buffers, corridors, stepping stones) and areas of refugia. Monitor species, communities and ecological processes. | NRM groups, LGAs, CCMA, PV, DELWP (regional) |

**(*impact ratings were used for soils, as explained in Section 4.5)**

## 7.6 Priority actions – Barwon River Catchment

**Overview**

The Barwon River Catchment encompasses the Bellarine Peninsula east of Geelong, the Barwon and Leigh River catchments and the landscape that immediately surrounds Lake Murdeduke. It is characterised by the Bellarine coastline, the inland slopes and plains of the Otway Ranges, the gorges extending along parts of the Leigh River and a large part of the region's volcanic plains. The Landscapes Zones of Leigh, Upper Barwon, Mid Barwon, Murdeduke and Bellarine are in this large catchment.

NRM groups include Leigh Catchment Group, Upper Barwon Landcare Network, Geelong Landcare Network and Bellarine Catchment Network. Public land managers include Parks Victoria, City of Greater Geelong, Barwon Coast Committee of Management, and Bellarine Bayside Committee of Management. A number of specialist environmental and agricultural industry groups e.g. Ballarat Environment Network and Southern Farming Systems also address NRM issues in the catchment. Local municipalities include Golden Plains, Surf Coast, Colac Otway shires and the cities of Greater Geelong and Ballarat and the Borough of Queenscliffe.

**Natural values**

The major river in this landscape zone is the lower Barwon River, which is the main source of fresh water to the lower Barwon wetlands and estuary. Sections of the river support good riparian environments that include red gum woodlands and a number of significant species. The estuarine reach of the Barwon River incorporates a system of wetlands and lakes listed as wetlands of international significance under the Ramsar Convention as part of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site. Examples include Lake Connewarre, Reedy Lake and Hospital Swamps.

This zone is part of the Victorian Volcanic Plain bioregion, which covers 2.3 million hectares, extending across south-west Victoria. It also contains highly valuable grasslands, grassy woodlands and scattered wetlands. Lake Murdeduke is a wetland listed under the Western District Lakes Ramsar site.

This is a productive agricultural region and was one of the first areas settled for agriculture around Geelong. Main agricultural practices include grazing, cropping and forestry.

**Potential impacts of climate change**

The Barwon River has a number of current challenges that climate change could exacerbate including reduced environmental flows and an increase of sediment loads from feeding tributaries.

These environmental challenges and the spread of drought tolerant invasive weed species, such as Tall Wheatgrass (*Thinopyrum ponticum*), will impact on already stressed ecosystems such as wetlands, fragmented remnant vegetation and riparian habitats. A warmer and drier climate, combined with an increase in groundwater demand, will cause many of the catchment's wetlands and swamps to dry.

The **fire regimes** of the more heavily vegetated areas of the upper catchments of both the Leigh and Barwon Rivers, will change under a warmer and drier climate, with more frequent and intense events.

Climate change may impact a number of species in this catchment.

Examples of flora include the Clover Glycine (*Glycine latrobeana*), Small Scurf-pea (*Cullen parvum*) and Bellarine Yellow-gum (*Eucalyptus leucoxylon subsp. bellarinensis*). Examples of fauna species include the Australian Grayling (*Prototroctes maraena*), Hooded Plover (*Thinornis rubricollis rubricollis*) and Growling Grass Frog (*Litoria raniformis*).

**Sea level rise** will impact the coastline areas of the Bellarine Peninsula. **Land use practices may change** to adapt to the drier and warmer climate, as well as the already reduced access to water such as the Barwon River and groundwater sources.

**Carbon sequestration opportunities**

Carbon sequestration opportunities include revegetation through shelterbelts, agroforestry, riparian protection and wildlife corridors. Opportunities for soil carbon may exist but more research is required to determine the best methods and locations. High opportunities for blue carbon sequestration exist in the Bellarine Landscape Zone with areas of Coastal Saltmarsh on both public and private land and seagrass communities in Swan Bay and coastal areas to the north of the peninsula.

***Barwon River. Photo: Alison Pouliot***

**Table 33: Barwon River catchment priority actions**

| Natural asset | Vulnerability rating* | Climate change threat (direct &/or indirect) | Guiding adaptation responses | Stakeholders |
|---|---|---|---|---|
| Major Waterway – Barwon River | Moderate - Low | Higher temperatures and longer periods without rainfall will lead to less flow and reduced areas of refugia for aquatic species. More intense rainfall events may lead to more areas susceptible to bank erosion. | Prioritise areas within reaches for targeted revegetation to improve shading and habitat as well as alleviate impacts of potential bank erosion. Protect riparian vegetation through fencing. Revegetate priority areas and provide instream habitat. Investigate options for removing artificial fish barriers e.g. weirs. Investigate feasibility of relocating isolated fish populations, e.g. Yarra Pygmy Perch. Collaboratively review and optimise water management to increase waterway resilience. | CCMA, NRM Groups, DELWP (ARI), Barwon Water, VEWH, Private landholders |
| Other Waterways – Mia Creek and Warrambine Creek | Very High | | | |
| Other Waterways – Waurn Ponds Creek, Dewing Creek and Pennyroyal Creek | High | | | |
| Other Waterways – Native Hut Creek, Boundary Creek and Yarrowee River | Moderate | | | |
| Other Waterways – Leigh River | Moderate - Low | | | |
| Barwon River Estuary | Moderate | A sea level rise of between 0.8-1.1 metres by 2100, hotter temperatures, a reduction in rainfall and an increase in extreme natural events e.g. flooding, are all expected to impact the ecology and dynamics of the Barwon River Estuary. | Investigate opportunities to upgrade infrastructure that becomes inundated with high estuary water levels, with 'green infrastructure'. Work with public land managers to improve resilience of estuarine vegetation to climate change. Protect riparian vegetation through fencing Restore riparian zone using appropriate revegetation. Maintain EstuaryWatch group for Barwon River Estuary to help monitor changes associated with climate change. | PV, Barwon Coast CoM, CCMA, NRM Groups |
| Native Vegetation – Wet or Damp Forests | Very High | A hotter and drier climate may cause existing vegetation communities to change in their composition and structure, with some species being replaced by others. Fire regimes will be modified, most likely with more frequent and intense events. Vegetation communities may be vulnerable to environmental weeds. | Management should focus on maximising the resilience of communities and maintaining ecosystem function. In many cases this will mean managing native vegetation as we do today. | NRM groups, CCMA, PV, LGAs, VicRoads, Trust, private landholders |
| Native Vegetation – Dry Forests, Plains Woodland or Forests, Lowland Forests, | Moderate | | | |

| Natural asset | Vulnerability rating* | Climate change threat (direct &/or indirect) | Guiding adaptation responses | Stakeholders |
|---|---|---|---|---|
| Lowland Slopes or Hills Woodlands, Riparian Forests or Woodlands | | Some vegetation communities will be more vulnerable than others to the direct impacts of climate change e.g. Riparian Woodland. | Improving the current condition is likely to be important for the long-term viability of a community, with those in better condition more resilient to change in the short term, and more adaptable in the long term, due to their greater genetic, floristic and structural diversity. | |
| Native Vegetation – Heathy Woodland, Salt Tolerant/ Succulent Shrublands, Coastal Scrubs Grassland/ Woodlands | Low | | | |
| Wetlands – Lake Gherang and Bingley Swamp | Very High | Wetlands that are highly vulnerable to a climate that is hotter and drier will reduce in both extent and quality. A reduction in rainfall and runoff could cause some temporary wetlands to dry up permanently. A reduction in water inflow may also cause an increase in the salinity of some wetlands, and changes in the types of vegetation communities that they can support. Wetlands that are reliant on groundwater/spring fed may also be impacted. | Management should focus on maximising the resilience of communities and maintaining ecosystem function. In many cases this will mean managing wetlands as we do today. Improving the current condition is likely to be important for the long-term viability of a wetland, with those in better condition more resilient to change in the short term, and more adaptable in the long term, due to their greater genetic, floristic and structural diversity. Research potential recycled water/stormwater sources from Point Lonsdale (both quality and quantity), for Lake Victoria. Develop a climate adaptation plan for Lake Victoria and Lake Murdeduke. Research 'blue carbon' opportunities of the catchment's wetlands. Research potential groundwater sources (both quality and quantity) for selected wetlands. | PV, CCMA, NRM groups, Private landholders |
| Wetlands – Lake Victoria and Lake Thurrumbong, | High | | | |
| Wetlands – Lake Murdeduke | Moderate | | | |
| Coastal Wetlands – Lake Connewarree/Reedy Lake/Hospital Swamp) and Salt Lagoon | Very High | Coastal wetlands are very vulnerable to climate change. Increased drought frequency and intensity, decreases in freshwater inputs, rising sea levels and increases in coastal storm surges may all impact these important ecosystems. These conditions may also change the character of coastal wetlands through a reduction in size, conversion to dryland or a shift from one wetland type to another e.g. brackish to saline. Under hotter and drier conditions and reduced inflows, acid sulphate soils in coastal wetlands will face an increased risk of exposure. The retention of coastal wetlands will require planning approaches which allow for the migration of wetland communities to avoid significant loss in both extent and character. | Management should focus on maximising the resilience of communities and maintaining ecosystem function. Improving the current condition is likely to be important for the long-term viability of flora and fauna communities. Assess the likely impacts of climate change on coastal wetland processes (i.e. tidal exchange, berm position and shoreline recession, entrance openings, water balance, geomorphology, water quality and biodiversity). Monitor sea level rise and associated impacts. Plan areas for marginal terrestrial vegetation e.g. Coastal Saltmarsh, migration due to sea level rise. Prioritise blue carbon habitats and investigate blue carbon opportunities. Investigate opportunities to upgrade infrastructure that becomes inundated with high sea water levels, with 'green infrastructure'. Develop an 'Adaptation Plan for the Lower Barwon Wetlands' including adjacent habitats. Establish the baseline condition and extent of all EVCs the Lower Barwon Wetlands to monitor impacts of sea level rise. | PV, NRM groups, CCMA, Private landholders |
| Coastal Wetlands – Swan Bay | Moderate | | | |

| Natural asset | Vulnerability rating* | Climate change threat (direct &/or indirect) | Guiding adaptation responses | Stakeholders |
|---|---|---|---|---|
| Agricultural Land | Low – Moderate | Climate change will have a direct impact on soil health and the ability of soil to support specific uses. Prolonged periods of higher temperatures and reduced moisture may lead to more areas being more susceptible to wind erosion. More intense rainfall events may also lead to areas of sheet, rill and gully erosion. Reduced vegetation cover due to climate change will also exacerbate these impacts. An increase in dryness and lack of moisture will also impact organic carbon in soil. Agricultural productivity may increase or decrease under a changing climate, depending on where it is located e.g. from grazing to cropping. | Addressing the impacts on soil will need to be assessed, planned and implemented at a site level due to a) the level of impact (often site-specific) and b) the adaptation response of the land manager of that site. A changing climate may mean that a current agricultural enterprise may need to also change to make better use of the climatic conditions, as well as changes to the soil properties that are expected. Research opportunities for soil carbon sequestration within this catchment should also be a priority. | Ag groups, NRM groups, CCMA, private landholders |
| Native Flora | Very High | The rate of climate change is likely to overtake the ability of most flora species to adapt and as a result, changes to the distribution of flora species are expected to occur. Changes in life cycle events e.g. flowering times, are also expected to greatly impact flora populations. There is also potential for greater tree mortality under climate change due to drought and temperature increases. | Management should focus on maximising the resilience of communities and maintaining ecosystem function. In many cases this will mean managing flora populations as we do today. Improving the current condition is likely to be important for the long-term viability of a community, with those in better condition more resilient to change in the short term, and more adaptable in the long term, due to their greater genetic, floristic and structural diversity. Protection and promoting the regeneration of large old paddock trees should be seen as a landscape priority due to their genetic capacity to survive through a significant range of climatic conditions and therefore provide a future seed source. | NRM groups, LGAs, CCMA, PV, DELWP (regional) |
| Native Fauna | Very High | The rate of climate change is likely to overtake the ability of most species to adapt and as a result, changes to the distribution of fauna are expected to be a major response to climate change. More mobile species may find refuge from increasing temperatures by shifting to higher, cooler elevations or cooler, south-facing slopes. Species already restricted to high altitudes without the option of upslope migration are expected to become extinct unless they are able to adapt. Some species will be more vulnerable than others to extinction. Species may not be able to shift to areas with suitable climatic conditions where they are located in fragmented habitats, or because of their limited dispersal ability. Species with small, isolated or fragmented ranges, or those with low genetic variation and specific climatic requirements, will be more vulnerable and local extinctions are likely. | Protect and enhance existing natural populations. Maintain and improve diversity. Accept and accommodate unavoidable loss and facilitate transformation, when possible. Reduce impacts from other impacts of climate change (i.e. invasive species & changes to flooding and fire regimes). Allow and create space for species shifts and movement throughout the landscape. Increase connectivity (i.e. buffers, corridors, stepping stones) and areas of refugia. Monitor species, communities and ecological processes. | NRM groups, LGAs, CCMA, PV, DELWP (regional) |

**(*impact ratings were used for soils, as explained in Section 4.5)**

## 7.7 Priority actions – Lake Corangamite Catchment

**Overview**

The Lake Corangamite Catchment is located in the region's north-west and includes the Woady Yaloak, Stony Rises and Lismore Landscape Zones. It is dominated by Lake Corangamite and other Ramsar listed lakes and wetlands, as well as the Victorian Volcanic Plain bioregion surrounding it, highlighted by extinct volcanoes such as Mount Elephant and Mount Leura.

Agriculture is the dominant land use with cropping, followed by grazing, the most common land use practices. The main NRM groups in the catchment are the Woady Yaloak Catchment Group, Corangamite Lakes Landcare Network and the recently formed Stony Rises Land Management Network.

Public land managers include Parks Victoria and to a lesser extent Colac Otway Shire.

A number of specialist environmental and agricultural industry networks, e.g. Ballarat Environment Network and Southern Farming Systems, also address NRM issues in the catchment.

Local municipalities include the Corangamite, Colac Otway and Golden Plains shires.

**Natural values**

The catchment has a number of creeks and streams that terminate at Lake Corangamite, which is the largest permanent inland lake in Australia. The Woady Yaloak River (the catchment's largest waterway) and Pirron Yallock Creek flow into Lake Corangamite. Lake Colac is also a dominant lake in the catchment.

The upper parts of the catchment are largely dominated by agricultural land, with internationally significant wetlands and small remnants of native grassland and grassy woodland still remaining. Main agricultural practices include grazing, cropping and dairy.

To the south of the catchment, large areas of volcanic rock, formed from the most recent volcanic activity, are largely dominated by woodland interspersed with spring-fed freshwater wetlands, and have helped shaped the characteristic Stony Rises landscape.

Many of these small wetlands are seasonal herbaceous wetlands (freshwater) of the temperate lowland plains, and are listed as under the Commonwealth Environment Protection and Biodiversity Conservation Act, 1999. Within the Stony Rises landscape zone, Lake Colongulac, Lake Beeac and Horseshoe Lake are included under the Western District Lakes Ramsar site.

**Potential impacts of climate change**

A warmer and drier climate, combined with an increase in groundwater demand may potentially lead to changes to **environmental flows** into Lake Corangamite, the **drying of lakes and wetlands** and **changes to land use practices.**

Increased impacts and spread of drought tolerant **invasive weed species**, such as Tall Wheatgrass (*Thinopyrum ponticum*), will have impacts on already stressed ecosystems such as wetlands and fragmented areas of remnant vegetation and especially the last remaining areas of native grassland on the volcanic plains.

Blackberry *(Rubus fruticosus aggregate*), a dominant weed species to the south of the catchment may reduce its spread through the catchment, while Gorse (*Ulex europaeus*), a dominant weed species to the north, may increase its range southwards under climate change.

The **fire regimes** of the more heavily vegetated areas of the southern areas of the catchment may also change under a warmer and drier climate, with more frequent and intense events.

Climate change may impact a number of species in this catchment.

Examples of flora include the Spiny Peppercress (*Lepidum aschersonii*), Enfield Grevillea (*Grevillea bedggoodiana*) and Salt-lake Tussock-grass (*Poa sallacustris*). Examples of fauna species include the Striped Legless Lizard (*Delma impar*), Corangamite Water Skink (*Eulamprus tympanum marnieae*) and Brolga (*Grus rubicunda*).

**Carbon sequestration opportunities**

Carbon sequestration opportunities include revegetation through shelterbelts to the north of the catchment and riparian protection and wildlife corridors to the south. Opportunities for soil carbon may exist but more research is required to determine the best methods and locations. Opportunities for blue carbon sequestration within the many lakes and wetlands in this catchment may exist but require further research.

***Lake Corangamite. Photo: Alison Pouliot***

**Table 34: Lake Corangamite catchment priority actions**

| Natural asset | Vulnerability rating* | Climate change threat (direct &/or indirect) | Guiding adaptation responses | Stakeholders |
|---|---|---|---|---|
| Waterways – Pirron Yallock Creek, Kuruc-a-Ruc Creek, Little Woady Creek, Woady Yaloak River, Naringhil Creek | Very High | Higher temperatures and longer periods without rainfall will lead to less environmental flows and reduced areas of refugia for aquatic species. More intense rainfall events may lead to more areas being susceptible to bank erosion. | Prioritise areas within reaches for targeted revegetation to improve shading and habitat as well as alleviate impacts of potential bank erosion. Protect riparian vegetation through fencing. Revegetate priority areas and provide instream habitat. Investigate options for removing artificial fish barriers e.g. weirs). Investigate feasibility of relocating isolated fish populations (Yarra Pygmy Perch). Collaboratively review and optimise water management to increase waterway resilience. | CCMA, NRM groups, PV, Water Authorities, VEWH, Private landholders |
| Waterways – Gnarkeet Chain of Ponds, Mundy Gully | High | | | |
| Native Vegetation – Riparian Forests or Woodlands | Very High | A hotter and drier climate may cause existing vegetation communities to change in their composition and structure, with some species being replaced by others. Fire regimes will be modified, most likely with more frequent and intense events. Vegetation communities may be vulnerable to environmental weeds. Some vegetation communities will be more vulnerable than others to the direct impacts of climate change e.g. Riparian Woodland. | Management could focus on maximising the resilience of communities and maintaining ecosystem function. In many cases this will mean managing native vegetation as we do today. Improving the current condition is likely to be important for the long-term viability of a community, with those in better condition more resilient to change in the short term, and more adaptable in the long term, due to their greater genetic, floristic and structural diversity. | NRM groups, PV, Trust, VicRoads, LGAs, CCMA, CFA, Private landholders |
| Native Vegetation – Plains Grassland/ Chenopod Shrublands | Very High - High | | | |
| ative Vegetation – Lower Slopes/ Hills Woodland | High | | | |
| Native Vegetation – Dry Forests and Plains Woodland/Forests | Moderate | | | |
| Wetlands – Banogill Network, Lake Milangil, Kooaweera Lakes, Lake Struan, Stony ford-Bungador Wetlands and Lake Ondit | Very High | Wetlands that are highly vulnerable to a climate that is hotter and drier will reduce in both extent and quality. A reduction in rainfall and runoff could cause some temporary wetlands to dry up permanently. A reduction in water inflow may also cause an increase in the salinity of | Management should focus on maximising the resilience of communities and maintaining ecosystem function. In many cases this will mean managing wetlands as we do today. Improving the current condition is likely to be important for the long-term viability of a wetland, with those in better condition more resilient to change | PV, NRM groups, CCMA, Private landholders |

| Natural asset | Vulnerability rating* | Climate change threat (direct &/or indirect) | Guiding adaptation responses | Stakeholders |
|---|---|---|---|---|
| Wetlands – Lake Kariah, Lake Beeac, Horseshoe Lake, Eurack Swamp and Lake Weering | High | some wetlands, and changes in the types of vegetation communities that they can support. Wetlands that are reliant on groundwater/spring fed may also be impacted. | in the short term, and more adaptable in the long term, due to their greater genetic, floristic and structural diversity.<br>Research potential recycled water and stormwater sources from Colac (both quality and quantity), for Lake Colac. Develop a climate adaptation plan for Lake Colac and Lake Corangamite. Research 'blue carbon' opportunities of the catchment's wetlands. Research potential groundwater sources (both quality and quantity) for selected wetlands. Research flora and fauna requirements of the littoral zone of major lakes in light of predicted changes caused by climate change. Explore feasibility of developing a 'Western District Adaptation Pathways Plan.' | |
| Wetlands – Lake Logan, Deep Lake, Lake Tooliorook, Lake Gnarpurt, Lake Corangamite, Lake Terangpom, Lake Rosine, Cundare Pool, Lake Martin, Lake Bullen Merri, Lake Colongulac, Lake Koreentnung, Lake Weeranganuk, Lake Coragulac, Lake Colac and Lough Calvert | Moderate | | | |
| Wetlands – Widderin Swamps and Dereel Lagoon | Low | | | |
| Agricultural Land | Low – Moderate | Climate change will have a direct impact on soil health and the ability of soil to support specific uses. Prolonged periods of higher temperatures and reduced moisture may lead to more areas being more susceptible to wind erosion. More intense rainfall events may also lead to areas of sheet, rill and gully erosion. Reduced vegetation cover due to climate change will also exacerbate these impacts. An increase in dryness and lack of moisture will also impact organic carbon in soil. Agricultural productivity may increase or decrease under a changing climate, depending on where it is located e.g. from grazing to cropping. | Addressing the impacts on soil will need to be assessed, planned and implemented at a site level due to a) the level of impact (often site-specific) and b) the adaptation response of the land manager of that site. A changing climate may mean that a current agricultural enterprise may need to also change to make better use of the climatic conditions, as well as changes to the soil properties that are expected. Research opportunities for soil carbon sequestration within this catchment should also be a priority. | Ag groups, NRM groups, CCMA, private landholders |
| Native Flora | Very High | The rate of climate change is likely to overtake the ability of most flora species to adapt and as a result, changes to the distribution of flora species are expected to occur. Changes in life cycle events e.g. flowering times, are also expected to greatly impact flora populations. There is also potential for greater tree mortality under climate change due to drought and temperature increases. | Management should focus on maximising the resilience of communities and maintaining ecosystem function. In many cases this will mean managing flora populations as we do today. Improving the current condition is likely to be important for the long-term viability of a community, with those in better condition more resilient to change in the short term, and more adaptable in the long term, due to their greater genetic, floristic and structural diversity. Protection and promoting the regeneration of large old paddock trees should be seen as a landscape priority due to their genetic capacity to survive through a significant range of climatic conditions and therefore provide a future seed source. | NRM groups, LGAs, CCMA, PV, DELWP (regional) |

| Natural asset | Vulnerability rating* | Climate change threat (direct &/or indirect) | Guiding adaptation responses | Stakeholders |
|---|---|---|---|---|
| Native Fauna | Very High | The rate of climate change is likely to overtake the ability of most species to adapt and as a result, changes to the distribution of fauna are expected to be a major response to climate change. More mobile species may find refuge from increasing temperatures by shifting to higher, cooler elevations or cooler, south-facing slopes. Species already restricted to high altitudes without the option of upslope migration are expected to become extinct unless they are able to adapt. Some species will be more vulnerable than others to extinction. Species may not be able to shift to areas with suitable climatic conditions where they are located in fragmented habitats, or because of their limited dispersal ability. Species with small, isolated or fragmented ranges, or those with low genetic variation and specific climatic requirements, will be more vulnerable and local extinctions are likely. | Protect and enhance existing natural populations. Maintain and improve diversity. Accept and accommodate unavoidable loss and facilitate transformation, when possible. Reduce impacts from other impacts of climate change (i.e. invasive species & changes to flooding and fire regimes). Allow and create space for species shifts and movement throughout the landscape. Increase connectivity (i.e. buffers, corridors, stepping stones) and areas of refugia. Monitor species, communities and ecological processes. Research potential translocation sites around Lake Colac for the Corangamite Water Skink from nearby vulnerable sites to climate change. Undertake an analysis of RAMSAR-listed criteria for the Western District Lakes against predicted climate change impacts and associated management responses. | NRM groups, LGAs, CCMA, PV, DELWP (regional) |

**(*impact ratings were used for soils, as explained in Section 4.5)**

## 7.8 Priority actions – Otway Coast Catchment

**Overview**

The Otway Coast Catchment stretches along the region's coastline from Peterborough to the west to Breamlea to the east and contains the Curdies, Gellibrand, Aire, Otway Coast and Thompsons landscape zones. The zone is on the coastal side of the Otway Ranges.

This landscape zone is internationally renowned for its coastline, which has been sculpted over thousands of years to become one of the most impressive natural sites of rock stacks in Australia including sheer limestone cliffs, arches, islands and blowholes that have been carved out of the soft cliffs by the wind and sea. The Twelve Apostles, Loch Ard Gorge, Bay of Islands Coastal Park, Shipwreck Coast and Port Campbell National Park are all in this zone

The formation of the Great Otway National Park has meant that conservation and associated tourism are the dominant land use in the catchment with the majority of the area managed by Parks Victoria. The catchment also has some of the largest milk producing regions in Australia.

NRM groups include the Heytesbury District Landcare Network, Southern Otways Landcare Network, Surf Coast and Inland Plains Network and various CoastAction groups. A number of environmental non-government groups, such as the Conservation Ecology Centre and ANGAIR, also occur in this area.

Public land managers include Parks Victoria, Bellarine Bayside Committee of Management, Wannon Water, Barwon Water and Surf Coast Shire. Local municipalities include Corangamite, Colac Otway, Moyne and Surf Coast shires and the City of Greater Geelong.

**Natural values**

The Great Otway National Park extends through the area and features rugged coastlines, sandy beaches, rock platforms and windswept heathland in the south. In the north, the park features tall forests, ferny gullies, magnificent waterfalls and tranquil lakes.

The catchment's main rivers include the Curdies, Gellibrand, and Aire rivers, which enter the Southern Ocean through a series of wetlands. The Aire is the region's only listed Heritage River. The catchment also has many smaller rivers, such as the Erskine, Kennett and Cumberland, which intersect with the Great Ocean Road before flowing into the sea. Further to the east of the catchment, Thompsons Creek is the dominant waterway, along with the Anglesea River. The latter is fed from tributaries from an increasingly urbanised area between the Otways and Bellarine Peninsula.

The main agricultural practices in this catchment are forestry, grazing and dairy.

**Potential impacts of climate change**

The main impacts of climate change to natural assets in this catchment include **reduced environmental flows**, **sea level rise, increase in fires** – both in number of events and intensity, and **vegetation communities to retract**, **evolve into new vegetation communities** or **disappear altogether**.

Many of the streams and creeks in the Otway Coast catchment are small and rely on the high level of rainfall the Otways provide. A warmer and drier climate will reduce vital runoff, causing many of these rivers and streams to only run intermittingly. This will have ramifications for fauna species that will not be able to adapt before these changes occur. The larger rivers in this catchment will be impacted by reduced runoff in the upper catchments due to agricultural industries and water authorities exploring options for harnessing water on their properties.

Many of the vegetation communities of the Otways will be impacted by climate change. The Cool Temperate Rainforests in the wetter parts of the ranges will most likely disappear or evolve into different vegetation communities; the result of a combination of a warmer and drier climate and the increase in fire events in the surrounding fire-dependent mountain ash forests.

Many of the catchment's estuaries intermittently open or close depending on the prevailing conditions e.g. freshwater flows, weather changes or tidal movements. Sea level rise will impact on these natural events causing inundation for longer periods of time and over greater areas. This can have adverse impacts to the estuarine environment, including the fauna and flora, which have evolved to the current inundation levels that we see today.

Sea level rise will also cause high levels of inundation on other coastal assets such as inter-tidal zones and rocky shorelines and cause coastal erosion to sandy beaches. More modelling is required to determine when and where these events will occur.

Serrated tussock (*Nassella trichotoma*) is a weed of national significance within the Thompsons Landscape Zone that may spread in its distribution under a warmer and drier climate. Under a more favourable climate, other environmental weed species may also increase their distribution into areas where they are currently absent.

The catchment has a number of species that climate change may impact.

Examples of flora include the Slender Tree-fern (*Cyathea cunninghamii*), Swamp Greenhood (*Pterostylis tenuissima)* and Anglesea Grevillia (*Grevillia infecunda*). Examples of fauna species include the Grey Goshawk (*Accipter novaehollandiae novaehollandiae*), Spot-tailed Quoll (*Dasyurus maculatus maculatus*) and Australian Mudfish (*Neochanna cleaveri*).

**Carbon sequestration opportunities**

Carbon sequestration opportunities include riparian protection and the establishment of wildlife corridors. Opportunities for soil carbon may exist, particularly in the wet forests where soil carbon levels are typically highest in the region, but more research is required to determine best methods and locations. Opportunities for blue carbon sequestration occur within the Otway Coast, mainly in the many estuarine habitats.

**Table 35: Otway Coast catchment priority actions**

| Natural asset | Vulnerability rating* | Climate change threat (direct &/or indirect) | Guiding adaptation responses | Stakeholders |
|---|---|---|---|---|
| Waterways – Ford River, Aire River, Parker River, Elliot River, Carlisle River and Barham River (West Branch) | Very High | Higher temperatures and longer periods without rainfall will lead to less environmental flows and reduced areas of refugia for aquatic species. More intense rainfall events may lead to more areas being susceptible to bank erosion. | Prioritise areas within reaches for targeted revegetation to improve shading and habitat as well as alleviate impacts of potential bank erosion. Protect riparian vegetation through fencing. Revegetate priority areas and provide instream habitat. Investigate options for removing artificial fish barriers e.g. weirs. Investigate feasibility of relocating isolated fish populations (Yarra Pygmy Perch). Collaboratively review and optimise water management to increase waterway resilience. | CCMA, NRM groups, DELWP (ARI), VEWH, Water Authorities, Private landholders |
| Waterways – Curdies River, Barham River (East Branch), Wye River, Kennett River, Cumberland River, Erskine River, St George River and Painkalac Creek | High | | | |
| Waterways – Scotts Creek, Cooriemungle Creek, Port Campbell Creek, Anglesea River and Thompson Creek | Moderate | | | |
| Waterways – Kennedys Creek and Gellibrand River | Low | | | |
| Estuaries – Curdies River, Gellibrand River, Aire River and Anglesea River | Very High | A sea level rise of between 0.8-1.1 metres by 2100, hotter temperatures, a reduction in rainfall and an increase in extreme natural events e.g. flooding, are all expected to impact the ecology and dynamics of estuaries. Existing threats, such as changes to natural estuary openings and increases in nutrient levels may also be exacerbated by the indirect impacts of climate change, in particular through sea level rise and increases in storm surges. | Assess natural freshwater flow regimes estuaries and determine options for improved flows. Investigate opportunities to upgrade infrastructure that becomes inundated with high estuary water levels, with 'green infrastructure'. Use LiDAR to identify latitudinal and elevational gradients, areas of refugia and opportunities to enhance connectivity. Establish management agreements with private landholders adjacent to estuaries to improve resilience of estuarine vegetation to climate change Protect riparian vegetation through fencing Restore riparian zone using appropriate revegetation. Explore opportunities for an EstuaryWatch group for Curdies River estuary and maintain existing groups to help monitor changes associated with climate change. | PV, LGAs, CCMA, NRM Groups, Private landholders |
| Coastal Wetlands – Lake Horden, Lake Costin, Lake Craven and Gellibrand Wetlands | Very High | Coastal wetlands are very vulnerable to climate change. Increased drought frequency and intensity, decreases in freshwater inputs, rising sea levels and increases in coastal storm surges may all impact these important | Assess the likely impacts of climate change on coastal wetland processes (i.e. tidal exchange, berm position and shoreline recession, entrance openings, water balance, geomorphology, water quality and biodiversity). Monitor sea level rise and associated impacts. Plan areas for marginal | PV, NRM groups, Private landholders |

| Natural asset | Vulnerability rating* | Climate change threat (direct &/or indirect) | Guiding adaptation responses | Stakeholders |
|---|---|---|---|---|
| | | ecosystems. These conditions may also change the character of coastal wetlands through a reduction in size, conversion to dryland or a shift from one wetland type to another (e.g. brackish to saline). Under hotter and drier conditions and reduced inflows, acid sulphate soils in coastal wetlands will face an increased risk of being exposed. The retention of coastal wetlands will require planning approaches which allow for the migration of wetland communities in order to avoid significant loss in both extent and character. | terrestrial vegetation (e.g. Coastal Saltmarsh) migration due to sea level rise. Prioritise blue carbon habitats and investigate blue carbon opportunities. Investigate opportunities to upgrade infrastructure that becomes inundated with high sea water levels, with 'green infrastructure'. Develop an Adaptation Plan for the Wetlands including adjacent habitats. Establish the baseline condition and extent of all EVCS to monitor impacts of sea level rise. | |
| Native Vegetation – Rainforests, Wet or Damp Forests and Herb-rich Woodlands | Very High | A hotter and drier climate may cause existing vegetation communities to change in their composition and structure, with some species being replaced by others. Fire regimes will be modified, most likely with more frequent and intense events. Vegetation communities may be vulnerable to environmental weeds. Some vegetation communities will be more vulnerable than others to the direct impacts of climate change e.g. Riparian Woodland. | Management could focus on maximising the resilience of communities and maintaining ecosystem function. In many cases this will mean managing native vegetation as we do today. Improving the current condition is likely to be important for the long-term viability of a community, with those in better condition more resilient to change in the short term, and more adaptable in the long term, due to their greater genetic, floristic and structural diversity. | PV, Trust, CCMA, NRM groups, Private landholders |
| Native Vegetation – Lowland Forests and Coastal Scrub Grasslands/ Woodlands | Moderate | | | |
| Native Vegetation – Heathy Woodlands, Riparian Scrubs or Swampy Scrubs/Woodlands and Heathlands | Low | | | |
| Wetlands – Brown Swamp | High | Wetlands that are highly vulnerable to a climate that is hotter and drier will reduce in both extent and quality. A reduction in rainfall and runoff could cause some temporary wetlands to dry up permanently. A reduction in water inflow may also cause an increase in the salinity of some wetlands, and changes in the types of vegetation communities that they can support. Wetlands that are reliant on groundwater/spring fed may also be impacted. | Management should focus on maximising the resilience of communities and maintaining ecosystem function. In many cases this will mean managing wetlands as we do today. Improving the current condition is likely to be important for the long-term viability of a wetland, with those in better condition more resilient to change in the short term, and more adaptable in the long term, due to their greater genetic, floristic and structural diversity. Develop climate adaptation plans for Lake Modewarre and Lake Purrembete. Research 'blue carbon' opportunities of the catchment's wetlands. Research potential groundwater sources (both quality and quantity) for selected wetlands. Research flora and fauna requirements of the littoral zone of major lakes in light of predicted changes caused by climate change. | PV, CCMA, NRM groups, Private landholders |
| Wetlands – Lake Modewarre | Moderate | | | |
| Wetlands – Lake Purrumbete | Low | | | |

| Natural asset | Vulnerability rating* | Climate change threat (direct &/or indirect) | Guiding adaptation responses | Stakeholders |
|---|---|---|---|---|
| Agricultural Land | Low – Moderate | Climate change will have a direct impact on soil health and the ability of soil to support specific uses. Prolonged periods of higher temperatures and reduced moisture may lead to more areas being more susceptible to wind erosion. More intense rainfall events may also lead to areas of sheet, rill and gully erosion. Reduced vegetation cover due to climate change will also exacerbate these impacts. An increase in dryness and lack of moisture will also impact organic carbon in soil. Agricultural productivity may increase or decrease under a changing climate, depending on where it is located e.g. from grazing to cropping. | Addressing the impacts on soil will need to be assessed, planned and implemented at a site level due to a) the level of impact (often site-specific) and b) the adaptation response of the land manager of that site. A changing climate may mean that a current agricultural enterprise may need to also change to make better use of the climatic conditions, as well as changes to the soil properties that are expected. Research opportunities for soil carbon sequestration within this catchment should also be a priority. | Ag groups, NRM groups, CCMA, private landholders |
| Native Flora | Very High | The rate of climate change is likely to overtake the ability of most flora species to adapt and as a result, changes to the distribution of flora species are expected to occur. Changes in life cycle events e.g. flowering times, are also expected to greatly impact flora populations. There is also potential for greater tree mortality under climate change due to drought and temperature increases. | Management should focus on maximising the resilience of communities and maintaining ecosystem function. In many cases this will mean managing flora populations as we do today. Improving the current condition is likely to be important for the long-term viability of a community, with those in better condition more resilient to change in the short term, and more adaptable in the long term, due to their greater genetic, floristic and structural diversity. Protection and promoting the regeneration of large old paddock trees should be seen as a landscape priority due to their genetic capacity to survive through a significant range of climatic conditions and therefore provide a future seed source. | NRM groups, LGAs, CCMA, PV, ANGAIR, CEC, DELWP (regional) |
| Native Fauna | Very High | The rate of climate change is likely to overtake the ability of most species to adapt and as a result, changes to the distribution of fauna are expected to be a major response to climate change. More mobile species may find refuge from increasing temperatures by shifting to higher, cooler elevations or cooler, south-facing slopes. Species already restricted to high altitudes without the option of upslope migration are expected to become extinct unless they are able to adapt. Some species will be more vulnerable than others to extinction. Species may not be able to shift to areas with suitable climatic conditions where they are located in fragmented habitats, or because of their limited dispersal ability. Species with small, isolated or fragmented ranges, or those with low genetic variation and specific climatic requirements, will be more vulnerable and local extinctions are likely. | Protect and enhance existing natural populations. Maintain and improve diversity. Accept and accommodate unavoidable loss and facilitate transformation, when possible. Reduce impacts from other impacts of climate change (i.e. invasive species & changes to flooding and fire regimes). Allow and create space for species shifts and movement throughout the landscape. Increase connectivity (i.e. buffers, corridors, stepping stones) and areas of refugia. Monitor species, communities and ecological processes. | NRM groups, LGAs, CCMA, PV, ANGAIR, CEC, DELWP (regional) |

**(*impact ratings were used for soils, as explained in Section 4.5)**

# 8. Monitoring, evaluation, reporting and improvement

***Grasstrees at Ocean Grove Nature Reserve. Photo: Lachlan Manly***

The main objective of this NRM Plan for Climate Change is to provide support for the region to incorporate climate change mitigation and adaptation into the Corangamite RCS and other existing regional NRM plans. A combination of qualitative and quantitative data will be collected during the life of this plan to help inform the key evaluation questions of the RCS.

The plan will be revised and streamlined throughout its implementation to ensure it remains relevant. The plan will also need to be adaptive to take into account changes to the environment that will occur as a result of climate change.  This revision will occur as new and updated information becomes available, and will primarily occur through updates to the South West Climate Change Portal.

**Key Messages**

- Australia has a monitoring, evaluation, reporting and improvement (MERI) Framework
- The MERI framework for this plan will align with the Corangamite RCS MERI Plan

## 8.1 Aligning MERI to the Corangamite Regional Catchment Strategy

The national MERI Framework provides a generic framework for monitoring, evaluating, reporting and improving Australia's approach to managing natural assets. These important activities provide directions in determining the appropriateness, effectiveness, efficiency, legacy and impact of policies and programs, as well as identifying processes for accountability.

More information on the national MERI Framework can be found at:
http://nrmonline.nrm.gov.au/catalog/mql:2338

Monitoring, Evaluation, Reporting and Improvement for this plan will be undertaken as part of the MERI Plan developed for the RCS. The purpose of the RCS MERI plan is to guide monitoring and evaluation activities so its outcomes can be reported in accordance with Catchment and Land Protection Act, and other requirements as determined by the Victorian Catchment Management Council.

The RCS MERI plan provides the purpose, audience and methodology for the evaluation. It contains the following key components:

- Key evaluation questions
- A monitoring plan
- An evaluation and reporting schedule
- Plan implementation

The Key evaluation questions (KEQs) in the RCS MERI Plan that this plan contributes to are outlined in Table 37. A combination of qualitative and quantitative data, collected during the life of this plan, will be revised and streamlined during the plan's implementation, to ensure it remains relevant. This data will provide evidence to measure the key evaluation questions and determine the impact that the plan has had in improving how the region adapts and manages its natural assets to climate change.

***Corangamite Water Skink. Photo: Corangamite CMA***

**Table 36: RCS Key evaluation questions relevant to the NRM Plan for Climate Change.**

| Domain | # | KEQ |
|---|---|---|
| Impact | **KEQ1** | To what extent has the plan contributed to better management of the region's natural assets to climate change?<br>What, if any, unanticipated positive or negative changes or other outcomes have resulted? |
| Impact | **KEQ2** | To what extent have the four foundations for change from the Corangamite RCS been progressed directly through this plan:<br>To what extent has the breadth and depth of participation changed?<br>To what extent has investment and investor types changed?<br>To what extent has growth in and effectiveness of partnerships occurred?<br>To what extent has knowledge and skills changed?<br>To what extent has practice change occurred?<br>What, if any, unanticipated positive or negative changes or other outcomes have resulted? |

## 8.2 Plan review

It is important that this plan is adaptable and made continually relevant for the region. The plan needs to be reviewed and updated often enough to ensure it continues to provide direction for the region, to best manage its natural assets to adapting to climate change. As such, it is expected the key management actions will be reviewed annually, with key strategic directions reviewed in 2018, refined and incorporated into future developments of Corangamite's next RCS (due in 2020).

Key regional actions from this plan will be reviewed by the Corangamite CMA and key stakeholders identified as key delivers of the plan.

# 9. Appendices

## I. Abbreviations

| | |
|---|---|
| AG | Australian Government |
| Ag Groups | All agricultural industry based groups (i.e. Southern Farming Systems) |
| ARI | Arthur Rylah Institute |
| AVIRA | Aquatic Value Identification and Risk Assessment |
| BoM | Bureau of Metrology |
| CAG | Community Advisory Group (to the Corangamite CMA) |
| CAP | Coastal Action Plan |
| CCB | Central Coastal Board |
| CCMA | Corangamite CMA |
| CeRDI | Centre for eResearch and Digital Innovation |
| CFI | Carbon Farming Initiative |
| CMA | Catchment Management Authority |
| COGG | City of Greater Geelong |
| CoMs | Committees of Management |
| CEC | Conservation Ecology Centre |
| CES | Commissioner for Environmental Sustainability |
| COS | Colac Otway Shire |
| CRC Project | Climate Resilient Communities Project |
| CSIRO | Commonwealth Scientific and Industrial Research Organisation |
| CWS | Corangamite Waterway Strategy |
| Deakin | Deakin University |
| DEDJTR | Department of Economic Development, Jobs, Transport and Resources |
| DELWP | Department of Environment, Land, Water and Planning |
| DSEWPC | Department of Sustainability, Environment, Water, Population and Communities |
| EnSym | Environmental Systems Modelling Platform |
| EPA | Environment Protection Authority |
| ERF | Emissions Reduction Fund |
| EVC | Ecological Vegetation Community |
| FedUni | Federation University |
| GA | Greening Australia |
| GCM | Global Climate Model |
| GHCMA | Glenelg-Hopkins CMA |
| INFFER | Investment Framework for Environmental Resources |
| IPCC | Intergovernmental Panel on Climate Change |
| LGAs | Local Government Authorities |
| M-CAS | Multi-Criteria Analysis Shell for Spatial Decision Support |
| MERI | Monitoring, Evaluation, Reporting and Improvement |
| NCCARF | National Climate Change Adaptation Research Facility |
| NRM | Natural Resource Management |
| NRM groups | All community based NRM and environment groups, including Landcare |
| NRMPP | Natural Resource Management Planning Portal |
| PV | Parks Victoria |
| RCP | Representative Concentration Pathways |
| RCS | Regional Catchment Strategy |
| REP | Regional Expert Panel |
| RMIT | RMIT University |
| RWAs | Regional Water Authorities |
| SCARP | Southern Slopes Climate Change Adaptation Research Partnership |
| SSC | Southern Slopes Cluster (of NRM Regions for Climate Change Adaptation) |
| SV | Sustainability Victoria |
| SWCCP | South West Climate Change Portal |
| SWIFFT | State Wide Integrated Flora and Fauna Team |
| TIA | Tasmanian Institute of Agriculture |
| Trust | Trust for Nature |
| VCC | Victorian Coastal Council |
| VEAC | Victorian Environmental Assessment Council |
| VEWH | Victorian Environmental Water Holder |
| VNPF | Victorian NRM Planners Forum |
| WCB | Western Coastal Board |

## II. Glossary

### Climate model

A numerical representation of the climate system that is based on the physical, chemical, and biological properties of its components, their interactions, and feedback processes, and that accounts for all or some of its known properties (IPCC, 2014).

### Climate projection

A projection of the response of the climate system to emissions or concentration scenarios of greenhouse gases and aerosols, or radiative forcing scenarios, often based upon simulations by climate models. Climate projections are distinguished from climate predictions in order to emphasize that climate projections depend upon the emission/ concentration/radiative-forcing scenario used, which are based on assumptions concerning, e.g., future socioeconomic and technological developments that may or may not be realised and are therefore subject to substantial uncertainty (IPCC 2012).

### Climate scenario

A plausible and often simplified representation of the future climate, based on an internally consistent set of climatological relationships that has been constructed for explicit use in investigating the potential consequences of anthropogenic climate change, often serving as input to impact models. Climate projections often serve as the raw material for constructing climate scenarios, but climate scenarios usually require additional information such as about the observed current climate (IPCC 2012).

### Climate variability

Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate at all spatial and temporal scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability) (IPCC 2012).

### Drought

A period of abnormally dry weather long enough to cause a serious hydrological imbalance. Drought is a relative term, therefore any discussion in terms of precipitation deficit must refer to the particular precipitation-related activity that is under discussion. A period with an abnormal precipitation deficit is defined as a meteorological drought. A megadrought is a very lengthy and pervasive drought, lasting much longer than normal, usually a decade or more. (IPCC 2012)

### El Niño-Southern Oscillation

The term El Niño is a warming of the tropical Pacific Ocean east of the dateline. This oceanic event is associated with a fluctuation of a global-scale tropical and subtropical surface pressure pattern called the Southern Oscillation. This coupled atmosphere-ocean phenomenon, with preferred time scales of 2 to about 7 years, is collectively known as the El Niño-Southern Oscillation. During an El Niño event, the prevailing trade winds weaken, reducing upwelling and altering ocean currents such that the sea surface temperatures warm, further weakening the trade winds. This event has a great impact on the wind, sea surface temperature, and precipitation patterns in the tropical Pacific. It has climatic effects throughout the Pacific region and in many other parts of the world. The cold phase of ENSO is called La Niña. (IPCC 2012)

### Greenhouse effect

Greenhouse gases effectively absorb thermal infrared radiation, emitted by the Earth's surface, by the atmosphere itself due to the same gases, and by clouds. Atmospheric radiation is emitted to all sides, including downward to the Earth's surface. Thus, greenhouse gases trap heat within the surface-troposphere system. This is called the greenhouse effect. An increase in the concentration of greenhouse gases leads to an increased infrared opacity of the atmosphere and therefore to an effective radiation into space from a higher altitude at a lower temperature. This causes a radiative forcing that leads to an enhancement of the greenhouse effect, the so-called enhanced greenhouse effect. (IPCC 2012)

**Greenhouse gas**

Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, which absorb and emit radiation at specific wavelengths within the spectrum of thermal infrared radiation emitted by the Earth's surface, by the atmosphere itself, and by clouds. This property causes the greenhouse effect. Water (H2O), carbon dioxide (CO2), nitrous oxide (N2O), methane (CH4), and ozone (O3) are the primary greenhouse gases in the Earth's atmosphere. (IPCC 2012)

**Heat wave**

A period of abnormally hot weather. Heat waves and warm spells have various and in some cases overlapping definitions (IPCC 2012).

**Global Climate Model**

Global Climate Models, are computer-driven models that are used for projecting weather, understanding climate, projecting seasonal and inter-annual climate and projecting climate change. They are mathematical representations of the real world which simulate processes in the Earth's atmosphere and oceans. There are only a handful of countries in the world that have developed Global Climate Models. Australia has developed the ACCESS1.0, ACCESS1.3 and CSIROMk3.6.0 models.

## III. Spatial vulnerability assessment: additional information

Background notes that outline the approach used to assess the likely impact of climate change on a range of natural asset types and values in the region are provided in the NRM Planning for Climate Change Final Project Report 1 – Impact and Vulnerability Assessment Process and Spatial Outputs available at www.swclimatechange.com.au.

The report also provides an overview of the spatial data outputs generated by the project as well as the values and ratings assigned, the rationale and criteria on which these are based and the calculations applied.

This document should be read in conjunction with a second project report (Report 2) that supports the integration of project impact assessment outputs with CMA decision making processes to identify priority landscapes for climate change adaptation and mitigation.

This second report is titled Final Report 2 – Decision Making Frameworks and Integration of Socio-economic Data as is available here at www.swclimatechange.com.au.

Table 37 summarises the climate stressors (exposures), climate stressor sensitivity considerations and adaptive capacity inputs applied to each of the key asset types to which the vulnerability assessment method was applied.

Future vulnerability assessments will have the option of adding and/or removing climate stressors, for example, native vegetation (e.g. future weediness, likelihood of plant species loss, sea level rise, etc.), estuaries (e.g. annual rainfall, estuary opening frequency, index of estuary condition, etc.) and wetlands (e.g. sedimentation, connectivity, groundwater dependency, etc.).

**Sensitivity – criteria applied**

Sensitivity refers to the degree to which assets respond to the climate stressors they face.

Some assets will have a proportionately large reaction compared to others, even of the same type. For example, some plant species may have a very narrow physiological tolerance to changes in temperature, while other more generalist species are sensitive only to very extreme changes in temperature (Spatial Vision and Natural Decisions, 2014).

Assessing sensitivity was done in relation to an agreed benchmark state. Table 38 provides a list of sensitivity criteria by which the likely impact of climate change stressors on the natural assets has been assessed as part of the spatial vulnerability assessment. This list of criteria has been used as the basis for sourcing and utilising spatial data to assign a state-wide rating in relation to these criteria wherever practical.

It is proposed that this list of sensitivity indicators be considered, applied and reviewed on a needs basis to refine the vulnerability assessment method process.

**Table 37: Summary of the climate stressors, sensitivity and adaptive capacity inputs applied**

| Asset Type | Climate Stressors | Sensitivity inputs | Adaptive Capacity inputs |
|---|---|---|---|
| **Native Vegetation**<br>(excludes wetlands) | Total Rainfall<br>Nov to April - daily<br>Max Temp | • EVC sub-groups | • Site condition<br>• Landscape connectivity |
| **Wetlands**<br>(excludes tidal wetlands and wetlands within anticipated 2100 SLR and storm surge extent) | Mar to Nov - Rainfall<br>Nov to April - daily Max Temp | • Wetland type<br>(FW meadows, marshes etc)<br>• Water Source (river, groundwater)<br>• Alpine/non-alpine<br>• Within 2100 SLR and storm surge extent | • % native veg presence within 100m<br>• Dominant native veg quality within 100m<br>• Dominant land use within 100m<br>• Presence of drain, levee or cropping |
| **Estuaries** | Mar to Nov - Rainfall<br>Sea Level Rise & Storm Surge | • Open – Permanent & Intermittent<br>• Regulated catchment or not<br>• Mouth type – bay / coast | • %native veg within catchment<br>• Quality of native veg within catchment<br>• Population & pop density within catchment |
| **Rivers and Streams**<br>(includes levels high and moderate in watercourse dataset) | Mar to Nov - Rainfall<br>Nov to April - daily Max Temp | • Regulated or not<br>• Perennial / permanent<br>• Terrain category – plains, intermediate, upper | • %native veg presence within 100m<br>• Quality of native veg within 100m<br>• AVIRA – reduction in high flow mag<br>• AVIRA – increase in prop of low flow<br>• AVIRA – change in monthly flow variability |
| **Soils and Land** | Total Rainfall<br>Nov to April - daily Max Temp | • Land system based soils<br>• Susceptibility to wind erosion<br>• Susceptibility to water erosion & terrain type | • Native vegetation cover<br>• Site condition & landscape context?<br>• Proposed - Current land degradation (salinity, erosion) (appears to be insufficient data) |
| **Coastal Wetlands**<br>(includes: tidal wetlands and wetlands within anticipated 2100 SLR and storm surge extent) | Mar to Nov - Rainfall<br>Sea Level Rise & Storm Surge | • Wetland type (Freshwater meadows, marshes etc)<br>• Wetlands Regime - Supratidal<br>• Water Source (river, groundwater)<br>• Within 2100 SLR and storm surge extent | • %native veg presence within 100m<br>• Dominant native veg quality within 100m<br>• Dominant land use within 100m<br>• Presence of drain, levee or cropping |

**Table 38: Criteria to be used to assign sensitivity to assets in relation to climate change stressors**

| Asset Type | Indicator No. | Sensitivity | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|
| | | Indicator | Very low | Low | Moderate | High | Very High |
| Native Vegetation | 1 | Condition and intactness | No loss of habitat quality and key ecosystem processes | Some loss of habitat quality and minor degradation of ecosystem processes | Significant loss of habitat quality but ecological processes remain largely intact | Major loss of habitat quality and long-term impact on ecological processes | Irreversible loss of habitat quality and ecological processes |
| | 2 | Landscape context | Extent and connectivity unaltered | Minor loss of habitat extent and some increased fragmentation of habitat - short-term recovery expected | Moderate loss of habitat extent with significant increase in fragmentation | Major loss of habitat quality and increased fragmentation with long-term effects | Irretrievable loss of habitat extent |
| | 3 | Biodiversity | Nil/minimal loss of ecosystem components and species | Loss of some ecosystem elements and/or species but repair and recolonisation within short time-frame | Some ecosystem components and species lost | Significant damage to key ecosystem components and long-term loss of species | Irretrievable loss of key ecosystem components and species |
| Threatened/ significant species | 1 | % of range and distribution | Less than 5% of species overall range and number of populations | Less than 25 % of overall range and number of populations | 25-50% of overall range and number of populations | 50-75% of overall range and number of populations | Represents the entire range of species distribution |
| | 2 | Viability trend | Improving | Stable | Shows some decline | Suffers significant decline | Critically endangered and suffering irreversible decline |
| | 3 | Habitat dependency | Species found across a wide range of habitats of varying quality | Species occurs across multiple habitat types of acceptable quality | Species occurs across multiple habitat types of varying quality | Species is dependent on a restricted number of habitat types in good condition | Species is highly dependent on restricted habitat type of high quality |

| **Asset Type** | **Indicator No.** | **Sensitivity** | **1** | **2** | **3** | **4** | **5** |
|---|---|---|---|---|---|---|---|
| | | Indicator | Very low | Low | Moderate | High | Very High |
| Wetlands | 1 | Hydrological processes | Processes unaffected | Minor and short-term loss of hydrological function | Significant but recoverable loss of hydrological function | Major loss of hydrological function | Irretrievable loss of hydrological function |
| | 2 | Catchment and buffer integrity | Nil/minimal impact | Minor damage to contributing catchment and buffer | Moderate damage to catchment/buffer with some long-term impacts | Major alteration to catchment and buffer with long-term effects | Irreversible damage to catchment and buffer integrity |
| | 3 | Biodiversity | Nil/minimal loss of ecosystem components and species | Loss of some ecosystem elements and/or species but repair and recolonisation within short time-frame | Some ecosystem components and species lost | Significant damage to key ecosystem components and long-term loss of species | Irretrievable loss of key ecosystem components and species |
| Estuaries | 1 | Hydrological character | Processes unaffected | Minor and short-term change | Moderate change recoverable in medium term | Major change but recoverable in the long-term | Irretrievable loss of hydrological function |
| | 2 | Catchment and buffer integrity | Nil/minimal impact | Minor damage to contributing catchment and buffer | Moderate damage to catchment/buffer with some long-term impacts | Major alteration to catchment and buffer with long-term effects | Irreversible damage to catchment and buffer integrity |
| | 3 | Biodiversity | Nil/minimal loss of ecosystem components and species | Loss of some ecosystem elements and/or species but repair and recolonisation within short time-frame | Some ecosystem components and species lost | Significant damage to key ecosystem components and long-term loss of species | Irretrievable loss of key ecosystem components and species |
| Rivers/streams | 1 | Streamside zone - condition and intactness | No change to habitat quality and connectivity | Habitat quality suffers minor degradation but key ecological processes remain intact | Significant loss of habitat quality and connectivity but ecological processes remain largely intact | Major loss of habitat quality and increased fragmentation with long-term effects | Irretrievable loss of streamside zone extent |
| | 2 | In-stream habitat | In-stream habitat remains in near pristine condition | Minor alteration to quality and composition of in-steam habitat, natural repair processes intact | Moderate alteration to habitat quality and composition, with some long-term effects | In-stream habitat substantially degraded | Irreversible damage to in-stream habitat values |

| Asset Type | Indicator No. | Sensitivity | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|
| | | Indicator | Very low | Low | Moderate | High | Very High |
| | 3 | Ecosystem water quality | No discernible human impact | Minor damage to water dependent ecosystems, where full recovery could be expected | Moderate damage to water dependent ecosystems, where recovery would have minor long term effects | Major damage to water dependent ecosystems, where recovery would have significant long term effects | Irreversible damage to water dependent ecosystems |
| Marine habitat | 1 | Biodiversity | Nil/minimal loss of ecosystem components and species | Loss of some ecosystem elements and/or species but repair and recolonisation within short time-frame | Some ecosystem components and species lost | Significant damage to key ecosystem components and long-term loss of species | Irretrievable loss of key ecosystem components and species |
| | 2 | Condition and intactness | No loss of habitat quality and key ecosystem processes | Some loss of habitat quality and minor degradation of ecosystem processes | Significant loss of habitat quality but ecological processes remain largely intact | Major loss of habitat quality and long-term impact on ecological processes | Irreversible loss of habitat quality and ecological processes |
| Soils | 1 | Hydrological processes | Processes unaffected | Minor and short-term loss of hydrological function | Significant but recoverable loss of hydrological function | Major loss of hydrological function | Irretrievable loss of hydrological function |
| | 2 | Change in soil structure/properties | Soil physico-chemical properties unaltered | Some alteration to physico-chemical properties but capability and productivity largely unaffected | Significant changes to soil structure and properties reducing productivity in the short to medium term | Major alteration of soil physico -chemical properties with long-term impact on productivity | Irreversible changes to soil structure/properties |
| | 3 | Hazard - salinity, sodicity etc. | No change in area of affected land | Minor increase in extent of land affected but no off-site impacts | Significant increase in extent of land affected with some off-site impacts | Major increase in land affected with significant off-site impacts | Irreversible and catastrophic effects |

### Adaptive capacity – criteria applied

Adaptive capacity is the ability of an asset or system to adjust or adapt to climate change stressors (including variability and extremes, and direct and indirect variables).

Examples of natural systems with low adaptive capacity include species with limited genetic variability, or with very specialist requirements for breeding habitat or food sources, or habitats that are already degraded through the impacts of clearing, invasive species or excessive water extraction.

It is important to note that assessing the adaptive capacity of assets has been made with reference to their current state (which may be anywhere between pristine and degraded), rather than the benchmark state which was used when assessing sensitivity.

Judgement has been made, all things considered, in assigning an adaptive capacity as Very Low (1), Low (2), Moderate (3), High (4) or Very High (4).

**Table 39: Adaptive capacity criteria**

| Asset Type | Criteria for consideration in assigning adaptive capacity | | | |
|---|---|---|---|---|
| Native Vegetation | Current condition | Landscape context – patch size, fragmentation and connectivity | Level of other threats (if known) | |
| Threatened/ significant species | Number of populations/ individuals | Species mobility | Breadth of habitat niches | Level of other threats (if known) |
| Wetlands | % of native vegetation within 100 metres | Quality of dominant native vegetation within 100 metres | Dominant land use within 100 metres | Presence of a drain, levee or cropping within wetland |
| Estuaries | % tree cover within estuary catchment | Population and population density within catchment | AVIRA catchment ratings for:<br>• Reduction in high flow magnitude<br>• Increase in proportion of low flow<br>• Change in monthly flow variability | Level of other threats (if known) |
| Rivers/streams | % native vegetation within 100 metres | Quality of native vegetation within 100 metres | AVIRA catchment ratings for:<br>• Reduction in high flow magnitude<br>• Increase in proportion of low flow<br>• Change in monthly flow variability | Level of other threats (if known) |
| Marine habitat | Current condition relative to benchmark | Current extent relative to benchmark | Proximity to coast | Level of other threats (if known) |
| Land/soils | Native vegetation cover | Level of degradation – salinity, erosion, acid sulphate soils where applicable | Ground cover | |

Table 39 above provides a list of adaptive capacity criteria by which the likely impact of climate change stressors on the natural assets that have been assessed in this project.

As with sensitivity, this list of criteria has been used as the basis for sourcing and utilising spatial data to assign a state-wide rating in relation to these criteria wherever practical. For example, the size and shape of an asset may be viewed as an important indicator of adaptive capacity. Further, in relation to adaptive capacity, a broader range of contextual parameters that can be derived from spatial data has also been considered. For example, the fragmentation or an asset, or its place in a catchment.

As with sensitivity, it is proposed that this list of adaptive capacity indicators be considered and applied by NRM planners, at the regional or local level, to review and refine the state-wide vulnerability assessment method outputs.

Tables 40 – 45 list the climate change sensitivity ratings to all the natural assets that were assessed as part of the vulnerability assessment.

For further information on the calculation of impact and vulnerability ratings, including how sensitivity to stressors and adaptive capacity measures were applied to each asset, please refer to the NRM Planning for Climate Change Final Project Report 1 – Impact and Vulnerability Assessment Process and Spatial Outputs available at www.swclimatechange.com.au

## Tables 40 - 45: Climate change sensitivity ratings assigned to assets

**Native Vegetation Asset Class – Sensitivity Rating**

| NV CLASS | NV CLASS Description | Sensitivity to Annual Rainfall Variation (change in mm) | | | | | | Sensitivity to Max Nov to Apr Temp Variation (change in Deg C) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | | 1 | 2 | 3 | 4 | 5 |
| | | Response type | +/-5mm | -6 to -15 | -16 to -3 | -35 to -4 | gt -46 | Response type | 0 to 0.9 | 1.0 to 1.9 | 2.0 to 2.9 | 3.0 to 3.9 | 4.0 to 10. |
| 11 | Coastal Scrubs Grasslands and Woodlands | B | 1 | 2 | 2 | 3 | 3 | C | 1 | 2 | 3 | 4 | 5 |
| 21 | Heathy Woodlands - Dry and/or better drained | A | 1 | 1 | 1 | 2 | 2 | B | 1 | 2 | 2 | 3 | 3 |
| 22 | Heathy Woodlands - Damp and/or less well-drained | C | 1 | 2 | 3 | 4 | 5 | C | 1 | 2 | 3 | 4 | 5 |
| 31 | Lowland Forests | B | 1 | 2 | 2 | 3 | 3 | C | 1 | 2 | 3 | 4 | 5 |
| 41 | Box Ironbark Forests or dry/lower fertility Woodlands | B | 1 | 2 | 2 | 3 | 3 | C | 1 | 2 | 3 | 4 | 5 |
| 51 | Lower Slopes or Hills Woodlands - Seasonally inundated and/or shrubby | D | 1 | 2 | 4 | 5 | 6 | E | 1 | 3 | 5 | 6 | 6 |
| 52 | Lower Slopes or Hills Woodlands - Grassy | B | 1 | 2 | 2 | 3 | 3 | C | 1 | 2 | 3 | 4 | 5 |
| 53 | Lower Slopes or Hills Woodlands - Herb-rich | D | 1 | 2 | 4 | 5 | 6 | D | 1 | 2 | 4 | 5 | 6 |
| 61 | Dry Forests - Exposed and/or lower altitude | B | 1 | 2 | 2 | 3 | 3 | C | 1 | 2 | 3 | 4 | 5 |
| 62 | Dry Forests - Sheltered and/or higher altitude | C | 1 | 2 | 3 | 4 | 5 | C | 1 | 2 | 3 | 4 | 5 |
| 71 | Wet or Damp Forests - Wet | D | 1 | 2 | 4 | 5 | 6 | D | 1 | 2 | 4 | 5 | 6 |
| 72 | Wet or Damp Forests - Damp | D | 1 | 2 | 4 | 5 | 6 | D | 1 | 2 | 4 | 5 | 6 |
| 81 | Riparian Scrubs or Swampy Scrubs and Woodlands - Riparian Scrubs or Swampy Scrubs or Woodl | B | 1 | 2 | 2 | 3 | 3 | B | 1 | 2 | 2 | 3 | 3 |
| 82 | Riparian Scrubs or Swampy Scrubs and Woodlands - Riparian Forests or Woodlands | B | 1 | 2 | 2 | 3 | 3 | B | 1 | 2 | 2 | 3 | 3 |
| 91 | Rainforests | E | 1 | 3 | 5 | 6 | 6 | E | 1 | 3 | 5 | 6 | 6 |
| 101 | Montane Grasslands, Shrublands or Woodlands - Shrublands or Grasslands | E | 1 | 3 | 5 | 6 | 6 | E | 1 | 3 | 5 | 6 | 6 |
| 102 | Montane Grasslands, Shrublands or Woodlands - Woodlands | C | 1 | 2 | 3 | 4 | 5 | D | 1 | 2 | 4 | 5 | 6 |
| 111 | Sub-alpine Grasslands, Shrublands or Woodlands - Shrublands or Grasslands | B | 1 | 2 | 2 | 3 | 3 | C | 1 | 2 | 3 | 4 | 5 |
| 112 | Sub-alpine Grasslands, Shrublands or Woodlands - Woodlands | B | 1 | 2 | 2 | 3 | 3 | C | 1 | 2 | 3 | 4 | 5 |
| 121 | Plains Grasslands and Chenopod Shrublands - Clay soils | B | 1 | 2 | 2 | 3 | 3 | B | 1 | 2 | 2 | 3 | 3 |
| 131 | Plains Woodlands or Forests - Freely-draining | B | 1 | 2 | 2 | 3 | 3 | B | 1 | 2 | 2 | 3 | 3 |
| 132 | Plains Woodlands or Forests - Poorly-draining | B | 1 | 2 | 2 | 3 | 3 | B | 1 | 2 | 2 | 3 | 3 |
| 133 | Plains Woodlands or Forests - Lunettes or beach ridges or shallow sands | C | 1 | 2 | 3 | 4 | 5 | C | 1 | 2 | 3 | 4 | 5 |
| 134 | Plains Woodlands or Forests - Semi-arid(non-Eucalypt) | A | 1 | 1 | 1 | 2 | 2 | A | 1 | 1 | 1 | 2 | 2 |
| 141 | Riverine Grassy Woodlands or Forests - Broader plain | B | 1 | 2 | 2 | 3 | 3 | C | 1 | 2 | 3 | 4 | 5 |
| 142 | Riverine Grassy Woodlands or Forests - Creekline and/or swampy | B | 1 | 2 | 2 | 3 | 3 | C | 1 | 2 | 3 | 4 | 5 |
| 151 | Herb-rich Woodlands - Alluvial terraces and/or creeklines | C | 1 | 2 | 3 | 4 | 5 | C | 1 | 2 | 3 | 4 | 5 |
| 152 | Herb-rich Woodlands - Damp Sands | D | 1 | 2 | 4 | 5 | 6 | D | 1 | 2 | 4 | 5 | 6 |
| 161 | Heathlands - Sandy and/or well drained | A | 1 | 1 | 1 | 2 | 2 | B | 1 | 2 | 2 | 3 | 3 |
| 162 | Heathlands - Not well drained | A | 1 | 1 | 1 | 2 | 2 | B | 1 | 2 | 2 | 3 | 3 |
| 163 | Heathlands - Sub-alpine | E | 1 | 3 | 5 | 6 | 6 | E | 1 | 3 | 5 | 6 | 6 |
| 171 | Mallee - Siliceous sands | A | 1 | 1 | 1 | 2 | 2 | A | 1 | 1 | 1 | 2 | 2 |
| 172 | Mallee - Calcareous dunefields | A | 1 | 1 | 1 | 2 | 2 | A | 1 | 1 | 1 | 2 | 2 |
| 173 | Mallee - Clay plains | B | 1 | 2 | 2 | 3 | 3 | C | 1 | 2 | 3 | 4 | 5 |
| 174 | Mallee - Sandstone ridges and rises | A | 1 | 1 | 1 | 2 | 2 | A | 1 | 1 | 1 | 2 | 2 |
| 181 | Wetlands - Freshwater | E | 1 | 3 | 5 | 6 | 6 | E | 1 | 3 | 5 | 6 | 6 |
| 182 | Wetlands - Brackish/estuarine | A | 1 | 1 | 1 | 2 | 2 | B | 1 | 2 | 2 | 3 | 3 |
| 191 | Salt-tolerant and/or succulent Shrublands - Coastal | A | 1 | 1 | 1 | 2 | 2 | B | 1 | 2 | 2 | 3 | 3 |
| 192 | Salt-tolerant and/or succulent Shrublands - Inland | A | 1 | 1 | 1 | 2 | 2 | B | 1 | 2 | 2 | 3 | 3 |
| 201 | Rocky Outcrop or Escarpment Scrubs | D | 1 | 2 | 4 | 5 | 6 | D | 1 | 2 | 4 | 5 | 6 |

## Wetlands Asset Class – Sensitivity Rating

| WL CLASS | WL CLASS Description | Sensitivity to Rainfall_Mar_to_Nov Variation (reduction in mm) | | | | | | Sensitivity to Max_Temp_Nov_to_Apr Variation (increase in Deg C) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | | 1 | 2 | 3 | 4 | 5 |
| | | Response type | +/-5mm | 6 to 14 | 15 to 22 | 23 to 30 | gt 31 | Response type | 0 to 0.9 | 1.0 to 1.9 | 2.0 to 2.9 | 3.0 to 3.9 | 4.0 to 10.0 |
| 10 | 1 - Flooded river flats | E | 1 | 3 | 5 | 6 | 6 | D | 1 | 2 | 4 | 5 | 6 |
| 20 | 2 - Freshwater meadow | E | 1 | 3 | 5 | 6 | 6 | D | 1 | 2 | 4 | 5 | 6 |
| 21 | 2 - Freshwater meadow - GW source | E | 1 | 3 | 5 | 6 | 6 | D | 1 | 2 | 4 | 5 | 6 |
| 22 | 2 - Freshwater meadow - GW & River source | E | 1 | 3 | 5 | 6 | 6 | D | 1 | 2 | 4 | 5 | 6 |
| 23 | 2 - Freshwater meadow - River source | E | 1 | 3 | 5 | 6 | 6 | D | 1 | 2 | 4 | 5 | 6 |
| 30 | 3 - Shallow freshwater marsh | D | 1 | 2 | 4 | 5 | 6 | C | 1 | 2 | 3 | 4 | 5 |
| 31 | 3 - Shallow freshwater marsh - GW source | D | 1 | 2 | 4 | 5 | 6 | C | 1 | 2 | 3 | 4 | 5 |
| 32 | 3 - Shallow freshwater marsh - Alps - GW source | E | 1 | 3 | 5 | 6 | 6 | D | 1 | 2 | 4 | 5 | 6 |
| 33 | 3 - Shallow freshwater marsh - GW & River source | E | 1 | 3 | 5 | 6 | 6 | D | 1 | 2 | 4 | 5 | 6 |
| 34 | 3 - Shallow freshwater marsh - River source | E | 1 | 3 | 5 | 6 | 6 | D | 1 | 2 | 4 | 5 | 6 |
| 40 | 4 - Deep freshwater marsh | B | 1 | 2 | 2 | 3 | 3 | A | 1 | 1 | 1 | 2 | 2 |
| 41 | 4 - Deep freshwater marsh - GW source | A | 1 | 1 | 1 | 2 | 2 | A | 1 | 1 | 1 | 2 | 2 |
| 42 | 4 - Deep freshwater marsh - Alps - GW source | C | 1 | 2 | 3 | 4 | 5 | B | 1 | 2 | 2 | 3 | 3 |
| 43 | 4 - Deep freshwater marsh - GW & River source | C | 1 | 2 | 3 | 4 | 5 | B | 1 | 2 | 2 | 3 | 3 |
| 44 | 4 - Deep freshwater marsh - River source | C | 1 | 2 | 3 | 4 | 5 | B | 1 | 2 | 2 | 3 | 3 |
| 50 | 5 - Permanent open freshwater | A | 1 | 1 | 1 | 2 | 2 | A | 1 | 1 | 1 | 2 | 2 |
| 51 | 5 - Permanent open freshwater - GW source | A | 1 | 1 | 1 | 2 | 2 | A | 1 | 1 | 1 | 2 | 2 |
| 52 | 5 - Permanent open freshwater - GW & River source | B | 1 | 2 | 2 | 3 | 3 | B | 1 | 2 | 2 | 3 | 3 |
| 53 | 5 - Permanent open freshwater - River source | B | 1 | 2 | 2 | 3 | 3 | B | 1 | 2 | 2 | 3 | 3 |
| 60 | 6 - Semi-permanent saline | C | 1 | 2 | 3 | 4 | 5 | A | 1 | 1 | 1 | 2 | 2 |
| 61 | 6 - Semi-permanent saline - GW source | C | 1 | 2 | 3 | 4 | 5 | A | 1 | 1 | 1 | 2 | 2 |
| 70 | 7 - Permanent saline | B | 1 | 2 | 2 | 3 | 3 | A | 1 | 1 | 1 | 2 | 2 |
| 71 | 7 - Permanent saline - natural - GW source | B | 1 | 2 | 2 | 3 | 3 | A | 1 | 1 | 1 | 2 | 2 |
| 220 | 20 - Sewage oxidation basin | X | 99 | 99 | 99 | 99 | 99 | X | 99 | 99 | 99 | 99 | 99 |
| 225 | 21 - Salt evaporation basin | X | 99 | 99 | 99 | 99 | 99 | X | 99 | 99 | 99 | 99 | 99 |
| 960 | 99 - No Category - natural - Alps | E | 1 | 3 | 5 | 6 | 6 | D | 1 | 2 | 4 | 5 | 6 |
| 961 | 99 - No Category - natural - Alps - GW source | E | 1 | 3 | 5 | 6 | 6 | D | 1 | 2 | 4 | 5 | 6 |
| 962 | 99 - No Category - natural - Alps - GW & River source | E | 1 | 3 | 5 | 6 | 6 | D | 1 | 2 | 4 | 5 | 6 |
| 963 | 99 - No Category - natural - Alps - River source | E | 1 | 3 | 5 | 6 | 6 | D | 1 | 2 | 4 | 5 | 6 |
| 970 | 99 - No Category - natural | B | 1 | 2 | 2 | 3 | 3 | A | 1 | 1 | 1 | 2 | 2 |
| 971 | 99 - No Category - natural - GW source | A | 1 | 1 | 1 | 2 | 2 | A | 1 | 1 | 1 | 2 | 2 |
| 972 | 99 - No Category - natural - GW & River source | B | 1 | 2 | 2 | 3 | 3 | A | 1 | 1 | 1 | 2 | 2 |
| 973 | 99 - No Category - natural - River source | B | 1 | 2 | 2 | 3 | 3 | A | 1 | 1 | 1 | 2 | 2 |
| 980 | 99 - No Category - artificial | B | 1 | 2 | 2 | 3 | 3 | A | 1 | 1 | 1 | 2 | 2 |
| 981 | 99 - No Category - artificial - GW | A | 1 | 1 | 1 | 2 | 2 | A | 1 | 1 | 1 | 2 | 2 |
| 982 | 99 - No Category - artificial - GW & River source | B | 1 | 2 | 2 | 3 | 3 | A | 1 | 1 | 1 | 2 | 2 |
| 983 | 99 - No Category - artificial - River source | B | 1 | 2 | 2 | 3 | 3 | A | 1 | 1 | 1 | 2 | 2 |
| 998 | 99 - No Category - artificial | B | 1 | 2 | 2 | 3 | 3 | A | 1 | 1 | 1 | 2 | 2 |
| 999 | 99 - No Category - unknown type | B | 1 | 2 | 2 | 3 | 3 | A | 1 | 1 | 1 | 2 | 2 |

## Rivers Asset Class – Sensitivity Rating

| RIV CLASS | RIV CLASS Description | Sensitivity to Total Rainfall Mar to Nov Variation (reduction in mm) | | | | | | Sensitivity to Max_Temp_Nov_to_Apr Variation (increase in Deg C) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | | 1 | 2 | 3 | 4 | 5 |
| | | Response | +/-5mm | 6 to 14 | 15 to 22 | 23 to 30 | gt 31 | Response | 0 to 0.9 | 1.0 to 1.9 | 2.0 to 2.9 | 3.0 to 3.9 | 4.0 to 10.0 |
| 112 | 1 - Regulated - Non-Perennial - Intermediate | C | 1 | 2 | 3 | 4 | 5 | C | 1 | 2 | 3 | 4 | 5 |
| 113 | 1 - Regulated - Non-Perennial - Lower | C | 1 | 2 | 3 | 4 | 5 | B | 1 | 2 | 2 | 3 | 3 |
| 121 | 1 - Regulated - Permanent - Upper | C | 1 | 2 | 3 | 4 | 5 | C | 1 | 2 | 3 | 4 | 5 |
| 122 | 1 - Regulated - Permanent - Intermediate | C | 1 | 2 | 3 | 4 | 5 | B | 1 | 2 | 2 | 3 | 3 |
| 123 | 1 - Regulated - Permanent - Lower | F | 1 | 1 | 3 | 4 | 4 | A | 1 | 1 | 1 | 2 | 2 |
| 129 | 1 - Regulated - Permanent - unclassified | F | 1 | 1 | 3 | 4 | 4 | A | 1 | 1 | 1 | 2 | 2 |
| 211 | 2 - Unregulated - Non-Perennial - Upper | E | 1 | 3 | 5 | 6 | 6 | E | 1 | 3 | 5 | 6 | 6 |
| 212 | 2 - Unregulated - Non-Perennial - Intermediate | D | 1 | 2 | 4 | 5 | 6 | D | 1 | 2 | 4 | 5 | 6 |
| 213 | 2 - Unregulated - Non-Perennial - Lower | C | 1 | 2 | 3 | 4 | 5 | C | 1 | 2 | 3 | 4 | 5 |
| 219 | 2 - Unregulated - Non-Perennial - unclassified | C | 1 | 2 | 3 | 4 | 5 | C | 1 | 2 | 3 | 4 | 5 |
| 221 | 2 - Unregulated - Permanent - Upper | D | 1 | 2 | 4 | 5 | 6 | D | 1 | 2 | 4 | 5 | 6 |
| 222 | 2 - Unregulated - Permanent - Intermediate | C | 1 | 2 | 3 | 4 | 5 | C | 1 | 2 | 3 | 4 | 5 |
| 223 | 2 - Unregulated - Permanent - Lower | B | 1 | 2 | 2 | 3 | 3 | B | 1 | 2 | 2 | 3 | 3 |
| 229 | 2 - Unregulated - Permanent - unclassified | B | 1 | 2 | 2 | 3 | 3 | B | 1 | 2 | 2 | 3 | 3 |
| 291 | 2 - Unregulated - unclassified - Upper | D | 1 | 2 | 4 | 5 | 6 | D | 1 | 2 | 4 | 5 | 6 |
| 292 | 2 - Unregulated - unclassified - Intermediate | C | 1 | 2 | 3 | 4 | 5 | C | 1 | 2 | 3 | 4 | 5 |
| 293 | 2 - Unregulated - unclassified - Lower | C | 1 | 2 | 3 | 4 | 5 | B | 1 | 2 | 2 | 3 | 3 |
| 299 | 2 - Unregulated - unclassified - unclassified | C | 1 | 2 | 3 | 4 | 5 | B | 1 | 2 | 2 | 3 | 3 |

## Estuaries Asset Class – Sensitivity Rating

| EST CLASS | EST CLASS Description | | Sensitivity to Total Rainfall Mar to Nov Variation (reduction in mm) | | | | |
|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 |
| | | Response type | +/-5mm | 6 to 14 | 15 to 22 | 23 to 30 | gt 31 |
| 1110 | 1 - Intermittently open - Coast facing - Modified | B | 1 | 2 | 2 | 3 | 3 |
| 1120 | 1 - Intermittently open - Coast facing - Unmodified | C | 1 | 2 | 3 | 4 | 5 |
| 1210 | 1 - Intermittently open - Bay - Modified | B | 1 | 2 | 2 | 3 | 3 |
| 1220 | 1 - Intermittently open - Bay - Unmodified | C | 1 | 2 | 3 | 4 | 5 |
| 2110 | 2 - Permanently open - Coast facing - Modified | A | 1 | 1 | 1 | 2 | 2 |
| 2120 | 2 - Permanently open - Coast facing - Unmodified | B | 1 | 2 | 2 | 3 | 3 |
| 2210 | 2 - Permanently open - Bay - Modified | A | 1 | 1 | 1 | 2 | 2 |
| 2220 | 2 - Permanently open - Bay - Unmodified | B | 1 | 2 | 2 | 3 | 3 |

**Soils / Land Asset Class – Sensitivity Rating**

| SOILS CLASS | SOILS CLASS Description | Sensitivity to Annual Rainfall Variation (change in mm) | | | | | | Sensitivity to Max Nov to Apr Temp Variation (change in Deg C) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | | 1 | 2 | 3 | 4 | 5 |
| | | Response | +/-5mm | -6 to -15 | -16 to -34 | -35 to -45 | gt -46 | Response | 0 to 0.9 | 1.0 to 1.9 | 2.0 to 2.9 | 3.0 to 3.9 | 4.0 to 10.0 |
| 111 | 1 - Wind_H - Wat_H - Ter_H | E | 1 | 3 | 5 | 6 | 6 | E | 1 | 3 | 5 | 6 | 6 |
| 112 | 1 - Wind_H - Wat_H - Ter_M | E | 1 | 3 | 5 | 6 | 6 | E | 1 | 3 | 5 | 6 | 6 |
| 113 | 1 - Wind_H - Wat_H - Ter_L | D | 1 | 2 | 4 | 5 | 6 | D | 1 | 2 | 4 | 5 | 6 |
| 121 | 1 - Wind_H - Wat_L - Ter_H | D | 1 | 2 | 4 | 5 | 6 | D | 1 | 2 | 4 | 5 | 6 |
| 122 | 1 - Wind_H - Wat_L - Ter_M | D | 1 | 2 | 4 | 5 | 6 | D | 1 | 2 | 4 | 5 | 6 |
| 123 | 1 - Wind_H - Wat_L - Ter_L | D | 1 | 2 | 4 | 5 | 6 | D | 1 | 2 | 4 | 5 | 6 |
| 129 | 1 - Wind_H - Wat_L - Ter_L | D | 1 | 2 | 4 | 5 | 6 | D | 1 | 2 | 4 | 5 | 6 |
| 211 | 2 - Wind_M - Wat_H - Ter_H | D | 1 | 2 | 4 | 5 | 6 | D | 1 | 2 | 4 | 5 | 6 |
| 212 | 2 - Wind_M - Wat_H - Ter_M | D | 1 | 2 | 4 | 5 | 6 | D | 1 | 2 | 4 | 5 | 6 |
| 213 | 2 - Wind_M - Wat_H - Ter_L | C | 1 | 2 | 3 | 4 | 5 | C | 1 | 2 | 3 | 4 | 5 |
| 219 | 2 - Wind_M - Wat_H - Ter_L | C | 1 | 2 | 3 | 4 | 5 | C | 1 | 2 | 3 | 4 | 5 |
| 221 | 2 - Wind_M - Wat_L - Ter_H | C | 1 | 2 | 3 | 4 | 5 | C | 1 | 2 | 3 | 4 | 5 |
| 222 | 2 - Wind_M - Wat_L - Ter_M | B | 1 | 2 | 2 | 3 | 3 | B | 1 | 2 | 2 | 3 | 3 |
| 223 | 2 - Wind_M - Wat_L - Ter_L | B | 1 | 2 | 2 | 3 | 3 | B | 1 | 2 | 2 | 3 | 3 |
| 229 | 2 - Wind_M - Wat_L - Ter_L | B | 1 | 2 | 2 | 3 | 3 | B | 1 | 2 | 2 | 3 | 3 |
| 311 | 3 - Wind_L - Wat_H - Ter_H | D | 1 | 2 | 4 | 5 | 6 | D | 1 | 2 | 4 | 5 | 6 |
| 312 | 3 - Wind_L - Wat_H - Ter_M | C | 1 | 2 | 3 | 4 | 5 | C | 1 | 2 | 3 | 4 | 5 |
| 313 | 3 - Wind_L - Wat_H - Ter_L | B | 1 | 2 | 2 | 3 | 3 | B | 1 | 2 | 2 | 3 | 3 |
| 319 | 3 - Wind_L - Wat_H - Ter_L | B | 1 | 2 | 2 | 3 | 3 | B | 1 | 2 | 2 | 3 | 3 |
| 321 | 3 - Wind_L - Wat_L - Ter_H | B | 1 | 2 | 2 | 3 | 3 | B | 1 | 2 | 2 | 3 | 3 |
| 322 | 3 - Wind_L - Wat_L - Ter_M | A | 1 | 1 | 1 | 2 | 2 | A | 1 | 1 | 1 | 2 | 2 |
| 323 | 3 - Wind_L - Wat_L - Ter_L | A | 1 | 1 | 1 | 2 | 2 | A | 1 | 1 | 1 | 2 | 2 |
| 329 | 3 - Wind_L - Wat_L - Ter_L | A | 1 | 1 | 1 | 2 | 2 | A | 1 | 1 | 1 | 2 | 2 |
| 411 | 4 - Wind_VL - Wat_H - Ter_H | D | 1 | 2 | 4 | 5 | 6 | D | 1 | 2 | 4 | 5 | 6 |
| 412 | 4 - Wind_VL - Wat_H - Ter_M | C | 1 | 2 | 3 | 4 | 5 | C | 1 | 2 | 3 | 4 | 5 |
| 413 | 4 - Wind_VL - Wat_H - Ter_L | B | 1 | 2 | 2 | 3 | 3 | B | 1 | 2 | 2 | 3 | 3 |
| 419 | 4 - Wind_VL - Wat_H - Ter_L | B | 1 | 2 | 2 | 3 | 3 | B | 1 | 2 | 2 | 3 | 3 |
| 421 | 4 - Wind_V - Wat_L - Ter_H | B | 1 | 2 | 2 | 3 | 3 | B | 1 | 2 | 2 | 3 | 3 |
| 422 | 4 - Wind_V - Wat_L - Ter_M | A | 1 | 1 | 1 | 2 | 2 | A | 1 | 1 | 1 | 2 | 2 |
| 423 | 4 - Wind_V - Wat_L - Ter_L | A | 1 | 1 | 1 | 2 | 2 | A | 1 | 1 | 1 | 2 | 2 |
| 429 | 4 - Wind_V - Wat_L - Ter_L | A | 1 | 1 | 1 | 2 | 2 | A | 1 | 1 | 1 | 2 | 2 |

## Coastal Wetlands Asset Class – Sensitivity Rating

| CWET CLASS | COASTAL WETLAND CLASS Description | Response | Sensitivity to Rainfall_Mar_to_Nov Variation (reduction in mm) | | | | |
|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 |
| | | | +/-5mm | 6 to 14 | 15 to 22 | 23 to 30 | gt 31 |
| 20 | 2 - Freshwater meadow | E | 1 | 3 | 5 | 6 | 6 |
| 21 | 2 - Freshwater meadow - GW source | E | 1 | 3 | 5 | 6 | 6 |
| 22 | 2 - Freshwater meadow - GW & River source | E | 1 | 3 | 5 | 6 | 6 |
| 23 | 2 - Freshwater meadow - River source | E | 1 | 3 | 5 | 6 | 6 |
| 30 | 3 - Shallow freshwater marsh | D | 1 | 2 | 4 | 5 | 6 |
| 31 | 3 - Shallow freshwater marsh - GW source | D | 1 | 2 | 4 | 5 | 6 |
| 33 | 3 - Shallow freshwater marsh - GW & River source | E | 1 | 3 | 5 | 6 | 6 |
| 34 | 3 - Shallow freshwater marsh - River source | E | 1 | 3 | 5 | 6 | 6 |
| 40 | 4 - Deep freshwater marsh | B | 1 | 2 | 2 | 3 | 3 |
| 41 | 4 - Deep freshwater marsh - GW source | A | 1 | 1 | 1 | 2 | 2 |
| 43 | 4 - Deep freshwater marsh - GW & River source | C | 1 | 2 | 3 | 4 | 5 |
| 44 | 4 - Deep freshwater marsh - River source | C | 1 | 2 | 3 | 4 | 5 |
| 50 | 5 - Permanent open freshwater | A | 1 | 1 | 1 | 2 | 2 |
| 51 | 5 - Permanent open freshwater - GW source | A | 1 | 1 | 1 | 2 | 2 |
| 52 | 5 - Permanent open freshwater - GW & River source | B | 1 | 2 | 2 | 3 | 3 |
| 53 | 5 - Permanent open freshwater - River source | B | 1 | 2 | 2 | 3 | 3 |
| 60 | 6 - Semi-permanent saline | C | 1 | 2 | 3 | 4 | 5 |
| 61 | 6 - Semi-permanent saline - GW source | C | 1 | 2 | 3 | 4 | 5 |
| 70 | 7 - Permanent saline | B | 1 | 2 | 2 | 3 | 3 |
| 71 | 7 - Permanent saline - natural - GW source | B | 1 | 2 | 2 | 3 | 3 |
| 220 | 20 - Sewage oxidation basin | X | 99 | 99 | 99 | 99 | 99 |
| 520 | 2 - Freshwater meadow - tidal | E | 1 | 3 | 5 | 6 | 6 |
| 521 | 2 - Freshwater meadow - tidal - GW source | E | 1 | 3 | 5 | 6 | 6 |
| 525 | 21 - Salt evaporation basin - tidal | X | 99 | 99 | 99 | 99 | 99 |
| 530 | 3 - Shallow freshwater marsh - tidal | D | 1 | 2 | 4 | 5 | 6 |
| 531 | 3 - Shallow freshwater marsh - tidal - GW source | D | 1 | 2 | 4 | 5 | 6 |
| 540 | 4 - Deep freshwater marsh - tidal | B | 1 | 2 | 2 | 3 | 3 |
| 541 | 4 - Deep freshwater marsh - tidal - GW source | A | 1 | 1 | 1 | 2 | 2 |
| 550 | 5 - Permanent open freshwater - tidal | A | 1 | 1 | 1 | 2 | 2 |
| 551 | 5 - Permanent open freshwater - tidal - GW source | A | 1 | 1 | 1 | 2 | 2 |
| 560 | 6 - Semi-permanent saline - tidal | C | 1 | 2 | 3 | 4 | 5 |
| 570 | 7 - Permanent saline - tidal | A | 1 | 1 | 1 | 2 | 2 |
| 575 | 7 - Permanent saline - supratidal | C | 1 | 2 | 3 | 4 | 5 |
| 599 | 99 - No Category - tidal | A | 1 | 1 | 1 | 2 | 2 |
| 595 | 99 - No Category - supratidal | C | 1 | 2 | 3 | 4 | 5 |
| 970 | 99 - No Category - natural | B | 1 | 2 | 2 | 3 | 3 |
| 973 | 99 - No Category - natural - River source | B | 1 | 2 | 2 | 3 | 3 |
| 980 | 99 - No Category - artificial | B | 1 | 2 | 2 | 3 | 3 |
| 983 | 99 - No Category - artificial - River source | B | 1 | 2 | 2 | 3 | 3 |
| 999 | 99 - No Category - unknown type | B | 1 | 2 | 2 | 3 | 3 |

## IV. Future planning for species under a changing climate

CSIRO, through the AdaptNRM program, has developed a number of climate change adaptation tools and resources for regional NRM bodies. AdaptNRM sets new directions for assessing the magnitude, extent and type of expected changes in biodiversity under climate change through introducing new modelling approaches and these are explained below.

**Ecological similarity** estimates change in species composition between a baseline period and a future time.

This modelling projects ecological change by 2050 under a high emissions scenario (RCP 8.5) and is one of two climate change scenarios informing this plan.

The **potential degree of ecological change** measures similarity between a baseline and future climate for every location within Australia: the lower the similarity, the greater the potential change in biodiversity.

This modelling has produced some alarming results at national level that can also be interpreted at a regional scale.

For example, under a high emissions scenario (RCP 8.5), modelling is showing that there will be a 50-75% ecological similarity to the future across continental Australia, suggesting that between 25-50% of our native species may go through some form of degree of ecological change by 2050.

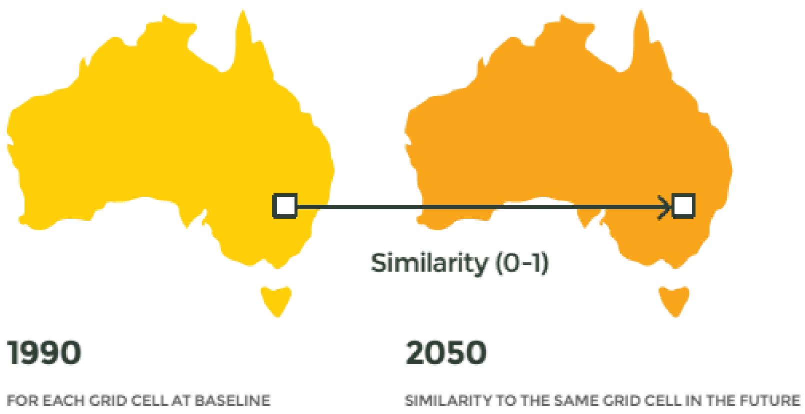



**Figure 25: Ecological similarity**

Potential degree of ecological change could be used to complement Corangamite CMA's vulnerability assessment to better incorporate the interactions between climate exposure and sensitivity. For example, the region's existing vulnerability modelling can use the models of potential degree of ecological change for vascular plants to substitute for the exposure and sensitivity variables for native vegetation as they may provide greater depth and rigour to the assessment of potential impact.

This is because the models that AdaptNRM used considered a broad range of climate variables and sensitivity that was fully modelled based on a range of environmental variables, including climate, that influence species compositions.

**Disappearing ecological environments** may become absent from the region in the future. Under the climate scenarios examined, very few of our more widespread ecological environments are likely to disappear completely by 2050, however, localised areas may disappear.

Plants and amphibians appear to be more at risk of disappearing ecological environments than mammals and reptiles. Models can provide an opportunity to engage communities and stakeholders about the potential need to consider adjusting responses to managing the region's biodiversity.

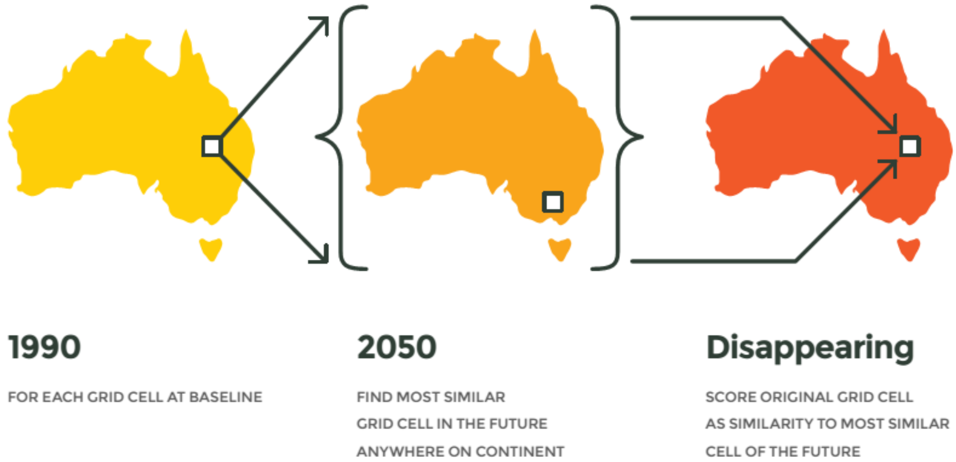



**Figure 26: Disappearing ecological environments**

**Novel ecological environments** are new environments that may arise in the future but which don't exist anywhere on the continent at present. Moderately novel ecological environments for all species groups may be expected for parts of Australia under a warmer future climate, with parts of the interior and the rangelands showing the greatest overall tendency to becoming novel. Given it will be difficult to project what these novel ecological environments will be like, or how they will need to be managed, monitoring now is crucial.

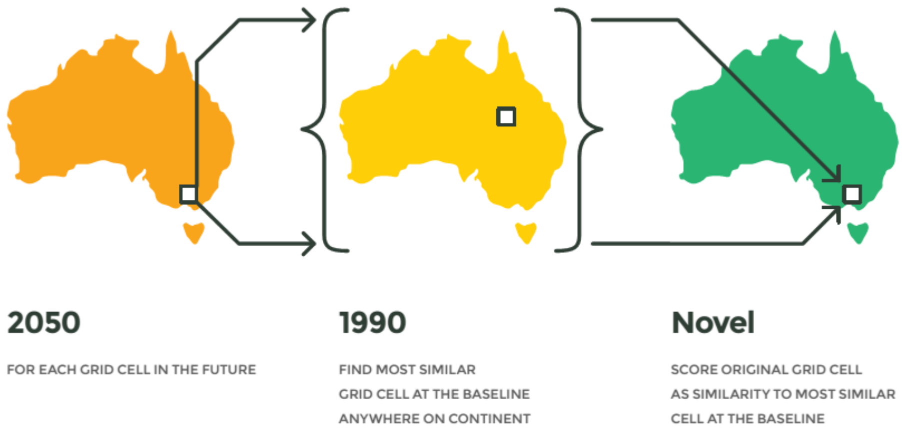



**Figure 27: Novel ecological environments**

The **effective area of similar ecological environments** is a measure of the total land area within a region or landscape suitable for the maintenance of its biodiversity. As certain ecological environments shrink in extent, due to climate change and/or land clearing, some species will be less able to persist over the long term.

Plants and amphibians may be facing greater overall loss in effective area of similar ecological environments, than mammals and reptiles. Mammals in particular are facing losses in effective area in northern Australia, whereas reptiles face such losses in the south. Historical land clearing has occurred in environments that are most favourable for people. The effects of climate change can be combined with those of land clearing, revealing very large losses in effective areas of ecological environments throughout Australia's intensively utilised agricultural zones.

Change in effective area of similar ecological environments could be used to integrate climate change with other threats in risk/vulnerability assessments.

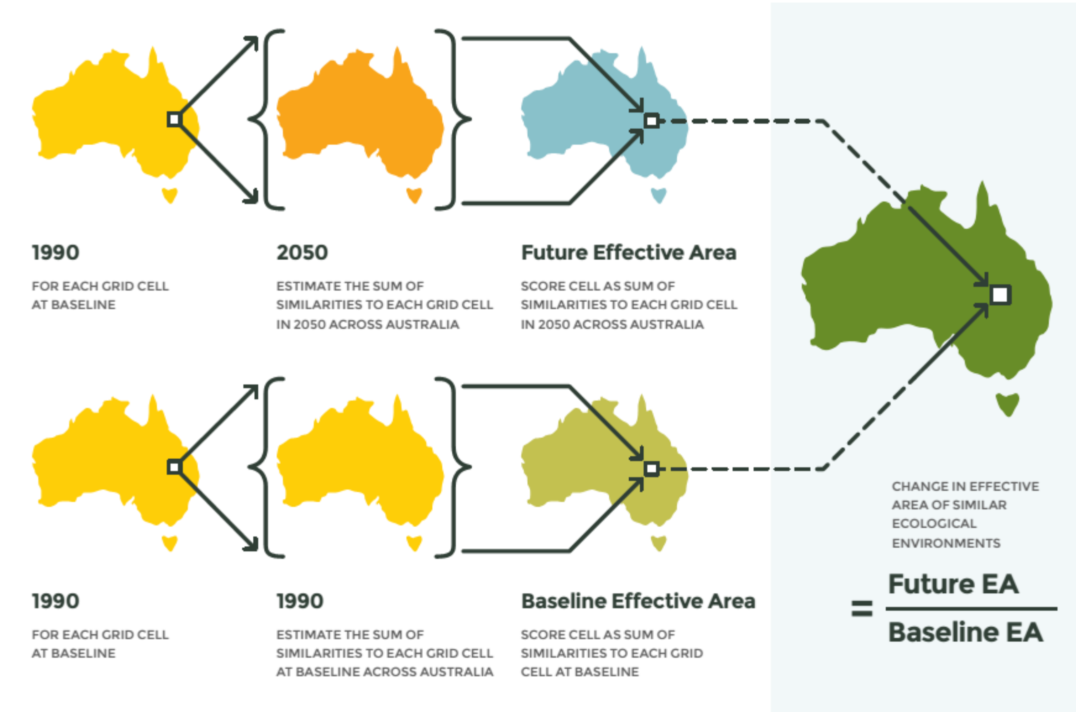



**Figure 28: Effective area of similar ecological environments**

AdaptNRM has integrated the *potential degree of ecological change* with the *degree to which ecological environments* that are becoming novel or disappearing to develop a composite measure, or **composite ecological change**.

The measure can show where different combinations of change may occur and how extreme the changes may be.

The different types of change vary within regions, particularly under the hotter future climate that AdaptNRM examined, suggesting that different strategic goals may be required within a single region and for different biological groups.

More information on AdaptNRM, including modules, can be found at www.AdaptNRM.org

## V. Decision-making tools

As part of the REP Workshops (refer to page 9), participants were asked for feedback on current decision-making tools that could be applied at a regional level to improve decisions for managing natural assets under climate change. This identified a number of tools and decision frameworks that can be used in their current form, or if needed, be modified to assist the region's NRM planners.

Many of the tools are specific to natural assets, such as CoastAdapt, which specifically assists NRM planners make better planning decisions around coastal assets, and their responses to sea level rise.

Others can assess multiple natural assets – many at the same time, over a range of different climate change predictions and/or timeframes. Some can help make better decisions to develop adaptation responses to climate change, some are used to determine landscape priorities for carbon sequestration options such as strategic revegetation programs. It is expected that as knowledge is improved and as current management practices are tested, new and more innovative tools will be developed.

Below is a list of current best practice decision-making tools that can be applied for managing the region's natural assets.

**Environmental Systems Modelling Platform (EnSym)** uses scientific models to understand the impact that actions e.g. revegetation, have on the landscape. Users can visualise, test and interpret results of changes in climate, land use and land management practices through a single interface. EnSym utilises temporal (rainfall and temperature) and spatial (soil type, elevation, land use and groundwater) data as inputs and other data sources added as required.

More information on EnSym can be found at https://ensym.dse.vic.gov.au/cms/.

**Multi-Criteria Analysis Shell for Spatial Decision Support (MCAS-S)** is a software tool developed by the Australian Bureau of Agricultural and Resource Economics and Sciences. It provides a powerful tool for spatial information assessment, conveying complex information in a readily understood manner. It provides an:

- Insightful desktop combination and study of different types of mapped information
- Understanding of the relationships between the decision-making process and the available spatial data
- Interactive 'live-update' and mapping of alternative scenarios

GIS programming is not required, removing the usual technical obstacles to non-GIS users. More information on MCAS-S can be found at www.agriculture.gov.au/abares/data/mcass.

**SimClim** is a computer modelling system for examining the effects of climate variability and change over time and space. It is a customised GIS which includes tools for the spatial analysis of climate variability and change and associated impacts on various social-economic sectors. It allows for customised models of scale and spatial resolution and additional impact models can be included for additional analysis.

More information on SimClim can be found at www.climsystems.com/simclim.

The **Investment Framework for Environmental Resources (INFFER)** assists decision makers through a series of facilitated workshops, to assess and rank environmental and natural resource projects, comparing aspects such as value for money, degrees of confidence in technical information and the likelihood of achieving stated goals. INFFER focuses on assets – specific areas of the natural environment that are considered to have high value from a public perspective. It can also factor in the impacts of anticipated climate change.

More information on INFFER can be found at www.inffer.com.au

The **Catchment Assessment Framework (CAF)** is a process-based deliberative tool that is used to assess the climate change adaptation potential of NRM actions, and by so doing allows the incorporation of climate change adaptation into NRM planning. It contains a series of preparatory steps that must be done in order to get to the assessment stage. It assists in defining strategic interventions (i.e. program planning). It should be used after the goals and management objectives have been set. As the tool is holistic and strategic it is not as useful for specific and detailed operational and project planning at a local level. CAF was developed to assist catchment-level management, but it can be adapted to apply at any scale.

More information on CAF can be found at www.csu.edu.au/research/ilws.

**AdaptNRM** is a national initiative that aims to support NRM groups in climate adaptation planning. Adaptation information is delivered at a national scale, but is designed to suit regions in order to complement other NRM projects and existing NRM activities that incorporate locally-specific issues and solutions. AdaptNRM uses a user-driven approach to developing NRM-relevant information. Information and materials are accessible through a series of five easy-to-understand modules which deliver simple, synthesised guidance which is supported by technical guides and data sets. The five modules are;

- The NRM Adaptation Checklist: Supporting Climate Adaptation Planning and Decision Making for Regional NRM
- Weeds and Climate Change: Supporting Weed Management Adaptation
- Implications of Climate Change for Biodiversity: A Community-level Modelling Approach
- Helping Biodiversity Adapt: Supporting Climate Adaptation Planning using a Community-level Modelling Approach Shared Learning

More information on AdaptNRM can be found at www.AdaptNRM.org

Currently being developed by NCCARF, **CoastAdapt** will provide practical guidance on how to manage the risks from climate change and sea-level rise, together with the associated physical, social and economic risks. The tool will be national in scope, and will include access to sufficient information and knowledge to ensure that it is applicable for the range of climates and regulatory and planning systems throughout Australia. CoastAdapt will focus on the needs of government, particularly at the local level, but will be applicable to the needs of all coastal managers including natural resource managers and coastal infrastructure operators. It will also consider natural and built assets and will be designed to meet planning and decision-making needs in coastal areas of high biodiversity, of new developments and where substantial assets are already at some risk from coastal climate hazards.

More information on CoastAdapt can be found at www.nccarf.edu.au/content/coastal-tool-overview.

The **Landscape Futures Analysis Tool (LFAT)** enables users to consider how their region may change under different combinations of climate, carbon and agricultural commodity prices, and the cost of agricultural production. It is based on good science, 'climate-ready' planning for biodiversity conservation, carbon sequestration, weed management and agricultural production. The computer-based tool is interactive and can compute hundreds of calculations to analyse complex interactions. It can readily generate 256 alternative scenarios of the future, drawing on different combinations of:

- Climate – four options, from 'baseline' through to 'severe warming and drying'.
- Agricultural commodity prices – four options for wheat, wool and sheep meat, from 50% to 200% of 2012 prices.
- Cost of production – four options, from 50% to 200% of 2012 commodity prices.
- Carbon prices – four options, from $15 to $60 per tonne CO2.

It can also project future distributions for about 400 native plant and 70 weed species, based on alternative climate scenarios. LFAT has been developed by the University of Adelaide and the CSIRO, in collaboration with regional NRM bodies and other interested parties.

More information on LFAT can be found at www.lfat.org.au

There are important considerations to be aware of when using climate change projections. The Climate Change in Australia portal provides information on how to use projections data, get help finding the information you want or obtain resources to assist your own communication efforts.

The portal contains a Decision Tree tool to guide you to information you might be looking for. This tool is particularly useful if you are undertaking an impact assessment or project that requires climate information and/or data. The portal also contains datasets for download, a publications library and other useful tools.

More information on the portal can be found at www.climatechangeinaustralia.gov.au/en/

## VI. List of contributing stakeholders

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- AdaptNRM
- A.S. Miner Geotechnical
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- Barwon Coast Committee of Management
- Barwon Water
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- Centre for eResearch and Digital Innovation
- City of Greater Geelong
- Colac Otway Shire
- Conservation Ecology Centre
- Commonwealth Scientific and Industrial Research Organisation
- Deakin University
- Department of Economic Development, Jobs, Transport and Resources
- Department of Environment, Land, Water and Planning
- Department of the Environment
- East Gippsland Catchment Management Authority
- Environment Protection Authority
- Federation University
- Greening Australia
- Goulburn Broken CMA
- Glenelg Hopkins CMA
- Interface NRM
- Mallee CMA
- Monash University
- Natural Decisions
- North Central CMA
- North East CMA
- Port Phillip Westernport CMA
- RMIT University
- Southern Farming Systems
- Southern Slopes Climate Change Adaptation Research Partnership
- Spatial Vision
- Sustainability Victoria
- Trust for Nature
- University of Tasmania
- Wannon Water
- Wimmera CMA
- West Gippsland CMA

## VII. References

Agawin NSR & Duarte CM. (2002) *Evidence of direct particle trapping by a tropical seagrass meadow.* Estuaries, 25, 1205–1209.

Bosomworth, K., Harwood, A., Leith, P., and Wallis, P. (2015) *Adaptation Pathways: a playbook for developing options for climate change adaptation in Natural Resource Management*. Southern Slopes Climate Change Adaptation Research Partnership (SCARP): RMIT University, University of Tasmania, and Monash University.

Carnell, P., Ewers, C., Rochelmeyer, E., Zavalas, R., Hawke, B., Ierodiaconou, D., Sanderman, J., and Macreadie, P. (2015) *The Distribution and Abundance of 'Blue Carbon' within Corangamite*. Deakin University.

Clarkson, T. (2007) *Corangamite Soil Health Strategy 2007*. Department of Primary Industries on behalf of the Corangamite Catchment Management Authority, Colac.

Commissioner for Environmental Sustainability. (2013) *Victoria State of the Environment Report 2013.* Commissioner for Environmental Sustainability, Melbourne.

Corangamite Catchment Management Authority. (2009) *Corangamite Marine and Coastal Biodiversity Strategy.* Corangamite Catchment Management Authority, Colac.

Corangamite Catchment Management Authority. (2012) *Corangamite Regional Catchment Strategy 2012 – 2018*. Corangamite Catchment Management Authority, Colac.

Corangamite Catchment Management Authority. (2014) *Corangamite Waterway Strategy.* Corangamite Catchment Management Authority, Colac.

Corangamite Catchment Management Authority. (2015) Aire River Estuary Management Plan (Draft). Corangamite Catchment Management Authority, Colac.

Costanza R. (1998) *Introduction- special section: forum on valuation of ecosystem services- the value of ecosystem services.* Ecological Economics, 25, 1-2.

CSIRO, Australian Bureau of Meteorology. (2014) *State of the climate report.*

Department of Sustainability and Environment. (2001) Australian Mudfish Action Statement: Flora and Fauna Guarantee Act 1988 No. 115. Department of Sustainability and Environment, Melbourne.

Department of Sustainability and Environment. (2003) *Port Phillip Bay (western Shoreline) & Bellarine Peninsula Ramsar Site: Strategic Management Plan.* Department of Sustainability and Environment, Melbourne.

Department of Sustainability and Environment. (2011) *Western Region Sustainable Water Strategy.* Department of Sustainability and Environment, Melbourne.

Department of Sustainability, Environment, Water, Population and Communities (2011) *National Recovery Plan for the Corangamite Water Skink (Eulamprus tympanum marnieae)* Department of Sustainability, Environment, Water, Population and Communities, Melbourne

Dunlop, M., Parris, H., Ryan, P., Kroon, F. (2013) *Climate-ready conservation objectives: a scoping study*. National Climate Change Adaptation Research Facility, Gold Coast.

Fourqurean JW, Duarte CM, Kennedy H, Marba N, Holmer M, Mateo MA, Apostolaki ET, Kendrick GA, Krause-Jensen J, McGlathery KJ, Serrano O. (2012) *Seagrass ecosystems as a globally significant carbon stock*. Nature Geoscience, 5, 505–509.

Gacia E, Duarte CM. (2001) *Sediment retention by a Mediterranean Posidonia oceanica meadow: the balance between deposition and resuspension*. Estuarine, Coastal and Shelf Science, 52, 505–514.

Grose, M. et al. (2015) *Southern Slopes Cluster Report, Climate Change in Australia Projections for Australia's Natural Resource Management Regions: Cluster Reports*, eds. Ekström, M. et al., CSIRO and Bureau of Meteorology, Australia.

Hamilton, L.C. (2015) *A Review of Carbon Sequestration in Vegetation and Soils: options, opportunities and barriers for Southern Slopes Cluster NRM organisations*. Southern Slopes Climate Change Adaptation Research Partnership (SCARP): Victorian Department of Economic Development, Jobs, Transport and Resources.

Haasnoot, M., Kwakkel, J.H., Walker, W.E., ter Maat, J. (2013). Dynamic adaptive policy pathways: A method for crafting robust decisions for a deeply uncertain world. Global Environment Change 23, 485–498.

Hendriks IE, Sintes T, Bouma TJ & Duarte CM. (2008) *Experimental assessment and modeling evaluation of the effects of the seagrass Posidonia oceanica on flow and particle trapping.* Marine Ecology Progress Series, 356, 163–173.

IPCC, 2007b. Intergovernmental Panel on Climate Change, Fourth Assessment Report (AR4), Synthesis Report, Summary for Policy Makers. IPCC, Geneva.

IPCC, 2007c. Annex I: Glossary. Climate Change 2007: Working Group II: Impacts, Adaptation and Vulnerability. IPCC, Geneva.

IPCC, 2012. Summary for Policymakers. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation, in: Field, C.B., Barros, V., Stocker, T.F., Qin, D., Dokken, D.J., Ebi, K.L., Mastrandrea, M.D., Mach, K.J., Plattner, G.-K., Allen, S.K., Tignor, M., Midgley, P.M. (Eds.), Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: Special Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom.

IPCC, 2013a. Summary for policymakers, in: Stocker, T.F., Qin, D., Plattner, G.-K., Alexander, L.V., Allen, S.K., Bindoff, N.L., Bréon, F.-M., Church, J.A., Cubasch, U., Emori, S., others (Eds.), Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom.

IPCC. (2014). Annex II: Glossary [Agard, J., E.L.F. Schipper, J. Birkmann, M. Campos, C. Dubeux, Y. Nojiri, L. Olsson, B. Osman-Elasha, M. Pelling, M.J. Prather, M.G. Rivera-Ferre, O.C. Ruppel, A. Sallenger, K.R. Smith, A.L. St Clair, K.J. Mach, M.D. Mastrandrea, and T.E. Bilir (eds.)], in: Barros, V.R., Field, C.B., Dokken, D.J., Mastrandrea, M.D., Mach, K.J., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., Girma, B., Kissel, E.S., Levy, A.N., MacCracken, S., Mastrandrea, P.R., White, L.L. (Eds.), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom.

Jacobs, B., Nelson, R., Kuruppu, N., and Leith, P. (2015). An adaptive capacity guide book: Assessing, building and evaluating the capacity of communities to adapt in a changing climate. Southern Slopes Climate Change Adaptation Research Partnership (SCARP), University of Technology Sydney and University of Tasmania. Hobart, Tasmania.

Kennedy H, Beggins J, Duarte CM, Fourqurean JW, Holmer M, Marba N & Middelburg JJ. (2010) *Seagrass sediments as a global carbon sink: isotopic constraints*. Global Biogeochemical Cycles, 24.

Leith, P., Harris, R.M.B., Bridle, K., Kemmerer, E., Baldwin, A. and Diddams, L. (2015). A Means-to-an-end: a process guide for participatory spatial prioritisation in Australian natural resource management. Southern Slopes Climate Change Adaptation Research Partnership (SCARP): University of Tasmania.

Mateo MA, Romero J, Perez M, Littler MM & Littler, DS. (1997) *Dynamics of millenary organic deposits resulting from the growth of the Mediterranean seagrass Posidonia oceanica*. Estuarine, Coastal and Shelf Science, 44, 103–110.

Pedersen MO, Serrano O, Mateo MA & Holmer M. (2011) *Temperature effects on decomposition of a Posidonia oceanica mat*. Aquatic Microbial Ecology, 65, 169–182.

Pendleton L, Donato DC, Murray BC, Crooks S, Jenkins WA, Sifleet S, Craft C, Fourqurean JW, Kauffman JB, Marba N, Megonigal P, Pidgeon E, Herr D, Gordon D & Baldera A. (2012) *Estimating global "blue carbon" emissions from conversion and degradation of vegetated coastal ecosystems*. Plos One, 7, 1–7.

Prober SM, Williams KJ, Harwood TD, Doerr VAJ, Jeanneret T, Manion G, Ferrier S. (2015) *Helping Biodiversity Adapt: Supporting climate-adaptation planning using a community-level modelling approach*. CSIRO Land and Water Flagship, Canberra.

Pendleton, L., Donato, D.C., Murray, B.C., Crooks, S., Jenkins, W.A., Sifleet, S., Craft, C., Fourqurean, J.W., Kauffman, J.B., Marbà, N., Megonigal, P., Pidgeon, E., Herr, D., Gordon, D., Baldera, A. (2012) *Estimating Global "Blue Carbon" Emissions from Conversion and Degradation of Vegetated Coastal Ecosystems*.

Rissik D, Boulter S, Doerr V, Marshall N, Hobday A and Lim-Camacho L. (2014) *The NRM Adaptation Checklist: Supporting climate adaptation planning and decision-making for regional NRM*. CSIRO and NCCARF, Australia.

Scott, J.K., Webber, B.L., Murphy, H., Ota, N., Kriticos, D.J. and Loechel, B. (2014) *AdaptNRM Weeds and climate change: supporting weed management adaptation.* CSIRO Land and Water Flagship, Canberra.

Spatial Vision and Natural Decisions. (2014) *NRM Planning for Climate Change: Final Project Report 1 – Impact and Vulnerability Assessment Process and Spatial Outputs*. Spatial Vision, Melbourne.

Spatial Vision and Natural Decisions. (2014) *NRM Planning for Climate Change: Final Project Report 2 – Decision making and Frameworks and Integration of Socio-economic Data*. Spatial Vision, Melbourne.

UNFCCC. (1992) Full text of the convention. Article 2: Objective. United Nations Framework Convention on Climate Change http://unfccc.int/key_documents/the_convention

Victorian Environmental Assessment Council. (2011) *Remnant Native Vegetation Investigation*. Victorian Environmental Assessment Council, Melbourne.

Wallis, P.J., Harwood, A., Leith, P., Hamilton, L., Bosomworth, K., Turner, S.L., Harris, R.M.B. and Bridle, K. (2015) *Southern Slopes Information Portal Report: Climate change adaptation information for natural resource planning and implementation.* Southern Slopes Climate Change Adaptation Research Partnership (SCARP), Monash University, University of Tasmania, RMIT University.

Williams KJ, Prober SM, Harwood TD, Doerr VAJ, Jeanneret T, Manion G, and Ferrier S. (2014) *Implications of climate change for biodiversity: a community-level modelling approach,* CSIRO Land and Water Flagship, Canberra.

Wimmera Catchment Management Authority. (2015) *NRMPCC Modelling Landscape Prioritisation Statewide Natural Resource Management Plan for Climate Change*. Wimmera Catchment Management Authority, Horsham.

Wise, R.M., Fazey, I., Stafford Smith, M., Park, S.E., Eakin, H.C., Archer Van Garderen, E.R.M., Campbell, B. (2014) *Reconceptualising adaptation to climate change as part of pathways of change and response*. Global Environmental Change 28, 325–336.

Woady Yaloak Catchment Group. (2012) *Trends in soil condition in the Woady Yaloak Catchment Part 2 - Analysis of historic soil test data (1992 to 2012)*. Woady Yaloak Catchment Group.

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