Preliminary adaptation pathways for the Coorong, Lower Lakes and Murray Mouth

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WATER FOR THE ENVIRONMENT







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Respect and reconciliation

Aboriginal people are the First Peoples and Nations of South Australia. The Coorong, connected waters and surrounding lands have sustained unique First Nations cultures since time immemorial.

The Goyder Institute for Water Research acknowledges the range of First Nations' rights, interests and obligations for the Coorong and connected waterways and the cultural connections that exist between the Ngarrindjeri Nations and First Nations of the South East peoples across the region and seeks to support their equitable engagement.

Aboriginal peoples' spiritual, social, cultural and economic practices come from their lands and waters, and they continue to maintain their cultural heritage, economies, languages and laws which are of ongoing importance.

Executive summary

The Coorong, Lower Lakes and Murray Mouth (CLLMM) region has experienced a very long history of change. As long as people have lived in the region, that history has been both biophysical and social, with the system supporting people and people having rules about and preferences for how they interact with the system. For tens of thousands of years First Nations people lived through these changes. Since European colonisation, changes have also been experienced and driven by various other groups with different interests in the CLLMM. With the cumulative regulation of flows in the Murray–Darling Basin (the Basin), changes in the CLLMM have been large, rapid and increasingly complex, with biophysical, social and institutional factors interacting at multiple spatial and temporal scales.

For the last several decades, changes were shaped by processes aligning to:

- National and international values and rules, which shape objectives for the CLLMM and affect how much water flows down the River Murray
- South Australian and regional decision-making institutions¹, including those providing excellent knowledge generation and sharing capabilities
- Community values, preferences, lifestyles and economic decisions about how and where to work, live and play, and priorities for management
- First Nations' culture, law, custodianship, rights, obligations, aspirations and livelihoods.

The change processes within these themes interact and have evolved over time, shaping the *complex social and institutional system* that governs decision making in the CLLMM. Future change has the potential to alter the ecological state of the CLLMM region significantly. This is likely to require or lead to potentially very significant, or *transformational*, changes in objectives and management.

We explored future change in the CLLMM system using two scenarios that provided common, evidencebased assumptions. The scenarios are different points along a *trajectory of greatest plausible change*. The first scenario represents the most extreme point of a drying trend caused by reductions in freshwater inflow and increased evaporation. The second scenario represents sea level rising to the point where it becomes the dominant driver of water level in the Coorong and the Lower Lakes, once the existing barrages are routinely overtopped and are less effective as barriers.

Examining potential ecological responses to these scenarios suggests they entail a significant change in ecological character of the CLLMM. While some species, communities and physical features will be significantly diminished or lost, especially those associated with permanent freshwater, many values that people hold for the CLLMM could continue to be present with appropriate management. The CLLMM will continue to be a large, diverse and dynamic system of permanent wetlands, with a capacity to support a high abundance and diversity of plants, invertebrates, fish, and birds. It will continue to be a place for drought refuge for domestic waterbirds and feeding ground for international migratory waterbirds. People who live in or visit the region will continue to enjoy a wide range of benefits, including evolving cultural connections and respecting valued features of the past that have declined. Based on this analysis, together with workshop participants we derived *climate-ready objectives* that focus on making the most of the values that can feasibly be retained as the system changes, while acknowledging and accepting inevitable change.

¹ In this report, we use 'institutions' to refer to the various formal and informal arrangements that shape decision making, as opposed to organisations. See the glossary.

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Key adaptation decisions that may confront managers and stakeholders along the trajectory of change were identified and mapped out onto an *adaptation pathway*. These decisions will have significant societal dimensions, as well as (difficult) technical dimensions. They essentially relate to changes in aspirations and management objectives about the ecological nature of the CLLMM, hence they are also policy decisions that are answerable to society. This report contains a *preliminary* mapping of potential adaptation pathways for addressing future decisions associated with five key issues:

- 1. reducing salt and nutrient loads in the South Lagoon
- 2. accommodating climate change in national policy
- 3. facilitating seawater exchange through the Murray Mouth, the Murray Estuary and along the Coorong
- 4. making the Lower Lakes more resilient as they dry
- 5. allowing seawater exchange with Lake Alexandrina.

The analysis identified and characterised a set of *enabling conditions* in the societal *decision context* that could help with making and implementing future decisions in a more effective and timely manner. Adaptation decisions and actions will be undertaken by South Australian Department for Environment and Water (DEW) and others, including First Nations, South Australian landscape boards, the general community and other Basin jurisdictions. This *preliminary* analysis focusses on adaptation decisions and enabling conditions most relevant to DEW. Potential enabling conditions were identified by deliberating about future change and possible decisions with DEW staff over the course of the project and in a dedicated workshop. These included:

- 1. people are free to consider transformational change
- 2. people have a good understanding of future change and are accepting uncertainty
- 3. people have realistic narratives recognising the inevitability of change and accepting some losses
- 4. values and preference are based on anticipated change not past states
- 5. institutions that accommodate large, complex and uncertain change.

These represent a logically connected sequence of conditions in the societal decision context that would enable adaptation by DEW and others in the CLLMM, and across South Australia, the Basin and elsewhere in Australia to collectively anticipate and plan for future climate change.

We then identified potential *near-term interventions* that could be undertaken by DEW to drive *learning with other* decisionmakers and stakeholders who are instrumental in creating these enabling conditions.

The future decisions identified in this analysis are things that might be deemed in the future by DEW and stakeholders as effective and desirable; they are not recommendations as such. Similarly, the near-term interventions are examples of the things that DEW could do to stimulate the creation of the enabling conditions. Some of them may not be suitable and there will be other actions DEW could take to the same effect. The important aspect of this analysis is the *strategic intent* of near-term interventions to address identified barriers and corresponding enabling conditions, *to create options for DEW to address future transformational impacts*. It is likely that the options that DEW and others will consider in the future have not yet been fully anticipated; rather they will continue to emerge from the processes, including research, deliberation, re-evaluation, conversation among all CLLMM stakeholders, and policy reform, that occur in response to the near-term strategic interventions undertaken by DEW.

The management issues and changes that may need to be considered in the face of transformational change are very different from the current issues and options. There are similarities with the types of issues being managed now (such as water level, salinity and habitats), but the magnitude of future change makes the situation increasingly novel and complex. Even contemplating these future changes and decisions requires new ways of thinking about the CLLMM, new knowledge, and engagement with emotional connections to the past and current CLLMM. This can be expected to require new capabilities within DEW for planning and supporting conversations about change with and among First Nations, local communities and other groups.

Further, DEW cannot make these decisions and implement changes in management on its own. The department depends on an enabling environment of *relevant information* about the decision options, stakeholders with *informed preferences* and national as well as state institutions that support decision making in the *context of uncertainty and continual change*.

This study has identified that many of the barriers to DEW being able to effectively consider and implement responses to transformational change are related to a persistent framing of the CLLMM system as *stationary*. A stationary system is one that varies about a well-defined mean or desired state. In contrast a *non-stationary* system is one where the central tendency (e.g. mean) changes as a trend or step change, or the regime of variation changes. Even though managers are often aware of the limitations of a stationary framing, it is present, in varying degrees, in the values, rules and knowledge shaping decisions, and at all levels from local, state, national to international. For example:

- Current values and preferences are largely related to preserving the current state or returning to past healthier version of it. Future focused preferences need to relate to the alternative ecological states that are feasible and available as the environment and hydrology of the CLLMM changes.
- Current rules for the system are largely about keeping it in a healthy version of its current or recent past/ideal state, maintaining salinity, and meeting fixed thresholds. Future focused rules would have built in mechanisms to revise objectives based on *anticipated* change.
- Current knowledge is largely about an ideal healthy state or departures from it and processes to return to that state. Future focused knowledge would be about future change trajectories and states, the ability of management to influence those trajectories, and about accommodating uncertainty.

This stationary framing not only presents barriers to making decisions, it also inhibits consideration of and deliberation about transformational futures even if those futures and the changes in policy and management are many decades away.

This report highlights a series of near-term actions to help DEW and stakeholders address embedded stationarity and navigate the long journey of adaptation. These include:

- Don't delay action. The process of updating and reforming these institutions can be expected to be complex and take many decades. While contemplating and planning for long-term climate change will have challenges, and the risks of failure to do so will increase over time.
- Incremental change. By planning for incremental change *with programmatic intent* it will be possible to start now with low risk steps. For example, analysis of and engagement about current issues can be framed in the context of a continually changing CLLMM (as opposed to returning to fixed or past 'normal') and emphasise aspects of the CLLMM that people connect to and value (as opposed to focussing solely on biophysical descriptors). Subsequent steps could include, stimulating and supporting deliberation about change including transformation, sharing lessons with other jurisdictions about transformational change, and building capacity to accommodate uncertainty and novel conditions.
- Accommodating ambiguity. The processes of anticipating transformational change, evolving
 institutions and contemplating challenging adaptation decisions will inevitably involve considerable
 uncertainty and ambiguity related to knowledge, preferences, rules, terminology, framing, and
 objectives. It will become necessary for individuals and agencies to learn to live with that ambiguity.

Create enabling environments. Action to promote and support deliberation about change, including
exploring its consequences, navigating uncertainty and reassessing preferences in the context of
future change will help people engage safely with future change. This may include identifying
changes to processes, polices and agreements that might be required to address transformational
change. This is needed at the local, within-agency and whole-of-Basin scale. An external commission
reviewing the institutional and societal challenges of transformational adaptation could help provide
independent authorisation and guidance and set expectations that agencies will consider
transformation. This could accelerate coordinated adaptation planning for the CLLMM and the Basin.

This analysis is labelled as *preliminary* because the engagement activities undertaken were restricted to DEW staff and researchers involved in the Healthy Coorong, Healthy Basin (HCHB) Program. Wider engagement, with First Nations and the general community, would be required to develop a more complete understanding of how climate change is expected to affect the diversity of ways the CLLMM is valued, and to explore the decisions that different groups might be confronted with, their preferences in the face of change and the barriers to decision making that they identify. Analyses, like this one, involving long-term change should always be regarded as preliminary as there will be a constant updating of foresight about the future and evolution of near-term opportunities for actions.

Acknowledgments

This project is part of the South Australian Government's Healthy Coorong, Healthy Basin Program, which is jointly funded by the Australian and South Australian governments.

The project would have been impossible without the considerable engagement by Department for Environment and Water (DEW) staff and other researchers from HCHB, as research partners, participants and advisors. We thank those people who participated in multiple workshops, meetings, interviews and collaborative development of various outputs. These partners provided us with invaluable information about the CLLMM and its management, insights about their organisations and themselves as individual policy makers, managers and people connected to the Coorong. Importantly, they were critical to the coproduction of important insights about the CLLMM and its management in the face of potentially transformational climate change.

We appreciate DEW and the Goyder Institute for Water Research supporting the approach to this adaptation project that we proposed, noting it was quite unfamiliar to many and full of ambiguity. We are particularly grateful for all those who were willing partners on the journey, their flexibility in how they engaged with the project findings and how they enabled flexibility in the delivery of the project in response to their needs, emerging project findings and other circumstances.

We thank the Goyder Institute, Kane Aldridge, Alec Rolston and the Goyder Management Board for their continual support as the project evolved and for a rigorous report review and finalisation process. And thanks to Amy Ide for assistance with finalising reports to meet the agreed scope.

Finally, the richness of the engagement with DEW and connection to their needs would not have been possible without the Project Advisory Committee and two DEW staff who joined our project team for different periods.

1 Introduction

1.1 Background

The Coorong, Lower Lakes, and Murray Mouth (CLLMM) system is culturally, environmentally and economically important at local, national and international scales but has experienced a long-term decline in its ecological condition due to reductions in freshwater inflows. While there has been recovery of some elements of the CLLMM ecosystems associated with increased inflows since the Millennium Drought ended in 2010, the Coorong South Lagoon has been recovering at a slower rate than expected. That ecosystem experienced a switch from being dominated by aquatic plants to algae, associated with eutrophication (nutrient enrichment), with subsequent impacts on invertebrates, fish and waterbirds. These changes in the ecosystem and the lack of recovery is likely caused by a number of complex, interacting factors, which are not well understood (DEW, 2021).

The Phase One Trials and Investigations (T&I) project of the Healthy Coorong, Healthy Basin (HCHB) Program consists of a series of integrated components that collectively provide knowledge to inform the future management of the Coorong. *Component 6 - Climate Adaptation* examines how the Coorong, Lower Lakes and Murray Mouth region might be affected by continuing climate change, how this could affect the various values people hold for the CLLMM and the options for preserving values in the face of change. It is structured into four phases that implement a sequence of steps over a two-year period which are designed to build the understanding and capacity of decision makers and other stakeholders. These phases and steps include:

Context:

- Synthesise the long history of environmental and social changes in the Coorong and Lower Lakes, as a context for analysing current and future change.
- Review anticipated long-term environmental and ecological impacts of climate change in the Coorong and Lower Lakes, with a focus on the breadth of change processes as well as the possible magnitude of change, to provide a robust understanding of future changes.
- Clarify the range of current management and research activities, and how they are expected to lead to behavioural and physical changes that contribute to the current objectives for the Coorong (using 'Theory of Change' methodologies).
- Explore the sensitivity of current activities (above) and ecological objectives to climate change.

Vulnerability

- Develop a set of trajectories of environmental and ecological change for the Coorong to provide a common platform for anticipating the implications of future change.
- Understand the diversity of values for the Coorong and Lower Lakes resulting from the multiple relationships people have with the Coorong and Lower Lakes and clarify the biophysical elements of those value relationships (the 'things' that are valued).
- Explore how these biophysical elements and values might be affected by different trajectories of change, recognising that depending on the specific trajectory many features and values might persist despite significant change.

Adaptation pathways:

- Construct visions of a 'healthy Coorong and Lower Lakes', or other versions of 'success', in the face of significant ecological change.
- Scope alternative sets of the key decisions, changes in management or new interventions (collectively making 'adaptation pathways') that would be needed to achieve the visions of a 'healthy Coorong' under different change trajectories.
- Assess the requirements for those decisions to be made in an informed manner.

• Identify near-term actions and interventions that will strategically overcome the decision-making barriers and increase the range of options available to manage the Coorong into the future.

Draw on insights gained during the project analyses to identify issues and opportunities to build capacity to assess, deliberate on and plan actions for adapting to future transformational impacts of climate change, both within DEW and with First Nations, the general community and other stakeholders.

This report, 'Preliminary adaptation pathways for the Coorong, Lower Lakes and Murray Mouth', is the final output of the Climate Adaptation project, Component 6 of the HCHB T&I project. It presents the results of work completed during the period from January to June 2022. Its aims are described in section 1.3.

This analysis is labelled as *preliminary* because the engagement activities undertaken were restricted to Department for Environment and Water (DEW) staff and researchers involved in HCHB. Wider engagement, with First Nations and the general community, would be required to develop a more complete understanding of how climate change is expected to affect the diversity of way the CLLMM is valued, and to explore the decisions that different groups might be confronted with, their preferences in the face of change and the barriers to decision making that they identify. Analyses, like this one, involving long-term change should always be regarded as preliminary as there will be a constant updating of foresight about the future and evolution of near-term opportunities for actions.

1.2 Transformational adaptation

People charged with adapting to climate change are faced with the challenge of balancing existing management objectives, the impacts of recent climate variability and change, climate change that is highly likely in the next few decades, and longer-term climate change that is more uncertain but includes the prospect of transformational changes. Some of the challenges that might be encountered in the face of future transformational change include novel hydrological and ecological changes, leading to significant decline or loss of many freshwater-dependent components of the CLLMM (regarded as critical to its ecological character), and large-scale changes to other components and processes in the system. Despite the significance of future change, it is likely that many of the values associated with the CLLMM could continue to persist if the system was carefully managed. However, doing so would likely require new management objectives and management regimes, affecting not only the hydrology and ecology of the whole system, but the way people use and value the system. Planning and implementing such changes in institutions, management objectives and management practice, with the support of First Nations, the local community, and other stakeholders, and in the face of much uncertainty is a significant challenge, especially at a time when the CLLMM is still recovering from the impacts of the Millennium Drought (1996–2010).

Adaptation pathways is an analytical approach developed over the last decade or more to help planners address large but uncertain future changes. A key feature of adaptation pathways approaches is that they move beyond focusing on impacts to focus on the key decisions that managers may need to take to support adaptation. They link current management strategies with responses to high-level change by anticipating how key management decisions might sequence in time. As environmental changes occur, decision makers will have more confidence about the details of previously anticipated changes, and management objectives

² Institutions is used in this report to refer to the formal and informal societal processes that combine to shape decision making (see Glossary).

² Goyder Institute Technical Report Series | Adaptation pathways for the Coorong, Lower Lakes and Murray Mouth

can be further revised. Styles of adaptation pathways have evolved over time. The first high profile application was scoping the management of the River Thames Estuary to avoid the flooding of London if, and when, the Thames barrages are overwhelmed by rising sea level (Reeder and Ranger 2011). This analysis linked together a series of options that were effective for different levels of sea level rise, and considered which near-term options might assist with future options. Jacobs et al. (2019) used adaptation pathways to sequence actions to address increasing climate change risks to multiple biodiversity and cultural heritage values associated with protected areas in New South Wales.

Haasnoot et al. (2013) examined sequences of management decisions that might be required to manage the Rhine delta in the face of sea level rise and flooding. This analysis highlighted that the preferred pathway of choices might depend on political perspectives (hierarchist, egalitarian or individualistic), pointing to the need for a political process as well as technical analysis in choosing adaptation responses. Wise et al. (2014) took this a step further by using conceptualised adaptation pathways as the evolution of the social-ecological system, with a range of system states, marked by key decision points, that provide sustainable outcomes and options for responding to future change, and other states with less desirable options and fewer response options. In this model the goal of adaptation is to direct the evolution of the system so it stays in the zone of states with good outcomes and options, and avoid getting locked into other states. This places the focus on the function and capabilities of the social-ecological system, rather than focusing on anticipating and analysing specific sequences of states of the physical system.

Colloff et al. (2021) refined this model and incorporated the values-rules-knowledge framework for considering the societal context that enables and restricts adaptation decision making (Gorddard et al. 2016). In this framing of adaptation pathways, adopted in the Coorong Adaptation project, near-term adaptation action focuses on interventions that are strategically designed to address identified barriers that future decision makers might encounter resulting from lack of knowledge, ineffective 'rules' (institutions and norms), and unsympathetic 'values' (aspirations and preferences of stakeholders). Future transformational changes, climate-ready objectives (Dunlop et al. 2013) and key management decisions are anticipated primarily for the purpose of understanding the scope of changes that future decision makers might encounter and types of barriers to decision making they might face.

Having identified these barriers, they are analysed to understand their sources in society, that is: who might need to change or do something differently to turn the barriers into enablers? Near-term interventions are then co-designed so that the lead agency (DEW in this case) can readily implement the interventions, possibly in partnership with those parties that may need to change. This starts the process of overcoming the barriers and thereby creating conditions that might allow future decision makers to choose management options that are more effective in the face of transformational change. In this model of adaptation pathways, while future objectives and key decisions are anticipated by the analysts, it is expected that as the near-term actions take effect, analysts and stakeholders will have updated perspectives on what changes might occur, what values might be given preference and what management might be most effective, leading to a new round of identifying barriers and near-term enabling actions. Thus, the pathway unfolds for the implementing agency, over years and decades, as a series of near-term interventions informed by an evolving understanding of future changes, in a process that is made faster and more effective by deliberate adaptation pathway analyses.

This project draws on the observation in many systems in Australia and around the world that the level of climate change impacts that might be experienced in the longer term may be significantly different from current and near-term impacts, exceeding the capacity of current policy and management frameworks, requiring transformational adaptation responses that include institutional and societal changes as well as

physical management changes (Stafford-Smith et al. 2011; Wise et al. 2014; Gorddard et al. 2016; Colloff et al. 2017; Van Kerkhoff et al. 2019). In their study of the limits to adaptation in the Coorong, Gross et al. (2012) suggested that the nature of future change meant new institutional arrangements would be required to enable effective long-term planning, including evaluation of alternative adaptation options, integration of scientific, community and government perspectives, and incorporation of the diversity of values held for the CLLMM region. They specifically identify the need to develop visions for the CLLMM that address the interests of different regional stakeholders and incorporate ongoing climate-driven ecological change, and the need for adaptive processes to act on those visions given the considerable uncertainty associated with future climate, ecological and social change affecting the region.

The transformation task for a system can be represented as a transition away from the current way of managing the system to a future way that is more effective as the climate, and other factors, change over time (Figure 1).



Figure 1. Transformational adaptation conceptual model.

The current approach to decision making and management (blue wedge) becomes less effective over time, with environmental, ecological, and social change. In the future an alternative approach will be required, but it cannot fully be defined now (*multiple* orange wedges). Transformational adaptation can be thought of as the transition from the current to future approaches, as opposed to action to extend the current approach. There are likely to be many barriers to such transitions (red lightning bolts). Near-term actions can be undertaken now to address the future barriers and create conditions that will enable future adaptation (hexagons). These actions may be fully within the current approach or maybe at the edge of it, requiring some non-standard action. Steps to understand and enable transformational adaptation include: (i) envisaging what management success could be in the face of change (using the 'climate-ready' concept; Dunlop et al. 2013), (ii) recognising social and institutional barriers to future adaptation decisions (using the 'values-rules-knowledge' framework; Gorddard et al. 2016), (iii) identifying near-term actions and decisions that create options for future adaptation decisions (using 'adaptation pathways'; Wise et al. 2014).

1.3 Aims

The aim of the Climate Adaptation project is to focus on the needs of decision makers in the context of the potentially transformational impacts of climate change in the CLLMM. This *transformation* may be in the form of major changes in ecological dynamic, how people relate to the CLLMM or how it is managed. The

needs of decision makers to successfully navigate these issues extends beyond an understanding of the biophysical characteristics of these problems to include consideration of the values at play and the rules that might best enable decision making. In this context, *decision makers* include river managers and policymakers and also society as a whole, as these issues will need to be navigated collectively by all those with a stake in the CLLMM region, as well as in the Murray–Darling Basin (MDB; the Basin) more broadly, and the elected officials who represent them in multiple jurisdictions. Focusing on a *futures context* does not mean ignoring near-term objectives to restore health and minimise change in character. Rather, it involves helping to plan and implement near-term actions so that they can address such objectives and also lay the foundation for navigating harder decisions to come, and specifically to ensure near-term actions are not 'maladaptive^{3'}. By *focusing* on these broad, long-term and societal needs, we do not imply this project alone will meet those needs; rather, the project can contribute to helping DEW and other key stakeholders better understand what they can do in the near term to help shape the ongoing evolution of knowledge, societal preferences and institutional settings to enable effective adaptation decisions for the CLLMM, to maintain its local, national and international significance as it responds to future climate change.

This approach – engaging with the governance of adaptation – differs from a traditional biophysical analysis of impacts and adaptation actions by focusing jointly on the technical knowledge and on the social and institutional context. This approach will determine which outcomes for the CLLMM region will be deemed preferable and which actions can be chosen and implemented. It is guided by experience with emerging global transdisciplinary adaptation research (Abel et al. 2016; Gorddard et al. 2016; Wyborn et al. 2016; Colloff et al. 2017; Stafford-Smith et al. 2022), and the Australian Government's guidance on climate adaptation for Commonwealth agencies (CSIRO 2018).

Specifically, the project sought to follow these principles (derived from Van Kerkhoff et al. (2019)):

- 1. Co-produce knowledge with stakeholders so they have ownership of the process, the knowledge is credible, and they have the ability and opportunity to use it.
- 2. Understand the context of the CLLMM region, including past changes over decades, centuries and millennia, the diverse ways the Coorong is valued, the multiple environmental pressures on the Coorong and the current initiatives to manage them.
- 3. Navigate considerable uncertainty and diversity of views about the future dynamics of the CLLMM, recognising that future-oriented decisions will need to be made despite this uncertainty.
- 4. Accommodate significant climate change, including the prospect of continuing transformational change.
- 5. Enable adaptation by evolving the decision context, recognising that the future of the CLLMM will be shaped by the evolving understanding and preferences of multiple stakeholders including people across Australian society and changing institutional arrangements across agencies, sectors and jurisdictions affecting layers of policy and decision making.
- 6. Identify opportunities for near-term management actions and engagement processes to help evolve decision contexts to provide future managers with the knowledge, stakeholder support and

³ Maladaptive refers to decisions that may be reasonable if evaluated only in terms of short-term outcomes but that make it harder to achieve successful outcomes as climate change becomes more severe. A classic example is the use of infrastructure to defend assets against a risk, which encourages further asset development, leading to much greater exposure when the defensive infrastructure is eventually overwhelmed by climate change.

institutional environments that create more-effective options for managing the Coorong as the climate continues to change.

Key activities and outputs of the Climate Adaptation project are shown in Figure 2. This adaptation pathways analysis builds upon the previous activities of the project, which are summarised as context in section 2.



Figure 2. Activities of the HCHB T&I Climate Adaptation project.

Activities associated with core project analyses and technical reports are underlined. As well as produce technical reports, the project aimed to build DEW's capacity to address transformational change.

The adaptation pathways analysis had three components:

- 1. characterise key elements of visions for a healthy CLLMM region in the face of climate change, using the climate-ready objectives concept
- 2. identify key management and policy decisions that might need to be made to achieve the climateready objectives as climate change progresses
- 3. identify key barriers that currently exist to making those decisions, and scope near-term interventions that can create the enabling conditions necessary for overcoming the barriers.

2 Context

2.1 Past change – current management

There is a long history of change in the CLLMM region, both environmental and social (Mosely et al. 2019). The River Murray Estuary formed as a result of tectonic subsidence over the past 66 million years (the Cenozoic era), and sea level fluctuations from 2.5 million to 11,700 years ago (the Pleistocene). The Coorong itself is thought to have formed by the creation and joining of a series of coastal barrier islands in the mid-Holocene by the combined influence of marine sediment transported by sea rising across the continental shelf, and freshwater flows from River Murray (Bourman et al. 2019). During the early Holocene, south-east Australia was warmer and wetter, and flows from River Murray were likely larger, delivering fluvial sediment as well as freshwater. There is evidence that the Lower Lakes were larger at this time than they are today, as a result of both higher sea levels and greater freshwater inflows. Over the last 6,000 years the climate has dried resulting in reduced freshwater flows, with the most recent drying phase commencing about 150 years ago.

The First Nations people began living in the Coorong somewhere between 18,000 years (Ngarrindjeri Nation 2007) and 8,000 years (O'Gorman 2016). Ngarrindjeri creation stories include changing coast lines due to rising sea levels and a time when Kangaroo Island was accessible by foot. Contact with Europeans began in about 1810, when European sealers began operating on Kangaroo Island (Ngarrindjeri Nation and Hemming 2019), while British colonisation began formally in the 1830s (O'Gorman 2016) under the *Letters Patent establishing the Province of South Australia*, of 1836.

Pastoralism was well established in the region by 1850, followed by the establishment of various towns and settlements on the lake shores. Wheat farming expanded in the early 1860s and 1870s, initially struggling with disease and nutrient issues. The River Murray became a major transport route for supplies and agricultural produce, with paddle steamers passing through the Murray Mouth and along the coast (DEH 2010). From the 1880s, irrigated agriculture began to drive rural development along the River Murray. The case for irrigation was further cemented as stream flows reduced through the Federation Drought (1895 to 1902) (DEH 2010). In 1915, the River Murray Waters Agreement offered a water sharing plan for Basin States and a proposal for constructing infrastructure along the river to help regulate it (DEH 2010).

Australian colonies were holding discourse about how to regulate the River Murray well before Federation – the first conference about managing the river was held in 1863; the Intercolonial Conference on Navigation and Management of River Murray (SLSA 2010). Developments in irrigated agriculture upstream have had major consequences for the CLLMM region. By 1900 the combined impact of drought and upstream water extractions was causing saline incursions in the system (DEH 2010). A century later, consumptive water use across the MDB has reduced average annual streamflow at the Murray Mouth by 61 percent, and that while the Murray Mouth would have been closed 1% of the time prior to development, it was estimated to be closed 40% of the time under 2008 levels of development (CSIRO 2008). The River Murray Commission built five barrages at the southern end of Lake Alexandrina between 1935 to 1940 in order to curb ingress of saltwater (DEH 2010).

Reduction in inflows to Lake Alexandrina greatly reduced flow of freshwater reaching the Coorong, leading to a net inflow of sand through the Murray Mouth and the requirement for dredging, originally temporarily and now permanently, to maintain the connection between the estuary and the Southern Ocean (Thom et

al. 2020). The reduction in freshwater inflow was exacerbated by construction of a scheme that drained wetlands to the southeast of the Coorong and diverted the flows to the south, rather than into the Coorong.

In the last 30 to 40 years, management of the CLLMM has been based on an intricate network of institutions and processes. These can be represented for four intersecting and evolving stories of change:

- 1. **Basin scale institutions** governing the allocation of water to jurisdictions across the Basin. Notably, these have included establishing caps on consumptive water use in 1996 and 2012 and the recovery of water from consumptive uses to increase the amount available for the environment.
- 2. Local / state management of the site, as a Ramsar site and National Park, including regulating flows through the barrages to achieve various ecological outcomes. This has also included three major research and management initiatives, the second two in response to the ecological impact during the Millennium Drought, Coorong, Lower Lakes and Murray Mouth ecology (CLLAMMecology), CLLMM Recovery and HCHB (focusing especially on the delayed recovery of the South Lagoon). This investment in, and understanding about, the CLLMM has supplied knowledge for decision making, management and deliberation by stakeholders.
- 3. Local community engagement and involvement in setting priorities for recovery and management objectives, as well as use of environmental water. The community experienced significant impacts during the Millennium Drought and had significant engagement with DEW during that time. Consequently, the community has come to expect a high level of information from, and engagement with, DEW.
- 4. **First Nations** as Traditional Owners and native title holders for the site, have a history of good engagement with DEW and development of their own management and governance plans (e.g. Ngarrindjeri Nation 2007). First Nations groups have experienced enormous change, affecting cultural connections and obligations to country (for instance, construction of the bridge to Hindmarsh Island eroding First Nation's confidence that their perspective will be respected).

The following themes are commonalities in the stories presented above:

- Water scarcity: even without drought, trade-offs between consumptive uses and environmental flows across the Basin restrict flows into the CLLMM resulting in constant trade-offs within the CLLMM about managing components of the system. People in each of the four stories above have had to think about and work with these trade-offs.
- **Millennium Drought**: while the full ecological impacts of the drought continue to unfold, it's worth noting that there were also significant social and institutional impacts, particularly, creating a social license for institutional action. It clarified the vulnerability created by freshwater extractions and united individuals under a common cause in the stories told above.
- **Ramsar listing**: the Ramsar listing of the Coorong and Lakes Alexandrina and Albert Wetland, and the consequent legal obligations, have been an important influence on the management of the region and has had interactions with each of the four stories told above.
- **High passions**: individuals have experienced and operated with high stakes, contested ideas about the past (e.g. when and how fresh Lower Lakes may have been) and future; as well as deep care and passion for the region.
- **Constant change**: change is the norm for the CLLMM, it occurs at multiple spatial and temporal scales, and it is very likely that climate change will lead to further significant change affecting each of the story themes above. A key observation is the creation in the Basin of new institutions to deal with emerging problems. This started with various institutions created to facilitate navigation and

manage over-extraction and has been concerned with implementing the national water reform agenda of improving water use and securing water for the environment⁴.

These narratives of change characterise the basis from which people valuing and managing the CLLMM will respond to future climate change, including the possibility of significant ecological change from further reductions in inflows and rising sea level.

Current arrangements appear not to be adequately supporting the range of values people hold for the CLLMM, given there has been a long-term decline in health of the Coorong South Lagoon. There is widespread recognition that climate change could lead to further change across the CLLMM. Current management efforts focused on near-term recovery may be insufficient for the longer-term challenges of climate change. Consequently, there is a need to scope these future challenges and explore the characteristics of institutional arrangements that might be required to address them.

Dunlop et al. (2016) define 'climate readiness' as the extent to which a management objective or decisionmaking institution can accommodate large climate change, increasing uncertainty and complexity, and climate impacts on multiple values. A preliminary scan of the system of decision-making institutions affecting the CLLMM suggests variable levels of climate readiness. The following features demonstrate climate readiness:

- the people of the CLLMM and other stakeholders (including policymakers, researchers and other interested communities) have extensive experience being confronted with large change, making sense of it, reorganising and making decisions in response
- high-level objectives of institutions express an intention to serve multiple values
- diverse stakeholders including First Nations, industry and other communities are deeply involved in CLLMM water management, on-ground works and infrastructure decision making. Programs like HCHB are actively building that capacity so that it endures beyond the life of any one initiative and stakeholders can be well informed about the state of the Coorong, re-evaluate their preferences, and be engaged in decision making as change occurs
- an enduring and strengthening capacity for knowledge generation and sharing that builds a sophisticated understanding of the dynamic complexities of the CLLMM system and enables context specific preferences to be formed and incorporated into decision making.

The following features demonstrate the beginnings of climate readiness that could be nurtured into enabling greater climate readiness:

- the history of water reform in the Basin has demonstrated a capacity to create new purpose-specific institutions to address emerging issues associated with novel and complex challenges, and that capacity could be developed to enable adaptation to transformational climate change
- local and MDB-scale institutions continually evolve. This includes reorganising to cooperate and work within new national institutions, responding to reviews, and adapting to new circumstances. This

⁴ **Institutional work done** (partial list): Forming a cross-jurisdictional platforms, agreement to cooperate and manage the MDB as a shared resource, coordinating the construction of infrastructure, adding water quality to MDB water agenda, stopping further extraction, separating land and water, establishing markets to trade entitlements, establishing that entitlements are 'share of a common pool', operating a mechanism to adjust that pool, establishing the environment has a right to water, agreement to recover environmental water, mechanisms to recover water, mechanism to hold and use that water creating a mechanism to recover water, evaluation of water arrangements.

Institutions (agreements and agencies) crated to do that work (partial list): Cowra conference (1902), River Murray Waters Agreement (1915), River Murray Commission (1917), River Murray Waters Agreement, MDBC (1985, 1993), 1996 Cap on extractions, National Water Initiative (2004), National Water Commission (2004), Water Act (2007), MDBA (2008), Inspector-General of Water Compliance, Commonwealth Environmental Water Holder, Guide to the Proposed Basin Plan (2010), Basin Plan (2012), Water trading rules (2014), SDL, Environmental Watering Plans (2015), SDLA (2017), Basin Plan Evaluation (2020).

evolution is an incremental, but sustained, response to large change, uncertainty, complexity, and multiple values

- multiple values are incorporated in decision making, but processes need to evolve to ensure that
 values and preferences are based on consideration of *anticipated* large change and the full suite of
 values held for the CLLMM are considered, so that shared objectives can be developed about
 managing the system in a changing climate
- there is a good understanding about the state and dynamics of the CLLMM; this understanding has
 evolved in response to changing circumstances as a result of a system of research, monitoring and
 information sharing that is trusted, supported by institutions, and integrated into decision making
 for increased accountability, adaptability, and responsiveness to diverse values
- decision makers are more accountable to an increasingly diverse range of stakeholders in South Australian, and decision-making processes are becoming more inclusive and transparent, supporting ongoing trust-building and learning from experience
- there is strong awareness that many current aspirations will not be feasible under future change and acknowledgment across stakeholder groups that resulting tensions need to be resolved, even if there are not yet formal mechanisms for doing so and there is no shared understanding of what CLLMM objectives might be appropriate in a future with less water
- water reform, the CLLMM Recovery program and other initiatives have demonstrated the capacity to respond to crisis, but there is less evidence for a capacity to act in anticipation of large, future change.

The following themes could potentially impede climate readiness:

- the CLLMM system is highly complex and influenced by multiple physical and institutional processes occurring at multiple scales, making coordinated, effective, and timely responses to anticipated large change particularly challenging
- the nature and magnitude of future, sustained change is likely to challenge existing values and understandings that are largely grounded in the expectation of a stationary system that can be restored to a desired past state
- one of the pivotal institutions shaping decision making about the Coorong, the Ramsar Convention, revolves around the concept of maintaining 'ecological character' that is usually interpreted as variable but within fixed bounds. Management objectives and narratives that are founded in such a stationary perspective will be barriers to making different types of decisions to adapt to significant climate change
- stated management objectives may not be realised under future reduced water availability and associated uncertainties. There are limited formal processes for resolving this to the satisfaction of all stakeholders
- there is a reluctance to contemplate large change in the future due to concerns that doing so will create the perception that large change should be acceptable now, even if it is currently avoidable, leading to loss of negotiation power and legal protections
- current decision making relies on good and timely understanding of the state and dynamics of the system, supported by effective mechanisms to 'fill knowledge gaps', however this will become a decreasingly effective strategy as climate change rapidly increases uncertainty and complexity
- there is an absence of agreed assessment and reporting methods for evaluating the capacity of programs to protect diverse values in the face of large change in the complex CLLMM system.

2.2 Impacts of climate change

The three major drivers of change to the CLLMM, likely to result from global climate change, are decreased rainfall, increasing sea level and warming of the land and water. Increasing temperature and rising sea level are projected with very high confidence for the near (2030) and long term, and there is high confidence that cool season rainfall will decline later in the century (2090) (Timbal et al. 2015).

The projected rate of drying across the MDB ranges from slightly wetter to 40% decrease in inflows to the River Murray by 2090 (Timbal et al. 2015; Zhang et al. 2020). Drying will likely also reduce freshwater inflows from the South East Drainage System and Eastern Mount Lofty Ranges tributaries. Despite the decline in average rainfall, there is expected to be an increase in the intensity of rainfall events (Timbal et al. 2015), leading to high confidence in an increase in the intensity of extreme rainfall events, and medium confidence in an increase in the time spent in drought. The extent to which those changes translate into changes to freshwater input to the CLLMM will depend on catchment hydrological processes, how river operation rules respond to reduced inflows and any future changes to water entitlements.

Sea level rise will be experienced as a gradually accelerating smooth rise due to thermal expansion of ocean waters. Projected sea level increases at Victor Harbor are from 0.39 to 0.84 m by 2090 for a high-level climate change scenario (RCP 8.5), relative to 1986–2005 baseline, and could be even higher under certain conditions (Timbal et al. 2015). Tidal activity and storms will provide short-term variability. Faster rates and much higher levels of change are possible if icesheet and glacier melt becomes significant (Timbal et al. 2015). Sea surface temperatures are also expected to increase by between 1.5 and 3.4 °C (by 2090 under a high emissions scenario), and the sea will become more acidic with increasing atmospheric carbon dioxide concentrations.

The MDB has already warmed by about 0.8 °C since 1910 (Timbal et al. 2015). Under a higher emissions scenario (RCP 8.5) temperatures in the MDB are expected to increase by between 2.7 and 4.5 °C by 2090 compared to 1986–2005, and between 1.3 and 2.4 °C for an intermediate emissions scenario (RCP4.5) (Timbal et al. 2015). The frequency of hot days and maximum temperature reached on hot days are both expected to increase significantly. In the South Australian MDB and South Eastern South Australian region, maximum daily temperature is projected to increase 2.7 to 4.5 °C and up to 5.0 °C in spring under a high emissions scenario (Charles and Fu 2015).

The high confidence in the key drivers means that they can be integrated into a single conceptual understanding of change that is robust, with the uncertainties being in the details of the magnitude, rate and specific impacts of change. These specifics will be determined by complex, unpredictable ecological and societal responses.

2.3 Greatest plausible change scenarios

The CLLMM is expected to change as the climate continues to change over coming decades, leading to a cascade of ecological impacts, potentially significantly altering the character of the CLLMM. Scenarios were developed to help people imagine, explore and prepare for the consequences of these possible changes (described in Rees et al. 2022). A single, robust trajectory of change was developed by overlaying the key drivers of increasing temperature, decreasing inflows of freshwater and rising sea level. The trajectory has three phases: a drying phase driven by decreasing freshwater flows and increased evaporation; a transition phase as the influence of sea level rise increases; and a phase where water levels across the CLLMM are dominated by rising sea level. The trajectory of change provided the basis for development of two scenarios

of change that lie at different times along the trajectory of 'greatest plausible change' in the physical and ecological dynamics as the CLLMM system responds to climate change.

The scenarios are intended to be compelling descriptions of how the system may change over the longer term (50–100 years) to help people vividly imagine the ecological and social consequences of future transformational changes and identify actions that could be taken now to prepare more effectively for a future with uncertain but potentially significant change. The picture is largely qualitative, as there is considerable uncertainty about many aspects of climate change and its impacts, but the quantitative information that is provided about climate change and ecological sensitivities gives a sense of the magnitude of possible future ecological change. The two scenarios were each developed for the Lower Lakes and Coorong.

- Lower Lakes Scenario 1: minimum inflows. Combined inputs from freshwater River Murray inflows and seawater (i.e. through sea level rise) to the Lower Lakes are at a minimum. There is an increase in the frequency of low flow years, and the frequency of medium and high flow years decreases. Average water levels in the Lower Lakes are reduced, with significant water level fluctuations within years and between drought and wet periods. Acid sulfate sediments (ASS) are exposed and periodically flooded, increasing acidity and the concentration of metals. There is frequently reduced connectivity between the Lakes, and salinity increases. Evapo-concentration processes and reduced freshwater flushing results in increasing nutrient concentrations that drive algal blooms, water quality deterioration, anoxic water, rapid nutrient cycling and impacts on benthic invertebrates. There are significant changes in the abundance and distribution of emergent and submerged macrophytes with the decreased water levels and increased turbidity. There is an increase in terrestrial vegetation and weeds fringing the Lakes. Barrage flows often fail to meet current management targets and fishways only operate during wet seasons and years. Loss of habitat and connectivity for fish communities has led to localised extinction of small-bodied threatened freshwater fish. Diadromous fish abundances are greatly reduced, and potentially zero, due to system disconnection. Waterbird diversity and abundance has generally declined although some taxa may increase in abundance due to declines in habitat elsewhere in the region. There is increased proliferation of salt-tolerant species in Lake Alexandrina but salt sensitive taxa are greatly affected.
- **Coorong Scenario 1**: **minimum inflows**. Inputs from freshwater to the Coorong are at a minimum and sea level rise is not yet having a significant impact. There are long periods with no effective freshwater flows over the barrages, and the North and South lagoons are poorly connected annually for long periods of time. The South Lagoon is hypersaline most of the time and there is a self-reinforcing cycle of nutrient accumulation, algal blooms, sediment deoxygenation and loss of benthic invertebrates, plants and animals. There is a loss of estuarine habitats and reduction in habitat diversity, and *Ruppia tuberosa* and other aquatic macrophyte and the species that they support are no longer present in the South Lagoon. While there is an increase in some bird taxa, overall, populations have declined.
- Lower Lakes Scenario 2: sea level rise dominates. As sea level increased, exchange of seawater between the Southern Ocean and the Lower Lakes has become significant. Water levels in the lakes are higher than present-day levels and are much more stable, with a tidal influence near the estuary. Significant portions of the barrier islands are frequently inundated. Salinity in Lake Alexandrina is variable, from largely fresh after prolonged periods of high River Murray flows, through to brackish to marine during protracted dry periods. Salinity is less variable and high in Lake Albert. There is no new exposure of ASS. Freshwater habitat declines significantly but remains permanently present in

small areas and expands during periods of significant freshwater inflow. Salinity is high in Lake Albert. There is a loss of freshwater plant taxa but salt-tolerant macrophytes have colonised fringing habitats. Estuarine taxa are now a key part of the fish and macroinvertebrate community. Diadromous fish and other migratory species are present in the lakes and upstream.

• Coorong Scenario 2: sea level rise and high exchange. Sea level rise is the dominant driver of water level in the Coorong. Increased tidal influence and higher water levels result in high rates of exchange through the Murray Mouth, into the Coorong and between the North Lagoon and South Lagoon, which have good connectivity most of the time. There is less seasonal variation in water level and salinity. There remains a gradient of increasing salinity from the Murray Mouth to the South Lagoon. The South Lagoon continues to be hypersaline, but the salinity levels are lower than in Scenario 1 and avoid very high peaks. Nutrient concentrations are lower than Scenario 1 due to increased flushing exchanges with the sea along the Coorong and possibly enhanced with pumping or other infrastructure, however nutrient concentrations remain relatively high. The system is predominantly marine, selecting for marine taxa, with occasional estuarine habitats re-establishing in some locations for short periods after episodes of significant freshwater flow. Periods of higher salinity lead to temporary loss of estuarine-dependent fish species. There has been and continues to be significant change in the location of habitats, including the loss of existing and creation of new saltmarsh and mudflats as coastal land is inundated.

The scoping and description of these scenarios focused on the physical and ecological outcomes, rather than the policy, management and infrastructure options that might contribute to them, however they do include some management-related assumptions. For example:

- Scenario 2 assumes high exchange of sea water with Lake Alexandrina, so sea level is the primary driver of average water levels in the lakes.
- Each scenario assumes allocations of water for the environment specified in the Basin Plan will be implemented in full and will not be significantly increased or decreased in the face of climate-related Basin-wide decreases in inflows.
- Each scenario assumes that the Murray Mouth will remain open, with dredging where needed and this may need to be enhanced if rising sea level leads to increase in sand transport into the estuary.

2.4 Vulnerability assessment

Thinking about, discussing, and planning for climate change is difficult for many reasons: the change is large, and likely to be transformational for ecosystems and people; there is much uncertainty about what the impacts will be on CLLMM ecosystems and people's relationships with them; and there are diverse and deeply held values at stake. The HCHB T&I Climate Adaptation project conducted a *preliminary* vulnerability analysis of the CLLMM system (Grigg et al. 2022) using the methodology developed for the Australian Government by CSIRO (Dunlop and Grigg 2019).

Part of that analysis included developing potential future scenarios to provide common, evidence-based assumptions for exploring implications of future change as described in section 2.3. We conducted workshops with DEW staff to deliberate over each feature while being mindful of assumptions and uncertainties and established a shared understanding of which attributes are likely to change which are likely to persist in the face of climate change. Together with DEW, we used a structured series of analysis questions to make a preliminary assessment of what increases or decreases the vulnerability of the CLLMM to climate change, and implications for management.

It was also an opportunity to introduce new concepts and tools to DEW to enable them to think about transformation change in a structured way, liberated from the currently dominant, stationary narrative of preservation and restoration, as well as an understanding of vulnerability beyond biophysical aspects (i.e. vulnerability as 'failure to protect values that might persist', as opposed to 'likelihood of change in character or loss of values'). This process drew on key lessons from the Millennium Drought, including about the risks of transitions to unhealthy system states that become ecologically 'locked in' and are difficult to recover from even during periods of favourable conditions.

The assessment identified that with a sustained reduction in rainfall and River Murray inflows (Scenario 1), there is likely to be a more frequent and sustained return to conditions experienced during the Millennium Drought, with low water levels, poor connectivity, salt and nutrient accumulation, hyper-salinity and elevated nutrient availability in the South Lagoon, and disruption to food webs and the lifecycle of many species. These changes would correspond to changes in character for most valued features, and would likely lead to the loss of many societal values associated with CLLMM. Despite these changes, it was assessed that a range of values associated with the site could persist and the site would still likely meet the Ramsar criteria for a Wetland of International Importance, assuming suitable management.

In contrast, with sustained increases in sea level and action to ensure effective exchange of seawater between the Southern Ocean, the Murray Estuary, the Lower Lakes and the Coorong (Scenario 2), the system could experience a general improvement in ecological health (compared to Scenario 1) and significant spatial rearrangement in habitats and species. In particular, there would likely be an improvement in the condition of the South Lagoon with a reduction in peak salinity and nutrient levels. However, in the Lower Lakes there would be a significant decline in the abundance and extent of freshwater habitats and species. These critical components were assumed to persist in low abundance during dryer times when salinity would increase, then expand during high flow events when salt was flushed from the system. These changes would likely correspond to a change in the ecological character of the Lower Lakes, and a partial restoration of ecological character for the Coorong (compared to Scenario 1). The assessment suggests that despite the significant hydrological and ecological changes most of the societal values associated with the CLLMM would be retained, notwithstanding that the way in which they are experienced might be altered (in different locations or abundances), but that there would be significant loss of societal values that were associated with the declining freshwater communities and species.

Participants found the use of the two scenarios and the deliberate attention to attributes that might persist as well as those that are likely to change, and mapping of different expression of values to those attributes, to be useful. It enabled them to take a long-term perspective of the CLLMM, recognise that the system has the potential to retain significant values despite significant ecological change and uncertainty about it, and that there are clear opportunities for management to increase the persistence of many values.

3 Methods

This adaptation pathway analysis used established climate adaptation methods (created and applied in other contexts by CSIRO), with content from DEW staff members and researchers involved in HCHB obtained via workshops and previous project activities. Workshop participants were identified by DEW and selected for a broad variety of disciplinary expertise. This analysis is identified as a *preliminary* analysis, recognising that the project did not engage First Nations or the broader community, and that they hold values for the CLLMM not included in the analyses, and they may have different preferences for how the CLLMM might be managed in the face of transformational climate change.

There were multiple objectives for this activity:

- generate insights about the CLLMM system for use in planning and management, to help DEW prepare for potentially transformational climate change
- build an awareness of the issues involved with understanding and addressing future change
- introduce and develop competency with some new concepts to help do this and support subsequent engagement with First Nations and the community about transformational change
- progress conversations within DEW about addressing future transformational change.

Workshops were conducted using MS Teams and workshop data were collated on a collaborative online whiteboard (Miro⁵) for further analysis. Ethics permission was sought and obtained from the CSIRO Human Research Ethics Committee (application 078/21). More detailed methods follow in subsequent sections.

3.1 Climate-ready objectives

Climate-ready objectives were developed for the CLLMM in recognition that existing objectives may not be feasible or fit-for-purpose in the face of long-term ecological change resulting from climate change (Pittock et al. 2010; Dunlop et al. 2013; Finlayson et al. 2017; Dunlop and Grigg 2019).

The climate-ready framing for conservation objectives provides criteria to help develop objectives that remain effective in the face of significant climate change (Dunlop et al. 2013, Dunlop and Ryan 2016). Climate-ready conservation objectives accommodate:

- a large magnitude of ecological change and significant loss
- considerable uncertainty and complexity in the detail of ecological changes
- different impacts on multiple valued aspects of biodiversity.

Preliminary climate-ready objectives were developed in a workshop conducted on 24 May 2022. We used the *HCHB Action Plan* (DEW 2019) management goals as a starting point:

- The Coorong is a healthy, productive and resilient wetland system that maintains its international significance.
- Filamentous green algae is reduced to manageable levels, allowing for expanded distribution and improved health of aquatic plant meadows.
- Fish and bird communities are healthy and thriving.

⁵ www.miro.com

- Water quality and environmental outcomes improve as a result of optimised water delivery to the Coorong.
- First Nations and local communities are empowered and engaged in managing the Coorong.

In previous workshops, we heard that these HCHB goals were designed with future environmental change in mind: they are not prescriptive about which species should be there and nor do they aspire to lock in a particular reference or historic state. At the same time, these goals are consistent with maintaining current condition; an important feature of climate-ready objectives is that they explicitly acknowledge that the current condition will change and will not be maintained. For this reason, the workshop activity involved being more explicit about what will change, and what can be maintained in the face of that change.

3.2 Adaptation pathway

An adaptation pathway for the CLLMM was developed to explore the temporal dependencies between drivers, changes in the CLLMM and various key decisions that could ensure the climate-ready objectives are met on a trajectory of climate through Scenario 1 to Scenario 2. The decisions selected for the adaptation pathway were those that had emerged over this and previous workshops.

Information about future changes and decisions that might arise from them, elicited in previous project activities, was distilled and represented graphically in a Miro board, this was validated and updated with DEW staff in a second workshop held on 2 May 2022 and then revised by the project team. The information included:

- key biophysical and other external change events
- important uncertainties
- key decisions, including the different options available to decision makers
- enabling conditions needed to support the decision makers
- management and policy actions that would support development of the enabling conditions.

These various factors were arranged in the diagram into two drivers, and three key outcome themes:

- Driver: Rainfall / River Murray inflows
- Driver: Sea level
- Theme 1: Lower Lakes: water level, salinity and nutrient status, ecological condition
- Theme 2: Exchange between the Southern Ocean, Murray Estuary and the Coorong (enabling transport of salt and nutrient)
- Theme 3: South Lagoon: salinity and nutrient status, ecological condition.

The factors were arranged and linked with arrows so the temporal dependencies were explicit. Contemporary issues were located to the left of the board, issues corresponding to Scenario 1 (low inflows to Lake Alexandrina) toward the centre of the board, and issues associated with Scenario 2 to the right of the board. Location on the board corresponds to the unfolding of events, not the linear progress of time. Actions that could be undertaken in the near term to enable orderly strategic consideration of key decisions were highlighted with a red star. The project team then developed narratives describing the key decisions. These were based on discussions about these issues with DEW staff and HCHB researchers in the adaptation pathways workshops and over the course of the Climate Adaptation project. They included why and when the decisions might be encountered, some of the main considerations involved in the decisions, the social

and institutional conditions necessary to enable the decisions, and near-term actions that may help create those conditions (see sections 3.3 and 6).

3.3 Barriers, enabling conditions and near-term interventions

The first workshop explored the types of changes in management or policy that may be required to implement the climate-ready objectives in the future and discussed the types of barriers or constraints restricting those decisions that might currently be in effect. Past analyses and engagements of the Climate Adaptation project were also reviewed for potential barriers and issues that had been previously identified (summarised in section 2). These included an analysis of the network of institutional factors, at local, state, Basin, national and international scales, that shape decision making in the CLLMM; a summary of how these have evolved over the last 40+ years; and a preliminary screening of emergent properties or themes in that system that might hinder or enable future adaptation.

The barriers to decision making experienced by DEW can be conceptualised as arising from the knowledge, values and rules that prevail upon or are available to DEW as part of the societal and institutional decision context in which DEW operates (Gorddard et al. 2016). The current decision context enables DEW to effectively make many management actions. This analysis focused on actions that DEW might want to take in the future, as a result of climate change, but that are currently restricted due to factors in the decision context outside of their direct control. These barriers stem from society, including decision makers in other jurisdictions, researchers and different communities with a stake in the CLLMM. Addressing the barriers, to creating enabling conditions for DEW, requires these other people to do something differently, such as make different rules, express different preferences or provide different knowledge.

The logic is that:

- should DEW wish to take these actions in the future, the enabling conditions would need to be in place first: the presence of those conditions would give DEW many more options for responding to climate change in the future
- 2. DEW cannot force these societal changes, but there are things that DEW could do to *encourage* the evolution of those enabling conditions
- 3. it could take decades for that evolution to occur, so it needs to be addressed strategically and proactively.

There are likely to be many activities DEW could undertake in the near term to stimulate those changes in the decision context. To be effective, these actions would often need to be done in partnership with those people who are responsible for or directly influence the barriers, people who can have the agency to help create the enabling conditions. These activities by DEW can be thought of as 'interventions' to provoke change in the 'complex system' of the CLLMM decision context (Snowden 2005; see glossary entry for 'Interventions'). These interventions could be as simple as requesting researchers study a possible future change process or providing information about future change in the CLLMM to stakeholders to help them develop future-oriented, as opposed to backward-looking, preference. Or they could be more ambitious, such as arranging a cross-jurisdiction review of emerging water management issues, so that Basin partners and stakeholders gain a more intimate understanding of the issues they, and South Australia, may face, and in the process become supportive of consideration of future transformational change at the Basin and site scale.



Figure 3. A generic theory of change for enabling adaptation in the CLLMM.

Near-term interventions by DEW (hexagons) stimulate learning by others (clouds) that leads them to change their behaviour or preferences, leading to enabling conditions (stars) in the decision context (Gorddard et al. 2016), that support future adaptation decisions by DEW (oblongs).

The second workshop explored the nature of the barriers, where they originate from (what groups or agencies outside of DEW) and the near-term interventions to provoke enabling conditions. Further analysis was conducted by the research team to cluster issues and shape logical sequences (like a theory of change) for flipping the barrier to an enabling condition (Figure 3). A narrative for each barrier / enabling condition was then described with the following structure:

- <u>DEW</u> near-term intervention: actions taken by DEW in the near term to address the barrier and enable future adaptation decisions
- Learning: what others might learn from DEW's actions
- Enabling conditions: changes in behaviour by others that create the enabling conditions for DEW
- Future decision / management: decisions or actions <u>DEW</u> could then be enabled to take.

For each enabling condition, the above steps were described in the reverse order, with the desired outcome first and then working back through the steps needed to achieve it.

3.4 Contributions to project analyses and findings

During the course of this project, questions were occasionally asked about the source of the findings. 'Are they the research team's opinions?' 'Are they the opinions of workshop participants (e.g. DEW staff)?' 'Are they deduced from published literature?'. The answer is, the findings are an inextricable blend of all these. Below we outline why this in inevitable for work investigating long-term issues in social, institutional and ecological system.

This work set out to explore:

- the types of decisions that might confront DEW and others in the face of potentially transformational climate change
- the conditions that might be necessary, in the future, to make these decisions effectively
- the types of actions or interventions that could be take in the near term to create those enabling conditions.

Any actual transformational decisions that will be made by DEW in the future will be made based on extensive analyses, consultations and policy reforms, which will be conducted incrementally by DEW and partners over a period of decades. The intent of the Climate Adaptation project was to start scoping the nature of that required enabling work. Near-term interventions to help provoke the development of enabling conditions are the primary output of this analysis.

To scope those interventions, we and those consulted in this project, had to have an understanding of the types of decision problems that would confront DEW and partners in the face of transformational change in the CLLMM. We constructed scenarios of environmental and ecological change and possible key management decisions. These scenarios were a blend of publicly available scientific information, publicly available policy documents, additional technical information from DEW, expert knowledge from DEW and HCHB researchers, and the CSIRO team's knowledge and experience with transformational climate adaptation. The scenarios also included various assumptions or settings that were chosen when there were key uncertainties. Some of these uncertainties and assumptions were significant and were discussed at length in expert workshops, and the rationales for the chosen setting were documented (e.g. concerning future levels of hydrological connectivity; rates of transport of salt, nutrients and sediment; the effectiveness of local management; the effectiveness of water management; regimes of variation in flows and salinity; responses of different groups of species to that variation; societal preferences).

These and many other uncertainties may not be fully known until during or after transformational changes have started occurring. However, by carefully imagining these changes, it is possible to anticipate the broad types of decision challenge that will confront DEW and others, and the types of societal conditions (knowledge, values and rules) that DEW may need to make these decisions effectively. Then, considering DEW's current scope of work, it is possible to imagine activities that could be done to help create the enabling conditions.

Over the course of eight activities in the Climate Adaptation project, the research team drew on published literature, unpublished analyses and policy documents, and on many discussions and workshops with DEW and HCHB researchers. With this we drafted scenarios, climate-ready objectives, key decisions, barriers/enabling conditions and near-term interventions. Some drafts were rejected, others were validated and enriched in workshops, further exchanges with DEW and consultations with additional technical experts. These products were then further analysed, synthesised and documented by the research team drawing on all of this information and their knowledge of transformational adaptation. It is not feasible to untangle which parts of which findings were based on any one source of information.

While the details in the scenarios are quite uncertain, we contend that the core elements of the scenarios are robust, to enable consideration of 'greatest plausible changes'. Similarly, we believe the nature of the decisions that were identify are robust, along with the barriers and enabling conditions. Noting, this study focused on DEW, as a *preliminary* analysis, and additional important issues, decisions and enabling conditions would be identified through engagement with other groups.

The process to develop the project outputs was carefully designed, detailed, extensive and highly consultative. However, we suggest that ultimately the legitimacy, credibility and relevance of these project outputs rests primarily on:

- the logic of the narratives that link the drivers of change, scenarios, key decisions, enabling conditions etc
- the extent to which these narratives are compelling to people interested in the CLLMM, even if they are challenged by them
- the intended use of the outputs.

Insights from the research are 'offered', to be considered by users, not to be taken as facts or prescriptions. The analyses are labelled preliminary, in part due to the limited consultation, but also recognising that analyses like these can never be definitive, and they should be updated periodically as more information about the future becomes available, preferences evolve and opportunities for action change.

We note this approach is different from quantitative biophysical analyses, based on experiments, field analysis and modelling, that are more familiar to many people interested in the CLLMM. However, we suggest that any attempt to seek to understand the nature of coupled social-institutional-environmental challenges facing future decision making will need to draw on and integrate a range of knowledge types similar to those that we used. Indeed, this is part of the ambiguous reality we, as society, need to become comfortable with if we seek to proactively plan to navigate future transformational changes in the CLLMM or elsewhere.

4 Climate-ready objectives

The development of climate-ready management objectives provides an explicit way to think about whether management objectives will be effective under climate change (Dunlop et al. 2013). A climate-ready objective articulates what management is seeking to maintain, while also being explicit about what is expected to change. A typical syntax is: 'Maintain [features that can persist] while there is change in [features expected to change]'.

Discussions in Workshop 1 generated seven provisional climate-ready objectives for the CLLMM (Table 1). The first six objectives were drafted as long-term objectives for when sea level rise is the dominant driver of water levels and salinity in the system. The first five of these were derived from objectives in the *HCHB Action Plan* (DEW 2019) which were then modified to explicitly accommodate large ecological change, high levels of uncertainty and complexity, and multiple societal values. The sixth objective is specific to freshwater species, and it was added due to their specific vulnerability to Scenario 2, as highlighted in the Activity 6.6 preliminary vulnerability assessment (Grigg et al. 2022). The final objective in Table 1 addresses specific issues associated with the expected transition period where the CLLMM is affected by increased warming and evaporation and reduced freshwater inflows (Scenario 1) prior to significant impacts of sea level rise.

Table 1. Provisional climate-ready objectives for the CLLMM.

PROVISIONAL CLIMATE-READY OBJECTIVES*	RATIONALE AND COMMENTS
1. Maintain ecological health, productivity, resilience and	Original HCHB objective: The Coorong is a healthy, productive and resilient wetland system that maintains its international significance.
international significance of the CLLMM, while there is change in the abundance, diversity and	The climate-ready revision to this objective introduces an explicit acknowledgment of future change in multiple ecosystem attributes, including the particular risk of declining freshwater components.
distribution of species and ecosystem types, including significant decline in freshwater components.	Discussion around this objective included reflections that the term 'international significance' may be 'too easy' because the site is always likely to meet one of the Ramsar criteria for international significance even if its condition deteriorates significantly. This reveals a need to be able to better characterise legitimate grounds for concern, domestically and internationally, about change. This may involve developing clearer guidelines to define what change in ecological character is inevitable and 'acceptable' and what change might be deemed unacceptable. (See also Pittock et al. 2010; Dunlop et al. 2013; Finlayson et al. 2017; Dunlop and Grigg 2019). Discussion noted that, in this context, the term 'resilience' should be interpreted as
	recovery from a disturbance to a healthy state, not necessarily recovery to the state described in the current Ecological Character Description (ECD). This can be described as 'bouncing forward' rather than 'bouncing back'.
2. Maintain water quality and environmental outcomes through	Original HCHB objective: Water quality and environmental outcomes improve as a result of optimised water delivery to the Coorong.
water delivery while there is change in specific outcomes of water delivery as total freshwater flows reduce.	If there are lower freshwater inputs and greater seawater inputs to the system, then the specific objectives sought from use of environmental water delivery may need to change. A climate-ready revision of this objective recognises that environmental water will still be used to improve environmental outcomes, but those benefits will be different to what might be feasible or prioritised now. For example, when sea level is a primary influence on Lake Alexandrina water level, environmental water delivery objectives could change from maintaining the level of Lake Alexandrina to maintaining a specific spatial and temporal distribution of salinity in Lake Alexandrina, providing freshwater triggers for migratory fish, or supporting specific habitats. The nature of the improved benefits needs to be chosen actively, based on an understanding of what is feasible and desirable in the future.

PROVISIONAL CLIMATE-READY OBJECTIVES*	RATIONALE AND COMMENTS
3. Maintain the keystone functions of healthy populations of aquatic plants, while there are changes in species composition and distribution of aquatic plant meadows in response to changing water level, salinity and nutrient regimes.	Original HCHB objective: <i>Filamentous green algae is reduced to manageable levels, allowing for expanded distribution and improved health of aquatic plant meadows.</i>
	original version as an indicator of undesirable eutrophic conditions. A climate-ready revision of this objective recognises that the keystone ecosystem functions from aquatic plants can be provided by different species and distributions in response to changing water levels and salinity and nutrient regimes. This is likely to include a shift to more estuarine vegetation and loss of emergent freshwater vegetation in many locations. Eutrophication remains a high risk, therefore it continues to be an imperative to reduce the availability of nutrients and prevalence of filamentous green algae and associated light limitation and smothering.
4. Maintain healthy and thriving fish and bird communities while there is change in the relative abundance of different groups, distribution of many communities, decline in overall diversity, and significant declines in freshwater-dependent species.	Original HCHB objective: <i>Fish and bird communities are healthy and thriving.</i> The climate-ready revision of this objective makes explicit that the fish and bird communities will change in abundance, diversity and distribution and there will be declines in freshwater-dependent species. Naming these changes ensures that the objective cannot be interpreted as maintaining the <i>current</i> fish and bird communities while freshwater inflows, habitat, food availability and connectivity are changing. The terms 'healthy' and 'thriving' could be replaced with more specific descriptions of the intended desired ecological attributes of these communities. For example, the aim could be to exclude invasive exotic species, to provide refuge in times of drought, and for there to be successful breeding seasons, and pulses of abundance when conditions are favourable (e.g. high flow periods for freshwater components).
	In recognition of the changes to freshwater-dependent species in particular, a new climate- ready objective was written with them as the focus (see Objective 6 below).
5. Maintain the aesthetic, cultural, emotional and experiential connections of residents and visitors	This is an attempt to develop a climate-ready version of the original HCHB objective; it should be noted that the revision is not informed by First Nations or local community perspectives.
to the CLLMM, and the involvement of local communities in all aspects of	Original HCHB objective: First Nations and local communities are empowered and engaged in managing the Coorong.
change in how people connect to the CLLMM, loss of some features that people are connected to, and evolving management objectives for	References to First Nations groups have been removed from the revised objective because First Nations people should be the authors of their own objectives. These workshops involved DEW staff only to familiarise DEW with climate adaptation planning, with the intention that DEW will involve First Nations in future analysis and planning.
evolving management objectives for the CLLMM.	The climate-ready revision of this objective makes it clear that there will be changes to some of the specific things people experience and connect to in the CLLMM, including loss of some valued features, but that people can continue to connect with the CLLMM as it evolves, and they can respect and remember valued features that are lost.
	Discussions in the workshop emphasised that DEW working to foster people's ongoing connection to the CLLMM is critical for building people's trust in DEW's management decisions. Participants also recognised the importance of culture and emotions and suggested this objective 'needs emotional words'. Participants recognised that stories and memories are an important part of people's connection to the CLLMM, and these can be maintained even as the system itself changes. Furthermore, the system can be managed, and people engage with it, so that it continues to be the source of new, valued stories and memories.
	The climate-ready objective also makes it explicit that local communities continue to be involved in managing the CLLMM and guiding the management undertaken by other agencies, while the nature of that management changes as the CLLMM changes.

PROVISIONAL CLIMATE-READY OBJECTIVES*	RATIONALE AND COMMENTS
6. Maintain the presence of freshwater species, habitats and wetlands in the system, with the capacity to expand in response to periodic high freshwater flows, while there is significant reduction in their abundance, diversity and distribution.	This is a new objective that recognises that freshwater species and ecosystems in the CLLMM are particularly vulnerable to climate change. Workshop participants emphasised the substantial value currently associated with the freshwater character of the Lower Lakes and the freshwater-dependent species, concern about the future of these components. There are uncertainties about the fate of freshwater habitats and freshwater-dependent species if there is seawater exchange with the Lower Lakes and a variable salinity regime.
	Discussions on feasible objectives included maintaining refuges of freshwater habitat so that populations of freshwater-dependent species had the capacity to flourish during high flow events after periods of low flows and salinity increase. It was expected the site will continue to provide critical habitat for threatened species, although some currently threatened species may be lost from the site in Scenario 2, and it was possible that there could be new threatened species. There was a desire to be alert to the needs of species that become threatened as a result of changing conditions, and to be aware of species that may become more abundant. Participants also recognised that 'threatened' only represents only one category of valued species, and it was important to be aware of changes with other cultural and socially important species and features.
7. Maintain the capacity for the CLLMM ecosystems and species to respond dynamically, becoming healthy and diverse, while there is reduction in health and abundance during periods where water levels are low and salt and nutrient accumulation is high.	This is a new objective, motivated by desire to maintain the ecological potential of the CLLMM during the initial period of drying (due to decreasing freshwater inflows and increasing evaporation: Scenario 1), before sea level rise becomes a dominant driver of water level and salinity in the system (Scenario 2). There was an appreciation that what happens during this period sets the 'starting condition' for what is possible in Scenario 2. Participants considered this to be a time for 'keeping options open', where options could include redesigning fishways to keep them functional during times of lower water levels in the lakes, engineering interventions to reduce the Lower Lakes to a size that could be maintained as fresh with reduced River Murray flows or creating refuge locations to support the persistence and potential relocation of freshwater components. There was much discussion on efforts to protect vulnerable components during the extremes, so they have the option to recover with more favourable conditions.
	There was a strong desire to maintain freshwater components and the ability for the freshwater character of the Lower Lakes to be maintained as long as possible. Participants acknowledged that if and when there is general acceptance that freshwater components cannot be maintained, then the decision to reduce those efforts can be made then rather than now. Navigating such a predicament was described as 'a long, 50-year conversation'.

* Climate-ready objectives are characterised by two elements, denoted in the bold text, the first is the feature to be maintained, the second makes explicit the change that is anticipated to occur, even if it is acknowledged as undesirable.

It was noted that the term 'resilience', used in climate-ready objective 1, is ambiguous in the face of climate change. In the absence of climate change, resilience is often taken to mean recovery after a disturbance to a normal baseline condition. In the context of climate change, resilience is sometimes used to describe an ability of an ecological system to resist climate impacts by returning to pre-climate change conditions in the face of extreme events that have been amplified by climate change. For significant climate change (e.g. Scenario 2), this is unrealistic, and in this context, resilience can be used describe the ability of a system to continually change with climate change, staying healthy and productive, and as it does so, retain the property of being able to return to a healthy productive state after being impacted by disturbance or extreme events. This highlights a key issue in transformational adaptation: the need to clarify the meaning of some language and concepts as some existing useful terms become ambiguous. New shared meanings need to explicitly accommodate inevitable ecological change to enable collective deliberation and analysis about future change.

The climate-ready objectives in Table 1 should be considered *preliminary*. They were crafted with workshop participants to enable DEW staff to gain an understanding of the nature of objectives that could be feasible in the future, or what success might look like in the face of change. In particular, they served as an introduction to subsequent stages of the adaptation pathway analysis. Future adaptation planning activities

could develop more complete climate-ready objectives with processes involving a broader set of participants, including First Nations groups, residents, visitors, managers, researchers and other stakeholders. These objectives were based on HCHB objectives (DEW 2019), and other high-level objectives exist for the CLLMM (e.g. DEH 2000, MDBA 2010, AWEEA GDH 2012, Lester et al. 2011, DEW 2020). Most of these could accommodate climate change, but they do not do so explicitly. To be operational as ecological change progresses, climate-ready objectives may need to become more specific, for example to specify how much change is appropriate, and the corresponding targets similarly accommodate the anticipated change. This will require new ecological knowledge about change processes, and extensive deliberation by stakeholders about their preferences in the context of their understanding and experience of a changing CLLMM.

The result was a set of climate-ready objectives that could:

- help characterise a vision of a healthy CLLMM in the face of climate change
- be feasible to achieve, with concerted management
- be relevant now and in the future (noting that the management to achieve them may be different in future)
- reveal key management issues or barriers that decision makers, managers and stakeholders might confront if climate-ready objectives were to be implemented
- point to appropriate management and policy responses.

The climate-ready objectives, as described here, meet the criteria of:

- accommodating large change
- not being sensitive to uncertainty (they do not specify outcomes beyond the scope of current understanding of change)
- as a set, cover multiple valued features, including ecosystem processes, habitats and species. In particular, they include threatened species, but also species in general and other socially and culturally important species.

5 Adaptation pathway for the CLLMM

The adaptation pathway shows the temporal dependencies between drivers, changes and various key decisions to ensure the climate-ready objectives could be met as the impacts of sea level rise and reduced river flows become significant in the CLLMM (Figure 4). The key decisions that were identified include whether and how to:

- 1. reduce salt and nutrient loads in the South Lagoon
- 2. accommodate climate change in national policy
- 3. facilitate seawater exchange through the Murray Mouth, the Murray Estuary and along the Coorong
- 4. make the Lower Lakes more resilient as they dry
- 5. allow seawater exchange with Lake Alexandrina.

The order in which these decisions will need to be made will depend on the relative rates of decreases in River Murray flows and sea level rise, and on evolving social and institutional factors. Future rainfall and river flows are uncertain, while they are more likely to decrease, they could increase with climate change; either way they are likely to continue to be very variable. Sea level rise, with an eventual overtopping of the barrages, is much more certain, although the rate of change will depend, in part, on future greenhouse gas emissions. Decisions 1, 3, 4 and 5 are specifically about the management of the CLLMM, whereas Decision 2 will be made at the whole of Basin scale, with implications for the CLLMM.

Each of these decisions is represented here as a single big decision, but each will involve multiple decisions, especially about how implementation might occur. Some of the elements of these decisions have been given some consideration, as a result of the Millennium Drought, however they have not previously been communicated explicitly as big decisions connected on an integrated pathway of responses to increasing climate change.

The intent of the pathways analysis is not to pre-empt the decisions, they will be made at the relevant times on the basis of what is judged *then* as effective and desirable. Rather, it is to characterise the challenges decision makers and stakeholders might confront, anticipate the *conditions* that could enable those challenges being addressed, and stimulate people to *start* considering these decisions early and together, so that *if and when needed* the decisions can be made with more options and in effective, collaborative and timely ways. It can take decades to evolve and navigate complex decision-making processes, especially if DEW is to make these decisions informed by stakeholders, extensive deliberation and long-term, goodquality information and enabled by policy and legislation.

While DEW will have oversight over decisions specifically about the CLLMM, DEW will not be able to make them alone. The conditions necessary to make the decisions will include new knowledge from researchers and other providers, guiding values and preferences of First Nations, resident and visitor communities and other stakeholders, and supportive policy and possibly legislation at the state and national level. Importantly, support of the other Basin States and the Commonwealth Government will be important for those decisions. Decision 2 is more explicitly a multi-jurisdictional decision.

1. A decision about actively reducing salt and nutrient loads from the Coorong South Lagoon

A decision about alternative actions for reducing salt and nutrient accumulation in the South Lagoon is currently being considered, as an integral part of the HCHB program, in response to prolonged accumulation of salt and nutrients in the system. In the event of future droughts leading to similar conditions, it is likely

that future interventions would be considered (as indicated in Figure 4), or they may become permanent management actions.

Future decisions about actively reducing salt and nutrient loads from the South Lagoon will be informed by what is learnt from current investigations and effectiveness of future actions. Given that the success of such actions in the future will depend in part on the other key events and decisions in the CLLMM, consideration of these future issues could usefully inform the analysis and implementation of any such actions.

2. A decision about accommodating climate change in national policy

Most national water policy was developed without considering the need to accommodate future changes in rainfall and river flows as a result of climate change. This means that some of those policies may be less effective in the face of altered flows, and they can restrict the ability of managers and policymakers seeking to plan for climate change. In particular, CLLMM stakeholders and planners need to be able to consider how water management actions are undertaken to achieve different objectives if the CLLMM undergoes transformational hydrological and ecological changes. Similarly, there may need to be a re-conceptualisation (at the national level) of how ecological character is defined and described, for Ramsar wetlands, to accommodate ecological change as a result of climate change.

Accommodating the prospect of large changes in water availability and the transformational impacts this could have on ecosystems and river communities is a complex process, with technical, social and institutional dimensions, and it is distinctly different from 'merely' accommodating interannual variability in flows. Because the nature of water and environmental governance is implemented through a highly connected system of many different institutions and jurisdictions, it is beyond the ability of any one institution to start accommodating transformational climate change on their own. This extends to it potentially being challenging for them to even consider the implications of *future* transformational change without a risk of stakeholders and other agencies questioning their commitment to *contemporary* arrangements.

However, as a potential near-term intervention, the project team suggests a commission or high-level enquiry that sits apart from existing institutions and has multi-jurisdictional support might be well positioned to examine the breadth of challenges that institutions and agencies could be expected to experience associated with planning for future transformational change. Its findings would help provide an environment for agencies and stakeholders to legitimately consider these issues, and enable appropriate reforms in a measured and timely manner. The specific challenges associated with considering transformational change are examined in section 6.

3. A decision about facilitating or resisting seawater exchange through the Murray Mouth, the Murray Estuary and along the Coorong

Dredging of the Murray Mouth was undertaken from 2002–2010, during the low flows of the Millennium Drought in response to net inflows of sand through the Murray Mouth. It recommenced in 2015 and is currently ongoing. Further recovery of water for the environment, as planned, may reduce the need for dredging in the near term. However, reduced river flows and rising sea level may lead to increased sand transport in through the Mouth and a need for increased levels of dredging, either on a permanent or periodic basis (Thom et al. 2020). Elements of this decision will also interact with Decision 1.

4. A decision about how to make the Lower Lakes more resilient as they dry

The scenarios used in this analysis start with a decrease in freshwater inputs to the Lower Lakes, leading to declining average water levels, increasing periods of evapoconcentration of salt and nutrients, increased
exposure of ASS, degrading freshwater habitats and declining populations of freshwater-dependent species (Scenario 1). This trajectory is eventually halted by hydrological connection of Lake Alexandrina to the Southern Ocean (Decision 5), with the lake levels largely being set by sea level, salinity in Lake Alexandrina varying from estuarine to predominantly fresh, depending on rainfall phases, and species and communities varying in space and fluctuating over time according to their salt tolerance (Scenario 2). There is considerable uncertainty about what ecological populations and communities might persist and thrive in the Lower Lakes in these conditions and how to manage the lakes, including environmental flows, to maintain diverse, abundant and resilient ecosystems (set of yellow boxes in the upper right part of Figure 4).

Decision 4 is about the critical question of how to manage the Lower Lakes, particularly Lake Alexandrina, during the drying phase (Scenario 1) so that they have the greatest possible potential to support a transition to healthy variable estuarine-fresh ecosystems anticipated in Scenario 2. Considerations for this decision could include:

- how to establish and maintain refuges for freshwater-dependent species that can be sustained, potentially with use of environmental flows, through Scenario 1 and Scenario 2
- management of shoreline vegetation and ASS as average water level declines
- maintaining connectivity and cues for migratory fish
- anticipating the establishment of estuarine aquatic plant, fish and invertebrate communities
- identifying and possibly creating new habitat for shorebirds and salt marshes.

Some of these issues were considered during the Millennium Drought, however the context was very different: then managers were anticipating a future recovery to a normal water level and fresh condition, as opposed to anticipating a transition to increasing water level and variable estuarine condition. These issues are a departure from the contemporary management and stakeholder considerations for the Lower Lakes, and they will be challenging to deliberate over without a supportive decision context of relevant knowledge, supportive stakeholders and enabling rules. Near-term interventions proposed by the project team to create support for considering how to manage future transformations could include engagement with First Nations, local communities and MDB-level management partners about the nature of long-term change and the possibility of different conditions and management objectives for the Lower Lakes, *in the future* should the more significant climate change impacts materialise.

5. A decision about allowing seawater exchange with Lake Alexandrina

A decision about whether and how to allow seawater exchange with Lake Alexandrina could be forced by a combination of frequent overtopping of the barrages and flooding of the barrier islands due to sea level rise and the declining water level and ecological condition in the Lower Lakes due to reducing River Murray flows (Chiew et al. 2020). Resisting seawater entering Lake Alexandrina is feasible, but would require upgrades of the barrages and new defences across the barrier islands, or construction of new barrages in a different location (Thom et al. 2020). This would potentially leave the Lower Lakes in a state of declining average water level, increasing evapoconcentration and accumulation of salt and nutrients, and potential negative water heads prohibiting outflow through the barrages.

Allowing seawater into Lake Alexandrina would result in a higher and more stable water level in both lakes, conditions that were estuarine but highly variable spatially across Lake Alexandrina and temporally within and between years with river flow. This would have significant ecological, social and economic consequences for the Lower Lakes, some negative and some potentially positive, especially compared to preceding conditions. There would be significant declines (relative to present-day conditions) in freshwater wetlands and freshwater-dependent species, increases in estuarine plant, fish and bird species, changes to fringing

wetlands, impacts on fisheries and infrastructure, and changes to other features of the Lower Lakes that are valued by First Nations, residents, visitors and business (Grigg et al. 2022). Salinity ingress would also affect the Lower River Murray and its communities. Lake Albert is likely to have been significantly affected by declining level of Lake Alexandrina (Scenario 1). More saline conditions will also provide different challenges (e.g. risk of permanent hyper-salinity and exposure of ASS) for management options for Lake Albert (Figure 4, top right yellow decision box).

A decision to allow seawater into the Lower Lakes would represent a substantial change from current management, expectations and policy. This is a decision that could potentially be taken at any time in a large time window. Controlled releases of seawater through the barrages are possible at any time sea level is higher than lake level should it be desirable for the Lower Lakes. Issues to be considered include increased acidification and heavy metal risks and rapid increases in salinisation due to evapoconcentration. The decision could be delayed until the barrages and barrier islands are frequently overtopped, which would occur with approximately 0.6 m of sea level rise. It is most likely exchange would be managed so there was a cycle of water flowing into and out of the lake, under the influence of tides, winds and seiches. Net flow would depend on River Murray flows and evaporation rates. Multiple options would exist for managing the rate and location of exchange in and out of Lake Alexandrina, to manage salinity, nutrient cycling, sediment movement, biotic exchange, local habitats and so on. It may be possible to experiment with controlled releases prior to a decision being made about permanent connection, and controlled releases could be used as part of the responses to issues being considered in Decision 4.

As with Decision 4, this decision is very complex with many considerations that will take a long time to deliberate over, and this deliberation will be challenging for managers without supporting knowledge, stakeholders and institutional contexts. While the decision is likely to be several decades away, near-term engagement with stakeholders and management partners about possible long-term impacts on the Lower Lakes could create support for the processes needed to investigate, deliberate over and plan for future transformational changes.

Section 6 examines in more detail the nature of the barriers that DEW may encounter making these decisions and explores changes in the decision context that could create conditions to enable DEW and partners navigate these key decisions more effectively.

<u>Adaptation Pathway</u>: key events, uncertainties, decisions, enabling conditions and actions to ensure climate-ready objectives as the CLLMM transforms in response to climate change





Figure 4. Adaptation pathway for the CLLMM.

This characterises key environmental events, decision points and outcomes for three key themes as the CLLMM experiences impacts from decreasing River Murray inflows and increasing sea level rise. Key decisions, discussed in the text, are indicated with numbers. Key near-term actions (interventions) to enable measured and timely decision making are indicated with red stars. Dashed boxes in the lower left represent actions being undertaken within HCHB.

6 Near-term interventions to create conditions enabling adaptation decisions

6.1 Five key enabling conditions

In the final workshop of the project, DEW staff explored five potential barriers to DEW's future adaptation decision making. These barriers had been identified in the analysis of previous workshop discussions and deliberations across all project activities. The barriers each represent a version of a 'stationary framing' of the CLLMM; that is an implicit or explicit assumption that the CLLMM has a desired state that is should and could stay in or return to after an extreme event (see Box 1 Stationarity vs non-stationarity). Rather than focus on what can't happen, the first step was to rephrase the barriers as corresponding 'enabling conditions' that represent various combinations of values, rules and knowledge that could enable future adaptation decisions that DEW staff anticipated may be required (Figure 5).

Barrier

Enabling condition

1	People feel or are restricted in their ability to consider transformational change	\rightarrow	People are free to consider transformational change
2	People have a limited understanding of future change and are challenged by the uncertainty	\rightarrow	People have a good understanding of future change and are accepting uncertainty
3	People have a strong desire to maintain current conditions or return the system to an ideal past condition	\rightarrow	People have realistic narratives recognising the inevitability of change and accepting some losses
4	Values used in objectives and to set preferences as based on past conditions	\rightarrow	Values and preference are based on anticipated change not past states
5	Institutions work for current issues, but not suited to large, complex and uncertain change	\rightarrow	Institutions that accommodate large, complex and uncertain change

Figure 5. Barriers to future adaptation decision making rephrased as enabling conditions that would be in place if the barriers were removed.

The enabling conditions can be arranged to describe a logically connected sequence of changes in the decision context. These changes could enable adaptation by DEW and others in the CLLMM and in other parts of South Australia, the Basin and elsewhere in Australia (Figure 6). A foundational enabling condition is for people to be free to consider future change including the prospect of transformation. This would require addressing factors that currently prevent open conversations about large, future change. With this foundation in place, the second enabling condition is easier to create: people have a good understanding of future change and are accepting uncertainty. Currently some people in DEW have a very good understanding of future change and uncertainties associated with that change, and DEW has access to good tools for exploring future scenarios. With enabling condition 1 in place, that understanding can be shared and explored more openly with different stakeholders. Both conditions 1 and 2 lay the groundwork for conditions 3 and 4. Condition 3 is that people have *realistic narratives* recognising the inevitability of change and accepting some losses. This condition relies on conversations that support people in coming to terms with

difficult and sometimes distressing change, and so the quality of conversations created through enabling condition 1, and knowledge shared in condition 2, both contribute to this enabling condition. Furthermore, once there are open conversations, grounded in good understanding of inevitable change and some loss, attention can be turned to what values and preferences can be retained and supported through such change, and indicators of success can be relative to what is feasible in the future rather than an ideal past state that will become less attainable as climate change progresses. Finally, all these enabling conditions would foster willingness and support for institutional responses that accommodate large, complex, and uncertain change in the service of multiple values.



Figure 6. Five key enabling conditions. Individually and together these conditions could help enable DEW make challenging decisions as climate change progresses, including decisions about potential transformational adaptation.

Box 1 Stationarity vs non-stationarity

A system can be described as 'stationary' when it is has a well-defined central tendency (normal or average) state (Milly et al. 2008). It might vary considerably about that on different time scales, but the central tendency is well enough defined to be useful for thinking about and managing the system. 'Non-stationary' can refer to an underlying trend in the central tendency, or step changes or irreversible transitions, and it can refer to changes in the variability. The concept applies to any biophysical variable of interest, including temperature, rainfall, inflows, sea level, salinity regime, species abundance, species composition, breeding success, and so on.

This concept is part of the global discourse on global environment change and it has significant entailments for how change is considered and managed at all scales, including locally.

While the CLLMM system has never been stationary, to a significant degree, managers and stakeholders have had to assume it is when defining expected or desired outcomes. For example,

the Ecological Character Description is defined by components and processes such as the water level in Lake Alexandrina, the salinity in the South Lagoon, the cover of Ruppia tuberosa, and the abundance of water birds, and there are specified thresholds on their ranges. Another example is that the water entitlements to different users across the Basin are ubiquitously referred to in volumetric terms (rather than their technical specification as a share of the common pool, which is non-stationary). People may know that ultimately these will change over time, but they find it useful or are required to make the operational assumption that these vary around a robust concept of normal or average or ideal.

This assumption has entailments for a range of things beyond immediate decision making. For example, it can affect:

- how people describe the state of systems, and change in systems
- what people think of as normal
- how people make sense of current change and the prospect of future change
- what people determine to be right or good, e.g. the state a system 'should' be in
- what management outcomes are regarded as legitimate and how people are held accountable for their management and decision
- *how people deliberate, negotiate and form agreements about systems.*

Stationarity is present to varying extents, in the system of institutions governing decisions about the CLLMM, in the knowledge, values and rules that apply, and across all scales, from local to international. The examples above are variables used to describe a system. The conceptual and numeric models people use to understand the dynamics of systems and the research undertaken also have elements of stationarity. For example, being oriented toward understanding the current state of a system, departure from the desired state and restoration to that state, rather than seeking to understanding future change processes and possible future states. The preferences and expectations people have for the CLLMM frequently hold that it could and should stay in or return to some desired state. And the agreements, policies, regulations, laws, and decision-making processes relevant to the CLLMM are largely framed assuming a fixed desired state and may explicitly include fixed targets.

All of these elements of the decision-making systems interact and depend on each other, so changes to accommodate non-stationarity would need to happen throughout the system, across the values, rules and knowledge and the multiple layers. These cannot be changed all at once, but it would also be difficult to reform some elements incrementally to accommodate non-stationarity while others remain framed in stationarity.

The framing of a system as stationary or non-stationary affects how vulnerability might be defined to be useful for planning and evaluation. In stationary framed systems, vulnerability is usually related to the likelihood of a system moving away from its preferred state or a given regime of variation around that. In systems where departure from stationarity is inevitable, that concept is not very useful; the alternative used in this project relates vulnerability to failure to meet objectives that explicitly accommodate anticipated change. The climate-ready objectives name specific attributes of the system that are valued and could feasibly be maintained, and attributes that are anticipated to change. Change in these second attributes may represent a loss of current value but not vulnerability of the system.

6.2 Near-term interventions to create enabling conditions for long-term adaptation decisions

Detailed descriptions of the five enabling conditions, with several themes within each, are provided in Appendix A. The descriptions emphasise the conditions that could enable future actions by DEW to address climate change, and the interventions DEW could take in the near term to stimulate learning and changes behaviour of other actors needed to create those enabling conditions. The description for each theme has the format described in Table 2. Note: The enabling conditions are presented in Appendix A in the *present tense*, describing the conditions as if they were in place.

Table 2. Layout of descriptions of each enabling condition.

SUB-HEADING	CONTENT
Future decisions and management by DEW	Decisions or actions <u>DEW</u> might want to undertake in the future and are enabled by
Conditions needed to enable future decisions	conditions resulting from changes in behaviour by <u>others</u> , as a result of
Learning (by others) needed to create enabling condition	<u>others</u> learning about the future issues facing DEW and other managers and decision makers, through
Near-term intervention by DEW to drive learning	targeted near-term interventions by <u>DEW</u> to help others understand the future management and decision challenges and the changes in the decision context that are needed to create options for those future decisions.

This above structure enforced a comprehensive logic for how near-term interventions could drive learning to create enabling conditions for different future management actions; we have labelled these as near-term 'interventions' to emphasise this intent. The descriptions in that format are lengthy and include repetition (see Appendix A). Below we present a synthesis of the near-term interventions and commonalities across the themes (Figure 7). Some near-term interventions in this condensed set contribute to multiple enabling conditions; similarly, each future action that DEW may want to take could be aided by multiple enabled conditions.

It is important to note that the near-term interventions described in Appendix A and Figure 7 are *indicative*. They are not specific recommendations of this project, but rather illustrative of the types of actions that were discussed in workshops that *could enable* future adaptation decisions by DEW. Similarly, we described future actions that we anticipate DEW and stakeholders might want to implement in response to unfolding climate change. Other interventions with the same intent could help evolve the decision context to create the enabling conditions. Similarly, as the decision context evolves, it is likely that other long-term management actions will be identified. The important aspect of this analysis is the strategic intent of interventions that can readily be implemented in the near term, to start addressing identified barriers and bring about corresponding enabling conditions that create options for DEW to address future transformational impacts.

The near-term interventions summarised in Figure 7 could be implemented as additions or amendments to existing or planned activities. For example, they could form the basis of a checklist that managers could use as prompts to identify opportunities to weave elements of these near-term interventions into their current activities. The interventions would need to be tailored to the activities at hand, but the important thing is that it would start the process of integrating the lessons of adaptation planning into existing DEW activities.

The summary in Figure 7 could also form the basis of a climate adaptation planning strategy for DEW in the CLLMM.

In the near term, DEW can convene discussions and processes of the kind that have been undertaken in this project. A key requirement for that to be successful is ensuring that any concerns associated with taking part in such discussions are heard and risks mitigated so that all parties are well-supported and not disadvantaged for being willing to talk about large, future change.

DEW can also focus on awareness-raising and capability building in the near term. For example, DEW's processes and products can better include descriptions of people's relationship with the CLLMM and their values, and how these things have been and will continue to be affected by large, uncertain change. DEW could also undertake near-term interventions focused on building awareness of and capacity for decision-making processes that cope with and accommodate uncertainty, especially when uncertainty cannot be reduced readily with further information, or if waiting for certainty would jeopardise other objectives or values.

Some stakeholders currently look to DEW to provide integrated leadership of the whole CLLMM system. DEW could advocate for it to have a more explicit integrated site management role so it can consider not only environmental management of the Ramsar site, but integrate the needs and priorities of other agencies such as the Landscape Boards and the CEWH. DEW, and the SA Government more generally, has useful experience with managing climate extremes and considering future climate change, and DEW can continue to share its experience with other jurisdictions. The purposes would be so that others can benefit from DEW's lessons and insights, and so that DEW can make other actors aware of changes that DEW needs that are outside its control or responsibility.

Together, these near-term interventions are intended to contribute to creating enabling conditions that make possible new options for DEW facing challenging adaptation decision in the future. Options that DEW may wish to exercise in the future include having well-established engagement with all stakeholders on planning for large, transformational change, well before there is a lot of certainty about the specific nature of future change and its impacts. DEW may wish to revise its management objectives and processes so that they are 'climate-ready', accommodating large, uncertain, complex change that affects multiple values. Being climate-ready also means being ready to be explicit about valued CLLMM features that can be preserved and those that may be lost, confident that stakeholders are prepared and supported in future-shifting of priorities, without jeopardising near-term management objectives.

Beyond the direct management of the CLLMM, DEW may also want to be prepared for encouraging, or even leading, initiatives to bring about broader institutional reform in preparation for future change, including revisions to environmental watering objectives, water sharing arrangements and management of Ramsar sites (again, without compromising South Australia's standing and entitlements under current arrangements).



Figure 7. Synthesis of near-term interventions that could contribute to enabling conditions for future management actions DEW may wish to take. Coloured stars next to near-term interventions indicate enabling conditions that they contribute most to. Coloured stars next to future actions indicate enabling conditions that most support that action.

7 Discussion

Adapting to significant ecological change in the CLLMM, resulting from climate change, will be complex. There is no one well-defined set of adaptation actions that can readily be implemented to keep the CLLMM healthy. Rather, adaptation will be a journey, one that cannot be clearly mapped out at the start, will have many unexpected waypoints, and does not have a clear endpoint or agreed measures of success. Uncertainties and multiple and evolving perspectives fundamentally limit the scope for determining a single fixed set of adaptation actions. In addition, the rate and direction of the journey will largely be out of the control of managers and stakeholders. The journey will require significant amounts of learning, recalibrating, and adapting. While it is likely climate change could lead to considerable ecological change, and decline and loss of some valued features, there is potential for the CLLMM to continue to retain many of the values people currently hold for it, if it is managed effectively (Grigg et al. 2022). One measure of success for that adaptation journey might be that it is actively navigated, through foresight and responsive decisions, so that values that could feasibly be maintained in the CLLMM do actually persist. This report describes key challenges that might be experienced and characterises some of the actions managers and stakeholders could potentially take to ensure they can be responsive and forward looking to help preserve as many valued features of the CLLMM as possible.

With a focus on the decisions that DEW make, this *preliminary* analysis explored the challenges that might confront CLLMM managers and stakeholders, both locally and at the Basin and national scale. The analysis covered climate-ready objectives that decision makers might seek to achieve, key decisions associated with critical hydrological and ecological processes or events, and the conditions of the decision context that would be needed to ensure those decisions could be made with options and in a timely manner. The analyses used a trajectory of change to a scenario of greatest plausible change driven by the joint impacts of significantly reduced freshwater inflows and sea level rise that overtops the barrages (as might be experienced towards the end of the century) leading to transformational impacts in the ecology of the system (Rees et al. 2022). The decisions are distributed along that trajectory (Figure 4), with later decisions responding to an increased likelihood of more severe impacts, and nearer decisions addressing lower-level impacts and preparing for the possibility of future more significant impacts.

Stationarity

This analysis, and previous activities in this project, have identified a range of issues or barriers that currently exist and would make addressing the future decisions challenging. Many of these barriers are instances or expressions of an overriding issue of a stationary framing of the CLLMM (Box 1), that is the assumption that the CLLMM can and should be maintained in an ideal past state. As climate change progresses this assumption will become increasingly unrealistic, and various entailments of the stationary framing will inhibit decision making and management. This stationary framing is not present in *every* process, but it is present to varying degrees across the complex system of institutions that govern decision making in the CLLMM. It is present from local through state, Basin, national to international institutions, and in the systems that provide knowledge to decision makers and stakeholders, the rules they follow, and the way stakeholders formulate and express their values and preferences. An overarching near-term objective of climate adaptation is therefore to evolve these institutions so that they can accommodate the changing nature of the CLLMM.

Don't delay

The process of updating and reforming these institutions can be expected to be complex and take many decades, likely including multiple drought and wet period cycles, which will then be followed by the extensive

processes of actually making those key adaptation decisions and implementing them. As such there is an imperative to commence the process well before decision-making processes are demonstrably compromised by climate change.

There is risk that starting to engage with stakeholders now about responses to long-term change may confuse deliberations about complex near-term management issues. And similarly, canvassing future changes to objectives and management in the CLLMM may confuse ongoing and imminent Basin processes such as continued water recovery, the review of the Basin Plan and planning for Basin Plan 2. However, there will always be 'near-term issues' at the local and Basin scale. There is never likely to be an 'ideal' or even 'better' time to start. Indeed, every delay risks such engagements running into 'crisis' conditions of the next severe drought.

There are three strategies for helping to start early and address the risks with considering transformation adaptation: incremental change, leaning into ambiguity and creating an authorising environment.

Incremental change

To an extent, evolving the institutions affecting the CLLMM to accommodate climate change can be seen as a natural progression of the Basin-wide water reform process which has been underway for multiple decades and is ongoing. Furthermore, the Millennium Drought stimulated or reinforced a number of features of CLLMM decision making that could help address significant ecological change. However, while these processes have led to many individuals contemplating how significant climate change impacts might be addressed, and to a number of research projects (usually focusing on the biophysical aspects), there have not been any formal processes for exploring climate adaptation in an integrated manner to support coordinated, cross-agency and cross-jurisdictional deliberation and planning.

Since the different institutions mesh with each other, no one institution can be reframed or significantly reformed on its own, and similarly no one agency can undertake the process on their own. The process is likely to be incremental, with multiple small steps in different institutions that hopefully encourage and accelerate reform throughout the system.

The initial steps in this incremental process are towards creating the conditions that enable comprehensive deliberation and decision making about more challenging long-term issues. These actions can be thought of as interventions designed to provoke evolution of the complex system of decision making (Snowden 2005). Such interventions could include:

- putting more emphasis on people, their values, and emotions
- communicating and deliberating about near-term issues in the context of a long history of change and future change
- sharing with other jurisdictions lessons about the institutional challenges associated with the processes of contemplating transformational adaptation (before deliberating with them about the detail of future decisions)
- building capacity of decision makers and stakeholders to accommodate increasing uncertainty
- seeking to build the capacity for integrated management of the CLLMM.

Interventions such as these are likely to help create conditions for contemplating future challenging decisions, and they should help build capacity to deal with near-term term issues. Specifically, these actions have reduced risk of leading to confusion with stakeholders as they avoid directly deliberating about responses to large future changes. Over time, interventions such as these can be implemented with

increasing detail of future change. Further deliberation, by DEW and others about the enabling conditions would likely identify other potential interventions. Ideally, interventions doing this work would also be implemented by other actors, such the Murray–Darling Basin Authority (MDBA), other Basin state agencies and stakeholder groups.

While change is likely to be incremental, to be effective those increments need to be anticipatory, directional and deliberate, guided by futures thinking and shaped by learning-oriented processes (reflexive practice and regular evaluation). Reactive incremental change once decision-making processes are demonstrably failing would be highly maladaptive. The set of enabling conditions (Figure 6), the program logic of the interventions to address them to enable specific future actions (Figure 7) and the pathway of key decisions (Figure 4) all provide guidance to designing interventions and ensuring they are implemented in a manner that is faithful with their intent.

The workplan for this project was revised mid-way through, in collaboration with DEW, the Goyder Institute and the Project Advisory Committee, in recognition that a more incremental process was required, so that capacity could be built to deal more effectively with the ecological changes and management responses that were being canvassed. The project outputs have been identified as 'preliminary' in recognition that further deliberation is required within DEW, and with the community, First Nations and other stakeholders.

Ambiguity

The processes of initially reforming institutions and then contemplating challenging adaptation decisions will inevitably involve considerable uncertainty and ambiguity. It will become necessary to learn to live with (and reduce risks associated with) that ambiguity. In addition to dealing with near-term and long-term issues, discomfort can arise from many tensions arising from contemplating large future change, for example:

- the uncertainty about future ecological change processes, and unknown effectiveness of various future management actions
- changing states and associated baselines, making it hard to make sense of experienced change, and faster rates of change, so there is even less sense of what 'normal' flow, water quality or ecological conditions might be
- the increasing gap between current official and widely held aspirations and commitments about the condition of the CLLMM and the reality of future change
- the unknown values and preferences of future stakeholders
- challenges to the identity of individuals whose work or lives are intimately connected with resisting change and restoring the CLLMM
- future objectives that accommodate decline and loss of some features that are currently highly valued
- the lack of unambiguous terminology to describe features and processes in the face of significant ecological change. For example, resilience, ecosystem health, habitat and species diversity can mean different things in a stationary and non-stationary context, and the non-stationary meanings are not well defined and agreed
- adaptation processes increasingly involving institutional reform, hard work in the hearts and minds
 of people with connection to the CLLMM, and dealing with the emotions of partners and
 stakeholders, as opposed to near-term issues which are usually largely framed as being hydrological
 and ecological issues that can be resolved with deliberations focused on the biophysical science
- the prospect of current arrangements not performing as expected in the future.

Becoming comfortable with this ambiguity is both a task for individuals and a matter of organisational culture for stakeholder groups, DEW, MDBA and Basin state agencies.

Enabling environment

One of the persistent themes we heard in this project was the need for people to have an enabling or safe environment to allow them to contemplate and deliberate about changes in conditions and objectives that represented a significant departure from the status quo or the 'sanctioned discourse'. This can be reinforcement for individuals that is okay to contemplate such change, creation of a culture in an agency that encourages collective deliberation, an understanding between different agencies in the Basin that such deliberations and analyses will be conducted and shared, through to authoritative guidelines about how to address transformational change and the challenges that can be expected in the process. Processes that could help create an enabling environment could include:

- support from DEW for community and First Nation groups and other local stakeholders; this could include communication, convening, facilitation or dedicated processes to enable people to discover, make sense of and deliberate about future issues
- internal communication about change and directives from executives within agencies
- cross-agency working groups or projects formed to focus on some aspect of the issue
- an external enquiry providing independent analysis and guidance.

External enquiry into transformational adaptation

The multi-decade water reform process demonstrates the effectiveness of creating new institutions to carry out specific tasks that contribute incrementally to the transformational change in water governance in the Basin. Such institutions are typically free of the constraints within existing institutions and can carry extra weight by being fresh and independent. In this spirit, an external commission could be created to undertake an independent review of the challenges that will be faced by all agencies in all jurisdictions as they consider and plan for long-term climate change, including possible transformation. This could be at the Basin or National scale, and it could focus on water or cover multiple sectors. This review would help create the conditions necessary for individual agencies and jurisdictions, including DEW, to innovate and explore how to approach the possibility of transformation, and thereby create the experience needed to develop national policy. Specifically, the enquiry would:

- give legitimacy to consideration of transformation and the difficulties that could be expected in that process (such as stationarity, uncertainty, changing values, ambiguity, emerging novel issues, complexity)
- clarify the distinction and relationship between near-term and long-term issues
- explore when and how objectives might need to be revised
- provide guidance about how to deal with some of the challenges
- scope the parameters of success of a long-term adaptation journey
- create an expectation that Basin States and stakeholders start considering long-term change.

This could be a standing long-lasting commission overseeing progress over a decade or more, or a one-off review. Either way it would be important for it and others to recognise its findings would themselves be a work in progress and need to be reviewed and updated regularly as people have more experience with climate change and contemplating transformation.

7.1 Limitations

The analyses presented in this report are described as '*preliminary*'. They were conducted with participation by staff from DEW with a range of expertise, experience and functional roles, and technical experts engaged in the other projects within T&I. These people provided enormous detail and enabled rich deliberation and many insights. However, this did not include the critically important participation of First Nations and the local community. It is anticipated that specific engagement processes and deliberation forums will be created to help these, and other groups, familiarise themselves with the long-term challenges of climate change, deliberate about responses to them and develop together and with DEW agreed pathways to proactively navigate change as it unfolds.

Climate change inevitably includes a very wide range of uncertainties. Through this project, participants in our workshops were uncomfortable speculating about future change that could unfold in many different ways. We offered assurances that many of these uncertainties would be addressed by considering a trajectory to a scenario of 'greatest plausible change' and with the adaptation pathways analyses (this report). These analysis approaches were to provide a template for responding to anticipated uncertainties and navigating unanticipated uncertainties. We believe the findings and insights generated through these analyses are relatively robust. We have been cautious to not extrapolate from individual uncertain details, rather focusing on issues emerging repeatedly or from more certain phenomena. However, there will be many changes and change processes, physical and especially societally, that have not been anticipated and will alter how climate change affects the CLLMM and how people choose to adapt to it.

Climate adaptation is a process that will play out in a complex adaptive system, part biophysical, part institutional and part social. As with any complex adaptive system, detailed predictions cannot be made and prescriptions should be approached with caution. In particular, the near-term interventions, and the long-term adaptation decisions we describe in section 6.2 (Figure 7) should not be interpreted as specific recommendations. They were developed to help analyse the enabling conditions future decision makers might need and explore the types of near-term interventions that logically could help create those conditions. Other near-term interventions could also be effective and may be more practical for DEW and others to implement within their contexts. Useful validation questions for these interventions could include:

- If the near-term interventions are things that DEW could implement, in what existing or new processes or projects might they be implemented?
- If they are viewed as potentially valuable but not practical to implement, then that reveals the presence of further barriers to climate adaptation planning, possibly at a finer scale than scoped in our analyses. DEW could then scope how to promote the enabling conditions required to remove those barriers, following the logic used in our analyses.
- If there are additional or alternative future adaptation actions that DEW may wish to contemplate, would they be possible now? If not, then what conditions would be required to enable them?
- For the long-term adaptation actions, is the theory of change logic linking near-term intervention, through learning and enabling conditions to future action robust?

In sum, we have attempted to provide some guidance for promoting evolution of the complex, multi-scale, coupled social-ecological system of the CLLMM in a direction that would appear to make it accommodate climate change better. However, as it evolves, perspectives will change, in DEW and among stakeholders, and alternative directions might emerge for the adaptation journey.

Glossary of climate adaptation terminology

Term	Definition		
Adaptation pathways	Adaptation pathways are sequences of actions, which can be implemented progressively, depending on future dynamics. (Werners 2021)		
Barriers to management of future issues	Outside the direct control of DEW / decision makers / managers, stemming from society. Overcome by others doing something differently, and in doing so enables decision makers choosing new management or policy options		
Climate-ready objectives	Climate-ready objectives are objectives that:		
	 accommodate large amounts of ecological change and the likelihood of significant climate change-induced loss in biodiversity remain relevant and feasible under the range of possible future trajectories of ecological change (as a set) seek to conserve the multiple different dimensions of biodiversity that are experienced and valued by society (Dunlop et al. 2013; Dunlop and Ryan 2016) 		
Counterfactual	'Counterfactuals are possible alternative system trajectories in the absence of an intervention. Comparing observed outcomes against the chosen counterfactual allows the impact (change attributable to the intervention) to be determined. Because counterfactuals by definition never occur, they must be estimated' Bull (2021).		
	In the context of managing the CLLMM, a counterfactual is when management objectives, measures of success, or preferences are expressed relative to what would happen <i>without</i> the management activities in question, rather than relative to a prior state that may no longer be physically possible under climate change even with the best management.		
Decision context	The circumstances that form the setting of the decision process; specifically, the interconnected systems of values, rules and knowledge that form the ways of viewing and framing the decision process (Gorddard 2016)		
Decision maker / environmental manager	Someone who is making decisions about the management of the CLLMM region, at the local, state, Basin, national or international scale		
Future issues	The issues that require management to achieve climate-ready objectives		
Institutions	The various formal and informal arrangements that shape decision making. These can include rules, such as legislating, policies, standards and guidelines; the systems that produce knowledge that decision makers use; and processes by which stakeholders formulate values and preferences, and how these are used to inform decision making. They include formal and informal processes.		
	Institutions in this context are distinct from organisations.		
Interventions	Actions taken by DEW, usually with actors in the decision context, to stimulate change in the decision context that overcomes barriers and		

Term	Definition
	creates conditions to enable future decision making and management (if and when needed).
	The term interventions is used to imply a provocation or probe to the complex system of decision-making interventions. See the Cynefin Framework (Snowden 2005)
Irreducible uncertainty	Uncertainty that cannot be reduced to any quantifiable risk
Millennium Drought	An Australian drought which impacted the Murray–Darling Basin over the period 1996-2010, and substantially impacted the Coorong over the period 2001-2010
Non-stationarity	A system that is variable about a shifting baseline (with trend change), as opposed to a system that is varying about a fixed (average) baseline
Rights holder	First Nations groups with title, ownership or rights over parts of the CLLMM
Stakeholder	A person, organisation or group with a professional or personal interest in or an influence on the CLLMM region, or who is influenced directly or indirectly by activities and management decisions in the region. Include actors locally, in the Basin and elsewhere.
	We use community to refer to people in the CLLMM region.
Theory of change	A comprehensive description and illustration of how and why a desired change is expected to happen in a particular context.
Transformational change	Transformational change involves significant changes to a biophysical system and the way people relate to, live within and manage the system
Values	Values held by people for the system as distinct from ecological attributes of the system persisting attributes
Vulnerability	In this project, vulnerability is framed as relating to the risk to the values held for the CLLMM that are associated with the attributes of the CLLMM that could feasibly persist (accepting the inevitability of some changes). This is in contrast to a traditional framing of vulnerability that relates to impact on any values, often highlighting those features of a system that are most likely to change.
	Vulnerability can include risks resulting from institutions as well as physical drivers of change.

Short forms

Acronym	Full form
ASS	Acid sulfate sediments
BOC	Basin Officials Committee
CEWH	Commonwealth Environmental Water Holder
CLLMM	The Coorong, Lower Lakes, and Murray Mouth region
CSIRO	The Commonwealth, Scientific and Industrial Organisation
DEW	South Australian Department for Environment and Water
ECD	Ramsar Ecological Character Description
НСНВ	Healthy Coorong, Healthy Basin
m AHD	Elevation in metres with respect to the Australian Height Datum
MDB	Murray–Darling Basin
MDBA	Murray–Darling Basin Authority
NRM	Natural Resource Management
SA	South Australia
T&I	Trials & Investigations

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Appendix A Enabling conditions and themes

The details raised in deliberating about interventions, enabling conditions and future adaptation actions were used to create clusters within each enabling condition, as follows:

- People feel or are restricted in their ability to consider transformational change → People are free to consider transformational change.
 - Theme 1: Safe to have conversations
 - Theme 2: Recognising entailments
 - Theme 3: Cross-jurisdictional support for engagement on transformation
 - Theme 4: Consider future change without under-mining near-term objectives
 - Theme 5: Starting now
- People have a limited understanding of future change and are challenged by the uncertainty →
 People have a good understanding of future change and are accepting uncertainty.
 - Theme 1: Understanding change
 - Theme 2: Accepting uncertainty
 - Theme 3: Decision making
- People have a strong desire to maintain current conditions or return the system to an ideal past condition → People have realistic narratives recognising the inevitability of change and accepting some losses.
 - Theme 1: Understanding and accepting change
 - Theme 2: Deal with grief and anchoring to past values
 - Theme 3: Community-centred discourse, processes and narratives
- Values used in objectives and to set preferences as based on past conditions → Values and preference are based on anticipated change not past states.
 - Theme 1: Awareness values will change
 - Theme 2: Being prepared to reform management instruments
- Institutions work for current issues, but not suited to large, complex and uncertain change →
 Institutions that accommodate large, complex and uncertain change.
 - Theme 1: Ramsar (Australian and international)
 - Theme 2: MDB Water sharing arrangements
 - Theme 3: Use of water for the environment
 - Theme 4: New institutional work

The detail of the possible interventions, enabling conditions and possible long-term adaptation actions, showing their logical connections, are included in the sections below. See section 6.2 for context and explanation of the intent of the structure.

Note, in the following sections, the enabling conditions are described as the conditions that are desired, in the style of a theory of change or scenario. That is, they are written in the <u>present tense</u>, as if they existed. The descriptions should <u>not</u> be interpreted as descriptions of the <u>current state</u> of the decision-making system.

A.1 Enabling condition 1: People are free to consider transformational change

Note, the enabling conditions are described as the conditions that are desired, in the style of a theory of change or scenario. That is, they are written in the present tense, as if they existed. The descriptions should not be interpreted as descriptions of the current state of the decision-making system.

A.1.1 Theme 1: Safe to have conversations

Future decisions and management by DEW

DEW and its local and Basin partners are able to think and talk together about transformation, considering long-term futures and objectives that are different from current aspirations and objectives, with reduced risks to current values, priorities and reputations. This includes minimising risks of being accused of 'giving up' or having a 'secret agenda', or negotiations about current objectives being compromised (see section A.1.4). These risks can be internal to an agency or between an agency and its external stakeholders⁶.

DEW includes narratives with significant change and implications of climate change in State of the Coorong and other documents, and promotes dialogue about environmental change in society (e.g. in cultural events like Adelaide Writers Festival, the Festival of Ideas and in other States).

DEW understands stakeholders' perspectives and concerns, and can participate in developing narratives with stakeholders.

Conditions needed to enable future decisions

People accept that it is necessary to start considering future change and the possibility of transformation, and doing so is not a challenge to current policy and aspirations.

People are curious and seek to become better informed about possible transformational change in the CLLMM.

People freely share their fears and aspirations for the CLLMM as it transforms, and they are keen to engage with DEW about future change.

Learning (by others) needed to create enabling condition

All stakeholders become aware of the drivers of change in the CLLMM, that the future change is different to current change processes and there is a possibility of transformational change.

DEW staff and stakeholders are confident that their fears and concerns about the future will be heard and respected.

⁶ We use stakeholders to refer to people with an interest in the CLLMM, generally this is primarily locally people but it does include those the Basin, and it includes the public and other agencies.

We use community to refer more specifically to people in the CLLMM region.

Near-term intervention by DEW to drive learning

DEW includes, in communication with stakeholders, information about future climate change and that the circumstances of the future will be different and may require different management and outcomes, in both the CLLMM and other ecosystems in South Australia.

DEW actively listens to reactions and concerns of stakeholders about near-term and long-term changes. They do this continuing to recognise that different groups within the community have different relationships with the CLLMM and will need different engagement approaches. Communication and engagements about future change accommodate plurality of perspectives and uncertainty.

DEW listens out for and acknowledges risks that stakeholders perceive about considering transformational change.

A.1.2 Theme 2: Recognising entailments

Future decisions and management by DEW

DEW considers the implications of possible future change for near-term management, research and monitoring, and any other relevant issues in a transparent manner.

Having considered future change, DEW can make decisions and change management during windows of opportunity.

Conditions needed to enable future decisions

Stakeholders are willing to deliberate about the implications of future change. Narratives of change include opportunities to protect values in different ways as the CLLMM transforms.

Learning (by others) needed to create enabling condition

Stakeholders recognise that future change has near-term entailments, and that it is better to understand these transparently and deliberately.

Stakeholders recognise that future change is not just about loss of values, it is also about changing management to protect values and make them more resilient as the CLLMM experiences transformational change.

Near-term intervention by DEW to drive learning

DEW starts communicating with stakeholders about long-term nature of environmental change and management responses, for example building on *State of the Coorong* (DEW 2021). This emphasises, that while the CLLMM may change significantly, many values will be protected, that changes in management may be needed to ensure those values are protected, and that change processes will take a long time, so people need to start thinking and deliberating about it now. Engagement about change is presented as an invitation to deliberate about future changes, and to identify activities that can help create future management options. These activities may include research about future change, and engagement about values in the context of change.

DEW engages with industries that might be affected by changes in management, to start dialogue about how their near-term planning might be affected by the possibility of future changes, for example investments in long-lived infrastructure, perennial agriculture and ecological restoration.

A.1.3 Theme 3: Cross-jurisdictional support for engagement on transformation

Future decisions and management by DEW

DEW can engage with stakeholders on the potential for transformation in the CLLMM, recognising the issues being addressed are relevant to other Ramsar sites in SA, the Basin and across Australia, and natural ecosystems and landscapes will similarly face the same issues.

DEW can engage with Australian and other State governments on transformational adaptation in the CLLMM and elsewhere. Modelling of long-term impacts and different management options across the Basin is conducted collaboratively and freely available to other agencies and stakeholders.

Conditions needed to enable future decisions

Australian Government and MDBA are keen to learn from DEW about the implications of climate change for the CLLMM in the knowledge other Ramsar sites, including others in the Basin, are also likely to face changing ecological character as a result of climate change.

To enable collaboration among agencies and with stakeholders, the MDBA regularly and transparently considers the social and ecological implications of climate change at the Basin level. Data and analysis about climate change is released when available. Other MDBA programs and initiatives (e.g. MDB Water and Environment Research Program) engage with whole-of-system implications and the possibility of transformational change, not just near-term and physical impacts.

An external enquiry is conducted into transformational impacts and adaptation, to explore the challenge being faced by agencies in all jurisdictions, giving legitimacy to consideration of transformation and setting expectations that jurisdictions do so. *This is a cross-theme enabling condition*.

The Australian Government provides a legitimising environment and tangible support to MDBA, other Commonwealth agencies and other jurisdictions to consider implications of climate change.

Learning (by others) needed to create enabling condition

Australian and other State governments understand that the long-term implications of climate change cannot be addressed by any one agency or jurisdiction on their own. They understand there are significant implications for the MDBA and cross-jurisdictional arrangements, these implications need to be investigated and factored into near-term planning, and that the investigation will be challenging and need significant support.

Near-term intervention by DEW to drive learning

Lessons learnt in the CLLMM from preliminary climate change investigations are shared with Australian and State governments, particularly that: the implications of climate change are complex and multi-jurisdictional, there are significant implications for MDBA and collaborative arrangements, these need to be investigated, and such investigation is challenging and needs to be adequately supported.

SA Government works with other States, the MDBA and Australian Government to create recognition that an environment that enables open deliberation about transformational change is needed. This will benefit all jurisdictions and is needed to consider implications for all aspects of water security (e.g. irrigation as well as environmental outcomes) and other sectors.

DEW builds on existing community and inter-agency conversations about change and stresses the need for relevant information and modelling to be deliberated upon in the public domain. For example, conversations started in *The Nature of SA* and during the Millennium Drought, and existing conversations in Basin Officials Committee (BOC) about climate change and water security.

A.1.4 Theme 4: Consider future change without under-mining near-term objectives

Future decisions and management by DEW

DEW and stakeholders are able to openly deliberate about future different management objectives and uses of environmental water without a risk of it affecting near-term negotiations about the water requirements for current objectives.

DEW, CLLMM stakeholders and other parties are able to transparently consider at what point and under what conditions different objectives might become preferred, accommodating the long-term nature of change and the uncertainty associated with the rate and detail of change.

Conditions needed to enable future decisions

Basin States and other parties do not use open deliberation about future change in the CLLMM as an argument for changes to current management objectives.

The Basin Plan explicitly provides a framework for deliberating over near-water recovery and targets and deliberating about future transformation. In the near term, Basin States do not confuse and conflate long-term issues with negotiations about water recovery for future revision of the Basin Plan.

Relevant parties differentiate between consideration of long-term issues for Ramsar sites and near-term obligations and reporting.

An external enquiry or independent review of transformational adaptation clarifies the distinction and relationship between near-term issues and long-term issues, and sets an expectation that parties will start considering transformational change.

Learning (by others) needed to create enabling condition

Australian and State governments recognise the difference between near-term water issues and consideration of long-term transformational issues.

Near-term intervention by DEW to drive learning

DEW communicates key lessons from considering transformational changes, the long timeframes involved and the distinction from and relationship to near-term site management issues. This could draw on the process and challenges of exploring transformation, rather than detail of alternative outcomes, and draw on lessons from transformational climate change from outside the Basin. DEW communicates about issues associated with wetlands experiencing significant long-term ecological changes using non-Ramsar site examples, to avoid conflation with Ramsar-specific objectives and rules.

A.1.5 Theme 5: Starting now

Future decisions and management by DEW

DEW can start convening dialogue with and within stakeholder groups about adaptation actions that might need to be taken in the CLLMM as climate change impacts progress, rather than waiting until more severe impacts are experienced or during the next drought.

Conditions needed to enable future decisions

Stakeholders are keen for dialogue, supported by analysis, about climate change impacts in the CLLMM and adaptation actions that may need to be taken as impacts progress, including possible future transformational changes.

Learning (by others) needed to create enabling condition

Stakeholders understand the urgency of considering the implications of climate change, because it is happening now, will only increase and will potentially involve very significant changes.

Near-term intervention by DEW to drive learning

DEW communication about CLLMM includes information about climate change, how the impacts will gradually increase, that a series of adaptation actions will be required, and that there is the potential for very significant impacts requiring transformational adaptation. Communication makes it clear that transformational impacts and adaptation will occur across many decades, but analysis of them and preparation for them will also take decades and so the time to start dialogue is now.

DEW to build upon its understanding of stakeholder issues (see Theme 1, section A.1.1), the entailments of climate change (Theme 2, section A.1.2) and opportunities for transformation (Theme 3, section A.1.3) to support different stakeholders in recognising the need to act now in anticipation of future climate change. This includes businesses and others with long-term planning requirements.

A.2 Enabling condition 2: People have a good understanding of future change and are accepting uncertainty

Note, the enabling conditions are described as the conditions that are desired, in the style of a theory of change or scenario. That is, they are written in the present tense, as if they existed. The descriptions should not be interpreted as descriptions of the current state of the decision-making system.

A.2.1 Theme 1: Understanding change is happening

Future decisions and management by DEW

DEW is able to deliberate effectively with local and Basin partners about adaptation responses to climate change, without getting caught up in debates about near-term versus long-term impacts or more-likely or less-likely impacts.

Conditions needed to enable future decisions

Stakeholders are interested in deliberating about adaptation actions that might be required under different circumstances.

Stakeholders have a working knowledge of climate change and ecological responses in the CLLMM, and they are able to make sense of climate change impacts and the events they experience, and deliberate about adaptation actions taken over time.

Learning (by others) needed to create enabling condition

Stakeholders understand that climate change is happening, it will increase over time and it has the potential to be transformational. They understand that some details of climate change and ecological impacts will remain hard to predict, but there may still be significant impacts.

Near-term intervention by DEW to drive learning

DEW engages with stakeholders about climate change impacts and also the reality of the nature of information about climate impacts and ecological responses.

A.2.2 Theme 2: Accepting uncertainty

Future decisions and management by DEW

DEW is able to engage with stakeholders about long-term impacts and adaptation responses that anticipate and respond to significant but uncertain change.

Conditions needed to enable future decisions

Stakeholders accept that there is uncertainty about some aspects of future change and that this does not reduce the consequence of those changes, and they are willing to accommodate the uncertainty in their assessment, analyses and planning.

Stakeholders expect DEW and other agencies to undertake future-oriented analyses, planning and implementation that effectively accommodates uncertainty.

Learning (by others) needed to create enabling condition

Stakeholders understand that there is uncertainty about some aspects of future change but that does not reduce the likelihood that climate change will have significant impacts, and that the uncertainty of an impact does not reduce its consequences.

Stakeholders understand there will also be unanticipated impacts of climate change that people need to adapt to as well as the impacts that are well characterised.

Near-term intervention by DEW to drive learning

DEW engagement with stakeholders about climate change includes discussion about the nature of what is knowable and what will remain unknown, how that does not affect consequences of impacts, and how uncertainty can be dealt with through planned adaptable responses.

A.2.3 Theme 3: Decision making

Future decisions and management by DEW

DEW analyses options and makes decisions related to ecosystem change and novel states supported by their stakeholders. Decisions made using alternative futures, rather than reference to a past base case. (That is, outcomes from proposed decision option or management action are compared to outcomes expected *without* the management actions, rather than relative to a past state that may not be feasible under climate change. Note, DEW has already started to adopt this approach.)

DEW is able to demonstrate, to Basin States and other stakeholders, improvements in outcomes they can achieve with available water for the environment, despite changing conditions.

DEW can make timely and effective decisions in the face of uncertainty, with improved capability and support of stakeholders. This may include using 'robust decision making', adaptive decisions, and a tolerance to making decisions with less-certain information than they have now, where necessary.

Conditions needed to enable future decisions

Science about the CLLMM focusses on supporting decision making in the face of significant ecological change. For example, drivers of change, ecological change, ecological processes and responses to extremes, ecosystem functions and functional diversity, habitat diversity and change and novel states. And it does so at the scale of the whole of the CLLMM site.

Information that is available characterises things that are important but uncertain as well as the better understood and more certain aspects of change in the CLLMM. Systems are in place to acquire monitoring and experimental data rapidly in response to change and provide useful knowledge despite variability, shifting baselines and short time series. DEW staff and stakeholders have a good understanding about future change, including awareness of what is knowable and what will remain uncertain.

Analyses in the CLLMM explore and contrast alternative outcomes and counterfactual, rather than comparing change to a fixed baseline.

Policy and tools are developed by the Australian Government to support agencies to make decisions in the face of uncertainty.

Learning (by others) needed to create enabling condition

Researchers aware of the need for decision makers to focus on change process, ecological function and future states at the whole-of-system scale and accommodate significant uncertainty.

Australian Government understands the implications of change and uncertainty for CLLMM, Ramsar wetland, and environmental management in the Basin, and the need for agencies to be supported.

Near-term intervention by DEW to drive learning

Communication with Australian and Basin State governments and stakeholders about the needs of decision makers and stakeholders facing future transformational decisions. DEW communicates about the need to make decisions that accommodate uncertainty, consider long-term changes, and the dependencies over time between decisions.

A.3 Enabling condition 3: People have realistic narratives recognising the inevitability of change and accepting some losses

Note, the enabling conditions are described as the conditions that are desired, in the style of a theory of change or scenario. That is, they are written in the present tense, as if they existed. The descriptions should not be interpreted as descriptions of the current state of the decision-making system.

A.3.1 Theme 1: Understanding and accepting change

Future decisions and management by DEW

DEW is able to engage with stakeholders about significant ecological change affecting features of the CLLMM that people value and how this might affect the way they relate to the CLLMM. Deliberations are about accommodating change and some losses in value, rather than about resisting change and preserving past conditions.

Conditions needed to enable future decisions

Stakeholders are aware of the inevitability of future change and that they are likely to involve decline and loss of some valued aspects of the CLLMM. They are prepared to contemplate and deliberate on what it means for how their relationship with the CLLMM might change along with their aspirations and preferences, and the priorities for future decisions and management actions.

Stakeholders have a more sophisticated understanding of transformation, are able to have conversations about it, and make sense of near-term events in terms of an ongoing trajectory of ecological change and change in how they relate to the CLLMM.

Learning (by others) needed to create enabling condition

Stakeholders understand that outcomes in the CLLMM are largely determined parameters that are outside the control of South Australian agencies and that are changing (rainfall, catchment hydrology, sea level), and by other factors they have very small influence over (Basin scale water recovery, and water delivered to the CLLMM).

Stakeholders understand that change is inevitable, and it will result in the loss of some things they value but some values can persist. And to ensure they persist there may need to be changes in priorities and management of the CLLMM.

Near-term intervention by DEW to drive learning

DEW communicates to stakeholders about the inevitable nature of climate change and ecological impacts in the CLLMM and the possibility of decline and loss of some valued features. DEW starts a dialogue with stakeholders to explore the implications of different types and levels of change for things people value.

Dialogue about management focusses more on the whole CLLMM, rather than South Lagoon, and ecosystem dynamics and diversity, rather than states and components.

DEW communicates about the need, in the long term, to focus on managing to protect values that can be maintained rather than resisting all losses of values.

A.3.2 Theme 2: Deal with grief and anchoring to past values

Future decisions and management by DEW

DEW is able to develop with stakeholders shared narratives and objectives that are realistic and optimistic, enduring and community owned. Narratives and decision making are informed by ongoing grass roots conversations about ecological change and future transformation.

DEW and others recognise and respect the losses of features that are currently valued, and acknowledge the emotions associated with that loss.

DEW supports the community remembering and honouring past and current features of the CLLMM that are valued but may be declining.

Conditions needed to enable future decisions

The community is able to express its grief, and other emotions, associated with the prospect of ecological change and decline or loss of features of the CLLMM they value. And they are able to reference their consideration of change in the CLLMM against alternative (counterfactual) future rather than against past conditions that will not persist.

The community have long-term trusting relationships with DEW staff, and capacities and settings that allow conversations within the community and the development of narratives that include significant change and loss of some values.

The community recognise that some past and present features of the CLLMM will change, but they can still be remembered, respected and honoured as significant and important.

Learning (by others) needed to create enabling condition

The community feel their perspectives and emotions will be heard and respected by DEW. Community members understand DEW staff are part of the CLLMM community, they care and they will be present with and for the community in an enduring manner.

The community see that there are ways that past and current values can be recognised and respected even if they cannot be fully protected in the long term.

The community understand there is no scope to prevent change and limited scope to direct it, so deliberation, decision making and management needs to focus on the options that are available to management to protect

those values that can feasibly be maintained. Community members understand they need to deliberate together about navigating future change, and they will be supported by DEW.

Near-term intervention by DEW to drive learning

DEW engage regularly with the community about the nature of change to hear their fears and grief about change. DEW run forums to foster community discussion about future change, what values might be affected, how to remember and honour values that might decline; taking the conversation beyond the existing consultative bodies. DEW and DEW staff share their fears and grief with the community.

DEW invests in expertise needed to support grief and other emotions related to change and loss, and provides enduring resourcing (not project based) for supporting deliberation and conversations in the community.

Incorporate into management documents, and other media, sections that remember and respect past valued features and those that might be declining, as well as sections that explore long-term change and its implications.

DEW commit to involving the community in development of narratives about the CLLMM, accommodating plural futures.

A.3.3 Theme 3: Community-centred discourse, processes and narratives

Future decisions and management by DEW

Rich, nuanced and well considered narratives about the future of the CLLMM representing community aspirations are available to DEW, MDBA and other agencies and are an integral part of their communication and decision making.

The narratives DEW tell and decisions they make are focused on people, their evolving relationships with the CLLMM, and the aspects of it they value, as well as the ecological aspects of the CLLMM.

First Nations traditional law and cultural practices in relation to change become an integral part of management of the CLLMM.

Conditions needed to enable future decisions

The community is empowered to engage with future change in the CLLMM in multiple and meaningful ways that suit different individuals and groups.

People feel safe and have the information they need to develop new expectations and preferences for the CLLMM in the face of change, to deliberate collectively about them and to represent their aspirations and values to DEW, MDBA and other agencies.

First Nations' management and governance frameworks are updated, as necessary, to address anticipated changes in CLLMM and its management as a result of climate change.

Learning (by others) needed to create enabling condition

Stakeholders understand that change and adaptation in the CLLMM, especially transformational adaptation, is as a social and cultural process (not just a technical / scientific one), and such processes need to be facilitated and supported.

People feel they and their values are respected.

First Nations understand that change is inevitable and could affect culturally important aspects of the CLLMM.

Near-term intervention by DEW to drive learning

DEW communicates that they recognise change in the CLLMM is a social and cultural process, and they will support those processes, as well as managing the ecological aspects of change.

DEW develop, foster and where necessary facilitate diverse and alternative forums for community members to engage with and deliberate about past and future change in the CLLMM, including the prospect of transformational change.

DEW systematically include people (their values, aspirations, emotions) in the objectives, content and narratives of projects and communication, in addition to engaging with people about projects.

DEW engages with First Nations about future ecological change and how it might interact with their connection to country and traditional law and cultural practices. First Nations are supported, as necessary, to update management and governance frameworks applicable to the CLLMM.

DEW builds on past relationships with First Nations and the local community, rebuilding connections and activity after interruptions due to Covid.

A.4 Enabling condition 4: Values and preferences are based on anticipated change not past states

Note, the enabling conditions are described as the conditions that are desired, in the style of a theory of change or scenario. That is, they are written in the present tense, as if they existed. The descriptions should not be interpreted as descriptions of the current state of the decision-making system.

A.4.1 Theme 1: Awareness values will change

Future decisions and management by DEW

DEW anticipates that values may change as conditions in the CLLMM change. Engagement about values with communities includes anticipated future change, instead of present or past conditions. Stated preferences for different management options are 'stress tested' with alternative futures, for example low flows and high sea level.

Conditions needed to enable future decisions

Communities anticipate future conditions and identify values that can be maintained in the face of change. When deliberating over different management options and activities, they express their preferences relative to counterfactuals, rather than a past state that may not be feasible under climate change.

Researchers pay attention to changing community values and preferences, and provide information and insights about the system so that people's values and preferences are grounded in what is feasible in the system now and in the future.

Learning (by others) needed to create enabling condition

Communities are aware of the sorts of changes that may be ahead, and that values are context specific. They understand that some of the things they value now may not be the same or available in the future. They recognise the benefits of ensuring their preferences are grounded in values that could feasibly be maintained in the future, rather than being based on an expectation or hope of return to their ideal (past) state.

Politicians, decision makers and researchers also understand that values and preferences are context specific and will change in response to future change. They recognise the need to identify values that can be maintained as the system changes, and keep updating their understanding of community preferences as change becomes imminent and unfolds.

Near-term intervention by DEW to drive learning

Engagement activities are created where people can more fully imagine or even experience future conditions, and they are asked to explore and express what such conditions would mean for them, their own values, and preferences.

Changing values and aspirations are included in descriptions and histories of the CLLMM in management plans and documents. DEW help people understand how preferences and values are context dependent and can be expected to evolve as the CLLMM changes.

A.4.2 Theme 2: Being prepared to reform management instruments

Future decisions and management by DEW

Managers are prepared to revise and reform management frameworks and instruments *before* they are operating outside the conditions they were designed for, in anticipation of future change.

Conditions needed to enable future decisions

MDBA and other partners routinely stress test management instruments and frameworks (e.g. water sharing rules) with large future change (e.g. much lower flows) to elicit preferences, check if objectives are reasonable, and whether the instruments would continue to be fit-for-purpose under changed conditions.

MDBA, Basin States, DEW, other managers and stakeholders are aware of the operating conditions under which current management instruments may no longer be fit-for-purpose. This includes awareness that even frameworks that are designed to cope with variation and appear climate-ready may no longer be fit-for-purpose under larger enough change. For example, a water sharing framework that defines water entitlements as proportions of a consumptive pool of variable volume may appear to be climate-ready, however it may fail to serve stakeholder interests if the volume of that consumptive pool falls by a larger amount than anticipated when the framework was designed, as illustrated during the Millennium Drought.

Learning (by others) needed to create enabling condition

Managers and stakeholders are aware that changes in flow, sea level and other factors may lead to management instruments and institutions ceasing to provide anticipated or desirable outcomes.

Near-term intervention by DEW to drive learning

DEW include stakeholders in the process of stress testing management strategies with large future change (e.g. much lower flows). DEW scopes the circumstances in which management instruments and frameworks may be operating outside the regime they were designed for.

A.5 Enabling condition 5: Institutions that accommodate large, complex and uncertain change

Note, the enabling conditions are described as the conditions that are desired, in the style of a theory of change or scenario. That is, they are written in the present tense, as if they existed. The descriptions should not be interpreted as descriptions of the current state of the decision-making system.

A.5.1 Theme 1: Ramsar (Australian and international)

Future decisions and management by DEW

DEW plan for possibility of transformational change in the CLLMM.

Key policy and management documents (ECD, Ramsar Management Plan) for the CLLMM include:

- long-term objectives considering anticipated change alongside near-term objectives
- explicit processes to address uncertainty and adapt to new information
- objectives are based on societal values for the CLLMM elicited in the context of anticipated change, not past biophysical condition.

DEW can effectively act as the manager of the CLLMM, integrating Ramsar objectives with other national and State objectives.

Conditions needed to enable future decisions

The definition of the 'ecological character' concept is revised or reinterpreted in Australian policy, and by Ramsar parties, to allow for ecological change as a result of climate change. This may involve focusing on ecological attributes anticipated to not change or specifying the desired trajectory of ecological change (with bounds) in response to climate change.

Guidelines for ECDs and Ramsar Management Plans specify inclusion of:

- near and long-term objectives that anticipate change
- objectives based on values, and inclusion of people and their values
- mechanisms to cope with uncertainty, including characterising it and anticipating how decisions will be made in the face of it, and enabling the use of qualitative as well as quantitative information

Australian Ramsar Management Principles⁷ include:

- Describe character in a manner that anticipates and accommodates ecological change due to climate change, with either climate-ready ECD or anticipate changes in ECD and a defined process for revision
- Include people and their values in descriptions and objectives for sites

⁷ https://www.awe.gov.au/water/wetlands/managing/australian-ramsar-management-principles

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• Processes are included to address uncertainty, such as: anticipate futures, identify future decisions, explicit adaptation processes

Australian Ramsar policy provides clarity about roles for Ramsar sites, including who is responsible for review and reforms needed in response to emerging climate change issues. Site managers have the capacity for integrated management of their sites and to adapt that management as necessary. Recognising that different actors (Australian Government, MDBA, States, Community) do lead on different issues and responsive cooperation is required.

Learning (by others) needed to create enabling condition

Australian Government and International Ramsar parties are aware climate change will lead to widespread changes in ecological character, and that this will create numerous complex problems for the implementation of the Ramsar Convention. These include the meaning of ecological character and the integrity of ECDs, assessment and attribution of change in character, reporting of condition of wetlands, and setting of management objectives.

They are aware the institutions that govern the management of Ramsar wetlands make a complex system, with intersecting knowledge, values and rules at multiple governance levels. Changes needed to address climate change will require linked reform at many levels.

Near-term intervention by DEW to drive learning

DEW share with Australian Government findings from the CLLMM that, under climate change, ecological character will likely change but the site has the potential to remain highly valued, if appropriately managed. But enabling this management will require changes in policy, site management objectives and decision-making processes. That reform process is likely to be challenging as the current system is multiple intersecting institutions, with different governance, but stationarity is well entrenched across many of them. A range of issues need to be addressed, including

- people and their values for the CLLMM are critical to developing effective objectives under climate change, but current process do not have values at the centre of objectives.
- uncertainty needs to be accommodated, it is unavoidable in planning for future change and needs to be addressed in decision-making processes, not only in information generation, for example by explicitly planning for anticipated futures and including planned mechanisms to adapt as change occurs or more information is available.

DEW include in CLLMM and other NRM documents, such as State of the Coorong, sections about anticipated long-term change and include an emphasis on people and their values (alongside the biophysical).

DEW share with the Australian Government the complexity of delivering integrated management for the CLLMM that accommodates climate change when there are numerous programs with different outcomes for different aspects of the Coorong.

A.5.2 Theme 2: MDB water sharing arrangements

Future decisions and management by DEW

DEW engages with CLLMM stakeholders about managing with reduced flows, based on transparent information, and is able to set objectives and plan for alternative volumes of environmental flows.
Conditions needed to enable future decisions

MDBA and States routinely engage with their stakeholders about alternative futures (including reduced flows due to climate change), to explore what they will or might value in those futures. Greater support for the inclusion of qualitative information and social information; e.g. principles for doing so developed.

Research and monitoring of the MDB comprehensively integrates people and the things they value. Analyses and policy start with people, the things they value and how these might vary, trade-off or be adapted, and works back to water usage, rather than the other way around.

Research and monitoring of the MDB anticipates change, scopes alternatives, characterises uncertainty, accommodates unanticipated uncertainties, explores novel changes and states, responds rapidly to events.

Learning (by others) needed to create enabling condition

Consumptive and environmental water outcomes are both (i) socially constructed and (ii) a function of catchment inflows, and both of these will vary over time as the climate changes and society evolves. The Australian Government, MDBA and Basin States recognise that water and outcomes are not absolutes and adaptive and deliberative processes are needed to transparently address impacts to different sectors.

Stakeholders recognise that current institutional arrangements may be inadequate for addressing future sustained reductions in rainfall, catchment inflows and river flows. Further, the process of reforming them would be complex, involve ambiguities, and need to address inevitable uncertainties. It would get harder the longer it is delayed, especially where that process overlaps with drought conditions.

Stakeholders understand the criticality of people and their values in determining desirable and feasible outcomes from water sharing in the face of reduced inflows, as opposed to framing such assessments as biophysical based on 'objective' environmental and industry needs. And they understand that people's values will vary depending on rainfall, flows and other conditions, and so processes based on elicited values need to be updated regularly.

Near-term intervention by DEW to drive learning

DEW share their experiences of considering transformational change and future (climate-ready) objectives. In particular, highlighting:

- future desirable outcomes depend on both available water and evolving societal preference
- people and their values for the CLLMM need a central role in analysis and description of outcomes under climate change
- current institutional arrangements may be inadequate to enable effective, transparent and legitimate consideration of feasible and desirable outcomes under anticipated future flows.

DEW provide leadership in MDB by developing draft principles for addressing future flows, addressing uncertainty and putting people and their values at the centre of outcomes.

A.5.3 Theme 3: Use of water for the environment

Future decisions and management by DEW

DEW engages with CLLMM stakeholders about managing with reduced flows, based on transparent information.

DEW analyses, deliberates with stakeholders and plans for different ecological objectives to be achieved with the use of water for the environmental under different climates. Analyses and plans accommodate short-term variation and long-term change in hydroclimate.

Conditions needed to enable future decisions

Objectives that are set for uses of water for the environment anticipate changes in flows and ecological change. Objectives are specified for the near term (with 'current' water) and for futures with different hydroclimates and river flows (spanning less and more water).

It is considered legitimate, and desirable, to consider different ecological outcomes that might be feasible and desirable under different climatic conditions.

There are agreed process for regularly revising objectives due to changes in: rainfall regime, new knowledge, stakeholder values. This may be technical for minor changes where agreed outcomes are not being delivered (rules not working as anticipated), and more deliberative where objectives need to change.

Learning (by others) needed to create enabling condition

Appreciation that achievable (and desirable) outcomes will vary depending on water availability due to rainfall.

Australian Government and MDBA understand that States need to plan for different outcomes in the longer term, without prejudice to near-term watering objectives and requirements.

There is an understanding that an agreed and transparent process is needed to review and revise ecological objectives from water for the environment, when required.

Near-term intervention by DEW to drive learning

DEW shares with the Australian Government and other partners the sensitivity of ecological outcomes to available water and sea level rise. For example, at some level of change CLLMM objectives and management may need to be revised, to ensure some core values of a healthy Coorong can be maintained while it experiences significant ecological changes, and this revision would require a transparent assessment and planning process.

A.5.4 Theme 4: New institutional work

Future decisions and management by DEW

DEW, MDBA and other agencies:

• are able to effectively evaluate outcomes in the context of change that is being experienced and that can be anticipated

- are supported to explore, deliberate with stakeholders, and plan for transformational change
- make decisions using values that are regularly reassessed as change occurs
- make decisions that accommodate uncertainty and significant change
- revise decisions and decision-making processes *before* they are found to be operating beyond the conditions they were designed for.

Reforms have enabled better coordination between Ramsar planning, water sharing and use of environmental water.

Conditions needed to enable future decisions

Changes in the institutional landscape to enable transformational adaptation create an authorising environment, providing support and guidance.

There is an expectation that all agencies and jurisdictions will start considering and plan for transformational change.

Tools, principles, and procedures are developed and agreed, and revised as needed, to help agencies accommodate change, uncertainty, and evolving values.

A temporary or permanent commission that is external to management agencies sets the framework for institutional reforms and innovations needed to enable adaptation and transformation, across sectors and jurisdictions.

Learning (by others) needed to create enabling condition

Governments, agencies and stakeholders understand the challenges of considering and planning for change including transformational change.

Near-term intervention by DEW to drive learning

DEW helps convene a body (external enquiry or new commission) to explore the challenges that will be faced by all agencies in all jurisdictions as they consider and plan for long-term climate change, including possible transformation.





The Goyder Institute for Water Research is a research alliance between the South Australian Government through the Department for Environment and Water, CSIRO, Flinders University, the University of Adelaide and the University of South Australia.