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Incorporating Climate Change Adaptation into Catchment Managment: A User Guide

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The role of NCCARF is to lead the research community in a national interdisciplinary effort to generate the information needed by decision-makers in government, business and in vulnerable sectors and communities to manage the risk of climate change impacts.

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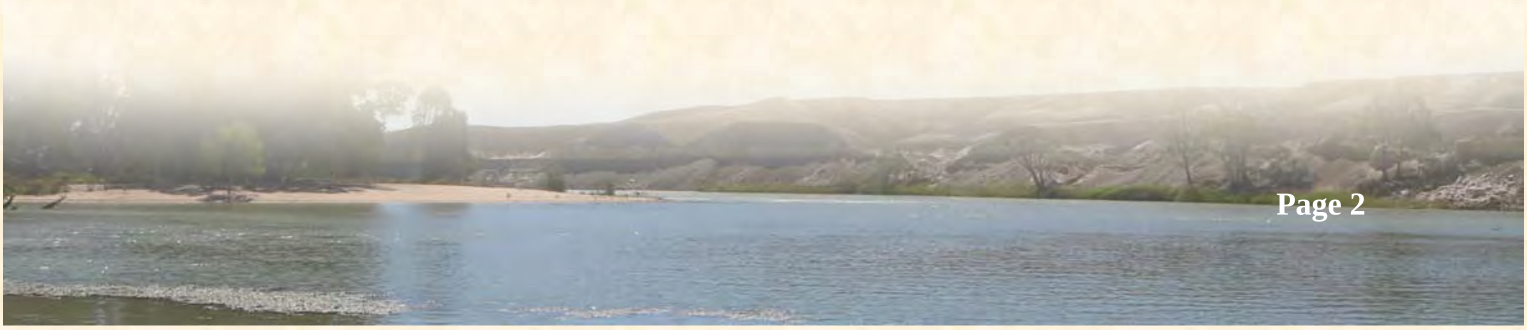

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PREFACE

This Guide provides step-by-step instructions for an assessment of the potential for climate change adaptation of natural resource management (NRM) actions. This assessment uses a Catchment Assessment Framework (CAF), a process-based tool that highlights how natural resource managers can incorporate climate change adaptation into their everyday management and planning activities. The CAF enables a qualitative assessment of different adaptation options to better inform decision-making.

Many activities undertaken by natural resource managers already contribute to building ecosystem resilience and counteracting negative impacts of climate change; however, these contributions remain largely unrecognised. Through the CAF, managers discuss, identify and assess these contributions against other criteria, such as the potential for climate change adaptation, other co-benefits, implementation constraints and risks of failure.

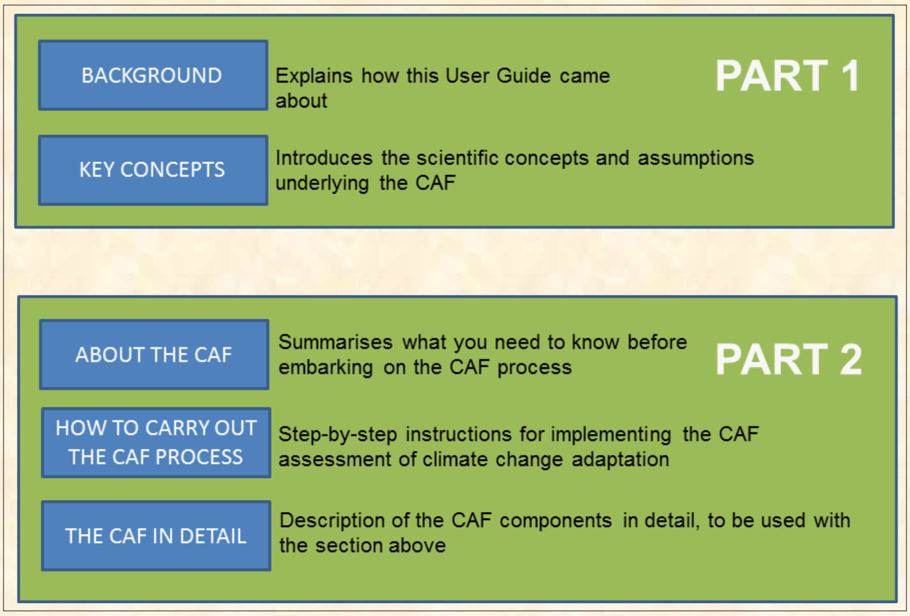
The CAF as a process-based tool helps to explore and assess management actions; as such the process and conversations involved are as valuable as the identification of management actions. The CAF is divided into seven parts that are explored, discussed and ultimately assessed. The results of each assessment are summarised in a table format. The CAF offers a 'holistic' look at the feasibility of different NRM actions as options for climate change adaptation. Its aim is to highlight those actions that present the maximum benefits along with the least risk.

We hope that you find this useful in preparing effective adaptation strategies and would welcome your feedback.

How to use this Guide

This document is divided into two main parts (Figure 1).

Figure 1: Structure of this User Guide



Part 1 is more theoretical and contains two sections that explain the origins of the CAF ('Background') and briefly introduces the key underlying concepts used in the development of the Guide ('Key Concepts').

Part 2 is the practical part, containing three sections that explain how to use the CAF. 'About the CAF' briefly explains the aims of the CAF, identifies the audience and explains how and when the CAF should be used. Exactly how to carry out the CAF process is explained in the next two sections: 'How to carry out the CAF process' outlines the steps necessary for implementing the CAF, with summaries of what needs to be done in each of the identified stages. 'The CAF in detail' explains the seven components of the CAF, how they work, and how to assess them.

BACKGROUND

The Catchment Assessment Framework (CAF) was developed through the "*Identifying low risk climate change mitigation and adaptation in catchment management while avoiding unintended consequences*" project funded by the National Climate Change Adaptation Research Facility (NCCARF). The aim of the project was to synthesise overarching lessons for mitigation and adaption that would apply to southern Australian rivers[1]. The project also developed and tested the CAF in four southern Australian catchments: the Murray, the Goulburn-Broken, the Lachlan and the North East. The framework was used to assess the climate change adaptation potential of nine natural resource management (NRM) actions in aquatic ecosystems and four in terrestrial ecosystems, as listed below.

Aquatic ecosystems:

- Environmental flows – releases of water for environmental purposes
- Environmental works & measures – structures designed to pool water on floodplains
- Thermal pollution control – devices to mitigate cold water pollution from dams
- Freshwater habitat connectivity – fish passage and removal of in-stream obstructions
- Restoration of riparian vegetation – fencing off riparian areas and revegetation with natives
- Conservation of more resilient landscapes – prioritising relatively undisturbed, more biodiverse areas
- Conservation of gaining reaches – areas where ground water flows into surface water
- Geomorphic restoration – re-snagging, removal of sand slugs and control of erosion
- Management of exotic species – removal or containment of non-native flora and fauna

Terrestrial ecosystems:

- Habitat connectivity
- Rehabilitation of refugia and habitats with favourable aspects
- Rehabilitation of large habitats
- Reduction of overgrazing

The above list is not exhaustive and other NRM actions could be assessed by the CAF, such as managed aquifer recharge, captive breeding programs or management of plantation forestry.

[1] The final report of that project can be found at: http://www.nccarf.edu.au/publications/low-risk-climate-adaptation-catchment-management

Usefulness and applicability of the CAF

The CAF is not method-dependent. In the NCCARF project the assessment included a review of published and unpublished documents and reference to expert opinion. However, it also lends itself to more quantitative assessments, including model-ling, and Bayesian Network Analysis. As an assessment and planning tool, it can be as detailed as managers need it to be.

Although developed for a project that focused on freshwater biodiversity, the CAF can be used to assess NRM actions undertaken in marine or terrestrial biodiversity conser-vation, or other NRM activities.

Adaptation actions are of better quality and more likely to be implemented when developed through a participatory process with key stakeholders. Given the different knowledge bases and varying understanding of adaptation concepts a lot of preparation is essential. To enable participants to exchange information and examine the options associated with adaptation measures we substantial preparation of background information followed by a two-day workshop process.

KEY CONCEPTS

This section explains the key terms used throughout this Guide as they pertain to climate change. Concepts such as resilience and vulnerability have multiple definitions in both social and biophysical disciplines. Similarly, resilience and adaptive capacity are described differently by some authors and used interchangeably by others. Because the literature is fragmented and confusing, the definitions provided here are broad and general.

Mitigation

Describes any action to prevent, reduce or slow climate change (Tompkins & Adger, 2003) by reducing greenhouse gas sources and emissions, or enhancing greenhouse gas sinks (Barnett et al., 2011).

Adaptation

Refers to the actions that people take in response to projected or actual climate change (IPCC, 2007b, p. 27). In human systems this is “*the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities*”. In natural systems, “*it is the process of adjustment to actual climate and its effects*” (IPCC, 2012, p. 3).

Maladaptation

Refers to actions that seek to avoid or reduce vulnerability to climate change, but end up increasing it in other systems, sectors or social groups (Barnett & O'Neill, 2010). Mal-adaptation does not just refer to unsuccessful adaptation (which implies that an action did not have the desired effect) but to actions that may have had the desired effect and also produced unintended consequences (Barnett, et al., 2011).

Vulnerability

Vulnerability is “*the propensity or predisposition to be adversely affected*” (IPCC, 2012, p. 3). It has a social and a biophysical dimension. The biophysical dimension focuses on exposure to hazards in terms of damage that occurs (Gitay, Finlayson, & Davidson, 2011), while the social dimension is concern-ed with social risks and capacities to absorb pressure. There are three elements to vulnerability: exposure, sensitivity, and adaptive capacity (Bates et al., 2010). These elements are usually attributed to biophysical systems, but can apply to social systems as well. Vulnerability is mediated by resilience (Williams, Shoo, Isaac, Hoffmann, & Langham, 2008).

Resilience

Denotes "*the ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions*" (IPCC, 2012, p. 3). Across many different disciplines, building resilience into both human and ecological systems is thought to be the optimal way to deal with future surprises, or unknowable risks (Tompkins & Adger, 2003). Resilience is thus a goal (or aspiration) for management of ecosystems, as well as an attribute of the system itself. It can be investigated at different levels, such as individual, community, organisation or eco-system (Boon, Cottrell, King, Stevenson, & Millar, 2011). However, resilience is a complex idea, as a resilient system is not necessarily a desirable one (Nelson, 2010).

<u>What constitutes climate change adaptation?</u>

In general, adaptation responses can either reduce vulnerability by insulating against harsh conditions, or increase resilience and/or adaptive capacity by modifying patterns of production and consumption to better suit the climate (Patt, 2009, p. 81). Adaptation requires flexible institutional and policy interventions across multiple sectors and jurisdictions (Dovers & Hezri, 2010). According to the IPCC (2007a), adaptation responses can be:

- Technological (e.g. dams & weirs)
- Behavioural (e.g. altered food and recreational choices)
- Managerial (e.g. promoting different farm practices); and
- Policy-based (e.g. planning and regulation)

Specific adaptation strategies described in the climate change literature (Bates, et al., 2010; Hulme, 2005; Lindenmayer et al., 2010; Pittock, Hansen, & Abell, 2008) include:

- Maintaining effective monitoring and adaptive management programs
- Incorporating climate change into current management practices
- Reducing the threats and impacts arising from climate adaptation initiatives in other sectors
- Reducing/tackling non-climate stresses on freshwater resources and ecosystems
- Protecting intact habitats which act as refugia[2] (including those designated as protected areas and those which are not)
- Ensuring appropriate connectivity between freshwater ecosystems
- Preserving genetic stock (including the relocation of endangered species and captive breeding programs)
- Reducing emissions and ensuring carbon capture (while this is actually a mitigation strategy, it does 'buy time' for adaptation)
- Preparing for major natural disturbances

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[2] A refuge is defined as a place of shelter, protection, or safety; while refugia are "areas where special environmental circumstances have enabled a species, or a community of species, to survive despite extinction in surrounding areas (Belski & Williams, 2012). Refugia thus protect biodiversity during extreme events such as floods and droughts (Steffen, 2009).

Climate change interactions with non-climate stressors

Numerous models about climate change impacts on different geographical regions have been run in many countries. However, in most cases, climate change is impacting on heavily altered and degraded ecosystems, rather than natural healthy ones. Hence, in terms of biodiversity, climate change is yet another stressor, interacting with and deepening existing problems (Lindenmayer, et al., 2010).

In the case of the southern Murray-Darling Basin, the interactions between existing stressors and climate change are explained by McAlpine et al. (2009) who noted that extensive clearing of native vegetation is likely to have contributed to a hotter and drier climate and exacerbated the El Niño effect in south-east Australia, which then put pressure on governments to allocate diminishing water resources between consumptive and environmental uses. Pittock, Hansen and Abell (2008) argue that the existing non-climate change related stresses and impacts from maladaptive policies will outweigh the negative impacts of climate change in the medium term. Kingsford (2011) shares this view, stating that the effects of river regulation remain the greatest threat to freshwater ecosystems in the foreseeable future. It is thus clear that climate change adaptation must take account of non-climate change related stresses in order to avoid maladaptation.

The CAF was developed to consider 'low-risk' actions that provided the most benefit to climate change adaptation by: a) either directly addressing or at least not increasing existing stresses, b) implementing 'no regrets' measures, and c) intervening with complementary measures that have different risks and so spread the overall risk. 'No-regrets' measurements are those where implementation will result in ecosystem benefit regardless of future climate change (Hallegatte, 2009).

Ecosystem-Based Adaptation

Ecosystem-based adaptation (EBA) aims for the maintenance of healthy, resilient ecosystems, that can adapt to climatic changes. Preserving and enhancing eco-systems enables society to better adapt to the unknown impacts of climate change and provides multiple co-benefits for climate change mitigation, protection of livelihoods and poverty alleviation (Munang, et al., 2013). In EBA, strategies to deal with climate change impacts include the maintenance and restoration of natural ecosystems, protection of vital ecosystem services, reduction of land and water degradation by controlling invasive, alien species and the management of habitats to ensure plant genetic diversity (The World Bank, 2009). In 2008, the IUCN proposed protected areas as one of the solutions to climate change (Dudley et al., 2010) and the World Bank (2009) stressed that natural systems not only provide goods and ecosystem services but also are a proven and cost-effective protection against climate change impacts. EBA is the underlying philosophy behind the CAF, which highlights the benefits of climate change adaptation and ecological resilience of NRM actions.

ABOUT THE CAF

What is the CAF?

The CAF is a process-based deliberative tool that is used to assess the climate change adaptation potential of NRM actions, and by so doing allows the incorporation of climate change adaptation into NRM planning. It contains a series of preparatory steps that must be done in order to get to the assessment stage. This Guide explains both the process (next section) and the tool (the CAF in detail). The CAF is expressed as a series of tables that summarises discussions around seven key components.

Who is it for?

CAF is aimed at NRM managers and planners at a regional (catchment) scale and anyone who is interested in the practical application of the principles that govern climate change adaptation. We envision that NRM planners and managers from NRM bodies as well as planners within state and Commonwealth environmental departments will find it a useful tool. Potential end users include catchment management authorities (CMAs) or NRM boards, government water, environment or conservation agencies or authorities, as well as local government, and community-based or non-governmental organisations.

When should it be used in the planning process?

CAF assists managers in defining strategic interventions (i.e. program planning). It should be used after the goals and management objectives have been set. As the tool is holistic and strategic it is not so useful for specific and detailed operational and project planning at a local level. Figure 2 is an extract from a flyer produced by the Murray CMA showing where the CAF should be applied in the CMA's planning structure.

'How to use the CAF process' details the four main stages of the CAF process, which culminate in the actual CAF assessment. We envision that the results of this assessment will be incorporated into program planning and then be evaluated through an existing institutional evaluation processes. It is thus vital that the assumptions and reasoning behind the assessment are documented along with the assessment results to enable the CAF to be used as part of adaptive planning.

At what scale should this tool be used?

CAF was developed to assist catchment-level management, but could be adapted to apply at any scale to any adaptation challenge. In this Guide, we have focussed on adaptation in NRM at regional (sub-national scales). How the CAF is applied will largely depend on the level that the NRM planner or manager works at. We suggest two possibilities:

Ecological communities - bioregions

We suggest a focus on ecological communities as an appropriate scale; however, management will need to take account of administrative boundaries. There are a number of guidelines as to what constitutes a bioregion and ecological communities. For example, the *Environment Protection and Biodiversity Conservation (EPBC) Act 1999* directs Australian NRM towards the Interim Biogeographic Regionalisation for Australia which provides nationally established and supported delineations of the continent into 89 bioregions and 419 subregions (Commonwealth of Australia, 2013a). Other types of bioregions include World Heritage-defined areas, such as the Great Barrier Reef, Southwestern Tasmania or the Wet Tropics.

NRM regions - administrative regions

Australia is divided into 54 NRM regions (Commonwealth of Australia, 2013b) governed by regional NRM bodies variously called Catchment Management Authorities, Councils and NRM Boards. These regions are different, but complementary to the bioregions and sub-bioregions identified above. CAF Activities by regional NRM bodies may be specifically directed at ecological communities that have been identified as endangered or threatened, or may be directed towards subsystems or sub-catchments of larger regions.

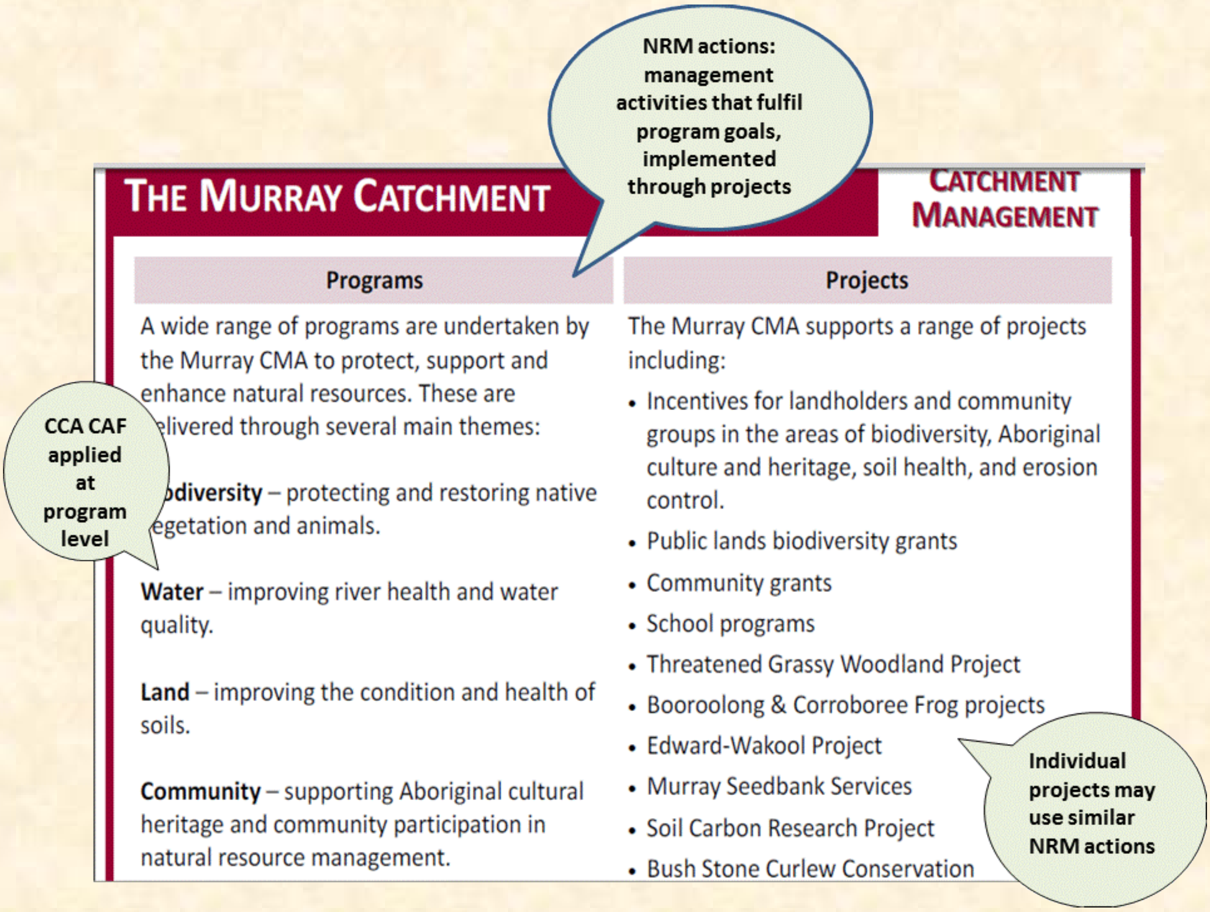

Figure 2: Where the CAF fits in NRM planning (from the Murray CMA).

HOW TO CARRY OUT THE CAF PROCESS

Assessing NRM actions for their climate change adaptation potential requires significant preparation. This section goes through a step-by-step process detailing what you need to do to complete a CAF assessment. Figure 3 shows seven steps of the CAF process, summarised under four headings of identification, information gathering, communication and the actual assessment. These are examined below.

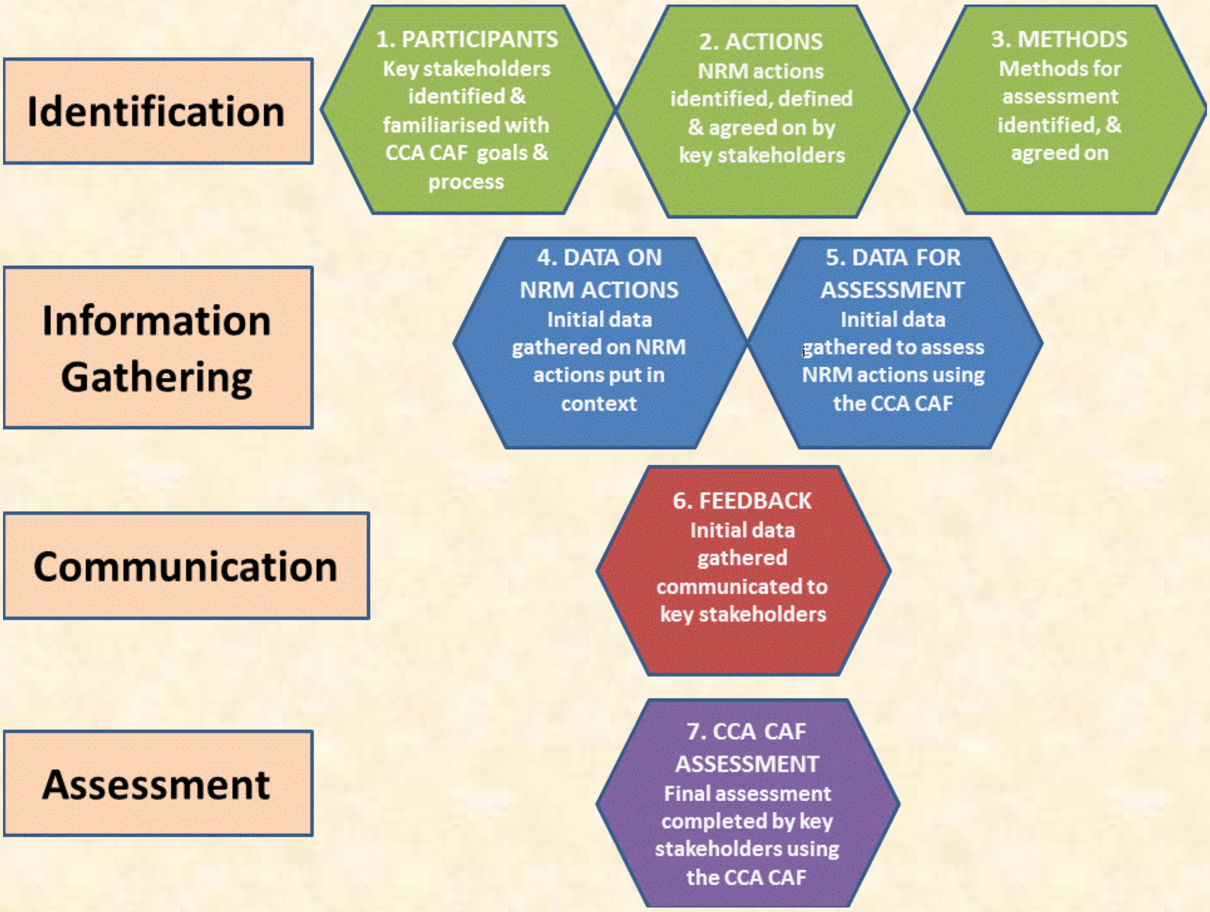

Figure 3: Steps of the CAF process

Stage 1: Identification

The first step is to work out what is going to be assessed, by whom and what methods will be used to gather the necessary data.

Participants

The identification of key stakeholders is the starting point. Questions to consider when doing this include:

- Who will actually do the assessment?

This could be simply the planning/ management team responsible for program planning. Alternatively, key stakeholders could also include project officers, community representatives or NGO partners.

- Who is going to provide information for the assessment?

As a rule, the more informants the better. If the assessment is to be done by a small group of people, it would be wise to look for more knowledge and expertise from outside of the group. As the CAF includes consideration of ecological, economic and social costs, benefits and risks, we encourage consultation with key stakeholders representing these from across the area of interest.

- To whom will the assessment be communicated?

Ideally, the CAF should be included in the broader planning process.

NRM Actions

Deciding on actions to assess is a crucial step, requiring liaison with and guidance from key stakeholders. NRM actions must be well-defined and explained in the context of the catchment or bioregion in order to enable assessment. People can't asses what they don't understand.

Methods

The CAF is not method-specific - the choice of methods will depend on available time, budget, information sources and expertise. 'The CAF in detail' section offers suggestions of a range of possible methods for each part of the framework and these are briefly summarised in the table below. Data-gathering methods should be established well ahead of the information gathering stage since time-intensive data collection methods, such as semi-structured interviews with key stakeholders or modelling of impacts under various climate change scenarios, must be undertaken well before the actual assessment and the results made available to all participants prior to the assessment.

Table 1: Possible data gathering methods appropriate for different parts of the CAF

	Expert knowledge	Document analysis	Literature review	Stakeholder interviews	Focus group/ Workshop	Scenario modelling
Catchment Relevance	✓	✓		✓	✓	
CCA Potential	✓	✓	✓	✓	✓	
Effectiveness under different projections	✓	✓		✓	✓	✓
Maladaptation	✓	✓		✓	✓	
Ecosystem Benefits	✓		✓	✓	✓	✓
Compatibility	✓		✓	✓	✓	
Socio-Economic Outcomes	✓			✓	✓	
Implementation constraints	✓			✓	✓	
Risks	✓			✓	✓	✓

Stage 2: Information gathering

Data on NRM Actions

NRM actions to be considered in the CAF should be developed with key stakeholders to draw on their expertise and to develop a common understanding of the actions being assessed. For example, what is meant by 'reforestation' and how does this differ from 'afforestation'? Whichever actions are chosen, participants must be given enough information to visualise both the actions and their impacts.

Data for assessment

Table 1 provides an overview of possible methods for gathering information in different parts of the CAF. These methods have disadvantages and advantages, as summarised in Table 2. A common assertion in the climate change adaptation literature is that, while there are national and continental projections, there is little appropriately scaled information of climate change impacts that could aid in the planning process (Aldous, et al., 2011; Patt, 2009). When asked to consider the effectiveness of actions under different climate change scenarios, managers and planners may struggle to apply catchment-scale predictions of water availability and temperature increases to specific sub-systems within the catchment. The lack of information about climate change scenarios at a local scale can be a constraint in the assessment process.

Table 2: Advantages and disadvantages of proposed methods for CAF

	Description	Advantages	Disadvantages
Expert knowledge	Reliance on the professional knowledge of planners/managers	Does not take much time or expense	May offer limited range of insights
Document analysis	Reading of relevant policy/planning documents to gain specific information	Does not take much time or expense	Sought-after information may not be available in the documents
Literature review	Reading of academic literature	Does not take much time or expense	Requires familiarity with academic literature Specific, local information may not be available
Stakeholder interviews	Interviews with key stakeholder representatives	Provides wealth of information from key stakeholder representatives	May take considerable time and effort to plan, conduct and analyse interview data; requires interviewing skills
Focus group/ Workshop	facilitation of a group meeting to elicit information	Provides wealth of information from key stakeholder representatives	May take considerable time and effort to organise focus groups Requires facilitation skills
Scenario modelling	The building of a range of future scenarios incorporating future climatic projections, demographic or other economic data to discuss impacts of proposed actions	Provides detailed, illustrative information at an appropriate level to enable fruitful discussions	Requires considerable knowledge & expertise to develop models Requires specific local level information that may not be readily available

Part 2: Using the CAF

Stage 3: Communication

Communication between those carrying out the CAF assessment and identified key stakeholders is an ongoing necessity. Although Figure 3, which explains the CAF process, is structured hierarchically for clarity it is part of an adaptive management context with iterative feedback between all steps. While communication is ongoing there must be a decisive stage where information is passed on to the stakeholders who will be doing the assessment.

Stage 4: Assessment

The actual assessment may take several days especially where it involves project partners whose expertise is being relied on in the assessment. A separate workshop can be used for the assessment (in addition to the use of workshops in the information gathering stage). This workshop should be scheduled well after the information gathered has been communicated to workshop participants so they have adequate time to digest this and prepare for the assessment. Background information should be presented on the first day to ensure that all participants are familiar with the assumptions and concepts behind the CAF. This could include:

- Overview of climate change adaptation concepts such as resilience and vulnerability.
- Explanation of the ecosystem-based approach to climate change adaptation.
- Introduction of the NRM actions to be assessed.
- Overview of how the information was gathered.

The actual assessment can be undertaken in either one or two days, broken up into the seven components used in the CAF (see 'The CAF in Detail).

These four stages of the CAF process should be considered as part of adaptive planning. Figure 4 illustrates how the CAF can be incorporated into planning and where lessons learned can be integrated into subsequent plans.

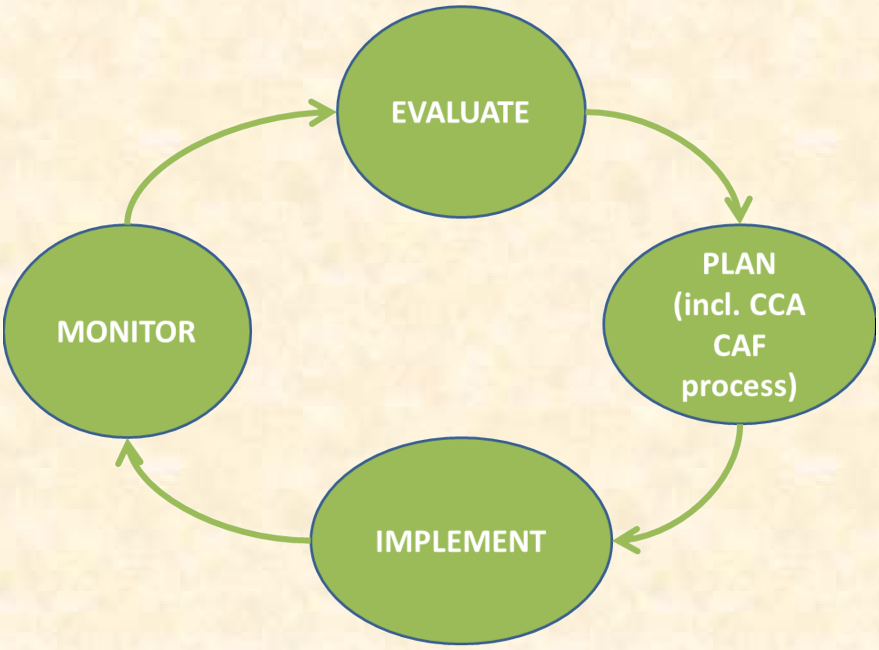

Figure 4: Where the CAF fits in the adaptive planning process.

THE CAF IN DETAIL

The CAF is divided into seven components. In this section, each part is individually explained, with examples and suggested methods for information gathering.

1. Catchment relevance:	Establishes specific projects that are either undertaken or considered by the managing body. Specifying actual projects or programs allows the evaluation to be more practical.
2. Climate change adaptation:	This part is further divided into three parts: 1. Consideration of whether the NRM action contributes to reducing non-climate change stressors or to increasing resilience to climate change shocks. 2. Assessment of the effectiveness of NRM actions under different climate change scenarios. 3. Consideration of the potential for maladaptation (unintended consequences).
3. Ecosystem services benefits:	Looks at the ecosystem benefits provided by the NRM actions. The ecosystem-based approach to climate change adaptation highlights the need to have healthy, functioning ecosystems to build resilience to climate change impacts, sequester carbon (in itself a climate change mitigation strategy), attenuate natural disasters and meet other human needs.
4. Compatibility	Highlights how the actions interact with one another. This aspect is qualitative but assessments can include listing actions that: 1. must be done together to gain the greatest positive effect 2. will positively enhance the effects of others 3. will negatively affect the effects of others
5. Constraints to implementation:	Constraints can either prevent or limit the adoption of individual adaptation actions. These can be physical, financial, social and institutional.
6. Socio-economic considerations:	Assesses the positive and negative socio-economic implications of individual projects.
7. Risk of failure:	Looks at the risk (probability x consequence) of the action failing to achieve its goals under different climate change scenarios. While similar to the assessment of action effectiveness under different climate change scenarios, the risk of failure considers not just the bio-physical risks but the added institutional or socio-economic risks that may be overlooked in assessments.

Part 2: Using the CAF

An example of the CAF is presented in Table 3. The example is hypothetical, designed to show how the different components work to highlight the overall desirability, or otherwise of different actions. While it may be of limited value at first glance, the process of assessing each individual component of the CAF has proved to be of enormous assistance to CMA personnel. Each component of the CAF has its own table and Table 3 is a summary of all of them.

Table 3: A Hypothetical CAF

Catchment Name						
Description of each action			Action 1	Action 2	Action 3	Action 4
Catchment Relevance	Extent to which the action exists in the catchment		Currently Implemented	Considered & Rejected	Not Applicable	Not Yet Implemented
Climate change adaptation potential	Climate change adaptation benefit	Reducing vulnerability caused by non-climate change stressors	✓		✓	✓
		Increasing resilience to climatic shocks/changes	✓	✓		✓
	Effectiveness under changing climate change scenarios	Current conditions				
		Wet				
		Moderate				
		Dry				
		Very Dry				
	Potential for maladaptation	Increasing emissions		HIGH		NEGLIGIBLE
		Disproportionate burden on most vulnerable	UNKNOWN	HIGH	MEDIUM	MEDIUM
		High opportunity costs	NEGLIGIBLE	HIGH	NEGLIGIBLE	MEDIUM
		Reducing incentive to adapt	NEGLIGIBLE		UNKNOWN	UNKNOWN
		Path dependency		UNKNOWN	NEGLIGIBLE	HIGH
		Increasing existing stressors	MEDIUM	MEDIUM	NEGLIGIBLE	HIGH

Part 2: Using the CCA CAF

Ecosystem Services Benefit	Provisioning	✓	✓		✓
	Regulating	✓	✓		✓
	Supporting	✓	✓	×	✓
	Cultural	✓	✓	?	✓
Compatibility	Must be done with	Actions 2 & 3			Actions 1 & 2
	Will positively enhance		Actions 1 & 4		Action 1
	Will negatively affect				
Constraints to implementation	Physical	NEGLIGIBLE	NEGLIGIBLE	HIGH	
	Financial		HIGH	HIGH	HIGH
	Socio-political	MEDIUM		UNKNOWN	HIGH
	Institutional	HIGH	HIGH		
Actual, Perceived or Hypothetical Socio-Economic Outcomes		✓✓	✓✓	✓	✓✓
		××	×	×	
Risk Assessment	Wet	L	L	M	L
	Moderate	M	L	M	L
	Dry	H	M	L	L
	Very Dry	E	H	M	L

Catchment Relevance

This component describes the relevance of the NRM actions to be assessed using categories such as:

- Currently Implemented (CI)
- Not Yet Implemented (NYI)
- Considered & Rejected (CR)

Information for this can be gathered through expert knowledge, stakeholder interviews and/or review of relevant documents.

Climate change adaptation potential

This component is further split into three parts. First, it considers whether the NRM action being assessed offers a climate change adaptation benefit. Next, this benefit is assessed under different climate change scenarios. Once this is known, the potential for maladaptation (unintended consequences) is considered.

The assessment of this component can be based on expert opinion or quantitative modelling. The assessment of each action considers only the climate change adaptation benefit, not the overall environmental/social/economic desirability of the action.

Climate change adaptation benefit

The climate change adaptation potential is established by considering how each action either reduces vulnerability to existing stressors and/or increases resilience to climatic changes. For example, inland water bodies are affected by habitat fragmentation, river regulation, rising salinity, erosion, biodiversity loss and decreasing water quality, as well as climate change impacts (Kingsford, 2011). Non-climate stressors affecting terrestrial ecosystems include land clearing (leading to the loss and fragmentation of core habitats and migration corridors), unsustainable land use activities leading to habitat degradation (especially over-grazing and logging), water diversions, changed fire regimes, invasive weed species and animal pests (Mackey, et al., 2008).

Table 4 shows several criteria that can be used to determine the adaptation potential of actions (through reviewing climate change literature, consultations with experts and a technical workshop). These criteria include both terrestrial and aquatic ecosystems and can be modified depending on the assessment. For example, it may not be necessary to consider whether NRM actions for an aquatic ecosystem mitigate the impacts of changed fire regimes. The table indicates the *presence* and *desirability* of impacts for each action.

Table 4: CCA Potential of each NRM action

Climate change adaptation benefit					
		Action 1	Action 2	Action 3	Action 4
Reducing vulnerability caused by non-climate change stressors	Conserves or restores past or existing habitat refugia	✓	✓	✓	✓
	Mitigates impact of changed hydrological regimes (e.g. decreased flows)	×	?		✓
	Reduces sediment influxes	✓		✓	✓
	Mitigates impacts of changed fire regimes	✓		?	✓
	Prevents or reduces invasion by exotic species	×	×		✓
Increasing resilience to climatic shocks/changes	Conserves or enables access to future habitat	✓	✓		
	Extends habitat connectivity and migration paths for biota				✓
	Mitigates changes in water volumes	✓	✓		
	Mitigates changes in water temperature	✓	?	?	✓
	Mitigates changes in the timing of water flows	✓	✓		
	Mitigates changes in air temperature	✓		?	✓
	Mitigates carbon emissions	✓	✓		
	Improves genetic diversity				✓
	Preserving genetic stock	✓	✓	✓	✓

Legend for Table 4

✓	Potentially directly beneficial
×	Potentially directly detrimental
?	Unknown impact
	No direct impact

Adaptation effectiveness under different climate change scenarios

Once the climate change adaptation potential of NRM actions has been established, natural resource managers need to consider how their effectiveness would be affected by climate change projections. This assessment can use expert judgment as a method, but some form of modelling of the various scenarios would provide a more quantitative and comprehensive assessment. This is where scenario building can be used and this can be as detailed or as basic as existing time, budget and information availability allows. Regardless of detail some time must be taken to consider what these scenarios could mean for the catchment and the ecosystem in question.

The reason for considering different climate change scenarios is to avoid overly-narrow adaptation (e.g. infrastructure measures that fail past a possible climate threshold) by assessing the effectiveness of adaptation measures against a range of possible climate change scenarios, as well as a constantly changing climate and extreme variability, not just the average conditions.

The *magnitude* and *desirability* of impacts for different actions are shown in Table 5 where a traffic light approach has been used to categorise each action under the four climate change projections and current conditions. This is a similar approach to that used by Gross et al. (2011) in their study of climate change adaptation limits in the Coorong and Lower Lakes.

Table 5: Assessing the effectiveness of NRM actions under different climate change projections

CCA Actions	Wet	Moderate	Dry	Very Dry
Action 1				
Action 2				
Action 3				
Action 4				

Legend for Table 5

	Likely to be effective and beneficial
	Less effective or with lower benefits
	Not effective or redundant
	Not currently implemented or applicable

An action (such as environmental works and measures for wetland conservation) will thus be rated likely to be effective and beneficial (green) if it meets the criteria established in Table 4. However, the same action may be rated as less (Amber) or not (red) effective under a different climate change projection.

For example, infrastructure to water a floodplain forest may work in the next few decades, but then fail if there is too little water to operate it regularly beyond that. If the action is not currently implemented its effectiveness under different climate change scenarios can be projected.

Potential for maladaptation

Literature on climate change adaptation identifies six types of maladaptation (Barnett & O'Neill, 2010):

- Increasing emissions
  - Adaptation is maladaptive if actions end up contributing to climate change. For example, the increased use of energy-intensive air conditioners in response to the health impacts of heat-waves
- Disproportionate burden on the most vulnerable
  - Adaptation actions are maladaptive if, in meeting the needs of one sector or group, they increase the vulnerability of those most at risk (like minority groups or low-income households) or shift the consequences to another sector or group
  - Vulnerable ecological communities and species should also be considered in this context
- High opportunity costs
  - Approaches may be maladaptive if their economic, social, or environmental costs are higher relative to alternatives
- Reducing incentive to adapt
  - If adaptation actions reduce incentives to adapt, for example by encouraging unnecessary dependence on others, stimulating rent-seeking behaviour, or penalising early actors, then such actions are maladaptive.
- Path dependency
  - Large infrastructural developments commit capital and institutions to trajectories that are difficult to change in the future, thus decreasing flexibility to respond to unforeseen changes in climatic, environmental, economic and social conditions
- Increasing existing stressors
  - Adding further stress to already degraded ecosystems reduces their adaptive capacity to deal with climate change impacts. For example, actions like promoting plantations for carbon sequestration may lead to reduced water availability downstream which may place further stress on already degraded water ecosystems

Apart from considering climate change adaptation benefits and effectiveness, managers must also consider mal-adaptation. This can be assessed using expert judgment, focus groups or more quantitative knowledge. There is no need to extend the potential for maladaptation across different climate change projections since maladaptive potential does not change. The ranking in Table 6 represent the *magnitude* of impacts for different actions.

Table 6: Maladaptation potential of the NRM actions

	Increasing emissions	Disproportionate burden on the most vulnerable	High opportunity costs	Reducing incentive to adapt	Path dependency	Increasing existing stressors
Action 1		UNKNOWN	NEG	NEG		MEDIUM
Action 2	HIGH	HIGH	HIGH		UNKNOWN	MEDIUM
Action 3		MEDIUM	NEG	UNKNOWN	NEG	NEG
Action 4	NEG	MEDIUM	MEDIUM	UNKNOWN	HIGH	HIGH

Legend for Table 6

NEG	Negligible maladaptive potential
MEDIUM	Medium maladaptive potential
HIGH	High maladaptive potential
UNKNOWN	Maladaptive potential is unknown

Ecosystem Services Benefits

This analysis can be based on information from stakeholder interviews or a review of technical reports. It is based on the concept of ecosystem services described in the Millennium Ecosystem Assessment (2003) and by Reid-Piko et al. (2010) for the Murray-Darling Basin. Table 7 shows how different adaptation options may influence the importance of different ecosystem services. The types of ecosystem services identified are explained and listed below. The listing of ecosystem services can be modified depending on catchment characteristics and needs of the assessment.

Provisioning services	Provide, or produce, goods such as food, fibre, fuel, genetic resources, biochemicals, natural medicines and pharmaceuticals, ornamental resources and fresh water.
Regulating services	Include benefits gained from regulation of ecosystems such as air quality regulation, climate regulation, water regulation, erosion regulation, water purification and waste treatment, disease regulation, pest regulation, pollination and natural hazard regulation.
Supporting services	These underpin the other services and include soil formation, photosynthesis, primary production, nutrient cycling and water cycling. Also include criteria such as ‘natural or near-natural ecosystems’, which can be used to judge the degree of change of the rest of the environment; and ‘priority species and ecosystems’, which may not be ecologically threatened or endangered but still hold important socio-economic values
Cultural services	Can include non-material benefits such as cultural diversity, spiritual and religious values, knowledge systems, educational values, inspiration, aesthetic values, social relations, sense of space, cultural heritage values and recreation and ecotourism.

Table 7: The potential for positive and negative impacts of NRM actions on ecosystem services

Ecosystem Services		Action 1	Action 2	Action 3	Action 4
Provisioning Services	Drinking water for humans and or livestock	✓			✓
	Food for livestock				✓
	Food for humans				
	Wood, reed, fibre and peat	✓	✓		✓
	Medicinal products	✓	✓		✓
	Other products and resources, including genetic material	✓	✓	✓	✓
Regulating Services	Groundwater replenishment	✓			
	Water purification/waste treatment or dilution	✓	?	✓	
	Biological control agents for pests/disease				✓
	Flood control, flood storage		✓	?	✓
	Coastal shoreline and river bank stabilisation and storm protection	×	✓		✓
	Local climate regulation/buffering change				✓
	Carbon storage/sequestration	✓	✓		✓
	Erosion control		?	✓	✓
	Air quality maintenance			✓	✓
	Pollination	✓	✓	✓	✓
Supporting Services	Nutrient cycling	✓	✓		✓
	Primary productivity	✓	✓		✓
	Sediment trapping, stabilisation and soil formation	✓		×	✓
	Systemic consequence (ecological surprise)	✓	✓	×	
	Natural or near-natural ecosystems	✓	✓	×	✓
	Priority species and ecosystems	✓	✓	×	✓
	Ecological connectivity				
	Threatened species, habitats and ecosystems	✓	✓	✓	✓
Cultural Services	Science and education values	✓	✓	?	✓
	Cultural heritage and identity	✓	✓	?	✓
	Contemporary cultural significance				
	Aesthetic and sense of place values	✓	✓	?	✓
	Spiritual, inspirational and religious values				

Legend for Table 7

✓	Potentially directly beneficial
×	Potentially directly detrimental
?	Unknown impact
	No direct impact

Compatibility

The CAF aims to identify a suite of no-regrets, low-risk NRM actions that increase ecosystem resilience to climate change impacts and reduce ecosystem vulnerability to non-climate stressors. It is not the intention of the CAF to pick out one or two winners, rather the intention is to assess and identify the adaptation potential of a suite of complementary actions. This component allows the exploration of interactions between different actions. For example, for habitat restoration to achieve its desired goals, connectivity between different parts of the environment may also be needed and sufficiently high environmental flows provided to enable native aquatic biota to colonise restored sites. At the same time, invasive species must be prevented from dominating restored habitats and the restoration must provide refuge habitats to counteract other pressures affecting the larger landscape, such as thermal pollution from upstream dams (Bond & Lake, 2008). Therefore, ideally the restoration of riparian vegetation, freshwater habitat connectivity, provision of environmental flows and the management of exotic species should be implemented together (see the example in Table 8)

This component is qualitative. Many compatibility issues will be revealed through discussions of the prior components. Suggested methods include expert knowledge, literature review, focus groups and/or semi-structured interviews.

Table 8: Compatibility examples of aquatic ecosystem NRM actions

CCA Actions	Compatibility
1. Environmental Flows	Will enhance effects of Restoration of Riparian Vegetation, Freshwater Habitat Connectivity, Conservation of More Resilient Habitats & Geomorphic Restoration
2. Environmental Works & Measures	Assists efficient implementation of Environmental Flows
3. Thermal Pollution Control	Will enhance effects of Freshwater Habitat Connectivity, Conservation of More Resilient Habitats, Conservation of Gaining Reaches & Geomorphic Restoration
4. Restoration of Riparian Vegetation	Will enhance effects of Geomorphic Restoration
5. Freshwater Habitat Connectivity	Must be done with Management of Exotic Species
6. Conservation of More Resilient Habitats	Must be done with Management of Exotic Species
7. Conservation of Gaining Reaches	Must be done with Management of Exotic Species
8. Geomorphic Restoration	Must be done Management of Exotic Species
9. Management of Exotic Species	Will enhance effects of all other actions

Constraints to implementation ranking

Constraints to implementation of climate change adaptation are divided into four categories in the literature (Arnell & Charlton, 2009).

- Physical — Either in terms of infrastructure or natural conditions — Constrains performance of the action, for instance, will all migratory fish use a fish ladder?
- Financial — Cost & funding — Refers not only to absolute cost of the action but also to ability of the implementing organisation to fund the action in the future, for instance, operating and maintenance costs of environmental works
- Social — Includes community and government attitudes, landholder personality and the landholder's economic circumstances that may prevent them from adopting the actions — Reactions and attitudes of stakeholders, affected parties and pressure groups to each adaptation action, for instance, the risk of a new government changing an adaptation policy measure

• Institutional	Refers to complexity (no of different entities involved), knowledge (whether agencies have the skills, data, etc.) & responsibility (accountability for outcomes)	Institutional factors within the implementing organisation, regulatory or market constraints for the action, for instance, can the managing agencies concerned make decisions fast enough to get desired benefits from environmental flow releases for waterbird breeding events?

The ranking in Table 9 represent the *magnitude* of impacts for different actions without indicating whether it is desirable, positive or negative. These rankings can be based on expert judgment, focus groups or more quantitative surveys, and/or a review of relevant literature. The constraints do not necessarily prevent the adoption of an action, but may limit its applicability or popularity. In other words they impact on the scale of uptake. For example incentives to undertake riparian reforestation are regularly utilised in the catchments but the scale of their uptake is still constrained by social and economic circumstances.

Table 9 provides examples of constraints that can affect the effectiveness of adaptation options. Funding has been identified as a major constraint for most options. Community attitude is a prominent example of a socio-political constraint for those options that required the cooperation of private landholders. The list of examples for the four types of implementation constraints is not exhaustive.

Table 9: Extent of cconstraints to the implementation of NRM actions

Constraints		Action 1	Action 2	Action 3	Action 4
Physical	Infrastructure	NEG	NEG	HIGH	
	Natural	NEG	NEG		
Financial	Funding		HIGH	HIGH	HIGH
Socio-political	Landholder values, attitudes & self-identity	MEDIUM		UNKNOWN	HIGH
	Landholder ability / capability	HIGH	HIGH	HIGH	HIGH
	Community attitudes	MEDIUM		MEDIUM	HIGH
	Economic circumstances			UNKNOWN	HIGH
Institutional	Complexity		MEDIUM		
	Knowledge				
	Responsibility	HIGH	HIGH		

Legend for Table 9

NEG	Constraint is negligible. It exists, but does not prevent implementation of action
MEDIUM	Constraint preventing the action from being fully or largely realised
HIGH	Constraint significantly preventing uptake among a majority of stakeholders
UNKNOWN	The extent of the constraint cannot be accurately gauged
	Constraint not applicable to the action or not mentioned

Socio-Economic Outcomes

This component summarises the socio-economic outcomes of the actions. This can be done through qualitative analysis of interviews, focus groups, or surveys with key stakeholders. Ideally, this data is gathered in the preparation stage and presented to the project partners for discussion. The analysis can focus on existing projects and be a grounded cost/benefit analysis or it can be more preliminary and qualitative analysis to highlight potential issues with proposed projects. Table 10 shows an example of how issues can be summarised qualitatively. The specific examples of issues in Table 11 are those that came up in completed workshops. The positive and negative issues are summarised with ticks and crosses for the sake of brevity in the final assessment (Table 3).

This component identifies the social and economic trade-offs of the different actions. As such it is useful to identify sections of the community that may either gain or lose access or benefits of the ecosystem.

Table 10: Possible socio-economic outcomes

	Positives	Negatives
Action 1	✓ Benefits for recreational fishing	× Possibility of flooding infrastructure/crops
	✓ Reactivation of soil moisture	× Landholders lose access to parts of their property
Action 2	✓ More control & ability to water isolated wetlands	× Potentially detrimental for native fish and recreational fishing
	✓ Building of infrastructure provides local economic benefits	
Action 3	✓ Benefits for recreational fishing	× Responsibility for maintenance and replacement falls on individual landholders
Action 4	✓ Green spaces provided a psychological positive for communities during droughts	
	✓ Economic benefits (feed for stock, assistance with drought-proofing and increasing carrying capacity of the land)	

Risk Assessment

This component looks at the likelihood and consequences of the adaptation action failing. A risk assessment matrix consistent with Australian Standard AS4360 on Risk Management, where risk is the sum of Likelihood and Consequence, is shown below. The following tables explain the Consequences and Likelihood classifications, as they relate to natural environment (adapted from Umwelt, 2009).

Table 11: Matrix for undertaking a risk assessment of NRM actions

Likelihood of the Consequence	Maximum Reasonable Consequence				
	(1) Insignificant	(2) Minor	(3) Moderate	(4) Major	(5) Catastrophic
(A) Almost certain	High	High	Extreme	Extreme	Extreme
(B) Likely	Moderate	High	High	Extreme	Extreme
(C) Occasionally	Low	Moderate	High	Extreme	Extreme
(D) Unlikely	Low	Low	Moderate	High	Extreme
(E) Rare	Low	Low	Moderate	High	High

The following two tables explain the Consequences and Likelihood classifications.

Table 12: Explanation of the consequences classification

(1) Insignificant	Limited damage to minimal area of low significance
(2) Minor	Minor effects on biological or physical environment. Minor short-medium term damage to small area of limited significance
(3) Moderate	Moderate effects on biological or physical environment (air, water) but not affecting ecosystem function. Moderate short medium-term widespread impacts.
(4) Major	Serious environmental effects with some impairment of ecosystem function. Relatively widespread medium-long term impacts.
(5) Catastrophic	Very serious environmental effects with impairment of ecosystem function. Long-term, widespread effects on significant environment.

Table 13: Explanation of the likelihood classification

(A) Almost certain	Consequence is expected to occur in most circumstances
(B) Likely	Consequence will probably occur in most circumstances
(C) Occasionally	Consequence should occur at some time
(D) Unlikely	Consequence could occur at some time
(E) Rare	Consequence may occur in exceptional circumstances

A risk assessment looking at the consequences of action failure can incorporate risk of failure under different climate change scenarios and/or differentiate between social, economic and environmental risks. For example, the failure of an environmental flow to achieve a desired result may have only a low or medium consequence and likelihood of occurrence, giving it a relatively low risk rating, but the economic damage may be quite high and the social backlash could make future watering more difficult or costly.

The risk assessment can be based on qualitative analysis of interviews and or focus groups, surveys with key stakeholders, or it can be decided on at the assessment workshop.

Table 14 is an example where both climate change scenarios and socio-economic, as well as environmental risks are specified. This is a more 'complicated' version of the risk assessment that can be simplified by either removing the environmental, social and economic sub-divisions or by removing the climate change scenarios. The environmental, social and economic categorisations have been removed from the hypothetical CAF presented in Table 3. It must be noted that if the 'complicated' version is used, then the social and economic description of consequences would be different to those presented in Table 12, which focuses on environmental consequences.

Table 14: Risk Assessment of the different NRM actions

Climate Change Scenarios		Action 1	Action 2	Action 3	Action 4
Wet	Environmental	L	L	M	L
	Social	L	L	M	L
	Economic	H	L	M	L
Moderate	Environmental	L	L	L	L
	Social	M	L	M	L
	Economic	H	L	H	L
Dry	Environmental	L	M	H	L
	Social	H	M	L	L
	Economic	H	H	L	M
Very Dry	Environmental	M	H	E	L
	Social	E	H	M	L
	Economic	E	M	M	M

A FINAL WORD

The CAF is designed to help catchment and other natural resource managers systematically assess the risks, costs and benefits of different adaptation actions to identify low-risk, no regret measures. It has been developed in a project that promoted an ecosystem-based approach to climate change adaptation.

Often one particular measure is perceived to be the answer for adaptation. The value of this framework is in helping decision makers consider whether it has perverse impacts that have not been considered, to ask whether an intervention that may work in the next decade could later fail with a changing climate, and whether there are better alternatives. There are no quantitative answers, only better informed qualitative judgements. This framework is thus not designed to find the 'winning' action. Rather, it should be used to identify suites of complementary actions that together are practical and spread risk.

The CAF is fairly flexible and it is not method-dependent. We have highlighted a number of methods that could be used with each component. The specific criteria used in each component can also be adapted to suit your institution's needs. However, the robustness of the results obtained will depend on how well individual methods (such as interviews or modelling) are applied in each case.

At the conclusion of the assessment the user will have:

- An assessment of the climate change potential (including the maladaptive potential) of different NRM actions
- Consideration of ecosystem services, socio-economic impacts, constraints and risks of these NRM actions to complement the assessment of their climate change potential

This will ideally lead to a comprehensive suite of NRM actions that address specific conservation goals as well as form part of a broader climate change adaptation strategy that can then be evaluated and updated during subsequent planning cycles.

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