

Climate Change Vulnerability Assessment and Adaptive Capacity of Coastal Wetlands

Decision Support Framework – Volume One



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Contents

Executive Summary	2
1. Introduction	4
1.1 Background.....	4
1.2 Project objectives.....	5
1.3 Volume One Report.....	5
2. Vulnerability Assessment Framework and Decision Support Framework	7
2.1 Overview of vulnerability assessment framework.....	7
2.2 Decision Support Framework.....	8
2.2.1 What is the Decision Support Framework Meant to do?.....	8
2.2.2 Approach to developing the Decision Support Framework.....	9
3. Decision Support Framework user guide	10
3.1 Step 1 – How to identify your wetland type.....	10
3.2 Step 2 – How to determine the potential impacts from climate change on your wetland.....	11
3.3 Step 3 – What are your management objective and actions for the site?.....	14
4. Case study application	18
5. References	19
Appendix A Sensitivity tables	20
Appendix B Adaptive capacity of wetland types	21
Appendix C Decision Support Framework template	22
Appendix D Decision Support Framework case study application	30

Executive Summary

This report presents a Decision Support Framework (DSF) to assess the vulnerability and adaptive capacity of coastal wetlands in Victoria to the impacts of climate change.

The report also provides guidance on management objectives and actions for those coastal wetland systems likely to be affected by climate change. The project was commissioned by the Victorian Government's Department of Environment, Land, Water and Planning (DELWP) and was undertaken by Jacobs Group (Australia) Pty Ltd (Jacobs) and Dodo Environmental (Professor Paul Boon).

The Victorian Government has invested in climate change vulnerability projects in order to facilitate an adaptive management approach for ecosystems under climate change and inform Victorian water resource policy. Understanding the vulnerability and adaptive capacity of wetlands based on future conditions helps guide investment and predict longer term viability of management. Projects that have been undertaken in Victoria include the Government's Future Coasts Program, which aimed to better understand and plan for the risks associated with sea level rise and storm surge for coastal wetlands in Victoria. The Victorian Coastal Inundation dataset and Victorian Coastal Hazard Guide were developed as part of this work and provide mapping and guidance about the potential risks from sea level rise along the Victoria coastline. An indicative assessment of climate change vulnerability for wetlands in Victoria (SKM, 2013) was also undertaken with a particular emphasis on understanding likely changes in hydrological regimes and the regional distribution of these changes across Victoria. This project will build on these previous projects with a focus on coastal wetlands systems in Victoria and their vulnerability and adaptive capacity to the impacts of climate change.

The high level objectives of this project are to:

1. identify the different types of coastal wetlands in Victoria;
2. assess the level of exposure and sensitivity of these wetlands to the impacts of climate change and thereby estimate the level of potential impact;
3. identify how wetland processes, components and values are likely to be affected;
4. provide guidance on potential management responses through the development of a DSF.

It is intended that project outputs will be used by DELWP and Victorian wetland managers to better understand the vulnerability and adaptive capacity of a coastal wetland systems in the State and to help guide investment and predict longer term viability of management actions. A high priority for the project was therefore to develop a framework and methods that do not require users to have detailed climate change vulnerability and adaptive capacity expertise.

The report is presented in two volumes, this volume (Volume One) presents the framework and methods for assessing the vulnerability and adaptive capacity of coastal wetland in Victoria and guidance on potential management objectives and actions that could be adopted for those coastal wetland systems likely to be affected by climate change. This volume also provides a case study application of the framework for a selected Victorian coastal wetland. The second volume presents supporting technical information required to apply the framework and describes the logic and assumptions behind each of the considerations underpinning the DSF.

The broad approach applied is shown below. The DSF is a three step approach that is closely aligned with the project objectives:

- **Step 1: Wetland type** – identification of wetland type (e.g. mangrove, saltmarsh) using a combination of the coastal wetland dataset developed as part of this project and existing knowledge of the site. This step guides the sensitivity assessment undertaken in Step 2.
- **Step 2: Assess potential impacts from climate change** – based on the position of the wetland in the landscape, identification of which component of climate change the wetland is sensitive to. This step involves undertaking the exposure and sensitivity components of the vulnerability assessment outline above using a combination of the exposure mapping, conceptual models and sensitivity tables provided in the Volume 2 report.
- **Step 3: Identify management objectives and actions** – identification of the adaptation mechanisms possible for the wetland and development of management objectives and actions. This step will inform the development of a management plan which is undertaken outside of the DSF.

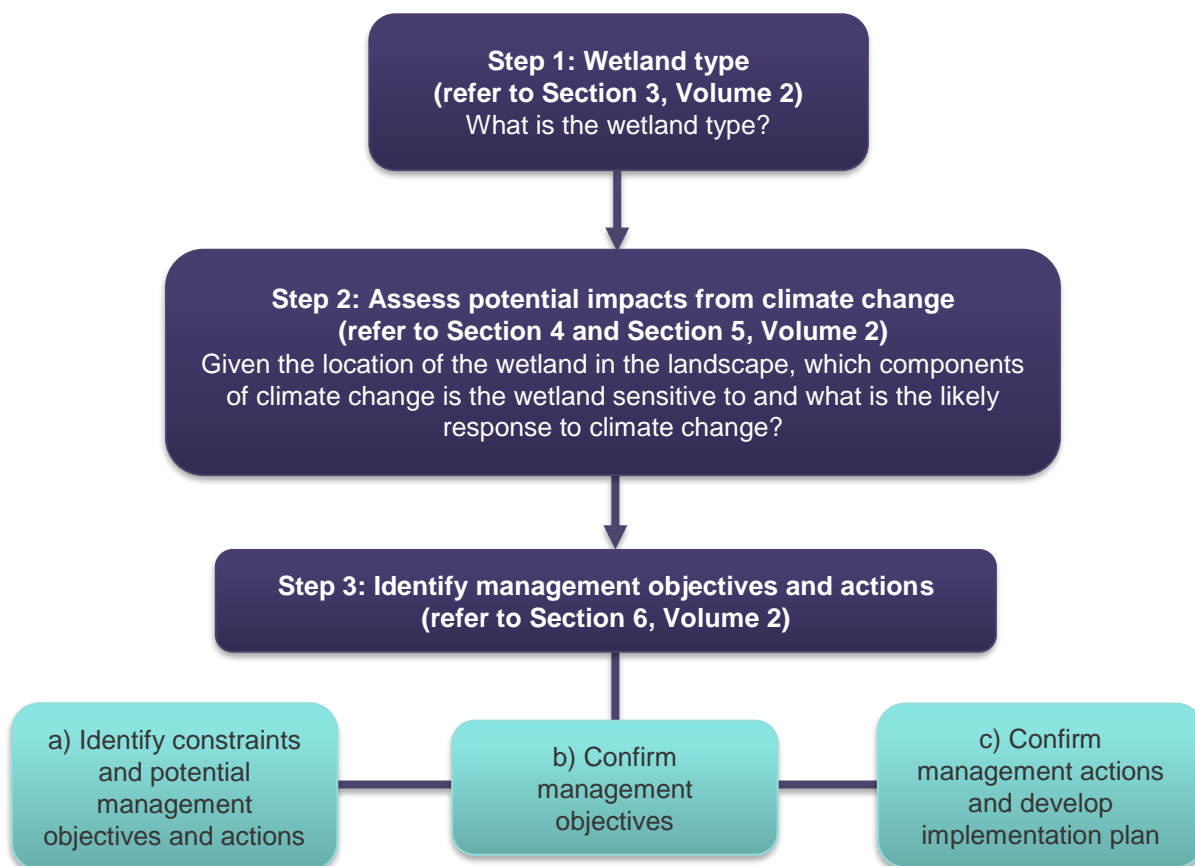


Figure 1: Decision Support Framework outlining the key steps to assess the vulnerability and adaptive capacity of an individual wetland type

A DSF template has also been developed as part of this project to provide wetland planners and managers with a user-friendly guide to the DSF in a step by step process. The template provides a consistent and concise approach to identifying wetland types, their vulnerability and adaptive capacity to climate change and developing agreed set of management objectives and actions that can be adopted for the wetland. This template could also be used to support an existing management plan for the wetland or as the basis for the development of one.

The DSF developed in this project has been applied to one wetland in Victoria, the Powlett River Estuary in West Gippsland. The wetland was selected by DELWP through a consultation process with Victoria wetland managers.

1. Introduction

1.1 Background

The climate of southern Australia is changing and will continue to change (CSIRO-BOM 2015a, b). Mean air temperatures have risen by 0.8–1.0°C over the past century and are projected with very high confidence to increase further. Rainfall, already variable at the regional scale, is projected to decrease overall, and winter and spring in particular to become drier. Extreme events, such as heat waves and extremes of rainfall and drought, are expected to become more common. Solar radiation will increase and relative humidity decrease, leading to changes in evaporative losses and a harsher fire climate and increased fire risk. All these factors will have significant impacts on Victoria's coastal wetlands, not only via direct effects on hydrology and related impacts on wetting and drying regimes but also indirectly through changes to myriad related processes such as sedimentation and erosion, nutrient cycling, salinisation and ecological connectivity. Some assessments have been made on likely impacts on Australian inland wetlands (Nielsen and Brock 2009; SKM 2013; Finlayson *et al.* 2013; Lovelock *et al.* no date), but there are few if any comparable studies for climate-change impacts on Victorian coastal wetlands. A study was made of possible sea-level rise impacts and mitigation strategies for Victorian seagrass systems (Morris 2013), but there is little on other Victorian coastal wetland systems such as mangroves, coastal saltmarsh, the wide range of estuarine wetlands, or for swamp scrubs and other wetland types vegetated with woody plants (Boon 2012). Comparable studies have been undertaken for some of these systems elsewhere in Australia (e.g., Gilman *et al.* 2008; Pralahad *et al.* 2011) but not for Victoria and it is not evident that they can be transferred to Victorian systems.

Coastal wetlands are especially susceptible to climate change because of their position near to the ocean and thus their exposure to rising sea levels. Mean sea levels are projected, with very high confidence, to continue to rise at rates of ~ 3 mm per year. The height and frequency of extreme sea-level events will also increase. CSIRO-BOM (2015 a, b) projected that by 2090, eustatic sea levels are predicted to rise by 0.27–0.66 m under an intermediate emissions case (RCP4.5) and by 0.38–0.89 m under a high-emissions scenario (RCP8.5). These changes alone will markedly alter the ecological structure, function and value of coastal wetlands and will exacerbate impacts caused by higher temperatures and altered river discharge. Higher mean sea levels, for instance, will modify the inundation regimes experienced by coastal wetlands, changing their wetting and drying cycles and their salinity regimes, and in some cases also contribute to the widespread loss of coastal wetlands due to shoreline erosion. Rises in eustatic sea levels, however, are not the only mechanism by which climate change will affect coastal wetlands (Osland *et al.* 2016): other impacts include those arising storm surges, altered freshwater runoff (with implications for the supply of sediments and nutrients to coastal systems), and changed fire frequency. Moreover, it cannot be assumed that the different types of wetlands that occur along the Victorian coast will respond in the same way to these various impacts, nor that the same suite of mitigation strategies will work equally well for each type (Friess *et al.* 2012).

We should be concerned about possible impacts of climate change on coastal wetlands for a number of reasons. First, the conservation and biodiversity value of coastal wetlands is well known: they provide habitat for a diverse range of plants and animals, they protect shorelines against erosion and they offer recreational opportunities to local and distant human populations.

Second, the coast of Victoria supports a wide range of important and different wetland types, including seagrass beds, mangroves, coastal saltmarshes, estuarine reedbeds and various types of swamp scrubs (Department of Sustainability and Environment 2012; Boon 2012; Boon *et al.* 2015a).

Third, these wetlands provide essential ecosystem services, including the provision of raw materials and food, coastal protection, erosion control, water purification, maintenance of fisheries, carbon sequestration, and tourism, recreation, education and research (Barbier *et al.* 2011). As far as we are aware they are no economic valuations available for Australian coastal wetland systems other than an old study of northern-Australian mangroves, which were estimated to generate \$14,000 AUD per hectare each year to commercial fisheries (Morton 1990). More recently, Creighton *et al.* (2015) have shown that returns to commercial and recreational fishing alone of rehabilitating estuaries and their associated fringing wetlands is one of the most effective investments that can be made by natural resource managers in Australia, far outweighing the returns that accrue from investment into inland wetlands.

Given the paucity of quantitative data for Australian coastal systems, it is necessary to turn to overseas studies that demonstrate the economic value of wetlands and coastal wetlands in particular. The ecosystem services provided by tidal marshes/mangroves globally was estimated in 2011 to be in the order of US \$194,000 ha⁻¹ y⁻¹ (Costanza *et al.* 2014). The economic value of ecosystem services quantified in the UK's 2011 National Ecosystem Assessment, which showed that coastal wetlands in the UK provided ecosystem services worth £1,534 million each year in terms of flood control and the protection of shorelines against erosion, £1,275 million annually in biodiversity value, £1,245 million in water-quality improvement, £514 million in the provision of clean water, and £1,081 million in amenity value. On a per-area basis, coastal wetlands were estimated to be worth £3,700 per hectare annually merely for the protection they offered to coasts against flooding and erosion.

Finally, human populations and economic activity are increasingly skewed towards coastal settings (Johnston *et al.* 2015). In Australia, for example, more than 85% of the population lives within 50 km of the coast; one-quarter of the population lives within 3 km of the coast (Zann and Dutton 2000). It is the wetlands that this population lives near to, and draws upon for various ecosystem services, that will be most strongly affected by climate change.

The Victorian Government's Department of Environment, Land, Water and Planning (DELWP) has invested in climate change vulnerability projects in order to facilitate an adaptive management approach for ecosystems under climate change and inform Victorian water resource policy. Understanding the vulnerability and adaptive capacity of wetlands based on future conditions helps guide investment and predict longer term viability of management. Projects that have been undertaken in Victoria include the Government's Future Coasts Program, which aimed to better understand and plan for the risks associated with sea level rise and storm surge for coastal wetlands in Victoria. The Victorian Coastal Inundation dataset and Victorian Coastal Hazard Guide were developed as part of this work and provide mapping and guidance about the potential risks from sea level rise along the Victoria coastline. An indicative assessment of climate change vulnerability for wetlands in Victoria (SKM, 2013) was also undertaken with a particular emphasis on understanding likely changes in hydrological regimes and the regional distribution of these changes across Victoria. This current study will build on these previous projects with a focus on coastal wetlands systems in Victoria and their vulnerability and adaptive capacity to the impacts of climate change.

1.2 Project objectives

The purpose of this project is to outline/assess the vulnerability and adaptive capacity of the range of coastal wetland systems in Victoria to the impacts of climate change, including sea-level rise, decreased freshwater inflows and increased frequency and severity of extreme events.

The project outputs will provide guidance for wetland managers in setting management objectives and in developing adaptation plans for coastal wetland systems likely to be affected by climate change, both at an individual wetland scale and a landscape scale.

In summary, the project objectives are to:

1. identify the different types of coastal wetland ecosystems in Victoria;
2. assess the level of exposure and sensitivity of these wetlands to the impacts of climate change and thereby estimate the level of potential impact;
3. identify how wetland processes, components and values are likely to be affected;
4. provide guidance on potential management responses through the development of a Decision Support Framework (DSF).

1.3 Volume One Report

An important outcome of the study is the development of a (DSF) which DELWP and Victorian wetland managers can follow to better understand the vulnerability and adaptive capacity of a coastal wetland systems in the State. This framework can be used to help guide investment and predict longer term viability of management actions.

This report (Volume One) presents the framework and methods for assessing the vulnerability and adaptive capacity of coastal wetland in Victoria and guidance on potential management objectives and actions that could be adopted for those coastal wetland systems likely to be affected by climate change. This volume also provides a case study application of the framework for a selected Victorian coastal wetland. Volume Two provides the supporting technical information required to apply the framework and describes the logic and assumptions behind each of the considerations underpinning the DSF.

The structure of this report is:

- Section 2 outlines the approach used to address the project objectives outline in Section 1.2. It includes an overview of the vulnerability assessment framework and the DSF.
- Section 3 provides step by step guidance on how to apply the DSF to undertake a vulnerability and adaptive capacity assessment for an individual coastal wetland or wetland mosaic and identify management objectives and actions to guide the development of a management/ implementation plan. This Section provides links to the Volume Two report to aid in the application of the DSF.
- Section 4 presents a case study application of the DSF, including the populated A4 booklet template developed to guide the DSF.

2. Vulnerability Assessment Framework and Decision Support Framework

2.1 Overview of vulnerability assessment framework

The vulnerability assessment aims to determine the vulnerability and adaptive capacity of wetlands in Victoria to the impacts of climate change. The evaluation is made using a risk based approach (Figure 2), which centres on a joint assessment of **exposure** of a given suite of wetlands to the impacts associated with specific components of climate change and the **sensitivity** of wetland values to these threats. These two elements are equivalent to 'likelihood' and 'consequence' in a traditional risk assessment approach consistent with the Australian Standard for risk assessments (AS/NZS ISO 31000:2009, Risk management - Principles and guidelines). In combination, they define the **potential impact** (or level of vulnerability). When potential impact is linked with **adaptive capacity** (either autonomous or by intervention) it is possible to make an assessment of the **vulnerability** (residual risk) of wetlands to the potential impacts of climate change.

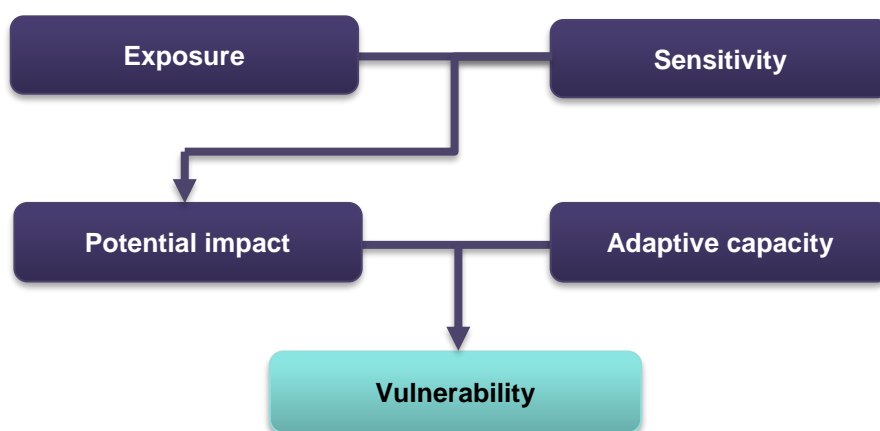


Figure 2: Assessment approach to determine the vulnerability and adaptive capacity of wetland in Victoria to the impacts of climate change

The following provides a definition of the vulnerability assessment components in the context of this project. Each component is explored in further detail in later sections of this report.

Exposure assesses the likelihood of a given group or type of wetlands being subject to the given climate change component (e.g. eustatic sea-level rise, increased concentration of atmospheric carbon dioxide). This is determined largely through the position of the wetland in the landscape, in particular elevation and distance from the sea, combined with current projections for the magnitude of each climate change component. For example, a coastal wetland located in the swales of a sand-dune system is unlikely to be affected by sea-level rise over the short term because it is isolated from the ocean by at least one sand dune crest, whereas a mangrove or saltmarsh system will be strongly affected because they are subject to recurrent tidal inundation. In contrast, all types of coastal wetland are likely to be affected to some degree or other by increases in air temperature and in concentrations of atmospheric carbon dioxide. Section 3 in Volume Two provides more detail.

Sensitivity is how a given wetland will respond to exposure to a specific climate change component. Wetland types that can tolerate significant changes prompted by a given climate change component (e.g. increased salinity, reduced rainfall, increased temperature) are assessed as having a low sensitivity, whereas wetlands that can tolerate only small changes in the external environment without being altered (e.g. via changes in productivity, species composition or, in the worst case, complete loss and possible replacement by another wetland type) are assessed as having a high sensitivity. In many cases, the sensitivity of a given wetland type is influenced strongly by the physiological tolerances of the biota. For example, saltmarsh plants are highly sensitive to subtle changes in inundation and salinity regimes and can be expected to be highly sensitive to changes in sea level and storm-surge impacts. Mangroves, by contrast, occur over a wide tidal range and although their elevational or lateral position in the landscape will change as a result of sea-level rise, their continued existence along a given stretch of coastline might not. All that would happen is they migrate to slightly higher land (if such space is available, as discussed later in the report). Sensitivity, therefore, is derived from the evaluation of the likely response of different wetland types to each

climate change component based on expert knowledge. Conceptual models have been developed to highlight the mechanisms by which a given wetland type may be sensitive to a given climate change component, and these are shown in Section 4 of Volume Two.

Potential impact is the product of **exposure** – largely determined by the position of the wetland in the landscape – and **sensitivity** – the capacity of the wetland to cope with the change.

Adaptive capacity describes the ability of the wetland to adapt to change as a result of the climate change component to which it is exposed. It is closely allied to both the **exposure** and the **sensitivity** assessments undertaken in the earlier stage of the vulnerability assessment. Adaptive capacity is therefore a combination of the sensitivity of a particular wetland type to climate change components and site-specific characteristics, especially degree of exposure, that may enhance or limit the wetland's ability to respond to local climate-change components. It is also influenced by site-specific physical constraints (e.g., location of seawalls that hinder landward migration of mangrove or saltmarsh communities) and management actions (e.g., capacity to control saline intrusions by creating levees, or to provide fresh water from further upstream via the construction of regulators and other water-control structures) that can help achieve management objectives. This matter is discussed in detail in Section 5 of Volume Two.

The overall **vulnerability** of a wetland is the product of the **potential impact** of climate change and its ability to adapt to cope with the impact, its **adaptive capacity**. Overall vulnerability, therefore, provides a measure of the potential change to an ecosystem (e.g., loss of habitat or species diversity, disruption to food webs, loss of ecosystem resilience, or an increase in habitat fragmentation) as a result of climate change.

2.2 Decision Support Framework

2.2.1 What is the Decision Support Framework Meant to do?

Through the course of this project it became clear that the variability of wetland types, their different locations and responses to climate change components, and the availability of useful data presented a significant challenge to the development of a single uniform vulnerability assessment approach that could be used to provide consistent outcomes across the State. Because of this complexity, a generic DSF was developed to enable DELWP and wetland managers to assess the vulnerability and adaptive capacity of an individual wetland type at the site or local landscape scale. The DSF uses knowledge of the likely physiological and ecological responses of the biota of a particular wetland type to climate change components (based on conceptual models developed for the current project: see Section 4.1 of Volume Two) and knowledge of site-specific constraints and available management actions that can assist in adaptation. The DSF can be used to help guide investment and predict longer term viability of various management actions associated with the management of coastal wetlands in response to the myriad changes likely to occur as a result of a globally changing climate.

The DSF is intended to provide guidance on:

- the range of different **wetland types** that occur along the Victorian coastline;
- determining the level of **exposure** and **sensitivity** (and thus **potential impact**) of an individual wetland type to the impacts of climate change in terms of wetland structure, processes and values;
- determining the likely outcome of the climate change component on the individual coastal wetland type or wetland mosaic at the site/ local landscape scale (based on **sensitivity** and site constraints, i.e. **adaptive capacity**);
- setting **management objectives** and **actions** for the individual coastal wetland type or wetland mosaic. This is an iterative process that considers constraints and available management actions. It provides the basis for the preparation of a management plan.

Given it is intended that the project outputs will be used by wetland planners and managers, the approach developed for the DSF does not require users to have detailed knowledge of coastal wetland processes, component and values likely to be affected by climate change. The conceptual models outlined in Section 4.1 of Volume Two are intended to provide guidance on these matters. Moreover, it is desirable to make the DSF as consistent with existing approaches and databases as possible. For this reason, the general

approaches outlined in subsequent parts of the report aim to draw upon existing information and existing approaches to classifying wetlands, their biota, and physical landforms.

2.2.2 Approach to developing the Decision Support Framework

The broad approach applied in the DSF is illustrated in Figure 3. The DSF is a three step approach that is closely aligned with the project objectives and the subsequent chapters in the report are arranged to help the user work through the DSF. The three steps include:

- **Step 1: Wetland type** – in this step you identify your wetland type (e.g. mangrove, saltmarsh) using a combination of the coastal wetland dataset developed as part of this project and existing knowledge of the site. This step guides the sensitivity assessment undertaken in Step 2.
- **Step 2: Assess potential impacts from climate change** – in this step you consider the position of your wetland in the landscape to determine which component of climate change your wetland is sensitive to. This step involves undertaking the exposure and sensitivity components of the vulnerability assessment outline above using a combination of the exposure mapping, conceptual models and sensitivity tables provided in the Volume 2 report.
- **Step 3: Identify management objectives and actions** – in this step you consider the adaptation mechanisms possible for your wetland and development of management objectives and actions. This step will inform the development of a management plan which is undertaken outside of the DSF.

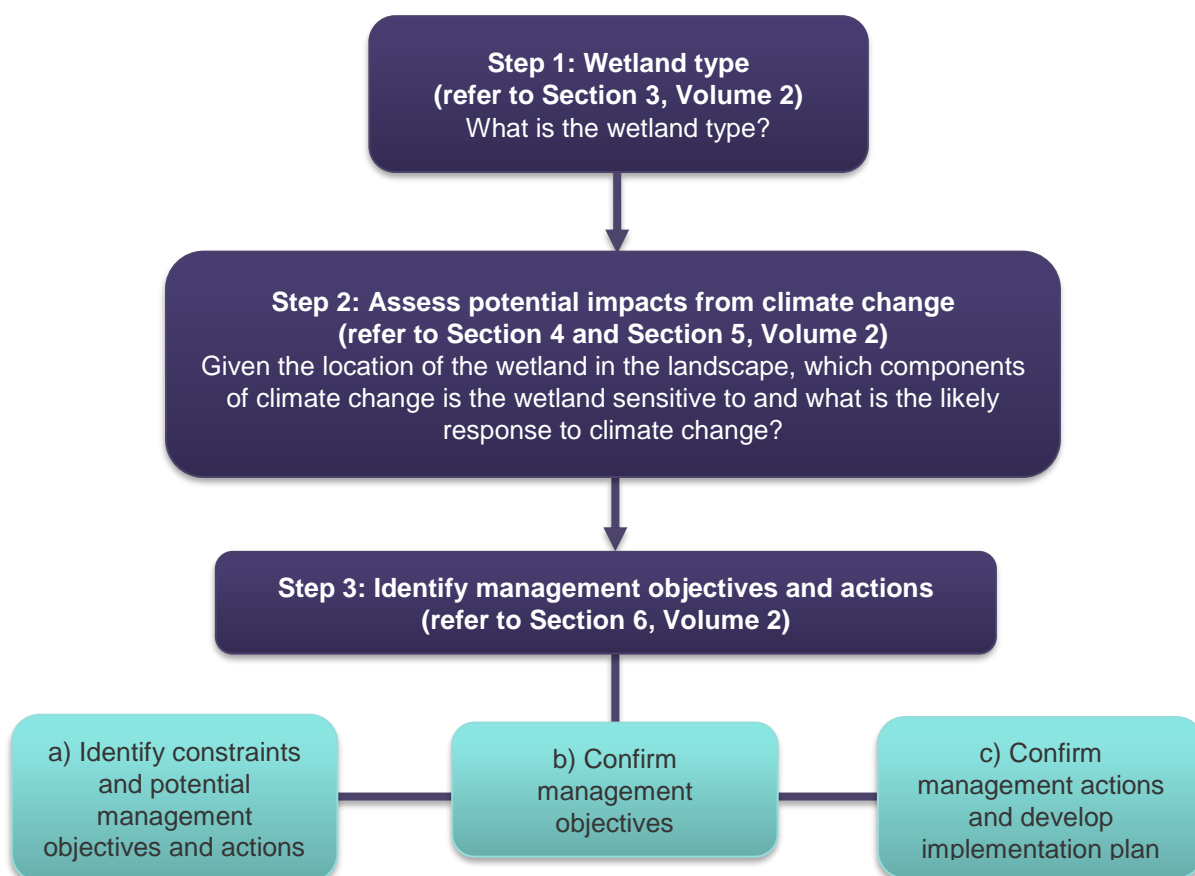


Figure 3: Decision Support Framework outlining the key steps to assess the vulnerability and adaptive capacity of an individual wetland type

3. Decision Support Framework user guide

The following sections provide guidance on undertaking the three steps (Figure 3) to assess the vulnerability and adaptive capacity of coastal wetlands to the impacts of climate change and the development of management objectives and actions to manage the impacts of climate change, both at an individual wetland type scale and a landscape scale.

A DSF template was also developed as part of this project to allow wetland planners and managers to work through the DSF in a step by step process. The template provides a consistent and concise approach to identifying wetland types, their vulnerability and adaptive capacity to climate change and developing agreed set of management objectives and actions that can be adopted for the wetland. This template could also be used to support existing management plans or as the basis for the development of one. The DSF is provided in a booklet in Appendix C. A case study of the application of the DSF was undertaken for the Powlett Estuary and is provided in Appendix D and discussed in Section 4. This case study has also been applied in Section 3.1 to Section 3.3 to provide examples of how each step of the DSF is completed.

3.1 Step 1 – How to identify your wetland type

In this step, you identify your wetland type. This will guide the sensitivity component of the risk assessment because different types of coastal wetlands will respond in different ways to different climate change components and to the different drivers these components generate.

1. Using the coastal wetland dataset (geospatial database) for Victoria generated as part of this project (refer to Section 2.5 of Volume Two) determine at your selected site:
 - a) The wetland category the wetland belongs to (e.g. marine embayment, estuarine, coastal floodplain etc.) (refer to Section 2.4 of Volume Two for detailed description of categories)
 - b) The wetland type/EVC group the wetland belongs to (e.g. mangroves, saltmarsh, freshwater wetland, estuary).
2. Confirm the wetland type/EVC group during either a site visit or with existing literature or local site knowledge. Descriptions of individual wetland categories and types are provided in Section 2.3 and Section 2.4 of Volume Two and can be used as an additional source of information to confirm the wetland type/EVC.
3. If your wetland type is an estuary, search your location on the interactive map on the Oz Coasts website (http://www.ozcoasts.gov.au/search_data/map_search.jsp) to determine its classification (e.g. wave dominated or tide dominated) and sub-classification (e.g. wave/ tide dominated delta or estuary, coastal lagoon, strandplain, tidal flat/ creek). Using local knowledge, determine the estuaries geomorphology (e.g. permanently opened, permanently closed or intermittently opened). This information is important to capture in the DSF because the function of an estuary varies between the different classifications and geomorphology and this is important when considering the impacts of climate change. For example, in the case of the Powlett River, if the estuary was permanently closed then that may help mitigate some of impact of sea level. However, if the estuary was to shift to a permanently open estuary, then the ecology of the estuary and associated wetlands would change due to the impacts of sea level rise.

It is important to note that at some sites, there might be multiple wetland types/EVC groups that make up a wetland. In this case the risk assessment should be undertaken at a landscape scale and all wetland types/EVC groups identified at the site should be considered when assessing the impacts of potential climate change components (Step 2) and identifying management objectives and actions for the site (Step 3).

3.2 Step 2 – How to determine the potential impacts from climate change on your wetland

In this step, you consider the position of your wetland in the landscape to determine which component/s of climate change your wetland is sensitive to. The outcomes of this step will determine the requirement of a management or adaptation plan for the wetland and if so, help guide the identification of management objectives and actions (Step 3).

1. Identify the climate change scenario RCP (4.5 and 8.5) and timeframe (2050, 2070, 2090) (see Section 3.3.3 in Volume Two) which will be used to inform management of your wetland. Multiple RCPs and timeframes can be used in this process, for example, consider medium case (i.e. RCP 4.5) and worst case (i.e. Business as usual RCP 8.5) scenarios. There are also short term and long term management timeframes that need to be considered, for example to inform when to bring forward, or delay, certain actions based on which climate change outcomes become most obvious or likely.
2. Using the maps of exposure of climate change components to coastal wetlands in Victoria generated as part of this project (refer to Section 3.3.4 in Volume Two) for the RCPs and timeframe/s selected, identify those components of climate change that your wetland is exposed to:
 - a) *Sea level rise* – any wetland within the area of coastal inundation boundary (Appendix F of Volume Two).
 - b) *Increased carbon dioxide concentration* - all wetlands will be exposed to the carbon dioxide concentration component of climate change and therefore no map is provided as part of this project.
 - c) *Altered rainfall* – consider the likely effects of predicted change in rainfall (Appendix F of Volume Two).
 - d) *Increased temperature* - consider the likely effects of predicted change in temperature Appendix F of Volume Two).
3. For each climate change component, note the magnitude of change predicted under the climate change scenario(s) selected at a site specific scale, for example:
 - a) *Sea level rise* – examine the coastal inundation mapping at your wetland site or alternatively use DELWP's Coastal Inundation dataset (available at www.data.vic.gov.au) to produce your own mapping (see case study application in Appendix D). Separate maps can be produced for sea level rise and storm surges.
 - b) *Increased carbon dioxide concentration* – no information is available to make predictions of the magnitude of change at a site specific scale.
 - c) *Altered rainfall* – examine details of the magnitude of change (mean surface temperature change) predicted for the site Section 3.3.2 of Volume Two. Also document any seasonal changes predicted (also see Section 3.3.2 of Volume Two).
 - d) *Increased temperature* - examine details of the magnitude of change in rainfall predicted for the site Section 3.3.2 of Volume Two. Also document any seasonal changes predicted (also see Section 3.3.2 of Volume Two).
4. Under each climate change component listed in the DSF, populate the sensitivity ranking (positive, negative and neutral) for those climate change components to which your wetland is exposed to. The sensitivity of the wetland type to the climate change component will be based on the rankings provided in Appendix A of this report and Section 4.2 of Volume Two. If multiple wetland types/EVC groups are identified at the site (see DSF step in Section 3.1) then separate sensitivity rankings should be populated for each wetland type/EVC group. For example, see Powlett River Estuary sensitivity analysis in Table 1.

Table 1: Sensitivity analysis for Powlett River Estuary

Climate change component	Estuary	Saltmarsh	Estuarine Wetland	Swamp scrub	Swampy riparian woodland
Sea level rise and storm surge					
Chronic salinisation	Neutral	Positive	Neutral	Negative	Negative
Episodic salinisation	Negative	Negative	Negative	Negative	Negative
Erosion/ shoreline recession	Negative	Negative	Negative	Negative	Negative
Increased carbon dioxide concentration					
Altered C3 and C4 relationship	Neutral	Negative	Neutral	Neutral	Neutral
Carbonate dissolution	Neutral	Neutral	Neutral	Neutral	Neutral
Decreased rainfall					
Chronic salinisation	Neutral	Positive	Neutral	Negative	Negative
Increased air temperature					
Phonological impacts/ altered primary productivity	Positive	Positive	Positive	Positive	Positive
Increased water temperature					
Phonological impacts/ altered primary productivity	Neutral	Neutral	Neutral	Neutral	Neutral

5. Based on the conceptual models for each climate change component provided in Section 4.1 of Volume Two and the adaptive capacity summary provided in Section 4.3 of Volume Two, populate the likely outcome of climate change for the wetland type. A summary of the likely outcomes of climate change for coastal wetlands is provided below (Table 2).

Table 2: Summary of the likely outcome of climate change for coastal wetlands

Climate change component	Likely outcomes for coastal wetland
Increased sea level and storm surge	<ul style="list-style-type: none"> • More permanent inundation or increased frequency and duration of inundation of wetlands. • Change in salinity and water regime in wetlands due to saline intrusion. • Changes in vegetation distribution along the elevational gradient from the sea, with possible landward migration: <ul style="list-style-type: none"> – Conversion of currently intertidal seagrass beds to subtidal systems, and an increase in depth of subtidal systems. – Replacement of areas currently vegetated with saltmarshes by more inundation-tolerant mangroves. – Replacement of areas currently vegetated with glycophytic (e.g. <i>Phragmites australis</i>) or brackish-water plants (e.g. <i>Melaleuca ericifolia</i>) by saltmarshes. – Changes in the floristic distribution of saltmarsh taxa along the elevational gradient from the sea. • Excessive sedimentation and erosion along shoreline impacts mangroves and coastal saltmarsh, effects can occur at both the establishment phase of young plants and adult plants. • Changes in distribution of plant propagules, via altered currents and tidal patterns. • Breakage of young plants by wind or waves during their establishment. • Modification of patterns and rates of coastal sedimentation and erosion, affecting the area suitable for mangrove or saltmarsh colonisation. • Geomorphic changes to estuary mouth and coastal barriers/ dunes due to sea level rise and storm surges (e.g. increased rates of erosion). • Saline intrusion into the upper estuary and lower freshwater reaches of the rivers due to increased sea levels and storm surge activity. Causes rise in saline conditions along riparian zone. • Saline intrusion into groundwater results in a changed wetland environment.

	<ul style="list-style-type: none"> Increased pressure from weed invasion.
Increased carbon dioxide concentration	<ul style="list-style-type: none"> Competitive interactions between plants will be affected. C3 plants will be advantaged (e.g. mangroves and most but not all saltmarsh plants and mangroves). Acidification of coastal waters causing major impacts on phytoplankton and possibly on submerged angiosperms such as seagrasses. Aquatic organisms that build calcareous or carbonate shells from aragonite (e.g. crustaceans) and some macroalgae that have calcified tissues may also be affected. Increased pressure from weed invasion.
Decreased rainfall	<ul style="list-style-type: none"> Change in water and salinity regime due to reduced freshwater inflows, decreased rainfall and increased flooding causing longer periods between freshwater inundation and development of hypersaline conditions. Replacement of areas of coastal wetlands currently vegetated with glycophytic (e.g. <i>Phragmites australis</i>) or brackish-water plants (e.g. <i>Melaleuca ericifoia</i>) by saltmarshes as a result of increased salinity. Changes in primary productivity and distributions of mangrove communities, probably towards increased vigour and a wider distribution. Modification of patterns and rates of coastal sedimentation and erosion, with effects on the area suitable for mangrove or saltmarsh colonisation. Saline intrusion into groundwater due to reduced groundwater recharge results in a changed wetland environment. Saline intrusion into the upper estuary and lower freshwater reaches of the river due to reduced rainfall/catchment runoff. Increased pressure from weed invasion.
Increased temperature	<ul style="list-style-type: none"> Impacts on flowering and germination of plants and the breeding success of invertebrates, fish and birds. Disruption of life histories of stenothermal invertebrates and fish, with consequences for growth, mortality and secondary productivity. Increased rates of primary production by saltmarshes and mangroves, unless other factors (e.g. hypersalinity, lowered nutrient availability, etc) intervene. Changes in primary productivity and distributions of mangrove communities, probably towards increased vigour and a wider distribution. Change in water and salinity regime due to increased evaporation losses causing reduction in permanence and an increase in ephemerality in coast wetlands. Increased pressure from weed invasion.

For example, the estuary and saltmarsh wetlands of the Powlett River Estuary have the following likely outcome:

Estuary:

- Potential in change from intermittently open estuary mouth to permanently opened or permanently closed estuary– may become more similar to Andersons Inlet
- Saline intrusion into the upper estuary and lower freshwater reaches of the river due to increased sea levels and storm surge activity and reduced rainfall
- Saline intrusion into groundwater results in a changed species composition year round

Saltmarsh:

- Permanent inundation or increased frequency and duration of inundation
- Change in salinity and water regime
- Changes in its distribution along the elevational gradient from the sea (migrates landwards)
- Possible invasion by mangroves if geomorphic changes result in a more permanent estuary opening

- Saltmarsh are C3 plants so potentially advantaged by increases in atmospheric CO₂ concentrations
 - Increased pressure from weed invasion
 - Saline intrusion into groundwater results in a changed species composition year round
6. Based on the main adaptive mechanisms and the main factors limiting adaptive capacity of your wetland (summary table provided in Appendix B and further detail contained in Section 4.3 of Volume Two), populate the table to reflect the likely adaptive capacity of your wetland type to climate change. For example, see analysis on the Powlett River Estuary adaptive capacity in Table 3.

Table 3: Adaptive capacity of Powlett River Estuary

Wetland type	Adaptive capacity	Main adaptive mechanism	Main limiting factors
Saltmarsh	Low	Sediment accretion, movement to higher elevations, positive response to increase temperature (variable responses to increased CO ₂)	Rate of sea level rise, storm surge intensity and shoreline erosion, seawalls and other physical impediments, impact of increased atmospheric CO ₂ impacts on floristic composition
Estuarine wetland	Moderate	Positive response to temperature, neutral to most other impacts until sea levels make the sites intertidal	Salinisation and waterlogging due to storm surges
Swamp scrub	Low	Positive response to temperature	Salinisation and waterlogging (i.e. changes to wetting and drying regimes)
Swampy Riparian woodland	Low	Positive response to temperature	Salinisation and waterlogging (i.e. changes to wetting and drying regimes)

Based on your knowledge of the wetland and its site specific characteristics (e.g. presence of barriers for migration), specific assessments of opportunities and constraints to adaptive capacity can also be undertaken to further inform this part of the DSF.

3.3 Step 3 – What are your management objective and actions for the site?

In this step, you consider the adaptation mechanisms possible for your wetland and develop management objectives and actions. The outcomes of this step will inform the development of management and implementation plans which would be undertaken outside of the DSF.

1. Identify the constraints to management for the site which may include barriers to migration, land ownership, available funding and knowledge and data availability (see Section 5.1 of Volume Two). For example, the Powlett River Estuary has the following likely management constraints:

Barriers to migration

- Powlett Road may restrict inland migration
- Rail trail towards Daylestone may restrict inland migration
- Small cluster of housing north east of the Estuary mouth may restrict inland migration

Land ownership

- The land in which wetlands could migrate in to is predominately private land used for agriculture (grazing and cropping).

Funding

- Limited funding available – not currently a priority site for intervention.

- Whilst there is good collaboration between agencies and landholders, there are different priorities for the funding available and therefore so some actions are difficult to agree to.

Limitations to knowledge and data

- What geomorphic changes to the estuary mouth are likely to occur as a result of climate change (i.e. changes in estuary dynamics)?
- Understanding the economic value of the estuary and coastal wetlands (e.g. value of wetlands versus the value of agricultural land)
- What happens to Acid Sulfate Soils as a result of climate change?

Other potential constraints

- Current State policies and procedures for statutory planning changes and land purchase to enable long term change in land use
 - Community understanding and expectation around estuary opening and closing.
2. Taking into consideration the main constraints to management of the site, develop and document, in consultation with relevant agencies and community stakeholders, a management objective for the site in regards to climate change adaptation using the broad management objectives provided in Table 4 (further discussed in Section 5.2 of Volume Two).

Table 4: Decision Support Framework – broad management objectives

Broad Management Objectives	
1	Save/maintain existing wetland in current position
2	Facilitate landward migration of existing wetland type
3	Facilitate transition to new wetland type in current location
4	No intervention

It is also important to consider wetland values, current threats to the wetland, local and regional objectives and adjacent habitat types/zones, wetland buffer zones and transition zone between wetland and terrestrial habitats (further detail on these considerations provided in Section 5.2 of Volume Two). For example, based on the pre-existing management objectives for the Powlett River Estuary, the site could have the following management objective:

To enhance and significantly increase Swamp scrub, Swampy riparian woodland and estuarine wetland vegetation communities through the facilitation of landward migration.

Combinations of the management objectives listed above may also be identified across a range of time scales in response to the degree of exposure of the wetland to the components of climate change (i.e. scenario planning), this is further discussed in Section 5.2 of Volume Two.

3. Based on the management objective identified, any pre-existing management actions and the management actions provided in Section 5.3 of Volume Two (summary provided in Table 5 below) select the most appropriate/feasible management actions to enable objectives to be achieved.

The development of objectives and actions is iterative and requires consideration of constraints and assessment of the feasibility of management options. Hence, this step may require an evaluation of a range of actions to identify those that are most feasible and likely to enable objectives to be met. If it turns out actions are not feasible, then objectives may need to be reviewed.

Monitoring is a critical part of all actions because it is used to inform timing of implementation and adaptive management. For example, the landward migration of the wetland will take many years and so some actions may not be required until landward movement has commenced or reached a certain extent, or may not be needed at all if monitoring reveals that the climate change component does not manifest at that location. Other actions, may require immediate implementation even though the benefits of that actions may not be realised until some time in the future, (e.g. land use planning rules or land

acquisition may be required now so that space is available in future years when climate change components manifest themselves).

Table 5: Decision Support Framework – how management actions relate to various management objectives

Management Actions	Save/ maintain existing wetland in current position	Facilitate landward migration of existing wetland type	Facilitate transition to new wetland type in current location	No intervention
Influence private land management	✓	✓	✓	–
Land acquisition/ planning	–	✓	–	–
Active revegetation	✓	✓	✓	–
Invasive species control	✓	✓	✓	–
New infrastructure on seaward side of wetland	✓	–	–	–
Infrastructure removal/ modification on landward side of wetland	–	✓	–	–
Education and community engagement	✓	✓	✓	–
Fire Management	✓	–	–	–

The suite of actions and timing of implementation are very much site/region specific. For example, the following management actions (new and adaption of existing management actions in place for the site) could be set for the Powlett River Estuary:

Table 6: Decision Support Framework – example management actions for the Powlett River Estuary

Management Action	Timeframe	Responsibility
Complete a study to assess the likely geomorphic changes to the estuary as a result of climate change.	2 years	WGCMA
Undertake scenario planning - refine management actions and objectives for Estuary based on finding of geomorphic study. This could identify nearby systems that could form a template for what Powlett River might look like in the future (e.g. Andersons Inlet)	2-5 years	WGCMA
Review Bass Coast Planning Scheme to understand any implications to future management actions/ works at the Powlett Estuary. Provide feedback to the State Government on any issues associated with State policies and procedures for statutory planning that may constrain long term management of the Estuary.	2-5 years	WGCMA
Resolve issues and complexities around the impacts of climate change (sea level rise) on crown land boundaries.	2-5 years	State Government
Resolve issues associated with State policies and procedures for statutory planning that may constrain long term management of the Estuary.	2-5 years	State Government
Estuary Management Plan Action E.31 (see above) – to become 2 actions: a. Investigate opportunities for land purchase within the current inundation areas of the estuary	8 years	WGCMA

b. Investigate opportunities for land purchase within the future inundation areas of the estuary		
Estuary Management Plan Action E.32 (see above) – include consideration of future inundation e.g. “Design and implement a program of stewardship payment for the seasonal inundation of estuary floodplain from estuary mouth closures <i>under both current and future inundation conditions</i> ”.	8 years	WGCMA
Estuary Management Plan Action E. 39 (see above) – to become 2 actions		
a. Investigate opportunities to encourage the conversion of current Crown land water frontage grazing licences to riparian management licences	8 years	WGCMA
b. Investigate issues and opportunities related to sea level rise impacts on Crown Land Water frontage grazing licences and riparian management licences (including how to define boundaries if existing boundaries are inundated by sea level rise).		
Estuary Management Plan Action E.44 (see above) – Undertake detailed risk assessment of potential and active acid sulfate soils.	8 years	WGCMA
Estuary Management Plan Action E.49 (see above) – Continue to build understanding of and plan for risks associated with climate change.	8 years	WGCMA

- Following the identification of objectives and actions the last step is to develop a management plan (or update existing plan) that provides the specific details around actions, responsibilities, monitoring and timeframes for implementation.

4. Case study application

In order to provide validation that the DSF can provide an assessment of the vulnerability and adaptive capacity of a coastal wetland in Victoria to the impacts of climate change, and guidance to wetland managers on potential management objectives and actions for those coastal wetland systems likely to be affected by climate change, the DSF was applied to a case study wetland in Victoria.

The case study wetland was selected by DELWP from a list of potential wetlands provided by the wetland managers from the working group established as part of the project. Wetland managers included representatives from the DELWP, Parks Victoria, West Gippsland Catchment Management Authority (CMA), East Gippsland CMA, Port Phillip and Westernport CMA, Glenelg Hopkins CMA and Corangamite CMA.

The wetland selected was the Powlett River Estuary in the West Gippsland CMA region. This decision was based on existing information available for the site (an existing estuary management plan was available), its value (listed as a Nationally Important Wetland and a habitat for the critically endangered Orange-bellied Parrot) and that the site provided a good balance between covering a number of different coastal wetland types (estuary, saltmarsh, riparian scrub, estuarine wetland, heathlands and woodlands) but without being too complex and large.

Consultation with West Gippsland CMA was undertaken throughout the case study application to ensure that local knowledge was incorporated and so that the wetland manager could provide input to setting the wetland management objectives and actions. The completed application of the DSF for the Powlett River Estuary is provided in Appendix D.

Through the case study application it became apparent that Step 1 (wetland type) could be largely completed by applying local knowledge of the wetland ecosystems found within the site. Step 2 (assess the potential impacts from climate change) however, requires more technical knowledge of the wetlands sensitivity and adaptive capacity to climate change and therefore requires close consultation with the supporting technical information contained in Volume 2. Volume 2 provides enough information for a wetland manager with limited climate change knowledge to complete this component of the DSF. Step 3 is then a combination of applying local knowledge to set management objectives and then using a combination of local knowledge and the supporting technical information contained in Volume 2 to develop management actions.

The maps included in the case study application use only publically available data (the coastal wetland dataset developed as part of this project and DELWPs coastal inundation dataset) and their manipulation and interrogation is well within the GIS capability within the relevant wetland manager's organisations.

The case study application of the DSF demonstrated its effectiveness at providing a framework for assessing potential impacts from climate change on Victorian coastal wetlands and will be a useful tool for assisting wetland managers to 1) understand and 2) develop objectives and actions for managing coastal wetlands in response to a changing climate.

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Appendix A Sensitivity tables

Wetland Type and corresponding EVC group		Climate change components and ecological consequences								
		Increased Sea level and storm surges			Increased carbon dioxide concentration		Decreased rainfall		Higher air temperature	Higher water temperature
		<i>Chronic salinisation</i>	<i>Episodic salinisation</i>	<i>Erosion/ shoreline recession</i>	<i>Altered C3 and C4 relationship</i>	<i>Carbonate dissolution</i>	<i>Chronic salinisation</i>	<i>Altered sediment load</i>	<i>Phenological impacts/ altered primary productivity</i>	<i>Phenological impacts/ altered primary productivity</i>
Marine Embayment	Mangrove	Positive	Neutral to Negative	Negative	Positive	Neutral	Positive	Positive	Positive	Neutral
	Seagrass (not mapped)	Positive	Negative	Neutral	Neutral	Positive	Positive	Negative	Positive	Positive
	Saltmarsh	Positive	Negative	Negative	Negative	Neutral	Positive	Positive	Positive	Neutral
Estuarine - Intertidal	Mangrove	Positive	Neutral to Negative	Negative	Positive	Neutral	Positive	Positive	Positive	Neutral
	Saltmarsh	Positive	Negative	Negative	Negative	Neutral	Positive	Positive	Positive	Neutral
Estuarine - supratidal	Heathlands	Neutral	Neutral	Negative	Neutral	Neutral	Neutral	Neutral	Positive	Neutral
	Herb-rich woodlands	Neutral	Neutral	Negative	Neutral	Neutral	Neutral	Neutral	Positive	Neutral
	Coastal scrubs and woodlands	Neutral	Neutral	Negative	Neutral	Neutral	Neutral	Neutral	Positive	Neutral
	Wetland - estuarine/ semi-permanent saline	Neutral	Negative	Negative	Neutral	Neutral	Neutral	Positive	Positive	Neutral
Coastal floodplain	Riparian scrubs or swampy scrubs and woodlands	Negative	Negative	Negative	Neutral	Neutral	Negative	Positive	Positive	Neutral
	Coastal brackish wetlands	Negative	Negative	Negative	Neutral	Neutral	Negative	Positive	Positive	Neutral
	Freshwater wetlands	Negative	Negative	Negative	Neutral	Neutral	Negative	Positive	Positive	Neutral
Dune systems	Freshwater wetlands	Neutral	Neutral	Negative	Neutral	Neutral	Neutral	Neutral	Positive	Neutral

Appendix B Adaptive capacity of wetland types

Wetland Type		Adaptive capacity ¹	Main adaptive mechanism	Main limiting factor to adaptation
Marine Embayment / estuarine - intertidal	<i>Mangrove</i>	Adaptable	Sediment accretion, movement to higher elevations, positive response to increased temperature and increased atmospheric CO ²	Rate of sea-level rise; storm surge intensity and shoreline erosion; seawalls and other physical impediments
	<i>Seagrass (not mapped)</i>	Adaptable	Positive response to increased salinity	Storm surge intensity; smothering by catchment-derived sediments; reductions in underwater light fields consequent to catchment-associated processes
	<i>Saltmarsh</i>	Adaptable	Sediment accretion, movement to higher elevations, positive response to increased temperature (Variable responses to increased CO ²)	Rate of sea-level rise; storm surge intensity and shoreline erosion; seawalls and other physical impediments; impacts of increased atmospheric CO ² impacts on floristic composition;
Estuarine – supratidal	<i>Heathlands</i>	Unknown	Positive response to temperature, neutral to most other impacts until sea levels make the sites intertidal	Salinisation and waterlogging due to storm surge
	<i>Herb-rich woodlands</i>	Unknown	Positive response to temperature, neutral to most other impacts until sea levels make the sites intertidal	Salinisation and waterlogging due to storm surge
	<i>Coastal scrubs and woodlands</i>	Unknown	Positive response to temperature, neutral to most other impacts until sea levels make the sites intertidal	Salinisation and waterlogging due to storm surge
	<i>Wetland - estuarine/ semi-permanent saline</i>	Unknown	Positive response to temperature, neutral to most other impacts until sea levels make the sites intertidal	Salinisation and waterlogging due to storm surge
Coastal floodplain	<i>Riparian scrubs or swampy scrubs and woodlands</i>	Non-adaptable	Positive response to temperature	Salinisation and waterlogging (i.e., changes to wetting and drying regimes)
	<i>Coastal brackish wetlands</i>	Non-adaptable	Positive response to temperature	Salinisation and waterlogging (i.e., changes to wetting and drying regimes)
	<i>Freshwater wetlands</i>	Non-adaptable	Positive response to temperature	Salinisation and changes to wetting and drying regimes
Dune systems	<i>Freshwater wetlands</i>	Unknown	Positive response to temperature, neutral to most other impacts	Physical loss of habitat; salinisation; possible changes to wetting and drying regimes

¹ where adaptive capacity is unknown, data gaps limit the ability to make clear assessment of adaptive capacity

Appendix C Decision Support Framework template

Coastal Wetlands and Climate Change

Decision Support Framework

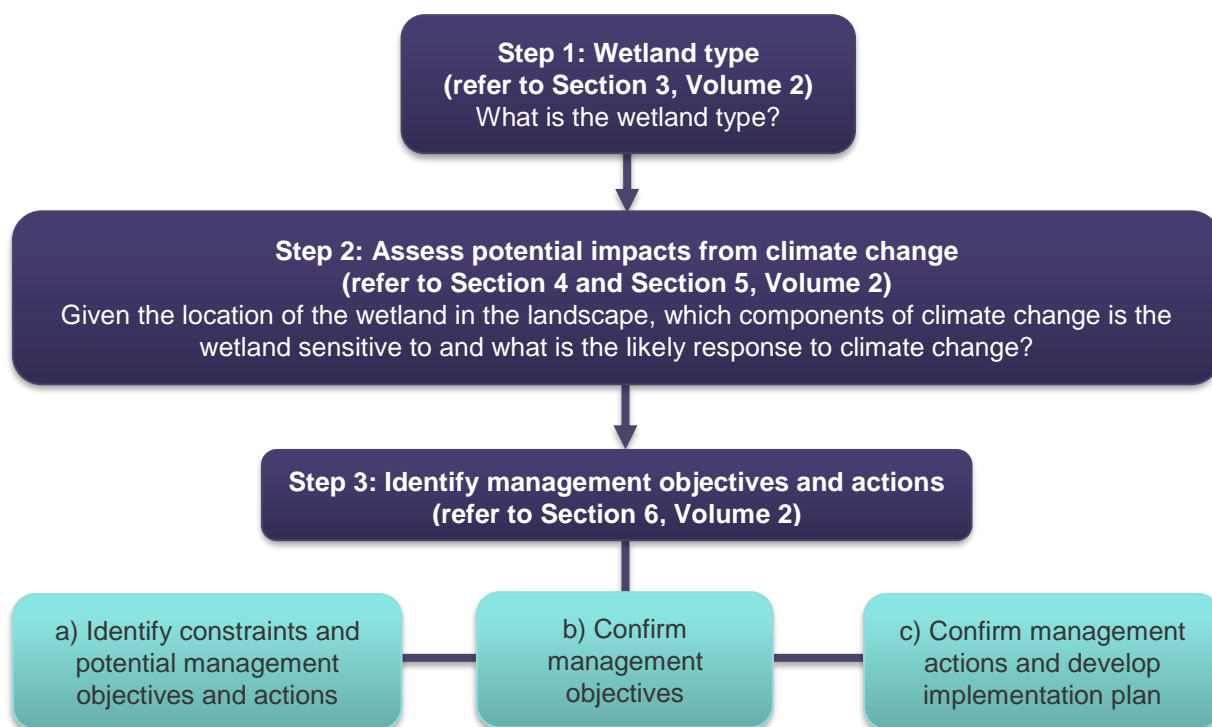
Site Name:

Purpose

This document provides a Decision Support Framework to enable wetland managers to assess the vulnerability and adaptive capacity of wetlands to climate change at an individual wetland or local landscape scale. The DELWP Climate Change Vulnerability Assessment and Adaptive Capacity of Coastal Wetlands report provides the background and supporting material for this assessment and should be used in conjunction with each stage of the assessment process, outlined below.

The broad approach applied in the Decision Support Framework is illustrated below. It is a three step approach that includes:

- **Step 1: Wetland type** – in this step you identify your wetland type (e.g. mangrove, saltmarsh) using a combination of the coastal wetland dataset developed as part of this project and your existing knowledge of the site. This step guides the sensitivity assessment undertaken in step 2.
- **Step 2: Assess potential impacts from climate change** – in this step you consider the position of your wetland in the landscape so you can determine which component of climate change the wetland is most sensitive to. This step involves undertaking the exposure and sensitivity components of the vulnerability assessment outlined above, using the exposure mapping, the conceptual models and the sensitivity tables provided in the supporting documents.
- **Step 3: Identify management objectives and actions** – in this step you consider the adaptation mechanisms possible for your wetland and develop management objectives and actions. This step will inform the development of a management plan which is undertaken outside of the DSF.



Decision Support Framework

1. Wetland identification (Section 2, Volume Two)

Name:	Insert wetland name	
Location/ address:	Insert generic location description	
	Easting:	Northing:
Bioregion:	Refer to http://www.depi.vic.gov.au/environment-and-wildlife/biodiversity/evc-benchmarks	
Wetland category (Section 2.4, Volume Two)	Tidal wetlands	Non-tidal wetland
	Marine embayment <input type="checkbox"/>	Coastal floodplain <input type="checkbox"/>
	Estuarine (intertidal) <input type="checkbox"/> Estuarine (supratidal) <input type="checkbox"/>	Dune system <input type="checkbox"/>
Wetland type/ EVC group(s) (Section 2.3, Volume Two and supporting geospatial dataset)	Seagrass <input type="checkbox"/>	Freshwater wetland (dune) <input type="checkbox"/>
	Saltmarsh <input type="checkbox"/>	Riparian/ swampy scrub <input type="checkbox"/>
	Mangroves <input type="checkbox"/>	Estuarine wetland <input type="checkbox"/>
	Brackish wetland <input type="checkbox"/>	Estuarine scrubs, heathlands and woodlands <input type="checkbox"/>
	Freshwater wetland (floodplain) <input type="checkbox"/>	
Estuary classification (if relevant) http://www.ozcoasts.gov.au/search_data/map_search.jsp	Classification	
	Wave dominated <input type="checkbox"/>	Tide dominated <input type="checkbox"/>
	Sub-classification	
	Wave dominated delta <input type="checkbox"/>	Coastal lagoon <input type="checkbox"/>
	Tide dominated delta <input type="checkbox"/>	Strandplain <input type="checkbox"/>
	Wave dominated estuary <input type="checkbox"/>	Tidal flat/ creek <input type="checkbox"/>
	Tide dominated estuary <input type="checkbox"/>	Other <input type="checkbox"/>
Estuary geomorphology (if relevant)	Permanently open <input type="checkbox"/>	Intermittently opened and closed <input type="checkbox"/>
	Permanently closed <input type="checkbox"/>	
Wetland values	See Section 4.4 of Volume Two for more detail.	

Decision Support Framework

Insert location map, including location of individual wetland/ EVC types

Decision Support Framework

2. Potential impacts from climate change to the wetland (Section 4, Volume Two)

<p>What is the climate change scenario/ timeframe</p>	<p>Select climate change scenario/ timeframe detailed in Section 3.3.3 of Volume 2.</p>
<p>Given the position of the wetland in the landscape, how exposed is the wetland to sea level rise and storm surge climate change components?</p>	<p>Insert exposure map for sea level rise and storm surges (See Appendix F of Volume Two. Coastal Inundation dataset is publically available at www.data.vic.gov.au).</p> <p><u>Sea level rise</u></p> <p><u>Storm surges</u></p>

Decision Support Framework

<p>Site specific infrastructure/ dynamics that would influence the impact from sea level rise and storm surges</p>	<p>Identify any specific infrastructure/ dynamics that may increase or decrease the impact from sea level rise and storm surges (e.g. presence of artificial barriers to restrict seawater intrusion).</p>																																																																						
<p>Given the position of the wetland in the landscape, how exposed is the wetland to temperature and rainfall climate change components?</p>	<p>Insert climate change projections for temperature and rainfall based on current CSIRO-BOM (2015) modelling provided in Section 3.3.2 of Volume Two.</p> <p>Temperature</p> <p>Based on CSIRO-BOM (2015) modelling the following predictions are made in regards to change in temperature:</p> <table border="1" data-bbox="363 801 1501 976"> <thead> <tr> <th>Magnitude of change (mean surface temp. change)</th> <th>Seasonality</th> </tr> </thead> <tbody> <tr> <td></td> <td>•</td> </tr> </tbody> </table> <p>Rainfall</p> <p>Based on CSIRO-BOM (2015) modelling the following predictions are made in regards to change in rainfall:</p> <table border="1" data-bbox="363 1122 1501 1256"> <thead> <tr> <th>Magnitude of change (change in rainfall)</th> <th>Seasonality</th> </tr> </thead> <tbody> <tr> <td></td> <td>•</td> </tr> </tbody> </table>	Magnitude of change (mean surface temp. change)	Seasonality		•	Magnitude of change (change in rainfall)	Seasonality		•																																																														
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Decision Support Framework

Likely outcome	Based on the Table 2 in Section 3.2 of Volume One and the conceptual models presented in Section 4.1 of Volume Two.																				
Adaptive capacity	<p>General adaptive capacity of wetland types present</p> <p>Describe based on the conceptual models presented in Section 4.1 of Volume Two and populated table based on table provided in Section 4.3 of Volume Two.</p> <table border="1" data-bbox="363 539 1517 808"> <thead> <tr> <th data-bbox="363 539 518 616">Wetland type</th> <th data-bbox="518 539 667 616">Adaptive capacity</th> <th data-bbox="667 539 1066 616">Main adaptive mechanism</th> <th data-bbox="1066 539 1517 616">Main limiting factor</th> </tr> </thead> <tbody> <tr> <td> </td> <td> </td> <td> </td> <td> </td> </tr> <tr> <td> </td> <td> </td> <td> </td> <td> </td> </tr> <tr> <td> </td> <td> </td> <td> </td> <td> </td> </tr> <tr> <td> </td> <td> </td> <td> </td> <td> </td> </tr> </tbody> </table> <p>Site specific adaptive capacity</p> <p>Need to consider site specific opportunities and constraints to adaptive capacity based on site specific characteristics.</p>	Wetland type	Adaptive capacity	Main adaptive mechanism	Main limiting factor																
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3. Management objectives and actions (Section 5 of Volume Two)

Constraints to management	<p>See Section 5.1 of Volume Two report for more detail.</p> <p>Barriers to migration</p> <p>Land ownership</p> <p>Funding</p> <p>Limitations to knowledge and data</p> <p>Other potential constraints</p>
Pre-existing threats	Identify pre-existing threats that may impact the wetlands capacity to cope with change.
Pre-existing management objectives	Document local and regional management objectives in pre-existing management plans and strategies.
Proposed management objective in relation to climate change	Based on wetland values and existing objectives, define the management objective for the wetland in relation to climate change. See Section 5.2 of Volume Two for more detail.

Decision Support Framework

Management actions to address climate change impacts and management objectives	Identify a suite of management actions for the site. See Section 5.3 of Volume Two for more details. May include existing and new management actions								
	Existing actions <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 80%;">Management Action</th> <th style="width: 20%;">Timeframe</th> </tr> </thead> <tbody> <tr> <td> </td> <td> </td> </tr> <tr> <td> </td> <td> </td> </tr> </tbody> </table>	Management Action	Timeframe						
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4. Recommendations

Identify any recommendations for management of the wetland e.g. addressing data gaps, further investigation required, development of management or implementation plan

5. Key management resource documents

Insert useful resource documents and web links associated with management at the site, including but not limited to:

1. Peters, G., Morris, K., Froud, D., Papas, P. and Roberts, J. (2015). A Guide to managing livestock grazing in Victoria's wetlands. Decision framework and guidelines - Version 1.0, Arthur Rylah Institute for Environmental Research Technical Report Series, Report number 265
2. Morris, K. and Papas, P. (2012), Wetland conceptual models: associations between wetland values, threats and management interventions, Version one, Arthur Rylah Institute for Environmental Research Technical Report Series, Report number 237.
3. DELWP wetland buffers guidelines (in prep.)
4. DELWP wetland revegetation guidelines (in prep.)
5. DELWP wetland invasive species management guidelines (in prep.)
6. SKM (2005). Guidelines for the design and operation of environmentally friendly wetland regulators (MDBC project report R2002). Report by Sinclair Knight Merz for the MDBC.

6. Key references

Insert key reference/ supporting documents used to populate decision support framework template.

Appendix D Decision Support Framework case study application

Coastal Wetlands and Climate Change

Decision Support Framework

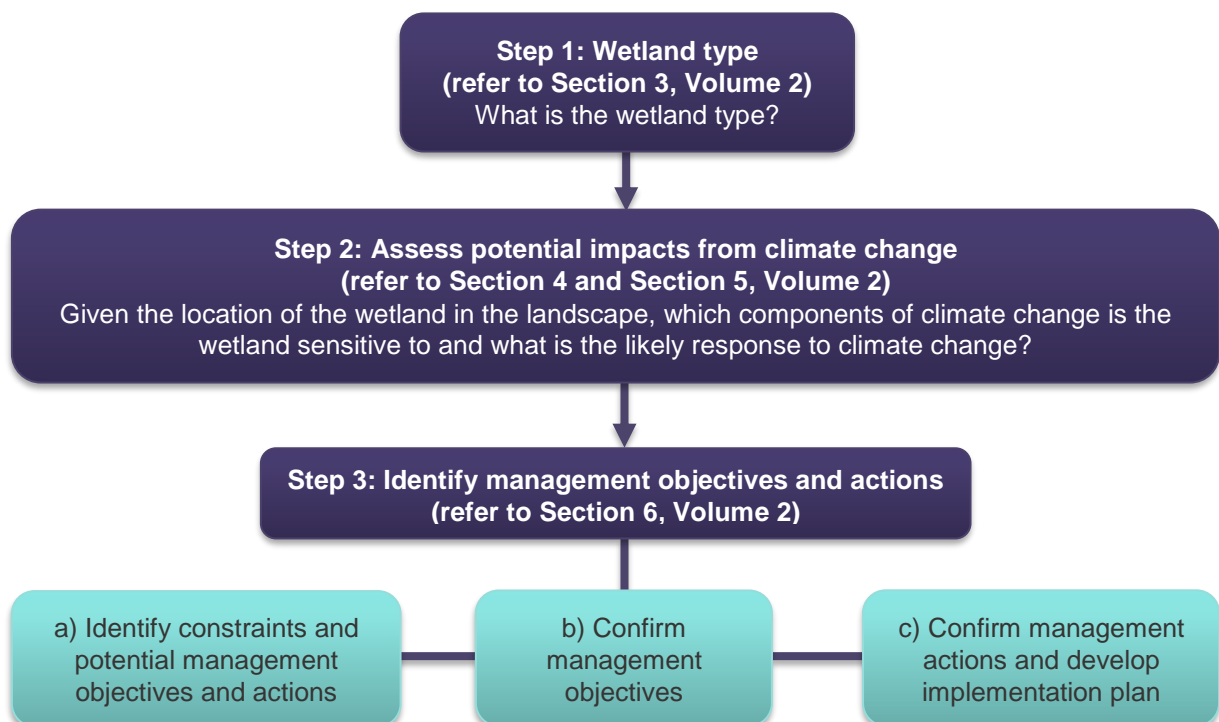
Site Name: Powlett River Estuary

Purpose

This document provides a Decision Support Framework to enable wetland managers to assess the vulnerability and adaptive capacity of wetlands to climate change at an individual wetland or local landscape scale. The DELWP Climate Change Vulnerability Assessment and Adaptive Capacity of Coastal Wetlands report provides the background and supporting material for this assessment and should be used in conjunction with each stage of the assessment process, outlined below.

The broad approach applied in the Decision Support Framework is illustrated below. It is a three step approach that includes:

- **Step 1: Wetland type** – in this step you identify your wetland type (e.g. mangrove, saltmarsh) using a combination of the coastal wetland dataset developed as part of this project and your existing knowledge of the site. This step guides the sensitivity assessment undertaken in step 2.
- **Step 2: Assess potential impacts from climate change** – in this step you consider the position of your wetland in the landscape so you can determine which component of climate change the wetland is most sensitive to. This step involves undertaking the exposure and sensitivity components of the vulnerability assessment outlined above, using the exposure mapping, the conceptual models and the sensitivity tables provided in the supporting documents.
- **Step 3: Identify management objectives and actions** – in this step you consider the adaptation mechanisms possible for your wetland and develop management objectives and actions. This step will inform the development of a management plan which is undertaken outside of the DSF.



Decision Support Framework

1. Wetland identification (Section 2, Volume Two)

Name:	Powlett River Estuary	
Location/ address:	Located in the West Gippsland Catchment Management Authority (CMA) region, near the coast between Kilcunda and Wonthaggi.	
	Easting: 370380.205	Northing: 5728345.662
Bioregion:	Gippsland Plain	
Wetland category (Section 2.4, Volume Two)	Tidal wetlands	Non-tidal wetland
	Marine embayment <input type="checkbox"/>	Coastal floodplain <input checked="" type="checkbox"/>
	Estuarine (intertidal) <input checked="" type="checkbox"/> Estuarine (supratidal) <input checked="" type="checkbox"/>	Dune system <input type="checkbox"/>
Wetland type/ EVC group(s) (Section 2.3, Volume Two and supporting geospatial dataset)	Seagrass <input type="checkbox"/>	Freshwater wetland (dune) <input type="checkbox"/>
	Saltmarsh <input checked="" type="checkbox"/>	Riparian/ swampy scrub <input checked="" type="checkbox"/>
	Mangroves <input type="checkbox"/>	Estuarine wetland <input checked="" type="checkbox"/>
	Brackish wetland <input type="checkbox"/>	Estuarine scrubs, heathlands and woodlands <input checked="" type="checkbox"/>
	Freshwater wetland (floodplain) <input type="checkbox"/>	
Estuary classification (if relevant) http://www.ozcoasts.gov.au/search_data/map_search.jsp	Classification	
	Wave dominated <input checked="" type="checkbox"/>	Tide dominated <input type="checkbox"/>
	Sub-classification	
	Wave dominated delta <input type="checkbox"/>	Coastal lagoon <input type="checkbox"/>
	Tide dominated delta <input type="checkbox"/>	Strandplain <input checked="" type="checkbox"/>
	Wave dominated estuary <input type="checkbox"/>	Tidal flat/ creek <input type="checkbox"/>
Tide dominated estuary <input type="checkbox"/>	Other <input type="checkbox"/>	
Estuary geomorphology (if relevant)	Permanently open <input type="checkbox"/>	Intermittently opened and closed <input checked="" type="checkbox"/>
	Permanently closed <input type="checkbox"/>	

Decision Support Framework

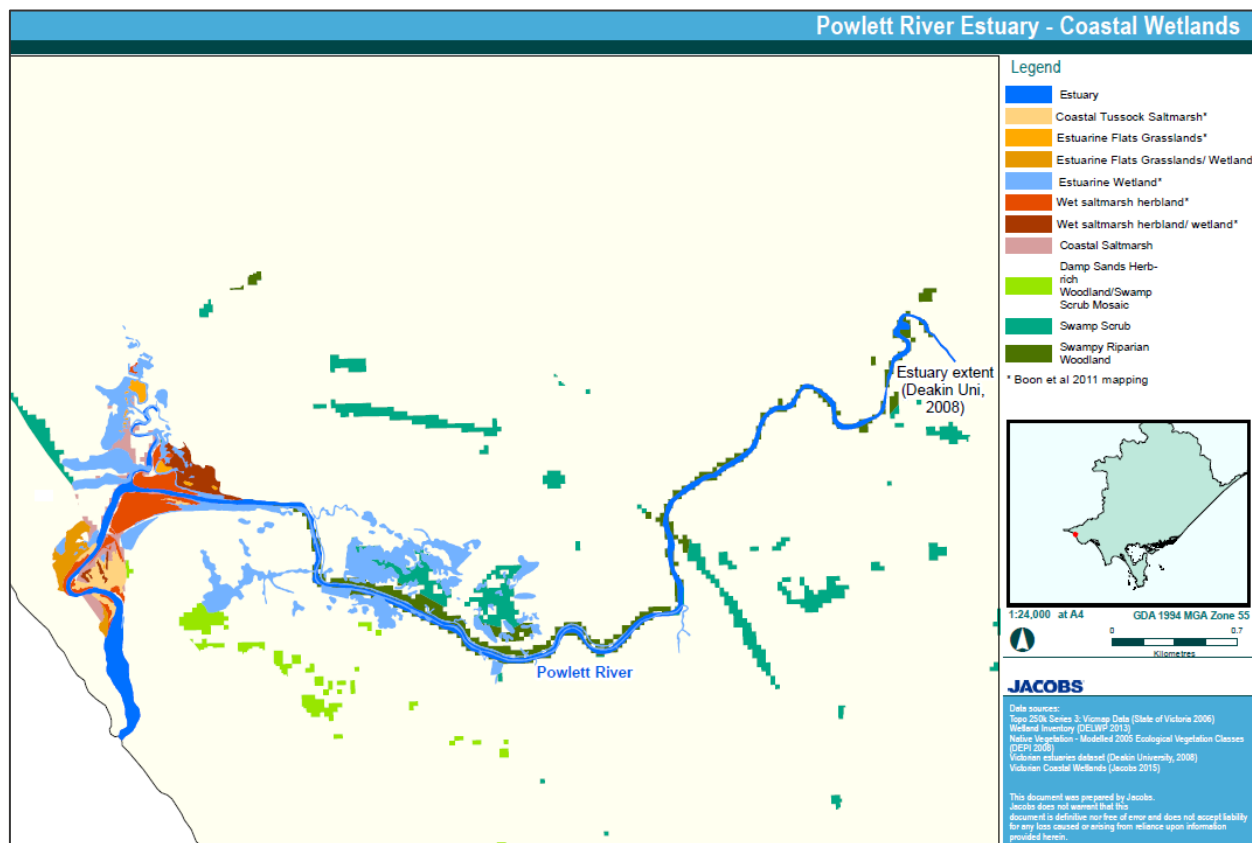
Wetland values

The Powlett River Estuary has a diverse range of bird, plant and fish communities:

- 5 different EVCs including coastal saltmarsh (Coastal Tussock Saltmarsh and Wet Saltmarsh Herbland), protected under the Environmental Protection and Biodiversity Conservation Act 1999 (EPBC Act).
- 22 fish species including the Australian Grayling, which is listed threatened under the Flora and Fauna Guarantee Act 1988 (FFG Act) and vulnerable under the EPBC Act.
- 31 State, Australian and Internationally listed bird species including the critically endangered Orange-bellied Parrot (WGCMA, 2015)

The Powlett River Estuary also has significant social and economic value:

- Recreational activities – fishing, sightseeing, swimming, walking, bird watching picnics etc.
- Coastal dunes near the mouth of the Estuary have Aboriginal cultural heritage significance (number of coastal midden sites recorded)
- Landholders commonly graze along the river upstream of the Mouth of Powlett Road.
- Water source for irrigation and stock and domestic water use (WGCMA, 2015).



Decision Support Framework

2. Potential impacts from climate change to the wetland (Section 4, Volume Two)

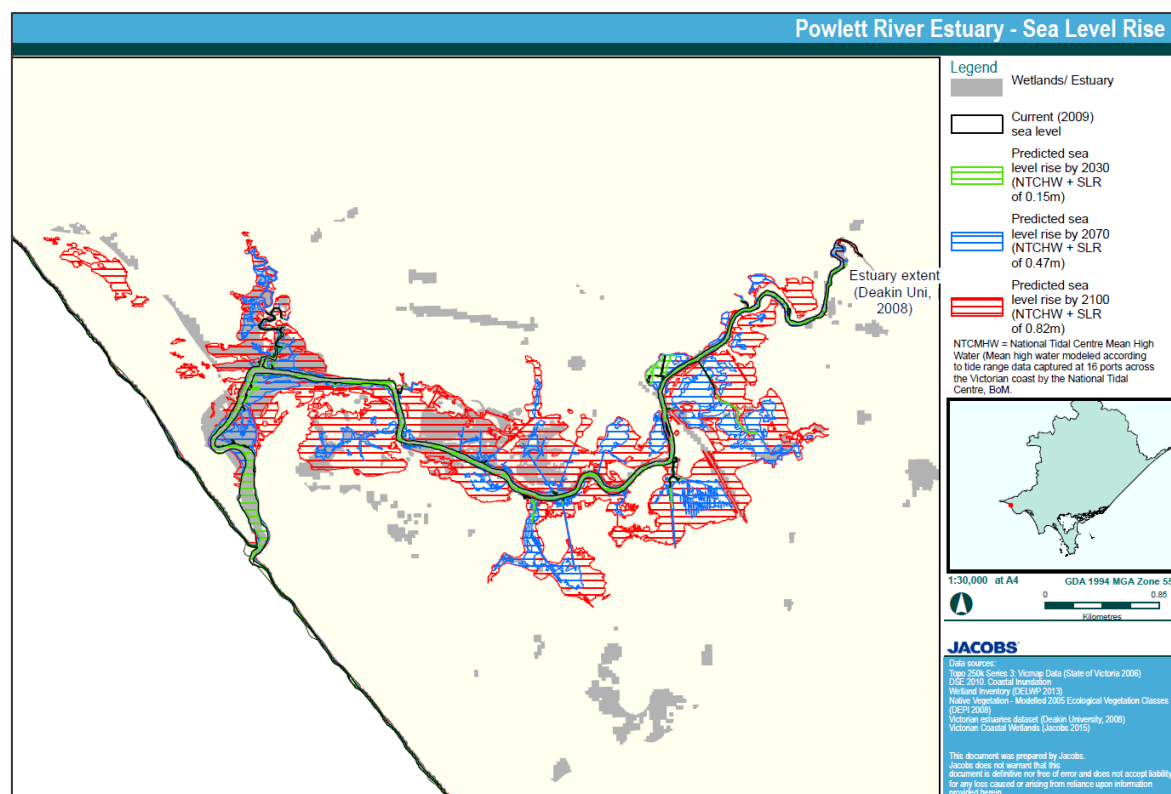
What is the climate change scenario/ timeframe

Based on CSIRO-BOM (2015) modelling RCP 4.5 (moderate response to climate change) and RCP 8.5 (worst case scenario/ business as usual response to climate change).

Timeframes 2050, 2070 and 2090 were all considered.

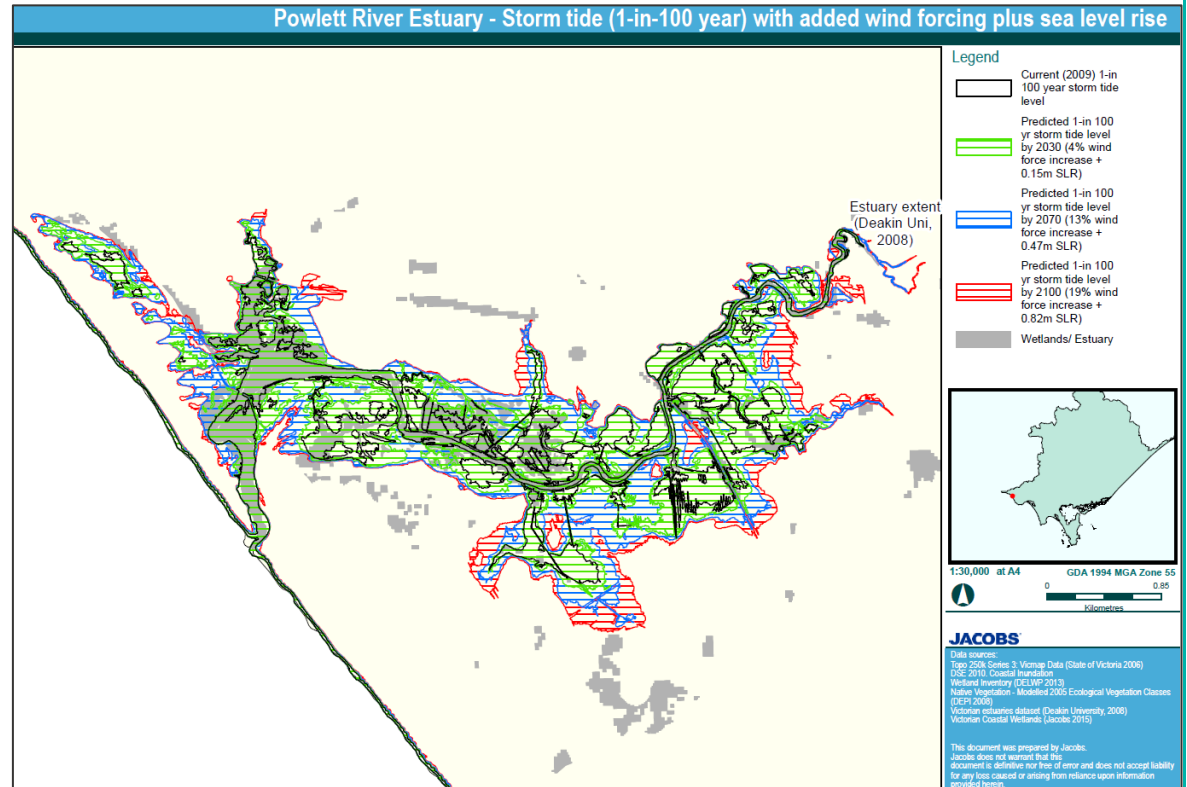
Given the position of the wetland in the landscape, how exposed is the wetland to sea level rise and storm surge climate change components?

Sea level rise



Decision Support Framework

Storm surges



Site specific infrastructure/ dynamics that would influence the impact from sea level rise and storm surges

There is currently no infrastructure at the Powlett River Estuary that would influence the extent of inundation from the projected sea level rise and storm surges.

When the mouth of the estuary is closed, this may help mitigate some of impact of sea level.

Given the position of the wetland in the landscape, how exposed is the wetland to temperature and rainfall climate change components?

Temperature

Based on CSIRO-BOM (2015) modelling the following predictions are made in regards to change in temperature:

Magnitude of change (mean surface temp. change)	Seasonality
<p>RCP 4.5</p> <p>2050 = 0.5 to 1°C</p> <p>2070 = >1 to 1.5°C</p> <p>2090 = >1 to 1.5°C</p> <p>RCP 8.5</p> <p>2050 = >1.5 to 2°C</p> <p>2070 = >2 to 2.5°C</p> <p>2090 = >3 to 3.5°</p>	<ul style="list-style-type: none"> Temperature increases are similar in all seasons, with some models simulating to some extent larger increases in summer and autumn than in other seasons. Projected changes for both daily maximum and minimum temperature generally follow those of the mean temperature; although there is somewhat lower warming in daily minimum temperatures than daily maximum temperatures in autumn, winter and spring. Increase in the temperature reached on the hottest days, an increase in the frequency of very hot days and duration of warm spells.

Decision Support Framework

<p>Given the position of the wetland in the landscape, how exposed is the wetland to temperature and rainfall climate change components?</p>	<p>Rainfall</p> <p>Based on CSIRO-BOM (2015) modelling the following predictions are made in regards to change in rainfall:</p> <table border="1" data-bbox="363 443 1501 1064"> <thead> <tr> <th>Magnitude of change (change in rainfall)</th> <th>Seasonality</th> </tr> </thead> <tbody> <tr> <td> <p>RCP 4.5</p> <p>2050 = 2.5 to 7.5%</p> <p>2070 = > -2.5 to 2.5%</p> <p>2090 = > -2.5 to 2.5%</p> <p>RCP 8.5</p> <p>2050 = > - 7.5 to -2.5%</p> <p>2070 = > - 7.5 to -2.5%</p> <p>2090 = > -12.5 to - 7.5%</p> </td> <td> <ul style="list-style-type: none"> • Rainfall declines are strongest in winter and spring. Projected reductions in winter rainfall in the Victoria/ NSW East region are up to 30 % in 2090 under high emissions. • There is little change projected in autumn and either increases or decreases in summer rainfall are possible. • Tendency for heavier rainfall interspersed by longer dry periods, with some extremely dry and wet years, with natural variability continuing to be a major driver of rainfall for the near future (2030). • Intensity of heavy rainfall events is predicted to increase, with timing and magnitude also driven by natural variability. • A decline in the number, but an increase in the intensity of east coast lows, impacting on average rainfall and heavy rain events. • Time spent in drought is predicted to increase over the course of this century in line with changes to average rainfall, and the frequency and duration of extreme droughts will increase. </td> </tr> </tbody> </table>	Magnitude of change (change in rainfall)	Seasonality	<p>RCP 4.5</p> <p>2050 = 2.5 to 7.5%</p> <p>2070 = > -2.5 to 2.5%</p> <p>2090 = > -2.5 to 2.5%</p> <p>RCP 8.5</p> <p>2050 = > - 7.5 to -2.5%</p> <p>2070 = > - 7.5 to -2.5%</p> <p>2090 = > -12.5 to - 7.5%</p>	<ul style="list-style-type: none"> • Rainfall declines are strongest in winter and spring. Projected reductions in winter rainfall in the Victoria/ NSW East region are up to 30 % in 2090 under high emissions. • There is little change projected in autumn and either increases or decreases in summer rainfall are possible. • Tendency for heavier rainfall interspersed by longer dry periods, with some extremely dry and wet years, with natural variability continuing to be a major driver of rainfall for the near future (2030). • Intensity of heavy rainfall events is predicted to increase, with timing and magnitude also driven by natural variability. • A decline in the number, but an increase in the intensity of east coast lows, impacting on average rainfall and heavy rain events. • Time spent in drought is predicted to increase over the course of this century in line with changes to average rainfall, and the frequency and duration of extreme droughts will increase. 																																																																		
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<p>Likely outcome</p>	<p>Estuary</p> <ul style="list-style-type: none"> • Potential change from intermittently open estuary mouth to permanently opened or more permanently closed estuary, depending on regional changes to rainfall/catchment runoff, river discharge, eustatic sea levels and storm surges. May become more similar to Andersons Inlet (marine embayment) to the east. • Saline intrusion into the upper estuary and lower freshwater reaches of the river due to increased sea levels and storm surge activity and reduced rainfall/catchment runoff. 																																																																						

Decision Support Framework

	<ul style="list-style-type: none"> • Saline intrusion into groundwater results in a changed in species composition year round <p>Saltmarsh</p> <ul style="list-style-type: none"> • More permanent inundation or increased frequency and duration of inundation • Change in salinity and water regime • Changes in distribution along the elevational gradient from the sea, with possible landward migration • Possible invasion by mangroves if geomorphic changes result in a more permanent estuary opening (e.g. similar to Andersons Inlet) • Many of the saltmarsh taxa at the site are C3 plants, so potentially advantaged by increases in atmospheric CO₂ concentrations • Increased pressure from weed invasion from surrounding agricultural land • Saline intrusion into groundwater results in a changed wetland environment <p>Estuarine Wetland</p> <ul style="list-style-type: none"> • Change in salinity and water regime (e.g. reduced freshwater inflows and saline intrusion, increased evaporation losses) • Increased pressure from weed invasion • Saline intrusion into groundwater results in a changed wetland environment <p>Riparian scrub and swampy riparian woodland</p> <ul style="list-style-type: none"> • Change in salinity and water regime (e.g. reduced freshwater inflows and saline intrusion, decreased rainfall, increased extreme flood events) • Rise in saline conditions along riparian zone • Replacement with saltmarsh as a result of increased salinity • Increased pressure from weed invasion • Saline intrusion into groundwater results in a changed species composition year round 																				
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Decision Support Framework

Site specific adaptive capacity

Not completed as part of case study – requires specific assessments of opportunities and constraints to adaptive capacity based on site specific characteristics.

3. Management objectives and actions (Section 5 of Volume Two)

<p>Constraints to management</p>	<p>Barriers to migration</p> <ul style="list-style-type: none"> • Mouth of Powlett Road is a barrier to wetland migration • Rail trail towards Daylestone provides a barrier to landward migration • Small cluster of housing north east of the estuary mouth similarly constrains landward migration. <p>Land ownership</p> <ul style="list-style-type: none"> • The land in which wetlands could migrate in to is predominately private land used for agriculture (grazing and cropping). <p>Funding</p> <ul style="list-style-type: none"> • Limited funding available – not a priority site State wide nor Ramsar listed. • Whilst there is good collaboration between agencies and landholders, there are different priorities for the funding available and therefore so some actions are difficult to implement. An example includes raising roads and carparks that experience inundation during closure events, or buying back regularly inundated marginal farmland. <p>Limitations to knowledge and data</p> <ul style="list-style-type: none"> • Uncertainty around the likely geomorphic changes to the estuary mouth (i.e. change in estuary dynamic) • Understanding the economic value of the estuary/ coastal wetlands (e.g. value of wetlands versus the value of agricultural land) • Uncertainty around acid sulfate soils as a result of climate change. <p>Other potential constraints</p> <ul style="list-style-type: none"> • Current State policies and procedures for statutory planning changes and land buyback to enable long term management • Community understanding and expectation around estuary opening and closing.
<p>Pre-existing threats</p>	<p>The key pre-existing threats identified in the Powlett River Estuary Management Plan that may influence the resilience of the estuary to climate change impacts include:</p> <ul style="list-style-type: none"> • Degraded water quality • Degraded riparian vegetation (large trees in particular) • Trampling and bank erosion associated with pedestrian access • Rural drainage and drain clearing • Channelisation of the river channel • Vehicle access • Livestock access • Pest plants and animals • Inappropriate recreation causing dune erosion • Disturbance of acid sulfate soils

Decision Support Framework

<p>Pre-existing management objectives</p>	<p>Regional catchment strategy No coastal wetland specific actions/ objectives for the Powlett River.</p> <p>West Gippsland Waterways Strategy (2014-2022) Regional objectives relating to the Powlett River Estuary as a coastal wetland:</p> <ul style="list-style-type: none"> • Maintain and improve the habitat and condition of waterways to support waterway dependent animals and plants. • Maintain the ecological character of significant wetlands and estuaries. <p>Catchment objectives for Powlett River Estuary relating to coastal wetlands include:</p> <ul style="list-style-type: none"> • Riparian vegetation provides improved visual amenity and contributes to community use of waterways • The extent of freshwater wetlands is maintained and their condition is improved <p>Powlett Estuary Management Plan Swamp scrub, swampy riparian woodland and estuarine wetland vegetation communities are enhanced and significantly increased in the area.</p> <p>West Gippsland Regional NRM Climate Change Strategy (2016) The strategy outlines approaches and options to support climate change adaptation and mitigation. The objectives of the adaptation and management strategies are linked to the 20 year objectives in the Regional Catchment Strategy. The Powlett River Estuary is located within the Bunurong Coastal planning area. The estuary is listed as one of the most vulnerable estuary assets to climate change across the region.</p> <p>Reports are available at <http://www.wgcma.vic.gov.au/our-region/waterways/powlett-river-estuary> [Verified 17/05/2016]</p>										
<p>Proposed management objective in relation to climate change</p>	<p>The following management objective is based the existing geomorphic characteristics of the estuary (i.e. intermittently closed estuary):</p> <p><i>To enhance and significantly increase Swamp scrub, Swampy riparian woodland and estuarine wetland vegetation extent through the facilitation of landward migration of these communities over the next 50 years.</i></p> <p>Climate change also poses a threat to non-wetland EVCs (e.g. Coast Banksia Woodland) and therefore even though they are not considered in this coastal wetland risk assessment they are still a management consideration for the CMA in the coastal zone.</p>										
<p>Management actions to address climate change impacts and management objectives</p>	<p>Existing actions Existing management actions provided in Section 8.1 of the Estuary Management Plan (WGCMA, 2015) that are related to climate change are listed below.</p> <table border="1" data-bbox="437 1626 1500 2051"> <thead> <tr> <th>Management Action</th> <th>Timeframe</th> </tr> </thead> <tbody> <tr> <td>E.31: Investigate opportunities for land purchase within the inundation areas of the estuary</td> <td>8 years</td> </tr> <tr> <td>E.32: Design and implement a program of stewardship payment for the seasonal inundation of estuary floodplain from estuary mouth closures. Priority should be given to enhancing coastal saltmarsh and estuarine wetland communities. Payments should be calculated and prioritised based on potential value to estuary health and ability to minimise artificial estuary mouth openings.</td> <td>8 years</td> </tr> <tr> <td>E. 39: Investigate opportunities to encourage the conversion of Crown land water frontage grazing licences to riparian management licences.</td> <td>8 years</td> </tr> <tr> <td>E. 43: Undertake hydraulic modelling and bathymetry survey of the Powlett</td> <td>8 years</td> </tr> </tbody> </table>	Management Action	Timeframe	E.31: Investigate opportunities for land purchase within the inundation areas of the estuary	8 years	E.32: Design and implement a program of stewardship payment for the seasonal inundation of estuary floodplain from estuary mouth closures. Priority should be given to enhancing coastal saltmarsh and estuarine wetland communities. Payments should be calculated and prioritised based on potential value to estuary health and ability to minimise artificial estuary mouth openings.	8 years	E. 39: Investigate opportunities to encourage the conversion of Crown land water frontage grazing licences to riparian management licences.	8 years	E. 43: Undertake hydraulic modelling and bathymetry survey of the Powlett	8 years
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Decision Support Framework

	estuary floodplain to understand the impacts and benefits of the structures (including levees and drains) and landforms that affect the movement of water before, during and after artificial estuary mouth opening, before considering any updates, changes or removal of these floodplain features.		
	E. 44: Undertake a detailed risk assessment, including on-ground mapping to identify potential and active acid sulphate soils with the Powlett estuarine floodplain.	8 years	
	E. 46: Investigate the use of the saltmarsh, wetlands and estuary channel by recreational fish species and other native fish species, particularly Black Bream and prioritise areas for further protection.	8 years	
	E. 49: Continue to build understanding of, and plan for, the risks associated with climate change, including sea level rise. This includes future flood risk.	8 years	
New actions			
The following additional management actions should be considered.			
	Management Action	Timeframe	Responsibility
	Complete a study to assess the likely geomorphic changes to the estuary as a result of climate change.	2 years	WGCMA
	Undertake scenario planning in consultation with Bass Coast Shire Council, VicRoads and Parks Victoria- refine management actions and objectives for Estuary based on finding of geomorphic study. This could identify nearby systems that could form a template for what Powlett River might look like in the future (e.g. Andersons Inlet)	2-5 years	WGCMA
	Review Bass Coast Planning Scheme to understand any implications to future management actions/ works at the Powlett Estuary. Provide feedback to the State Government on any issues associated with State policies and procedures for statutory planning that may constrain long term management of the Estuary.	2-5 years	WGCMA
	Consultation with other relevant managers in the area (including Council, VicRoads and Parks Victoria) to discuss potential issues associated road repairs, culverts and other flood mitigation measures in the area that may arise as a result of climate change.	2-5 years	WGCMA
	Resolve issues and complexities around the impacts of climate change (sea level rise) on crown land boundaries.	2-5 years	State Government
	Resolve issues associated with State policies and procedures for statutory planning that may constrain long term management of the Estuary.	2-5 years	State Government
	Community engagement and education program to provide the community with an understanding of the predicted impacts of climate change and enable them to play an active role in management.	2-5 years	WGCMA
	Estuary Management Plan Action E.31 (see above) – to become 2 actions: a. Investigate opportunities for land purchase within the	8 years	WGCMA

Decision Support Framework

	current inundation areas of the estuary b. Investigate opportunities for land purchase within the future inundation areas of the estuary.		
	Estuary Management Plan Action E.32 (see above) – include consideration of future inundation e.g. “Design and implement a program of stewardship payment for the seasonal inundation of estuary floodplain from estuary mouth closures <i>under both current and future inundation conditions</i> ”.	8 years	WGCMA
	Estuary Management Plan Action E. 39 (see above) – to become 2 actions a. Investigate opportunities to encourage the conversion of current Crown land water frontage grazing licences to riparian management licences b. Investigate issues and opportunities related to sea level rise impacts on Crown Land Water frontage grazing licences and riparian management licences (including how to define boundaries if existing boundaries are inundated by sea level rise).	8 years	WGCMA
	Estuary Management Plan Action E.44 (see above) – Undertake detailed risk assessment of potential and active acid sulfate soils.	8 years	WGCMA
	Estuary Management Plan Action E.49 (see above) – Continue to build understanding of and plan for risks associated with climate change.	8 years	WGCMA

4. Recommendations

- Climate change threats are currently implied within the management actions in the Powlett River Estuary Management Plan. It is recommended that additional material on climate change impacts be included and climate change threats addressed more explicitly in the management actions. This would meet Action E.49 in particular.
- Management objectives also need to consider management for a 30-50 year timeframe i.e. take in to consideration longer term climate change impacts, including on estuary mouth dynamics. A distinction between responses to current and future threats should be made.

5. Key management resource documents

- Peters, G., Morris, K., Flood, D., Papas, P. and Roberts, J. (2015). A Guide to managing livestock grazing in Victoria's wetlands. Decision framework and guidelines - Version 1.0, Arthur Rylah Institute for Environmental Research Technical Report Series, Report number 265
- Morris, K. and Papas, P. (2012), Wetland conceptual models: associations between wetland values, threats and management interventions, Version one, Arthur Rylah Institute for Environmental Research Technical Report Series, Report number 237.
- DELWP wetland buffers guidelines (in prep.)
- DELWP wetland revegetation guidelines (in prep.)
- DELWP wetland invasive species management guidelines (in prep.)
- SKM (2005). Guidelines for the design and operation of environmentally friendly wetland regulators (MDBC project report R2002). Report by Sinclair Knight Merz for the MDBC.

Decision Support Framework

6. Key references

1. WGCMA (2012). West Gippsland Regional Catchment Strategy 2013-2019. West Gippsland Catchment Management Authority.
2. WGCMA (2014). West Gippsland Waterway Strategy 2014-2022. West Gippsland Catchment Management Authority.
3. WGCMA (2015). Powlett River Estuary Management Plan. West Gippsland Catchment Management Authority.
4. WGCMA (2016). West Gippsland Regional NRM Climate Change Strategy – Final Draft. West Gippsland Catchment Management Authority.
5. CSIRO and BOM (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

