5 Regional risks and opportunities associated with climate change and variability

Natural resource managers and landholders across the region are already living with and responding to climate variability, but future climate trends may present new challenges. The projected changes in climate have the potential to impact on natural assets and land management practices in unexpected ways. It is important to understand how agricultural and public land managers within the region are planning to adapt in the face of climate change, the interaction between future land management practices and any potential impacts on the natural environment.

The implications of future changes in climate are likely to have a number of direct and indirect effects. Climate variables other than temperature and rainfall, which also influence processes in the landscape like plant growth and the hydrological cycle, are also important to consider.

By the end of the century the overall amount of rainfall may change significantly, a decline in winter-spring rainfall with potentially increased summer rainfall will result in more rainfall being lost to evaporation and evapotranspiration. This has implications for both natural assets and the implementation of NRM activities (such as the timing and methods for establishment of native vegetation). The availability of water will have implications for agricultural production, particularly for those industries reliant on irrigation and winter-filling of dams.

Projected decreases in average rainfall and higher rates of evaporation will result in reduced run-off and reduced inflows to rivers, estuaries and wetlands. Conversely an increased frequency and intensity of intense rainfall events may result in increased flooding.

The combination of decreased average rainfall, increased temperature and more variability (including more time in drought and increased intense rainfall events) is likely to lead to a shift in the flow regimes of rivers in West Gippsland.

Demand for water may also increase as a result of warmer temperatures and as the population grows, in line with projected demographic trends for the region. Therefore, the need to use water more efficiently will be even greater.

Climate change impacts on natural assets will likely be exacerbated by acting synergistically with other threats such as fire, flood, habitat loss and change in land-use and management practices, invasive animals and pests and diseases, and altered water availability and flow regimes.[15]

5.1 Region-wide issues

A key issue of concern for the region arises from issues that operate at a broad landscape scale with impacts across public and private land, and where urban areas and rural land meet. Landscape scale threats, such as invasive plants and animals and fire, may be elevated due to changing climate conditions, and have the potential to further impact on environmental values. Managing these issues across land tenure and landscape type is complex and requires collaboration between public and private land managers, combined with an improved understanding of the potential risks associated with these issues.

5.1.1 Invasive plants

Invasive plants (weeds) are one of the major threats to both natural assets and productivity of freehold land. Climate change will impact on weeds in two main ways, firstly the range of weed species present in the region will change, and secondly the invasiveness of weed species will change favouring some species over others. The main drivers for climate change on invasive plants include increased temperatures, changed rainfall, increased CO^2 levels, more extreme weather, more frequent frosts, changed phenology and changed land use. The rate of response of invasive plants is expected to be faster than for other plants, including native species and crops. Consideration should also be given to species not currently found in West Gippsland but with potential to establish under a changing climate.

5.1.2 Fire

The fires of 2006-07, 2009, 2013 and 2014 demonstrated the extent to which different types of fire (i.e. bushfire, grassfires and mine fire) impact on different landscapes in the West Gippsland region, and the scale of its impact.

Under a changing climate there is potential for an increase in both the frequency and intensity of bushfire, which would broadly:

- alter the distribution and composition of ecosystems,
- lower the yield and quality of water from fire-affected catchments,
- threaten the security of plantation forests,
- increase emissions of greenhouse gases to the atmosphere,
- increase damage to property, livestock and crops.[16]

Greater bushfire activity could temporarily contaminate water catchments with sediments and ash, along with posing more chronic issues for natural ecosystems with low bushfire tolerance.

Increased fire is also likely to magnify the impact of other threats, including invasive plants and animals, soil erosion and declining water quality, so consideration needs to be given as to how best to manage these risks in tandem.

5.1.3 Intense rainfall, flooding and erosion

Intense rainfall events increase the risk of severe flooding. This can cause direct impacts on infrastructure, such as damage to roads and bridges, as well as waterways and floodplains, with downstream impacts from erosion and sediment deposition. Flooding also impacts private assets such as farm infrastructure and soil, crops and livestock. Stormwater flooding caused by runoff from severe storms in areas with high degrees of imperviousness (due to roads, roofs, etc.) is also likely to increase and there may be more flash flooding in summer periods because of the increased frequency of intense rainfall events.

In the future, intense rainfall events will be increasingly likely to follow longer periods without rain (combined with higher temperatures and evaporation) that may correspond with lower ground cover. This has the potential to cause higher rates of soil erosion on land systems that are already susceptible due to factors such as slope and soil type. This has significant implications for lower landscape ecosystems, including the iconic Gippsland Lakes and Corner Inlet.

5.2 Implications for the natural environment

5.2.1 Rivers and inland wetlands

Most of the direct impacts of climate change on freshwater systems in southern Victoria are predicted to come from a decline in rainfall leading to a decrease in runoff, with impacts to flow regimes across the year.[8] Impacts will also arise for aquatic biota from increases in temperature and weather related events, such as fire and drought.

Increased frequency of higher intensity rainfall events has the potential to increase flooding, exacerbate bed and bank erosion in river channels resulting in increased turbidity and sediment loads, potentially with the introduction of pollutants and nutrients from adjacent catchments.

In contrast lower base flows in rivers and higher temperatures, as is currently typical in summer and autumn, combined with elevated nutrient levels will create a more favourable environment for algal blooms.[17] In West Gippsland, this may mean an increase in the occurrence of algal blooms in rivers and creeks.

A reduction in the frequency and duration of high flows and inundation of waterways may result in significant changes in plant and animal communities, particularly for rivers and wetlands that change state from permanently inundated to an alternating wetting and drying regime, whilst seasonal waterways will shift to a longer duration dry phase. These waterways are likely to lose species that require a frequent (or permanent) inundation for survival or critical life history requirements.[8]

These same waterways will also be less frequently connected to their primary water source and each other; reducing opportunities for movement and dispersal of plants and aquatic fauna and reducing genetic mixing.[18]

The rivers and streams that were assessed as having the highest potential vulnerability to climate change impacts under a high emissions scenario, by the year 2070 are presented in Appendix 3, together with an indication of whether the waterway assets are a priority within the West Gippsland RCS and which RCS Landscape Priority Area/s the asset relates to.

Analysis undertaken for wetlands across Victoria[18] concluded that the most vulnerable wetlands to climate change will be:

- rainfall-fed wetlands located in regions where reductions in rainfall are highest,
- river fed wetlands located on floodplains of rivers that will experience a large decrease in the frequency of high flow events,
- groundwater fed wetlands associated with local groundwater flow systems, and
- alpine wetlands.

For all inland wetlands, the primary impact of climate change, regardless of source water, will be a reduction in the frequency and duration of inundation events and an increase in the duration of dry periods. This is likely to manifest in a decrease in the number and area of permanent and seasonal wetlands and increase in the number of and area of intermittent wetlands.

The inland wetland assets (complexes) within the West Gippsland region that were assessed as having the highest potential vulnerability to climate change impacts under a high emissions scenario, by the year 2070 are presented in Appendix 3. These vulnerable wetland complexes include shallow freshwater marshes, freshwater meadows, deep freshwater marshes and alpine wetlands. An indication of whether the vulnerable inland wetland assets are a priority asset within the West Gippsland RCS and which RCS Landscape Priority Area the asset relates to is also provided.

5.2.2 Coasts, estuaries and coastal wetlands

Coastal areas are subject to a range of hazards including inundation, erosion and flooding, and there is potential for these to increase in frequency and extent under future climate scenarios. The drivers of these include changes in sea level rise, storm surge, tides and rainfall.[19] [20] [8]

In the shorter term storm surge is likely to cause damage through erosion and loss of vegetation, and in the longer term sea level rise has potential to impact on coastal habitats, agricultural and peri urban areas through inundation and salinisation. Increased flooding and inundation of coastal settlements is also likely to damage housing and infrastructure. Loss of habitat is possible where coastal habitats including beaches, intertidal flats, rocky shorelines, saltmarsh and mangroves get trapped between landward boundaries and rising sea level.[19]

Where newly inundated areas are available for colonisation, seagrass should be able to move into these new areas provided that the rate of change in sea level is not greater than the ability of an individual species to colonise new habitat, and provided that the newly inundated areas have suitable substrate for colonisation. *Zostera muelleri*, commonly found in intertidal zones in Victoria, is considered stable and persistent and can act as a pioneer species.[21]

The Gippsland coast is highly erodible and is at risk of subsidence, as well as sea level rise. Consequently impacts on non-vegetated soft sediment habitats are likely to be magnified. Where sea walls and levees exist, landwards migration of intertidal habitat in this area will constrain migration, as will sand dunes if they are not breached by storm surge events.[21]

Estuaries and coastal wetlands are complex, dynamic and variable environments, changing with both catchment inflows and marine currents and sand-sediment dynamics.[22] Due to their position in the landscape they are highly vulnerable to direct impacts from climate change.[23] Estuaries and coastal wetlands are likely to be highly vulnerable to climate change, including from changes to inflows, storm surge and sea level rise, with associated impacts resulting from erosion and changes to salinity and water quality.

Changes associated with climate change to dissolved carbon dioxide levels, temperature, rainfall and sea level are likely to interact to affect the circulation of water, levels of salinity, suspended sediments, dissolved oxygen and biogeochemistry of estuaries.[24] However, predicting impacts is difficult because changes are also likely to occur in freshwater and marine systems that subsequently influence estuaries.[24] For example, increasing temperatures and more frequent intense rainfall events are likely to continue to provide the conditions suitable for algal blooms in the Gippsland Lakes. However; reduced streamflows (resulting from reduced rainfall and runoff) and increasing salinity may result in conditions that are less suitable for algal blooms.

Like many natural assets the combined effects of threats from pollution, changes in land use and altered natural river flow patterns are expected to be exacerbated by the effects of climate change.[23]

Smaller riverine estuaries, typical of many of those along the Victorian coast, have been identified as being highly vulnerable to environmental change. This is because they are highly dependent on river flow and groundwater supply for good water quality and suitable habitat for animals and plants.[23]

There are opportunities for coastal wetlands to adapt and migrate inland as sea level rises. However, for bay or inlet estuary types they may become much more constrained as sea level rise pushes them back into the river channels. For many of these ecosystems, the biggest obstacle to migrate naturally inland is the presence of roads, houses and other infrastructure, such as seawalls and levees.

The coastal wetland assets (complexes) and estuaries that were assessed as having the highest potential vulnerability to climate change impacts under a high emissions scenario, by the year 2070 is shown in Appendix 3. An indication of whether the vulnerable coastal wetland and estuary assets are at risk of storm surge and sea level rise impacts is also provided. Appendix 3 details which vulnerable coastal wetland and estuary assets are priorities within the West Gippsland RCS and the RCS Landscape Priority Area the assets relate to.

5.2.3 Native vegetation

Climate change impacts are likely to affect native vegetation through reduced rainfall and increased temperatures.[24] Increased evapotranspiration will in turn impact on the availability of soil moisture and water availability for surface and groundwater systems. It is likely that this will result in a gradual change in the composition of vegetation communities, as some species are replaced by those suited to warmer, drier environments. Some changes may occur earlier, in response to the increased occurrence of extreme events such as droughts or because they are already close to a tipping point.[8] These impacts are likely to be greatest on seasonally dry ecosystems including wetlands and those dependent on shallow water tables (i.e. alpine peatlands and Banksia woodlands), and may be exacerbated by increased groundwater abstraction.[24]

Grasslands may be affected by elevated carbon dioxide and changes to soil moisture, with an increase likely to favour some types of grasses.[8] An increase in the density of tree and shrub species in favour of grassland species is already occurring and is likely to be a major issue across Australia.[19]

The combined effect of changes in climate variables and invasive plants on vulnerable communities poses a significant threat. The response is likely to be variable, however with tropical invasive species more likely to expand their ranges and cool-climate invasive species more likely to retract. Similarly, there could be additional interactions that result from other factors such as soils and land use change.[24] Increased threats from invasive species benefiting from climate change may exceed the direct threats of climate change to many vegetation communities.[24]

Other potential impacts for vegetation communities include:[19]

- Primary production could increase where rain is not limiting, due to increased carbon dioxide,
- Earlier flowering of a range of flora,
- Loss of carbon stocks through changed fire regimes, including more intense and frequent fires and drying of terrestrial vegetation,
- Increased mortality during drought of heat-sensitive species,
- Breeding failures due to loss or mismatch of pollinators,
- Seeding and germination failure due to too high temperatures or lack of soil moisture,
- Potential negative impacts of wildfires on long-lived species and irreversible changes to vegetation communities.

The broad native vegetation groups that were assessed as having the highest potential vulnerability to climate change impacts under a high emissions scenario, by the year 2070 is shown in Appendix 3. An indication of whether the vulnerable assets are a priority asset within the West Gippsland RCS and which RCS Landscape Priority Area the asset relates to is also provided.

5.2.4 Native Fauna

The key threats to fauna are generally associated with their habitat. Key concerns include habitat fragmentation and loss of habitat quality, poor water quality, altered hydrological regimes, barriers to fish passage, competition from invasive plants and animals, and altered fire regimes. Climate change is likely to amplify these existing threatening processes, making their impacts considerably worse. Future declines or losses of local populations of species, and species extinctions are possible as a result.

While the fauna of West Gippsland has adapted to a variable and episodic climate, the impact of future climate change is difficult to predict with any certainty. The effects of climate change on flora and fauna will occur at different levels, from individual to ecosystems. Species may alter distribution, abundance, behaviour and the timing of events such as migration or breeding. The most susceptible species will be those with restricted or specialised habitat requirements, poor dispersal abilities or small populations.[12]

Natural environments are already responding to climate change. Species are moving to higher elevations in alpine regions, some species' ranges are expanding southward to cooler climates, migratory birds are arriving earlier and departing later, and breeding seasons are occurring earlier.

Although many Victorian species appear able to withstand short-term climatic variability, longer-term shifts in climate and the increased frequency or intensity of extreme events will provide a significant challenge to the survival of many species because of their limited capacity to adapt to changing environments. If the adaptive capacity of species is exceeded, migration to more suitable conditions will be a necessity. A compounding factor in Victoria is that the high level of habitat fragmentation will limit the migration opportunities of the less-mobile species. Species inhabiting high-altitude or southerly habitats will have limited scope to migrate.[25]

There is a growing body of research associated with potential fauna impacts from climate change in alpine ecosystems. Australia's alpine fauna are thought to be highly vulnerable to the effects of climate change.[26] Shorter drier winters and reductions in snow cover are projected as the result of climate change, which will have implications for Victoria's unique alpine region and the flora and fauna species that live there, many of which are already endangered. Species endemic to the alpine regions will have nowhere to retreat to as the climate warms.[12]

Coastal wetlands and embayments provide critical habitat for a diversity of migratory waders and aquatic bird species, making this one of the most significant areas for these species in Australia. Future climate impacts associated with sea level rise and storm surge are likely to drive shifts in the extent and distribution of key habitats such as seagrass and mudflats, with potentially major impacts on species that depend on these ecosystems, including numerous significant bird and fish species.

5.2.5 Soils and land

The vulnerability of soils to climate change is dependent on the inherent properties of the soil as described by the soil type and the level of ground cover.

The consequences of a warmer and drier climate on soils include a reduction in soil carbon levels, increased risk of soil erosion and loss of nutrients, changes in land suitability for certain types of agriculture, increases in the occurrence of 'transient' salinity, and water quality impacts, particularly following bushfires.[27]

An increase in fire frequency and intensity, particularly in areas of permanent vegetation, will reduce the amount of ground cover and soil stability and consequently increase the risk of water erosion.[27] Soil erosion during intense rainfall events, following severe fires has been the cause of water quality issues in the West Gippsland region.

Maintaining ground cover to protect soils from both water and wind erosion will be greater under a changing climate. Soils without permanent vegetative cover (e.g. cropping lands) will be at higher risk than those with stable protection. Erosion puts the productivity of land at risk and increases the risk of unwanted effects on water quality and aquatic ecosystems through the movement of sediments and nutrients.

Hydrological changes as the result of increased rainfall or rising sea levels may increase the risk of dryland salinity, with adverse impacts on agricultural productivity and native vegetation. Increased salinisation in near-coastal areas is likely to occur if sea levels rise along the coastline.

The broad soil types that were assessed as having the highest potential vulnerability to climate change impacts under a high emissions scenario, by the year 2070 are presented in Appendix 3. An indication of whether the vulnerable assets are a priority asset within the West Gippsland RCS and which RCS Landscape Priority Area the asset relates to is also provided.

5.3 Implications for Aboriginal Cultural values

Traditional Owners have a strong connection to Country and the preservation of cultural heritage sites is extremely important. The Gunaikurnai peoples and Kulin peoples are the traditional custodians of the country covered by the West Gippsland region.[11]

Tribes of the Gunaikurnai peoples within the region include:

- Brataulaung
- Brayakaulung
- Tatungalung

Tribes of the Kulin peoples within the region include:

- Bunurong
- Boon Wurrung
- Wurundjeri

Traditional Owners core values radiate fundamentally from the preservation and protection of their culture. This includes preservation of language, stories, culture, networks, identity and the appropriate management of significant sites. A key objective of the *Aboriginal Heritage Act 2006* is to promote the management of Aboriginal cultural heritage as an integral part of land and natural resource management. There are many areas of Aboriginal cultural sensitivity within the West Gippsland region. Waterways, coastal landscapes and mountainous areas are of particular importance.

The 2015 Gunaikurnai Whole of Country Plan notes that 'climate change poses a further threat to our Country with decreasing rainfall and an increase in temperatures threatening the health of our rivers and land. Our towns and bush will come under threat from increased bushfire events, and the flooding of coastal environments and towns will have a major impact on cultural and natural values as well as the tourism industries'.[28]

Cultural values such as artefacts, scar trees, shell middens or burial sites may be damaged or lost as the result of climate change impacts (i.e. fire, flood, coastal erosion and shoreline retreat).

It will be important to work with Traditional Owners to protect or record cultural values before they may become impacted or lost due to climate change.

5.4 Climate change planning areas

The locations of the most vulnerable assets in the region, which have been identified within each asset class, were mapped and then overlaid to show where clusters of highly vulnerable assets occur in the landscape (Figure 7).[6]

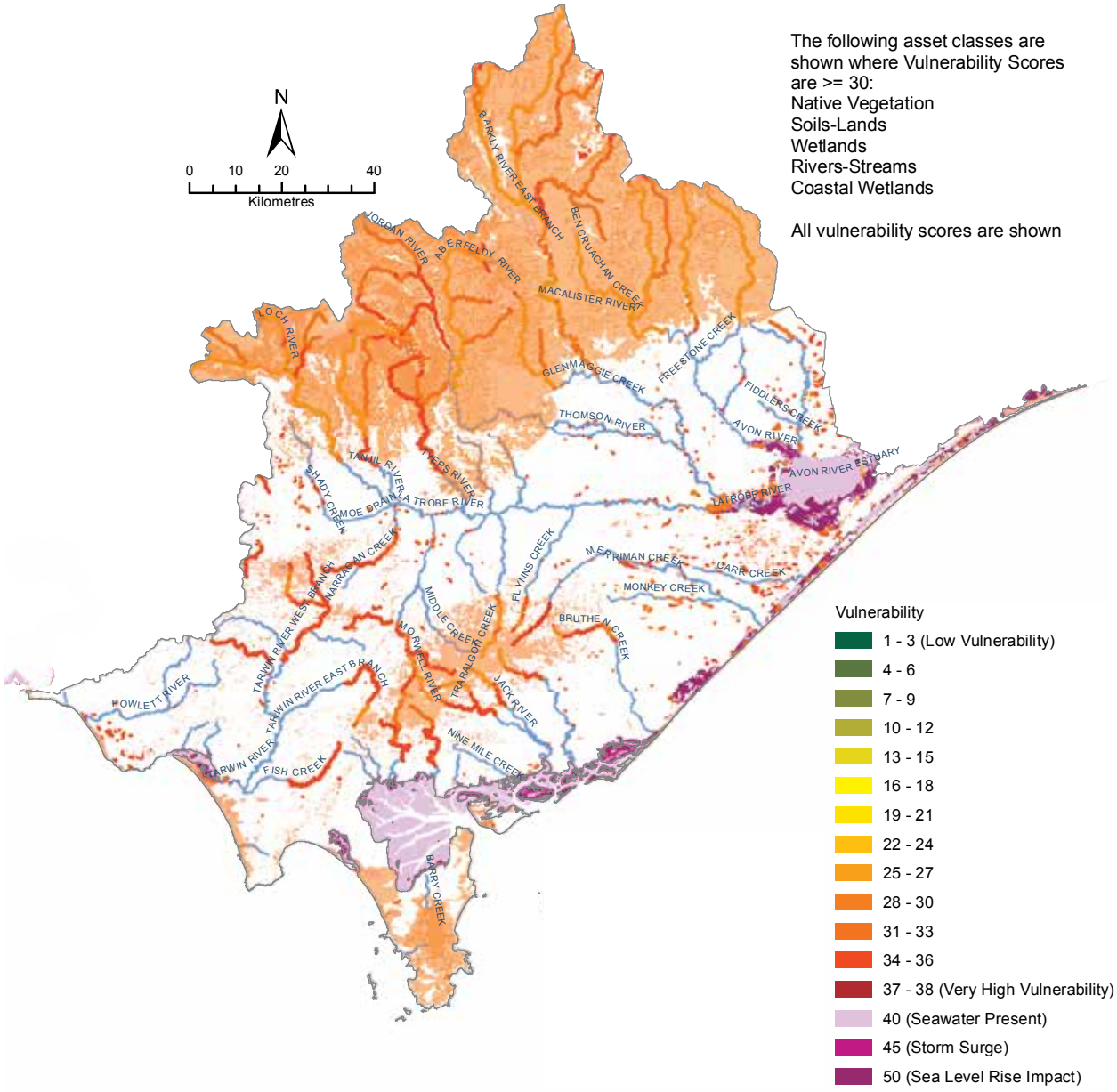

Figure 7: Location of natural assets with a very high vulnerability (including assets impacted by Sea Level Rise & Storm Surge) RCP 8.5 2070 Vulnerability score >= 30

The West Gippsland RCS priority landscape area boundaries were then applied to examine how they relate to the clusters of highly vulnerable assets (Figure 8).

As many of the highly vulnerable assets identified through the impact and vulnerability assessment process fall within the RCS landscape priority areas, a review of the existing threats to natural assets identified in the West Gippsland RCS was undertaken. This is because climate change impacts on natural assets will likely be exacerbated by acting in combination with other threats such as fire, flood, habitat loss and change in land-use and management practices, invasive animals and pests and diseases, and altered water availability and regimes.[19]

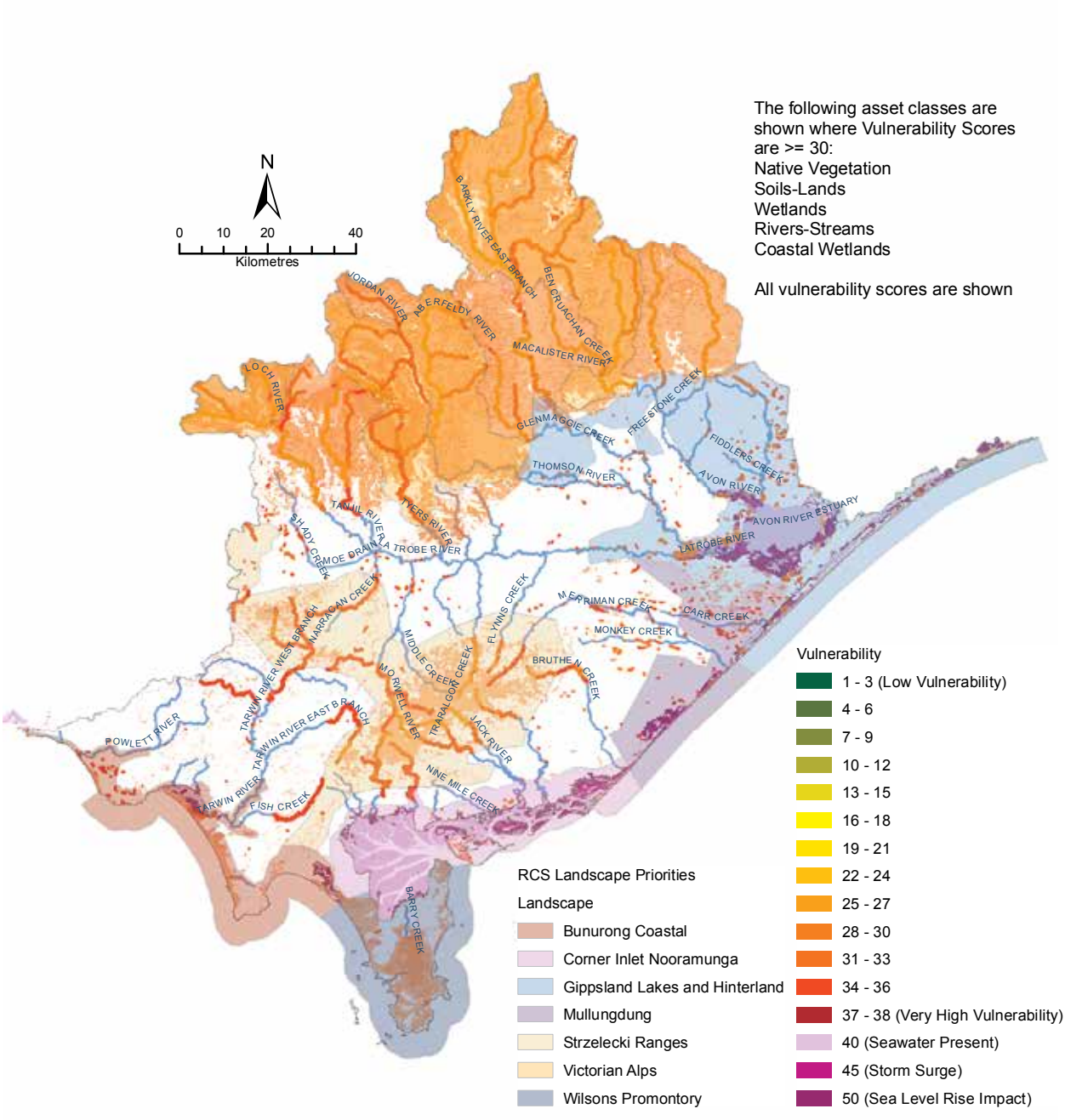

Figure 8: Location of RCS priorities in relation to natural assets with a very high vulnerability (including assets impacted by Sea Level Rise & Storm Surge) RCP 8.5 2070 Vulnerability score >= 30

The review assessed how the projected changes to climate variables may influence existing threats and provided a way of thinking about the likely impacts of climate change whilst considering existing threat levels. For example reduced rainfall and increased temperature are likely to have a direct impact on the threat of fire and when all the climate variables are considered it is likely that there will be a high level of increased impact from fire in the future. For each asset the assessment identified both the current level of threat and the likely change in threat in the future.

The review revealed that climate change will have the highest combined impact on the threats from:

- soil erosion,
- altered fire regimes,
- altered flow regimes,
- degraded water quality,
- livestock impacts/grazing pressure and;
- loss of native vegetation.

Together with the results of the vulnerability assessment and in consultation with regional stakeholders, the review assisted in identifying the most appropriate locations to focus climate change adaptation and mitigation planning efforts within the region. This led to the identification of the following five climate change planning areas (Figure 9):

1. Victorian Alps
2. Gippsland Lakes and Hinterland (including the Latrobe River system)
3. Strzelecki Ranges
4. Coastal landscapes (including Bunurong Coast, Corner Inlet Nooramunga and Mullungdung)
5. Wilsons Promontory

These five broad geographic areas have been used as the basis for the detailed Adaptation and Mitigation Plan described in Section 6. In this section we describe the current situation and issues to consider, along with proposed adaptation and mitigation strategies/options that have been identified with the assistance of regional stakeholders through workshops and further consultation. Each of the strategies and options were assessed for their adaptation or mitigation benefit; social, technical and economic feasibility; potential for maladaptation and relevance over time (i.e. 2030, 2050, 2070 and 2090).

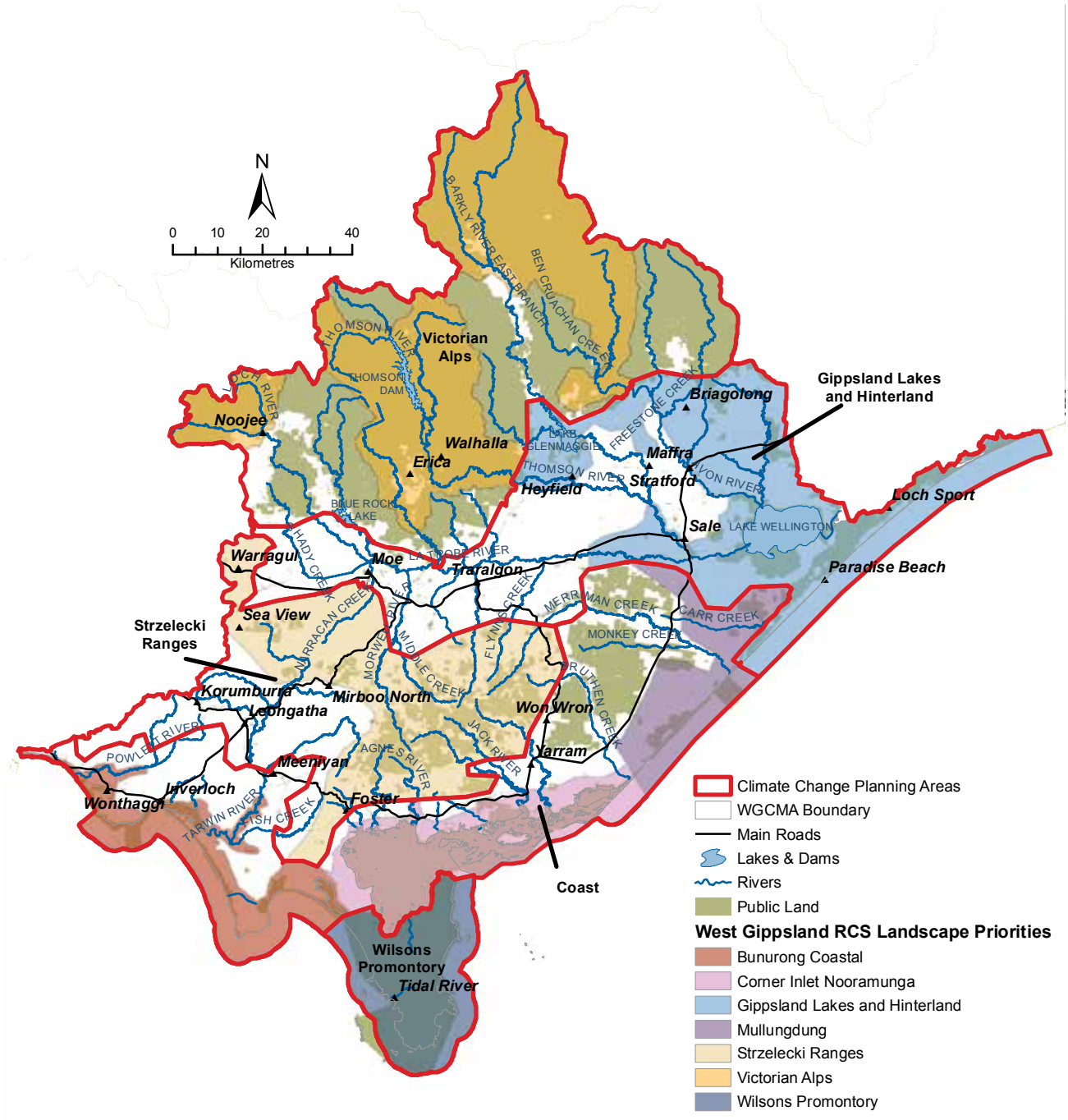

Figure 9: Planning areas for climate change adaptation and mitigation