Australian Government
Commonwealth Environmental Water Office

Black Box Management Framework:

A Framework for Managing Floodplain and Wetland Black Box Eucalypts in the Murray-Darling Basin

June 2018

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Acknowledgement of the Traditional Owners of the Murray-Darling Basin
The Commonwealth Environmental Water Office acknowledges and pays respect to the Traditional Owners, and their Nations, of the Murray–Darling Basin, who have a deep cultural, social, environmental, spiritual and economic connection to their lands and waters. The CEWO understands the need for recognition of Traditional Owner knowledge and cultural values in natural resource management associated with the Basin.

Executive Summary

Black Box (*Eucalyptus largiflorens*) is a small to medium sized tree that grows on the floodplains across the Murray-Darling Basin (the Basin), although it is more dominant in the southern basin.

There has been a significant overall decline in the condition of Black Box populations across the Murray-Darling Basin since the 1980s, brought about by factors including, but not limited to, drought, river regulation, river water extraction, irrigation drainage, grazing, and land clearance. In response to this decline, long term ecological objectives and outcomes have been set under the Basin-wide Environmental Watering Strategy (BWS) for Black Box vegetation.

This Black Box Management Framework was developed to *"assist practitioners in the assessment, planning and implementation of management practices, working towards sustainable ecological outcomes for the condition and extent of Black Box."* It is focused on the management of existing viable trees as part of a forest or woodland community. The Framework assumes that with an improvement in the condition of existing Black Box trees there will be associated benefits to the sustainability of the species and to the broader flora and fauna of Black Box forest and woodland communities.

The Framework seeks to provide practitioners with a broad, adaptable set of processes, tools and management options that can be applied to Black Box growing on the floodplain and near wetlands. The Framework provides a guided evidence based decision-making process to support the achievement of the ecological outcomes for Black Box, with advice on how to:

- Determine the need for management by assessing vegetation condition and stressors. This is undertaken by conducting a site investigation, to provide an evidence base for the understanding of the factors effecting Black Box condition and defining management objectives (Part A).
- Develop a range of potential management options for a site. This requires gathering and synthesising information through a combination of field and desktop research (Part A).
- Develop a Site Management Plan, which involves prioritisation of management options for a site through considering the vulnerability and the feasibility of various management actions to meet site objectives, available resources, and assessment of risks and benefits (Part B).
- Prioritise, through transparent and evidence-based assessment, management actions across the Basin. These include the assessment of submitted site scale plans in consideration of Basin objectives, available resources, and the distribution of Black Box condition, vulnerability and stressors (Part C).

Given the broad spatial extent of Black Box vegetation and the influence of regional groundwater and surface water processes on vegetation condition, effective management requires a holistic approach using multiple complementary interventions. The Framework outlines a suite of different options and tools that may be considered to manage the impact of underlining stressors affecting Black Box condition. The process and use of these tools at a site scale is demonstrated through a case study at Calperum Station in South Australia, part of the Riverland Ramsar Site. They are also applicable at multiple scales of management, and preliminary reach scale and Basin scale analysis is provided.

Uncertainty is inherent when working within complex eco-hydrological environments. Throughout the Framework, working with uncertainty is addressed through a confidence assessment process. This process provides a means to guide or evaluate information used for determining management requirements, and providing confidence in the decision for resource investment. The level of confidence that is required for a site should relate directly to the scale of the site, the proposed level of investment in management options, and the scale of benefits expected from management.

Resulting from analysis that have been undertaken at site, regional and basin scales, the Framework presents a key set of principles for management of Black Box. These include:

- Environmental water is likely to be effective where there are viable Black Box trees identified as "flow" stressed", but less effective where the floodplain is subject to salinity stress.
- The achievement of sustainable outcomes for Black Box populations is dependent on complementary land and water management interventions. Much of the Black Box throughout the Basin would require a combination of complementary measures as part of a management regime.

- As a long-lived and slow-growing tree, mature Black Box takes many years to transition between different condition states. The responsiveness of Black Box to change in condition is dependent on the severity of the stresses imposed. The setting of objectives and targeted outcomes for a site should therefore recognise the temporal commitment required and the interim measurable targets observable in pursuit of long term Black Box outcomes.

Vulnerability is a key factor in prioritising resources for Black Box management. It is a combination of condition, stressors, and the likelihood of decline. A preliminary basin wide analysis of vulnerability identified key zones of high and low vulnerability based on a combination of flooding frequency, groundwater salinity and groundwater depth information. This analysis identifies the Basin Plan regions of Macquarie-Castlereagh, Lower Darling, and lower River Murray as having the largest areas of vulnerable Black Box vegetation.

The Framework aims to provide a process to guide practitioners in determining the appropriate suite of management options targeting the maintenance and long-term improvement in the condition of Black Box trees and their ecosystem function. Principles and strategies for targeting the basin-scale outcomes aim to support planning and decisions for maximising the effective use of available resources.

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Glossary

Adaptive capacity	Adaptive capacity is a function of the ability of a tree or community to recover from impact (resilience) and its ability to adapt to new conditions (e.g. growing new roots or establishing in another part of the floodplain).
Black Box community	The term used for a group of Black Box trees such as a forest or woodland that supports a unique ecological community containing a variety of understorey vegetation and fauna.
Condition	The physical condition of Black Box trees that is akin to health. This is usually based on visual indictors of crown canopy cover but could also include physiological indicators. Tree health is not commonly used as this term implies a broader perspective than just condition.
Drivers	In the context of the Black Box Management Framework, drivers are those factors and management actions that increase or decrease the range and intensity of stressors. This can include river regulation, land clearing and climate change.
Ecological objectives	The high level ecological outcomes, aspirations and step changes that a practitioner is seeking to achieve at a site over the medium to longer term.
Ecological targets	Specify the ecological condition intended to be achieved because of an action, often described by a numerical value that allows for assessing and reporting change in condition against a benchmark over time.
Epicormic growth	Growth of leaves on the tree trunks rather than on outer branches. This is the tree's response to water stress as it cannot get the water to the outer extents of the tree canopy.
Exposure	A function of the external stressors to Black Box and their severity. These can be long term constant or chronic stressors (e.g. depth of saline groundwater) or acute events (e.g. frequency of droughts);
Management unit	A contiguous area of Black Box vegetation that is treated as a single area for management purposes. It has similar vegetation condition and similar stressor impacts. The framework focuses on management units rather than individual trees, as tree condition commonly varies from dead to very healthy within small areas due to spatial variability of soil types and individual characteristics of the trees. Additionally, the management options available for influencing Black Box stressors address large areas, rather than individual trees.
Resilience	Resilience is the ability of a tree or community to recover from impacts. Black Box trees are highly resilient to mild drought impacts and can recover fully, however severe, prolonged and frequent droughts may be too much for the trees in poor condition.
Resistance	Resistance to change or sensitivity (e.g. salt and drought tolerance) is a function of the current condition and the nature of Black Box physiology and the community structure (e.g. unit size).
Risk assessment	A systematic process of evaluating potential risks associated with an action, or series of actions. This involves assessment of the likelihood and consequences, and mitigation factors to reduce risks within acceptable levels.

Soil salinisation	The process of salt accumulating in the soil due to saline water rising from the groundwater due to evapotranspiration. The salt is accumulated in the soil as the water is used by plants or evaporated. The rate of soil salinisation depends on the soil type and the depth of saline groundwater. Soil salinisation usually occurs when saline groundwater is shallow (less than 6 metres from the surface).
Stressor	A stressor is a force, condition, event, or stimulus that causes stress to Black Box vegetation, resulting in decline in condition. This can include high soil salinity, reduced flood frequency or reduced rainfall.
Vulnerability	Vulnerability is the quality or state of being exposed to the possibility of being attacked or harmed. The Framework uses the term vulnerability to mean the likelihood of decline.

1. Introduction

1.1 Black Box Communities and the Need for Management

Black Box (*Eucalyptus largiflorens*) is a small to large sized tree that grows most commonly on the floodplain across the Murray-Darling Basin (the Basin) (see Figure 1-1). It is a key habitat forming species of the floodplain environment, providing high value habitat and ecosystem services for a range of floodplain flora and fauna. Black Box is a dominant floodplain species in the southern basin, extending south from Menindee Lakes and along the Lachlan, Murrumbidgee and Murray rivers. Black Box is not as common in the northern basin where the upper floodplains are more often dominated by Coolibah (*Eucalyptus coolabah*). Refer Figure 1-2 for Black Box distribution throughout the Basin. Black Box grows at higher elevations on the floodplain with its distribution representing recruitment episodes in response to historic natural flood events. While known to be relatively tolerant of drought and salinity, Black Box prefers areas that are intermittently flooded, and which are supplemented by other water sources (rainfall and groundwater) that can be accessed opportunistically depending on a range of physical and hydrological factors (Casanova 2015). A review of Black Box distribution, health trends and water requirements are provided in the supporting document: *Black Box Health and Management Options* (AWE, 2015).

Black Box tends to grow as a dominant or co-dominant species (e.g. with Coolibah (*Eucalyptus coolabah),* River Red Gum (*E. camaldulensis*), Buloke (*Allocasuarina leuhmannii)* or River Coobah (*Acacia stenophylla)*) over a sparse to dense understorey of small to medium-sized saltbushes and short-lived herbs and grasses, with occasional dense thickets of Lignum (*Duma florulenta*). Where the overstorey is sparser, *Chenopod* shrubland can also develop in the understorey (Smith and Smith 2014; Roberts J. 2004). The following Black Box community is formally protected by legislation:

- Coolibah - Black Box Woodlands of the Darling Riverine Plains and the Brigalow Belt South Bioregions (Endangered), *Environment Protection and Biodiversity Conservation Act 1999* (Aus.) and *Threatened Species Conservation Act 1995* (NSW).

Figure 1-1: A typical Black Box (Eucalyptus largiflorens) growing on a floodplain in the Lower River Murray (Southern Murray Darling Basin) (Photo: I. Overton, Jacobs)

Black Box communities provide a diversity of habitat that supports on-ground foraging within accumulated litter, and hollow nesting fauna in stands of an appropriate age. Black Box communities provide habitat and other resources to species of national conservation significance under the *Environment Protection and Biodiversity Conservation Act 1999* (in addition to many state species that are not listed below):

- Regent Parrot (eastern), *Polytelis anthopeplus monarchoides* (Vulnerable)
- Squatter Pigeon, *Geophaps scripta* (Vulnerable)
- Greater Long-eared Bat, *Nyctophilus corbeni* (Vulnerable)
- Five-clawed Work-skink, *Anomalopus mackayi* (Vulnerable)
- Ornamental Snake, *Denisonia maculata* (Vulnerable)
- Saltbush, *Atriplex infrequens* (Vulnerable)
- Mossgiel Daisy, *Brachyscome papillosa* (Vulnerable)
- Winged Peppercress, *Lepidium monoplocoides* (Endangered)
- Slender Darling-pea, *Swainsona murrayana* (Vulnerable)

As a consequence of river regulation, the natural flood events that once supported Black Box communities are now typically smaller in magnitude and duration, and much less frequent. Significant areas of Black Box communities now grow on the floodplain outside of the zone of influence of managed river flows. Thus, a holistic approach to management that extends beyond just environmental watering is needed. Black Box communities may display signs of response to a single watering event, however, achieving a sustained recovery and improvement in population condition is likely to require a long-term management commitment.

The Basin Environmental Watering Strategy (BWS - MDBA, 2014) provides objectives and outcomes for the management of Black Box communities. The long term general decline in Black Box condition and functionality across the Basin is the result of a combination of stressors. The influence of potential stressors varies across the Basin however they include:

1) reduced flooding frequency
2) elevated saline groundwater levels (South-West of the MDB)
3) reduced fresh groundwater levels (North-East and East of the MDB)
4) elevated soil salinities
5) overgrazing
6) tree clearing.

The continuing decline in the health and survival of a widespread floodplain species such as Black Box would have far reaching impacts to the associated ecosystem and physical characteristics of the environment. Large communities of Black Box across the Basin remain in poor condition indicated by the impaired condition of mature trees and the lack of multiple age classes (recruitment). A significant proportion of Black Box communities in the southern basin is in poor to severely degraded condition; where condition has been assessed (refer to Table 1.1, percent of vegetation assessed). Where present in the northern basin Black Box communities are generally considered in better condition than populations found in the southern basin, however significantly affected by land clearing and floodplain isolation (earthworks) (pers. comm. S. Bowen, NSW OEH, and S. Capon, Griffith University, 2016).

Table 1-1: Condition of Black Box trees in six major regions of the Basin (Source: BWS - MDBA 2014)

Basin region	Vegetation with condition score 0 – 6 (severely degraded – poor)	Vegetation with a condition score >6-10 (moderate – good)	Percent of vegetation assessed (for the managed[1] floodplain)
Lachlan	72%	28%	45%
Murrumbidgee	54%	46%	73%
Lower Darling	72%	28%	85%
Murray	35%	65%	28%
Wimmera-Avoca	42%	58%	26%
Goulburn-Broken	28%	72%	77%

[1]The concept of the managed floodplain is used within the BWS to differentiate between the extent to which flows can be *actively* managed on the floodplain using environmental water and existing infrastructure verses those areas which are out of scope for active flow management. Refer section 5.2 for a further description on managed and unmanaged floodplains.

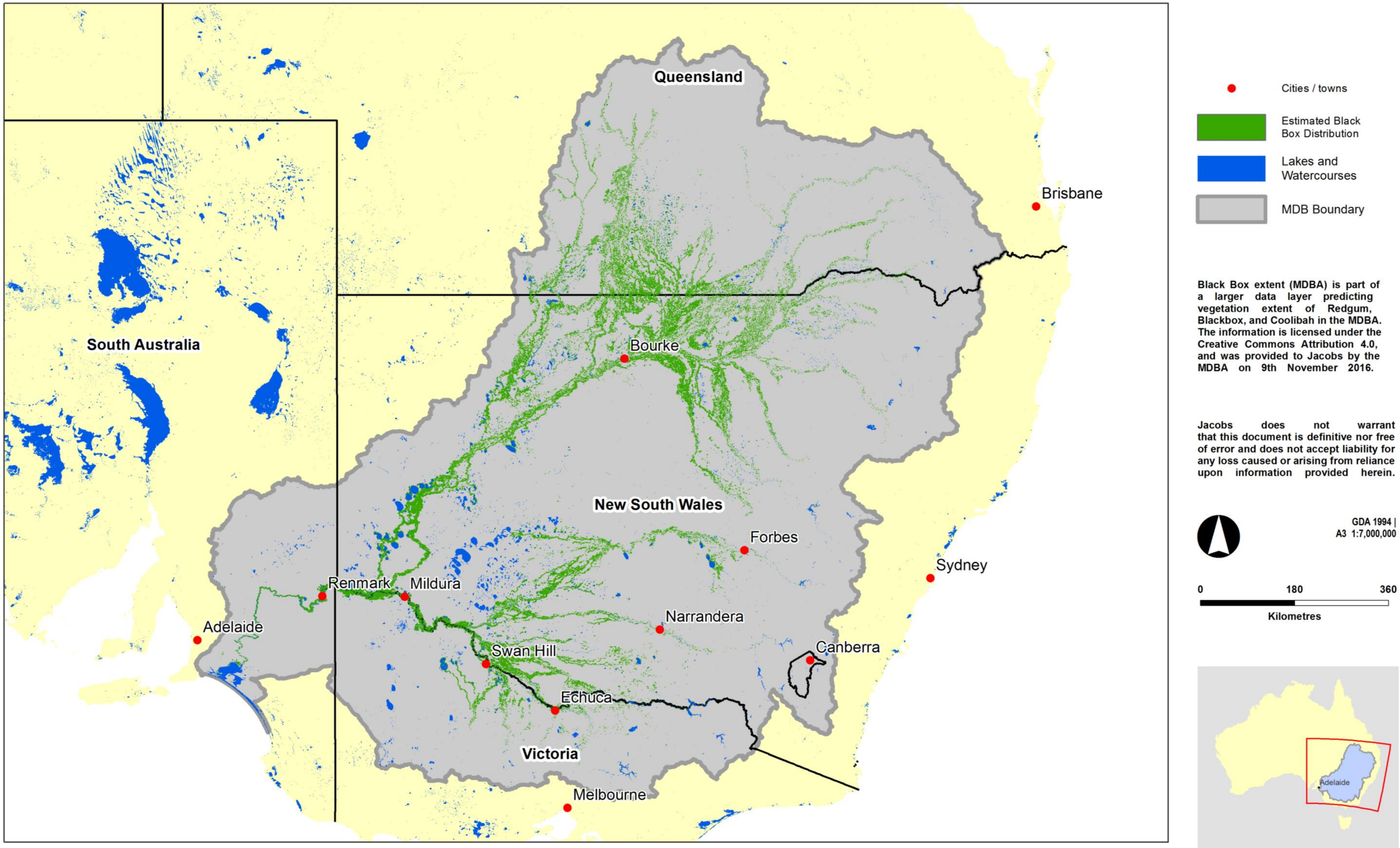

Figure 1-2: Estimated Black Box distribution at the Basin scale

1.2 Objectives of the Framework

The overarching vision for the Framework is that it should:

> *"Assist practitioners in the assessment, planning and implementation of management practices, working towards sustainable ecological outcomes for the condition and extent of Black Box."*

The Framework provides a guided decision-making process to support the achievement of ecological outcomes for Black Box, with advice on how to:

- Conduct a site investigation, with the objective of understanding the condition of Black Box, stressors affecting Black Box, objectives, and the range of management options available at a site.
- Develop a Site Management Plan. This involves prioritisation of management options for a site through considering the feasibility of various management actions to meet site objectives, available resources, and assessment of risks and benefits.
- Prioritise, through transparent evidence-based assessment, management actions across the Basin. This includes the assessment of submitted site scale plans in consideration of the Basin objectives, available resources, and the distribution of Black Box condition and stressors across the Basin.

The Framework aims to enhance the integration of complementary management options in conjunction with the use of environmental water, to target the long-term outcomes for Black Box as defined within the BWS. Principally, the BWS targeted outcomes seek to:

1) maintain the current extent of Black Box
2) arrest the decline in the condition of Black Box
3) improve recruitment opportunities for Black Box by 2024.

Black Box Health and Management Options (AWE 2015) is a companion document to this Framework providing detail on Black Box management requirements, particularly in relation to groundwater and salinity management. A broad range of other scientific literature should also be referred to for supporting the decision-making process, and a range of resources are provided in the Appendices to this Framework.

1.3 Focus and Scope of the Framework

The following points describe the scope, intent, and bounds of the Framework, to clarify its intended purpose and use:

- The focus of the Framework is on increasing the informed selection and effectiveness of management interventions to manage stressors (wherever practical) and improving the condition and recruitment success of existing Black Box populations. The intent is that by improving condition and functionality over the longer term, Black Box populations become more resilient and are able to respond and recruit during natural flood events. Whilst the Framework is focused on the maintenance and improvement in condition of existing viable trees, there are assumed benefits for the associated understorey vegetation and dependent fauna.

- It is not the intention of the Framework to prescribe interventions or procedures. Rather, it intends to provide the concepts, strategies and guidance that may be applied by practitioners to achieve the best possible outcomes for Black Box trees and, consequently, the associated forest and woodland communities.

- It is acknowledged that many sites or regions within the Basin are seeking to achieve multiple objectives through management, such as objectives for River Red Gum, Coolibah, fish, and birds. The focus of this Framework is on Black Box communities, and it does not intend to address other objectives. It is recognised that in some cases, targeting Black Box intervention may lead to positive or negative impacts on other environmental assets that need consideration in formulating a site management plan.

- The Framework is largely targeted at supporting the survival of existing adult Black Box trees. With healthy trees there is a good chance of having a healthy community of Black Box and consequently supporting a healthy forest or woodland ecosystem. Maintaining healthy adult trees is not the only requirement to support sustainable healthy Black Box ecosystems, however it is a critical component and targeting the adult tree helps simplify the management planning. Key aspects to consider include recruitment of Black Box juveniles through ensuring flowering, seed dispersal mechanisms and conditions to allow sapling establishment. Managing for Black Box trees also supports the maintenance of healthy understorey vegetation through provision of upper soil moisture, reduced surface salt and provision of shade.

- Black Box occurs in communities of various densities ranging from dense forests with touching canopies to open forest, woodlands, sparse woodlands and isolated trees. The Framework has suggested three categories of density – forest, woodland and sparse. Communities of different densities support unique ecosystems with associated wildlife. As such, management approaches should consider maintaining a diversity of densities. The Rapid Assessment Tool for Black Box condition assessment presented in chapter 3.4 includes a classification for density for this reason. Certain management actions will be more appropriate based on densities. For example, large scale flooding to improve the condition of a few isolated trees may not be the best approach.

- Project implementation is not considered in detail within this document. Implementation of selected management options will require engagement of the relevant state jurisdiction, regional authorities and resource managers.

- For sites in the Basin that have existing site management plans, the Framework is intended to complement and reinforce these planning instruments, not to replace them or provide an added layer of management complexity.

1.4 Who Should Use this Document?

This Framework has been developed for land, water and biodiversity practitioners. The Framework promotes sustainable management through developing a good understanding of the condition of Black Box within their management area, and the drivers and stressors identified as most likely causing this condition.

In many circumstances practitioners do not have comprehensive information or knowledge about a site, but the Framework can still be applied where knowledge gaps and uncertainly exist. The Framework provides guidance on how to reduce the uncertainty and make management decisions supported by an approach to confidence assessment, and decision making based on acceptable levels of uncertainty (refer to Section 3.2).

2. Black Box Management Framework

This section outlines the structure of the Framework and provides a roadmap for its use. The process embedded within the Framework includes four key parts, as described in Figure 2-1.

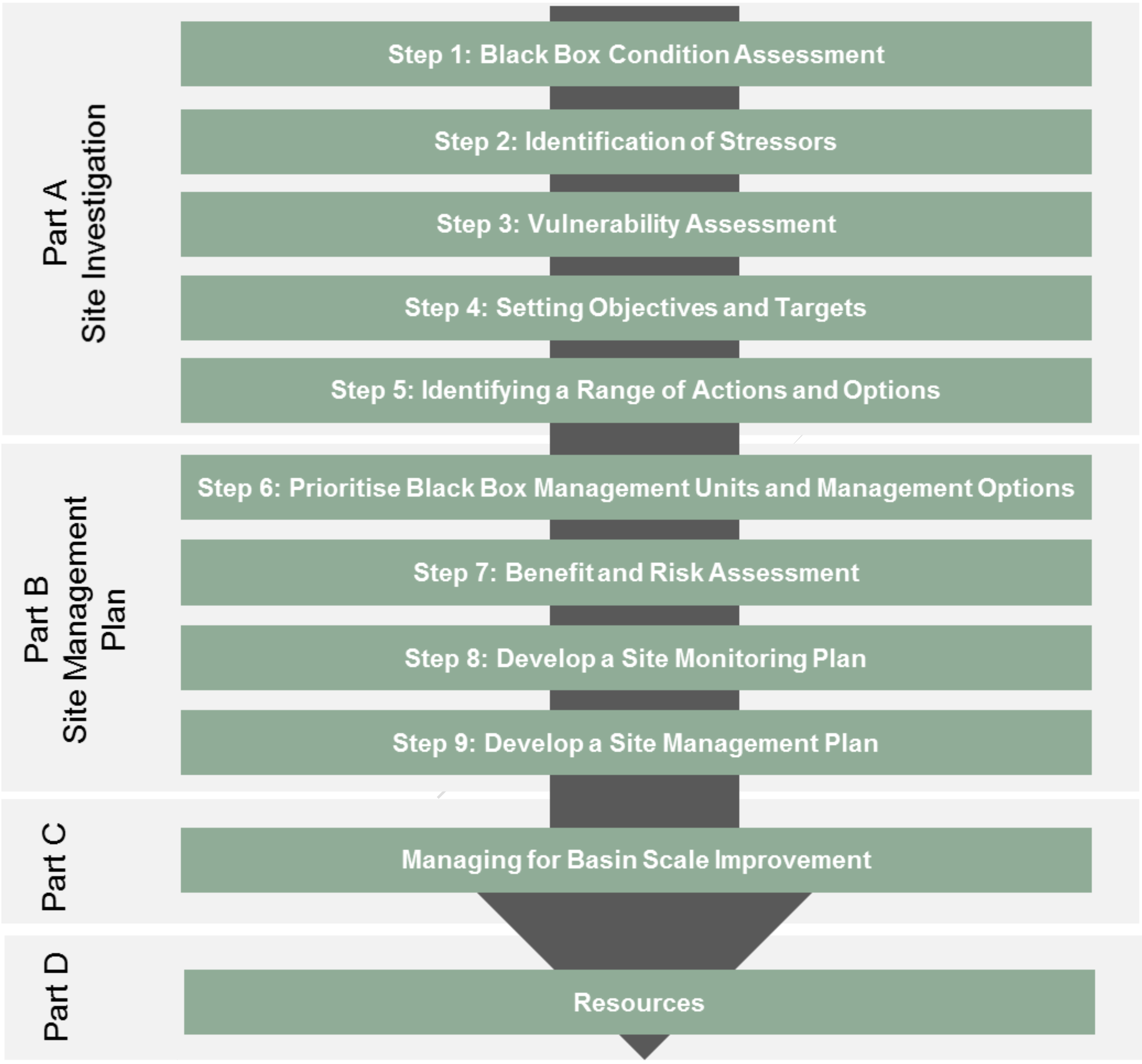

Figure 2-1: Overview of the four parts of the Black Box Management Framework

The purpose of *Part A: Site Investigation* is to understand the condition of Black Box, stressors affecting Black Box, objectives, and the range of management options available at a site. This requires gathering and synthesising information through a combination of field and desktop research. The information and analysis completed in Part A feeds in to the development of a Site Management Plan (Part B). Developing the Site Management Plan involves prioritising management options for the site through considering the feasibility of various management actions to meet site objectives, available resources, and assessment of risks and benefits. Following the prioritisation, a plan of action can be developed, including the development of any proposals for investment. Part C describes the process for prioritising management actions across the Basin that supports the assessment of submitted site scale plans in consideration of the Basin objectives, available resources, and the distribution of Black Box condition and stressors across the Basin. Part D provides a series of resources available to practitioners to access further information regarding Black Box management.

Parts A and B of the Framework are primarily concerned with the site scale (where a “site” is typically a single floodplain or location). These Parts are aimed as a guide for land, water and biodiversity practitioners to develop a good understanding of the condition of Black Box within their management area (Part A), and develop a plan of action for management of Black Box (Part B). Part C is concerned with application of the Framework to a range of scales, from floodplain, reach, region, up to the basin scale. It can be used by land, water and biodiversity practitioners to understand how their management area fits within the broader Basin wide context. It can also be used by Basin wide decision makers to prioritise management.

The parts of the Framework are described in more detail in the sub-sections below.

2.1 Part A: Site Investigation

The purpose of the site investigation is to understand the condition of Black Box, stressors affecting Black Box, objectives, and the range of management options available at a site. This requires gathering and synthesising information through a combination of field and desktop research, and involves the following steps:

1. Assessing Black Box condition
2. Identifying Black Box stressors
3. Vulnerability assessment - a combination of Black Box condition and the stressors affecting Black Box, leads to the overall vulnerability assessment
4. Developing management objectives and targets - comparing the current condition of Black Box with the ecological objectives. Objectives can come from the history of active management, and targets and objectives at a site/region/basin scale.
5. Developing management actions and options - investigating a range of management actions that could address the stressors. The management actions to be investigated will depend on the infrastructure and landscape relevant to the site.

The output of the site investigation feeds into an assessment of feasibility and prioritisation of management options, which is required to develop a site management Plan (Part B).

Refer to Chapter 3 for complete details for Part A: Site Investigation.

2.2 Part B: Site Management Plan

The purpose of *Part B: Site Management Plan* is to use the information and analysis completed in Part A to prioritise the available management options and develop a plan of action. The prioritisation process considers:

- The feasibility of various management actions to successfully meet the site objectives
- Available resources that would be required for various management actions, including water, finance, energy, labour
- Assessment of impacts, both positive and negative, and risks
- Alignment with basin objectives.

Following the prioritisation, a plan of action can be developed for the site, including the development of any proposals for investment. The site management plan is likely to consider management for a range of outcomes, not solely focused on Black Box. This Framework provides guidance on feasibility and prioritisation for Black Box outcomes only, consideration of other outcomes is outside the scope of the Framework.

Refer Chapter 4 for complete details for Part B: Site Management Plan.

2.3 Part C: Managing for Basin Scale Improvement

Part C applies the steps of the Framework to a regional and a basin scale. These analyses are intended as case studies to investigate the Framework's applicability at different scales. They also demonstrate how the Framework can be used to inform decision making on Black Box management and on prioritising management at varied scales.

The regional and basin scale analyses provide results of Black Box location, condition, influence of stressors and vulnerability, based on currently available spatial datasets. These results provide a basis for assessing basin wide strategies for Black Box management.

Refer Chapter 5 for complete details for Part C: Managing for Basin Scale Improvement.

2.4 Part D: Resources

Part D provides additional resources for implementing the Black Box Management Framework. It includes:

- Literature sources
- A summary of Black Box needs, stressors and indicators
- Condition assessment methods
- Description of options for management of Black Box vegetation
- Prioritisation methods and example criteria for prioritisation
- Discussion of managing salinity from environmental watering
- Risk assessment process
- Additional maps for the basin scale analysis.

Appendices A to M provide the Framework resources.

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PART A: SITE INVESTIGATION

3. Part A: Site Investigation

3.1 Introduction to the Site Investigation

This chapter outlines the process for understanding the condition of Black Box, stressors affecting Black Box, objectives, and the range of management options available at a site. Figure 3-1 outlines the approach for undertaking a Black Box Site Investigation.

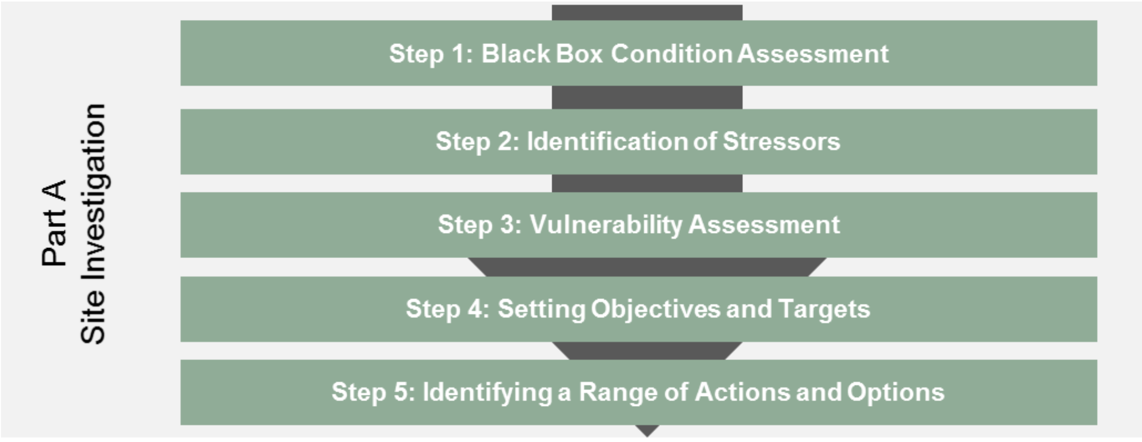

Figure 3-1: Overview of Part A of the Black Box Management Framework

While these sections are presented in a sequential order, the key elements are interrelated (as shown in Figure 3-2), and the most logical starting point. How these elements of the process relate to each other is likely to differ from site to site.

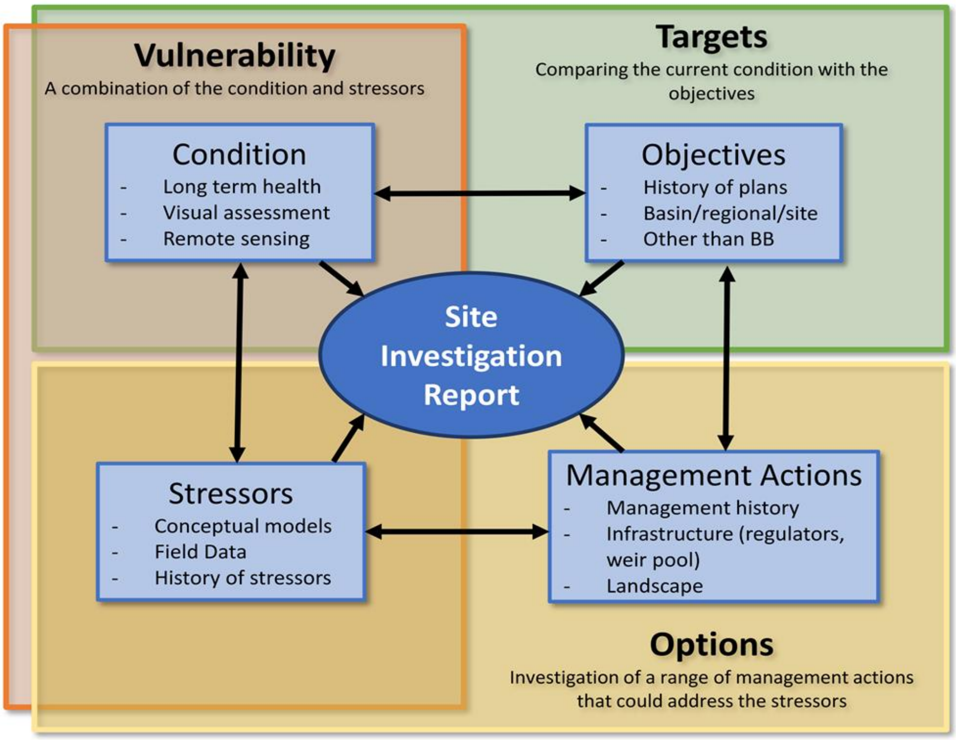

Figure 3-2: Part A: Approach for undertaking a Black Box site investigation

3.2 Working with Uncertainty

The assessment of key processes and site management requirements will always occur in the presence of incomplete knowledge, creating a level of uncertainty in the expected outcome. Uncertainty is inherent when working within complex eco-hydrological environments. It arises through most of the key aspects when completing a Black Box site investigation, including:

- Condition assessment
- Identification of stressors and an understanding of how the system works
- Vulnerability assessment
- Developing management options.

For each of these elements, a range of data sources and types can be used, ranging from anecdotal information to measured scientific data. Depending on what investigations have taken place at a site in the past, a range of different data sources may be available. This will influence the level of confidence, or uncertainty, in understanding the information relevant to the management of Black Box. As the level of understanding about the site increases, so does the level of confidence.

Throughout Chapter 3 a series of confidence assessment tables are provided which are intended to provide land managers with a quick reference guide of what they need to understand about their site and the level of effort and technical understanding that might be required for each step. This section describes the confidence assessment colour coding and additional information to complement the tables presented throughout this Chapter.

Table 3-1 provides a guide to what confidence levels may be appropriate for different types of sites. The level of confidence that is required for a site investigation should relate directly to the scale of the site, the proposed level of investment in management options and the scale of benefits sought from management. For example:

- Low, or Low/Moderate confidence may be appropriate for a small site, where simple, low cost management options are likely to be proposed. The level of investment required to obtain Moderate/High, or High level of confidence may not be achievable, or appropriate, for these sites.

- Moderate/High or High confidence may be required for larger sites, or where more water or investment is likely to be proposed for the management of Black Box and therefore certainty in the outcome must be greater. Investing in increased confidence at this early stage could provide benefits and efficiency in achieving the desired outcomes.

The outputs from a confidence assessment provide a useful hold point and check against each of the key steps outlined in Chapter 3. At each step, a decision will need to be made as to whether currently available data will provide an appropriate level of confidence, or whether investment is required to obtain additional data. Since the site investigation includes a range of data types for each element, there is likely to be a range of confidence levels achieved for different data sources. A key criterion for determining whether greater confidence is needed for a specific data type is the extent to which the increased confidence in that data type would improve the confidence in expected benefits being achieved through management decisions and assessment of unintended impacts. It is not the intention for the confidence assessment to be prescriptive, rather for it to provide guidance on appropriate levels of information. Trialling management options in situations of uncertainty provides the best knowledge to reduce the uncertainty and adapt management actions.

When all steps of the site investigation are completed, an overall confidence level for the site investigation can be determined through averaging the confidence scores for each of the steps of the assessment. Refer Chapter 3.9 for a description of the overall confidence assessment process.

Table 3-1: A guide to the confidence ratings and their meanings.

Confidence level	Confidence Score	Appropriate for
Low: Anecdotal or regional level information, providing a rough estimate of site conditions. No conceptual model of stressors.	1	Small manageable area of Black Box on site, <10 ha Low level of investment in management of the site The costs of completing further investigations are proportionately high compared with the benefits expected
Low/Moderate: Measured data from local sources, providing a better estimate of site conditions.	2	Small/moderate manageable area of Black Box on site, 10ha-100ha Low/moderate level of investment being sought in management of the site The costs of completing further investigations are proportionately high compared with the benefits expected
Moderate: Data measured at the site, but over a short timeframe, or with a high level of uncertainty. Reasonable conceptual model of stressors.	3	Moderate manageable area of Black Box on site, 100-1,000 ha Moderate level of investment being sought for management of the site Moderate confidence required to justify investment in site management
Moderate/High: Data measured at the site, over a longer timeframe, with a moderate level of uncertainty.	4	Moderate/large manageable area of Black Box on site, 1,000-10,000 ha Moderate/high level of investment being sought for management of the site Greater confidence required to justify investment in site management
High: Data measured at the site, over long timeframes and with low level of uncertainty. Good conceptual model or detailed site specific relationships for stressors.	5	Large manageable area of Black Box on site, >10,000ha Significant level of investment being sought for management of the site Greater confidence required to justify investment in site management

3.3 Case Study: Calperum Station

Throughout the document a series of case study boxes have been provided as a real-world example of the Framework's application. The case study was undertaken at Calperum Station in South Australia.

Case Study: Background

A case study site investigation at Calperum Station in South Australia was completed in 2017, with the following objectives:

- Improve management of Black Box at Calperum Station by undertaking a site investigation that is based on science and a structured framework
- Test the draft Framework, and refine the Framework based on the outcomes of the testing.

As a result of the case study, a range of recommendations were developed for finalisation of the Framework. While a range of management measures and pre-existing investigations have been completed at Calperum Station in the past, the case study focuses on investigations completed as part of the trial site investigation, for relevance to the Framework process. Refer "*Site Investigation for Black Box at Calperum Station"* (Overton, Boyd and Coff, 2017), for full documentation of the case study.

Calperum Station is located on the northern side of the River Murray in South Australia, approximately 20 km north of Renmark and immediately downstream of Chowilla floodplain (Figure 3-3). Managed by the Australian Landscape Trust, Calperum Station is part of the Riverland Ramsar wetland and is characterised by:

- 9,200 ha floodplain
- 2,700 ha Black Box and 1,000 ha Black Box / Red Gum woodland (total 3,700 ha)
- ~1,000 ha can be influenced by managed surface water inundation
- Lake Woolpolool, Woolpolool Swamp, Lake Merreti, Reny Lagoon and Rotten Lake, of which Lake Woolpolool and Lake Merreti are managed using flow-controlled regulators
- A long, adaptive management history including surface watering, weed / pest control, and conservation management, which is guided by conceptual models and ongoing monitoring and evaluation
- Management options that are shaped by available resources (money, people, technical skills available) and the influence of other external stakeholders
- Areas of Black Box that are affected by water stress and areas that are thought to be affected by both water and salinity stress.

The site investigation was undertaken to achieve a moderate (3) level of confidence level, as per Table 3-1. A conceptual model was already developed for the site that related the key stressors to Black Box condition.

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Figure 3-3: Map of Calperum Station showing major features

3.4 STEP 1: BLACK BOX CONDITION ASSESSMENT

This chapter outlines a range of methods and tools that can be used to determine the condition of Black Box vegetation at a site.

Black Box condition is influenced predominantly by the availability of soil water. Therefore, developing an understanding of the hydrogeological processes influencing water availability is critical to improving population condition. The potential timeframes for achieving the desired ecological outcomes and the sustainability of actively managing a site over those timeframes will be determined by current tree health and the extent to which these hydrogeological processes may be influenced. The heterogeneity of the soils (e.g. clays versus sands) and geomorphic variability across the floodplain mean that Black Box condition can vary significantly over a short distance. This landscape heterogeneity is likely to require the application of a range of different management approaches across a floodplain to achieve the desired ecological outcome.

Black Box, like other floodplain eucalypts, are opportunistic in the sources of water that they use and will switch between different sources depending on soil water availability within the soil profile. Soil water availability is influenced by a range of factors including soil type, soil and groundwater salinity, depth to groundwater, rainfall events, antecedent flood interval (duration since last inundation) and duration, and evapotranspiration (Walker *et al.*, 1996). Discussion on the life phases of Black Box and their water requirements (e.g. mature trees versus seedlings), stressors and indicators are provided in Appendix B. The ability of large eucalypts to switch between water sources as they become available, or to selectively vary the use of each available source, is an important strategy that provides a higher level of tolerance to saline floodplain conditions.

Assessing the condition of Black Box vegetation for the purposes of developing management strategies, requires assessment of a “stand” or “patch” of Black Box woodland, rather than assessing individual trees. The Framework describes these areas as management units as they are likely to respond in a similar way to broad management actions such as groundwater changes and flooding frequencies. The reason for providing a condition assessment of a unit rather than individual trees is that within a unit of Black Box individual trees can vary from dead to very healthy due to spatial variability of soil types and individual characteristics of the trees (Figure 3-4). Additionally, the management options available for influencing Black Box stressors address large areas, rather than individual trees. Although assessing condition of individual trees is necessary for monitoring changes over time, it is less useful in prioritising management actions across a floodplain when actions are likely to target larger areas.

Figure 3-4: A small management unit of Black Box trees that have a range of conditions from Good to Dead

When undertaking a Black Box condition assessment, the emphasis is generally on determining crown extent and density. The condition of the canopy crown is a strong indicator of the overall tree condition. Trees respond to water stress by dropping leaves and eventually branches. Other indicators such as epicormic and leaf tip growth are commonly used in the assessment of crown condition. Trees recovering from water stress are likely to put on epicormic growth rather than new leaves on the outer canopy. Refer to the intermediate stage in the Black Box State and Transition model (Section 3.5.1.4). The presence of tree recruitment, dead leaves, mistletoe and insect damage may also be used to develop an indication of the trajectory of population condition. Mistletoe will invade a stressed tree and generate further stress on that tree.

Various methods and tools can be used to determine the condition of Black Box vegetation at a site. The selection of an appropriate method will be determined by the available time, budget, resources, desired monitoring and evaluation program outputs, and/or any historic data and approaches to assessment. The following subchapters describe two condition assessment techniques that are available. Where appropriate the method used should be consistent with that previously used on site and able to be reliably repeated to track responses to management intervention over extended time periods.

3.4.1 Rapid Condition Assessment Methodology

The Rapid Condition Assessment Methodology can be used when there is little previous knowledge about the condition of Black Box at a site. This methodology was developed as part of the Calperum Station Case Study, specifically with the purposes of the Framework in mind. This condition assessment methodology was designed to support management planning and was driven by management actions affecting large areas. The methodology was also developed to be easy and quick to apply, allowing landholders to conduct surveys over large areas within reasonable timeframes.

The condition assessment methodology has been designed to allow landholders to identify and prioritise areas of Black Box which require immediate or long-term management. Although it can provide a simple method of monitoring, the classes are broad and are unlikely to detect short term and small changes in condition from management actions. The method supports the identification of Black Box management units and possible management actions.

The rapid condition assessment methodology is comprised of the following elements:

- Condition class based on canopy cover and epicormic growth (growth of leaves on the tree trunks rather than on outer branches which is a response to water stress)
- Growth form based on height and trunk diameter
- Density, the number of trees per hectare in the management unit.

Further validation could be undertaken using satellite image analysis, to support the field assessments of Black Box condition and provide historic assessments to detect trends in condition and link condition changes with known events or management actions.

Contiguous areas of Black Box that would all be affected in a similar way by broad management actions are mapped. These are designated as management units as they are areas that can be treated as a single unit for the purposes of condition assessment and management options.

Table 3-2 and Figure 3-5 provide details of the Black Box condition class assessment. The methodology, including the details used for the assessment of growth form and density is fully described in Appendix C.

Table 3-2: Black Box condition classification

Class	Description - Observed elements	Possible/recommended actions, considerations, management strategy
C1 – Good	>75% Canopy Cover, relatively non-stressed when compared to other Black Box	No action required, Black Box may be stressed but not in need of immediate attention
C2 – Medium	75-40% Canopy Cover, made up of original canopy and/or epicormic growth	Stressed Black Box - Monitoring recommended to determine condition trajectory (improve or decline), experimental watering to determine response to watering
C3 – Poor	<40% Canopy Cover, made up of original canopy and/or epicormic growth	Stressed Black Box in poor or critical condition, immediate action recommended
C4 – Dead	0% Canopy, tree is dead and will not recover	No watering action required, consider replanting action taking current stressors into consideration

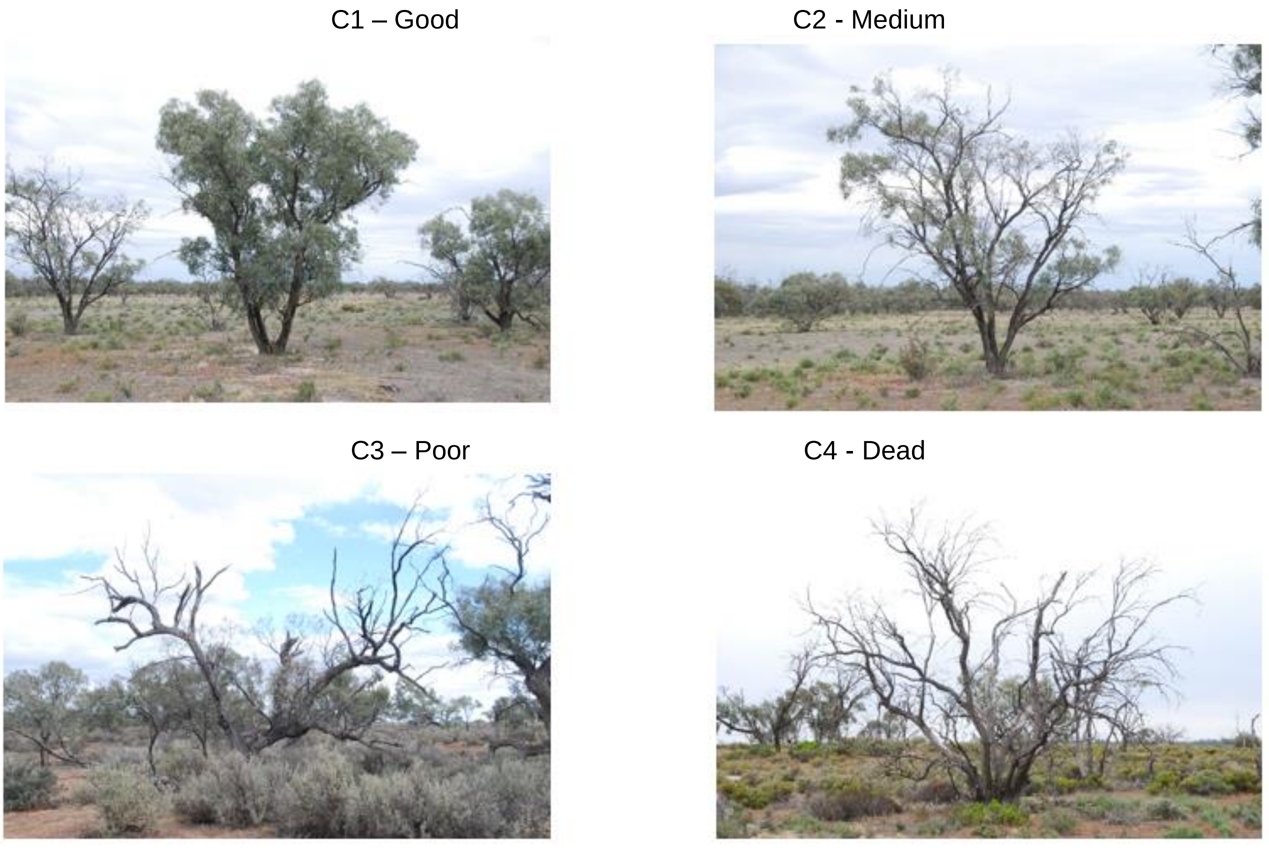


Figure 3-5: Black Box condition assessment. Top left: C1 Good - >75% original canopy; Top right: C2 Medium – 75-40% original canopy and/or strong epicormic growth; Bottom left: C3 Poor - <40% original canopy and/or small amount of epicormic growth; Bottom right: C4 Dead.

3.4.2 The Living Murray Condition Assessment Method

The Living Murray (TLM) initiative condition assessment method is widely employed across TLM icon sites in the southern basin (Souter *et al.*, 2010). The TLM method is a detailed approach, which can be adopted in part or in full to provide indicators tailored to the objectives and targets of a project.

Direct ecological indicators of Black Box stand condition included in the TLM method include:

- Average crown extent (percentage of the assessable crown in which there are live leaves)
- Crown density (amount of skylight blocked by the foliated portions of the crown)
- Diversity and distribution of age class (i.e. seedlings through to senescent trees).
  a. Ratio of live to dead Black Box on site
  b. Distribution of Diameter at Breast Height (DBH)
  c. Seedling counts
- Leaf condition:
  a. New tip growth
  b. Leaf-die off
  c. Dominance of epicormic growth
- Mistletoe dominance
- Insect damage (leaf and bark / trunk)
- Live Basal Area % for trees.

Determining the condition score using the TLM assessment requires a specific method of calculation (Souter *et al.,* 2010), which has been reinterpreted, processed and presented in different ways across the scientific literature. Key sources to review include Backstrom *et al.* (2010), Gehrig and Frahn (2015), Henderson *et al.* (2013), Bogenhuber *et al*. (2014), and Wallace (2015).

Table 3.3 provides a summary of the TLM Black Box crown condition ratings and scores plus a description of the corresponding condition of the trees.

Table 3.3: Black Box condition, crown condition scores and ecological state (Overton *et al.*, 2014, with TLM scores applied).

Condition	TLM crown condition score	Definition of Condition (Ecological State)
Good	70-100	Appearance is vigorous and healthy. Crown shape is defined by major branches and few if any of these are dead. Little to no epicormic growth evident.
Medium	40-70	Appearance is moderate but not vigorous. Canopy extent and crown shape are as for Good, but branches much more evident because foliage density is less, now being medium to sparse.
Poor	20-40	Appearance is not healthy. Crown shape may be same or less than Medium but more likely a few branches are dead or even lost (shed). Foliage is sparse.
Critical	0-20	Appearance is not healthy and not vigorous. Tree appears leafless or nearly so, or may have small tufts of epicormic growth, live or dead. Canopy Extent may be still as for Medium but more likely is reduced due to loss of dead twigs and branches.

Refer Appendix D for further details of the TLM tree and stand condition assessment tools.

3.4.3 Black Box Condition Assessment and Confidence Levels

A confidence assessment is required to determine the level of understanding of Black Box condition at the site, and whether currently available data is sufficient for management decisions. Investment in additional information that may be required is determined at this stage.

Table 3-4 provides a guide to a hierarchy of condition assessment methods for providing increasing levels of understanding about the condition of units of Black Box vegetation. As the level of understanding increases, so does the level of confidence. This table is intended to provide land managers with a quick reference guide to assist them in understanding what condition assessment methods may be suitable for their site. Refer chapter 3.2 for an explanation of the confidence assessment colour coding and explanation of what confidence levels are appropriate for different types of sites.

An important aspect of confidence is the temporal coverage of the data. If a single snap-shot of condition has been taken, it should be considered to have a lower confidence than if several assessments have been completed over time. More detailed methods will provide greater confidence for the trees being measured. However, in determining condition over a large area, increased confidence could be obtained using less detailed measurements (for example the rapid assessment method) if it can be applied over a greater area and with multiple measurements over time.

In determining which condition assessment is appropriate, it is necessary to consider the ongoing monitoring that would be required as part of any management action at the site. For a site where on-going management is likely to take place, the condition assessment becomes the baseline to which subsequent condition monitoring is compared, to understand the changes to Black Box condition over time. It is beneficial to undertake ongoing monitoring using a consistent methodology as the initial condition assessment. Monitoring of management actions is described further in chapter 4.3.

Table 3-4: Guide to a hierarchy of methods for undertaking a Black Box unit condition assessment

Confidence level	Confidence Score	Black Box Management Unit Condition
Low: Anecdotal or regional level information, providing a rough estimate of site conditions.	1	Anecdotal information from visual or photographic assessments (aerial or site based). Single 'snap shot' of condition, no temporal assessment.
Low/Moderate: Measured data from local sources, providing a better estimate of site conditions.	2	Review of satellite-based images of greenness as measured by the Normalised Difference Vegetation Index (NDVI) score.
Moderate: Data measured at the site, but with high level of uncertainty.	3	Rapid Black Box Condition Assessment methodology. Refer Appendix C for a complete description of this method.
Moderate/High: measured data at the site, with moderate level of uncertainty.	4	The Living Murray (TLM) initiative stand condition assessment. Refer Appendix D for a summary of the TLM tree and stand condition assessment tools.
High: Measured data at the site, with low level of uncertainty.	5	Measurement of sapwood area ratio throughout the management unit of Black Box vegetation to determine an overall rating for the health of the unit. Based on the ratio of stem sapwood cross-sectional area to stem basal area (Doody and Overton, 2009). The sapwood ratio can provide an indication of long term tree health, and ability to respond to management, rather than condition at a specific point in time.

Case Study Box 1: Rapid Condition Assessment at Calperum Station

The rapid condition assessment methodology was developed through an iterative process over the course of three field surveys, following feedback and discussions with the land manager. As shown in Table 3-4, this method has an associated confidence level of "Moderate", which was considered appropriate based on the time and resources available, the purpose of the investigation and complementary data sets.

A range of vegetation studies have previously been undertaken place at Calperum Station. The land manager provided vegetation mapping GIS layers, which described the locations of Black Box throughout the site. This was used as a starting point for defining Black Box patch units and as a basis for field investigations.

The elements which were completed as part of the condition assessment are described below:

1. Condition Class: Condition was assessed using a qualitative approach considering a combination of dieback, crown cover, and epicormic growth. Visual inspection was at a patch scale, with the estimation of condition taking into consideration the overall condition within a patch, rather than that of individual trees.
2. Growth Form: Growth form within patches was recorded to capture observed patterns between growth forms; for example, some patches contained small "good" to "medium" condition trees alongside tall "poor" or "dead" trees. These patterns may have implications for management planning and likely indicate different age cohorts and different water sources.
3. Density: Density classes were assigned to Black Box units on the ground and using aerial imagery as part of post-field survey digitisation of patches.
4. Condition verification via satellite image analysis: To support the field assessments of Black Box condition, satellite imagery was used to create a series of normalized difference vegetation index (NDVI) layers for the years 1988, 2005, 2012, and 2017. NDVI Change Detection was then performed using image differencing between the years 1988-2005, and 2005-2017.

Field surveys and mapping

Field surveys were conducted to map the presence and condition of Black Box vegetation patches. Existing Black Box unit boundaries at the site were redefined or verified, and sub-divided into specific units based on a visual assessment of condition. During the field surveys, a great deal of spatial variability of condition was observed within patches, some of which may be explained by individual variation and may not necessarily be due to stressors. As individual variability would not influence management planning, assessment of the most common condition was made at the patch scale. After each field survey was conducted Black Box attributes of condition and growth form that had been recorded on paper maps were digitised using spatial analysis software. Pre-existing vegetation polygons were modified, sub-divided, removed, or created to match the data recorded during the site visit.

Results

Following an assessment of the condition class, growth form, density, uncertainty and verification via satellite imagery, a final condition class was determined for each Black Box management unit by combining each of these assessed elements. The Table and Figure below show the number of Black Box management units for each condition class, the total area of Black Box, and the spatial distribution of Black Box condition.

Condition Class	Patch Count	Total Area [ha]
1 – Good	58	1282
2 – Medium	123	1852
3 – Poor	10	297
4 - Dead	31	212

Case Study Box 1: Rapid Condition Assessment at Calperum Station

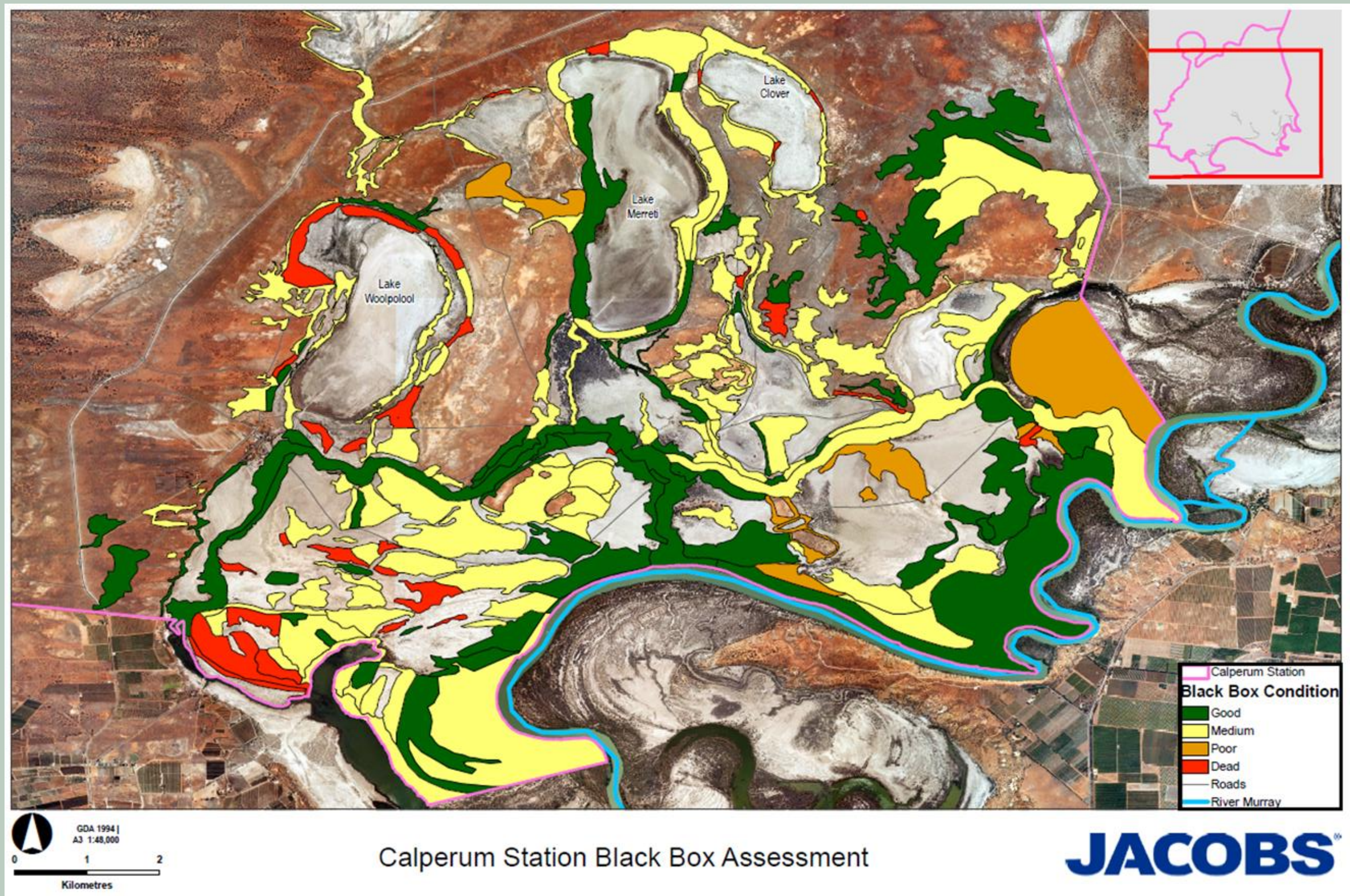


Figure 3-6: Calperum Station Black Box Condition

3.5 STEP 2: IDENTIFICATION OF STRESSORS

Identifying and understanding the stressors that are affecting Black Box condition is a key part of the site investigation process. This involves:

1. Review of general Black Box conceptual models and development of site specific conceptual models
2. Collection of information relating to the stressors throughout the site
3. Analysis and mapping of the stressors to validate the conceptual model and determine the degree to which the stressors are impacting, and therefore the potential to mitigate the stressors with management options.

Details for each part of this process are provided in the subchapters below. The Calperum Station case study has been included below to demonstrate an application of this process.

3.5.1 Conceptual Models

Conceptual models are used as a guide to inform site characterisation, identify stressors and associated ecological risks and benefits. Models are developed to represent the understanding of the relationship between the key physical processes and ecosystem functions. A good conceptual model helps identify the bounds and scope of the ecosystem of interest and provides a scientific framework for developing a targeted program of management. A conceptual model also helps in communicating the main factors impacting condition and how to address these.

Four conceptual models are presented in this chapter to assist identify the key bio-physical processes that may be affecting Black Box condition at multiple scales. These can be used by practitioners to understand the processes that influence Black Box condition and trajectory for change, as a first step in identifying relevant stressors at a site. The models included are:

1) *Regional Hydrogeological Conceptual Model* (Holland *et al.*, 2005), relating the influence of regional hydrogeological processes on the soil and groundwater salinity of the local floodplain
2) *Floodplain Response Model* (Walker *et al.,* 1996; Overton and Doody, 2008a; AWE, 2015), illustrating the key relationships between water management (groundwater and surface water management), soil and groundwater salinity and tree health response
3) *Soil Salinisation Model* (Jolly and Walker, 1995; Overton, 2011) identifies the balance between groundwater depth and flooding frequency in determining soil salinity
4) *Black Box Conceptual Model for Condition States and their Transitions (*Transition Model*)* (Overton *et al.,* 2014), modelling the decline and restoration pathways for mature Black Box related to water management.

The first three conceptual models present the relationship between hydrogeological processes and floodplain soil salinisation. Understanding these regional and local processes is useful to predict floodplain soil and groundwater conditions where physical data and other information (groundwater models, maps etc.) are limited. The conceptual model shown in the Floodplain Response Model was developed for the lower River Murray however the underlying principles used in its development are applicable across the Basin.

Spatial analysis can be used (where data is available) to determine the coincidence and relative importance of stressors to Black Box condition. This approach has been used for the Calperum Station case study (boxes presented throughout this chapter) and at the River Murray reaches scale (presented in Chapter 5).

It is important to acknowledge that the models presented within this Framework are intended to be a broad representation and are limited to the degree that they can represent heterogeneity across the site. Practitioners are encouraged to dissect model elements presented and to use these elements selectively (or build in their own elements as appropriate) to develop site specific models representing the factors influencing Black Box at their site.

3.5.1.1 Regional Hydrogeological Conceptual Model

The poor condition of Black Box populations throughout the lower River Murray is correlated with the salinity of the soil profile where trees have their roots above the water table (the unsaturated zone) and a reduced incidence of flooding. The construction of locks and weirs along the lower River Murray, water storage development at Lake Victoria and historic agricultural/irrigation development have collectively contributed to a rise in groundwater levels, and consequently floodplain salinisation (Holland *et al*., 2005; Woods *et al.*, 2016). The regional hydrogeological processes driving floodplain salinisation and groundwater rise are illustrated in Figure 3-7. The underlying geology influences these processes of groundwater recharge and rise, evapotranspiration and salt mobility (Woods 2015). The resulting effect of increased soil salinity is a reduction in available soil water of a quality that is accessible by Black Box vegetation.

The regional hydrogeological processes are influenced by factors at a spatial scale transcending the managed floodplain. Defining the hydrogeological setting provides an assessment of floodplain salinisation risk and context for devising sustainable management strategies.

A regional hydrogeological model should define:

- regional groundwater inputs to the floodplain
- the interaction between the rivers and streams and the floodplain
- likely occurrence or absence of freshwater lenses
- relative groundwater elevations and salinities and the risk of floodplain salinisation where specific monitoring data is limited.

The conceptual model presented in Figure 3-7 illustrates the hydrogeology typical of the lower River Murray floodplain. In this instance, the model represents a *gaining floodplain reach* where the regional groundwater discharges into the floodplain. Specifically, the model displays:

- regional groundwater discharging to the river and evaporating from the floodplain
- where the groundwater level intersects the clay layer, an increased rate of capillary rise, evaporation and soil salinisation is likely to occur
- the influence of soil type on both capillary rise and infiltration of surface water i.e. clay (low infiltration, high capillary rise) compared with sands (high infiltration and low capillary rise)
- recharge from highland irrigation districts (also associated broad acre tree clearing) enhances the rate at which groundwater discharges to the river/floodplain through seepage at the break of slope
- wetlands on the floodplain may provide either a groundwater discharge or recharge zone dependent on the groundwater water level.

A floodplain and river classification matrix is presented in AWE (2015) describing the characteristics of gaining and losing floodplain systems that may be used to define the regional setting appropriate to a specific locality. In summary, gaining floodplains are more likely to be associated with high groundwater salinity, and therefore high unsaturated zone salinity due to the discharge of saline regional groundwater to the floodplain. This contrasts with *losing floodplain reaches* where groundwater flows away from floodplain sediments to the regional groundwater system or *through-flow systems* where regional groundwater flows beneath or through more highly permeable floodplain soils. The risk of soil salinisation declines significantly for flow-through systems and for losing river/floodplain reaches.

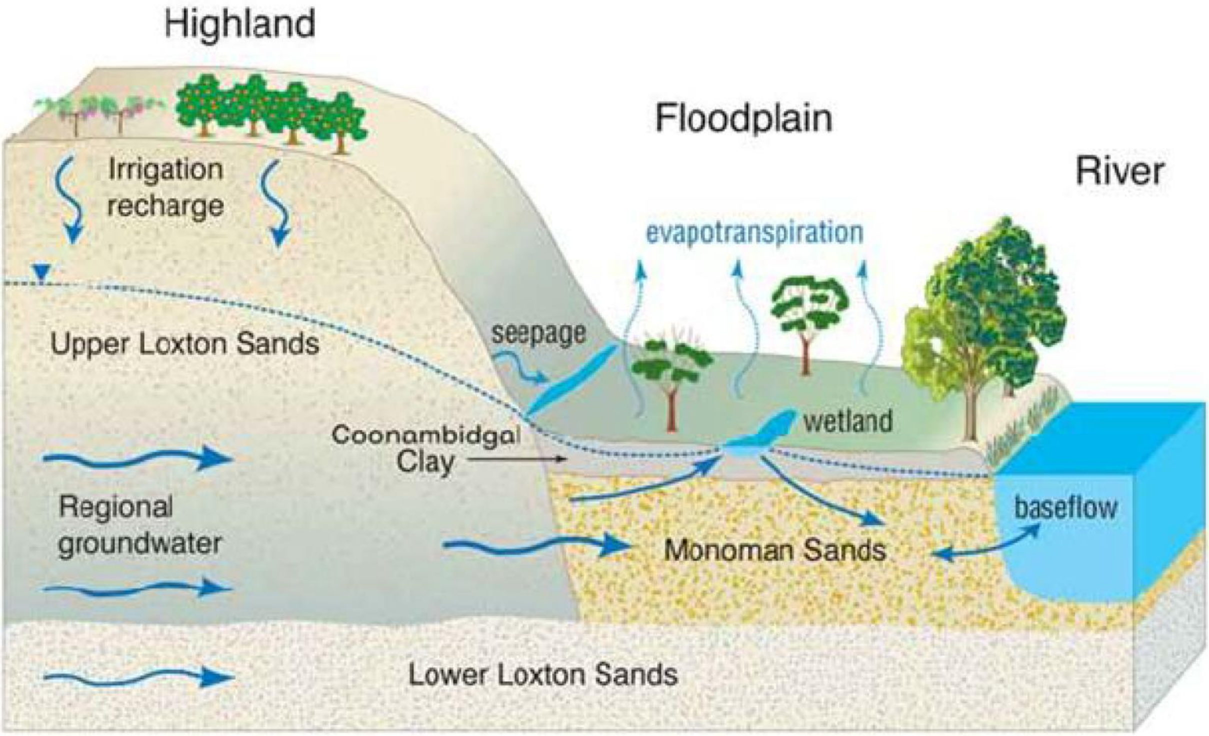


Figure 3-7: Conceptual model of the hydrogeology of the lower River Murray floodplain (Holland *et al.*, 2005)

Hydrogeological (groundwater) models and maps exist for many regions along the River Murray and the other rivers within the Basin (e.g. risk maps have been developed for South Australia) that may be used as a basis for establishing the regional context influencing vegetation condition.

3.5.1.2 Floodplain Response Model

The Floodplain Response Model (Figure 3-8) was developed to support the characterisation of localised hydrogeological processes acting upon floodplains in the lower River Murray region (Walker *et al.*, 1996; Overton and Jolly, 2004; Richardson *et al.*, 2007; Overton and Doody, 2008a). An alternate representation of the model is provided in Figure 3-9 (AWE, 2015). The models provide diagrammatic representation of the key relationships between water management (groundwater and surface water management), groundwater processes, the movement of salt between the saturated zone (below the water table) and the unsaturated zone (zone above the water table), and tree health response. Unsaturated zone soil salinity is a function of groundwater depth, groundwater salinity, soil type and surface water management.

The key premise behind these models is that to deliver long term improvements in the condition of Black Box, populations require interventions that influence groundwater salinity, and consequently increase the availability of soil water of an appropriate quality that can be accessed by floodplain vegetation. This model is therefore useful in guiding the assessment of management actions that may present a benefit or a risk to Black Box condition.

The labels in Figure 3-8 reflect the key processes in the Floodplain Response Model (described in detail in Richardson *et al.*, 2007; AWE, 2015):

- Evaporation and transpiration
- Precipitation and infiltration
- Salt accumulation and leaching
- Seepage and groundwater discharge
- Low salinity lenses (freshwater lenses) reducing the salinity of the overlying unsaturated zone
- Gaining and losing streams that can change during and after flood events

- The development of a flush zone upstream of a lock where the river is kept higher than the surrounding groundwater level.

The conceptual model at Figure 3-8 provides two cross-sections that show the difference between pre-flooding and flooding. Streams can either be losing or gaining depending on the relationship between the river height and the surrounding groundwater height. The flush zone represents an area of lateral recharge where freshwater from the river moves into the fringing soil profile and provides a good source of water to the trees.

In applying a Floodplain Response Model, the following factors need to be assessed when determining the likelihood of a positive change in Black Box condition resulting from management interventions within a salinised environment. These are presented in an indicative order of importance:

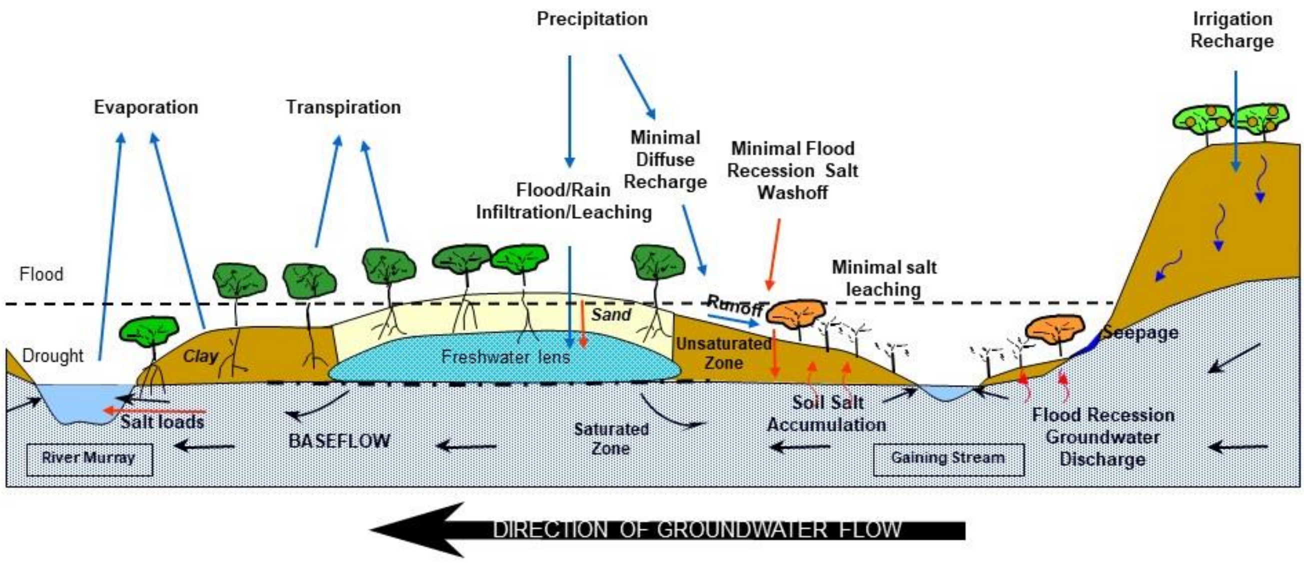
1) vegetation condition and trajectory of change (refer to chapter 3.5.1.4)
2) unsaturated zone (soil) salinity
3) saturated zone (groundwater) salinity (i.e. from below the water table)
4) depth to water table and/or evapotranspiration (ET) rates
5) unsaturated zone soil materials
6) access to sources of surface water – e.g. flood frequency, rainfall, freshwater lenses
7) responsiveness of groundwater to management intervention (i.e. recharge potential)

As a guide to assessing the likelihood of soil and groundwater conditions (average salinity) supporting healthy Black Box, salinity thresholds are provided below. These values have been derived based on literature review and data analyses that associated 75 per cent of healthy Black Box trees with soil and groundwater salinities below the suggested threshold limits (AWE, 2015). These simplified thresholds can be used for rapid assessment; however, the use of these thresholds should be considered in the context of soil texture, regional groundwater processes (including pressure gradients) and genetic variations that may confound the observed tree condition.

The salinity thresholds are:

- soil salinity of 39,000 mg/L (equivalent to 60,000 EC or 60,000 μS/cm)
- groundwater salinity of 22,000 mg/L (equivalent to 33,850 EC).

Management strategies are likely to be more effective for sustainable improvement in Black Box condition where soil and groundwater salinities are below the above threshold values; a correlation between salinity and tree health is presented in Chapter 5.



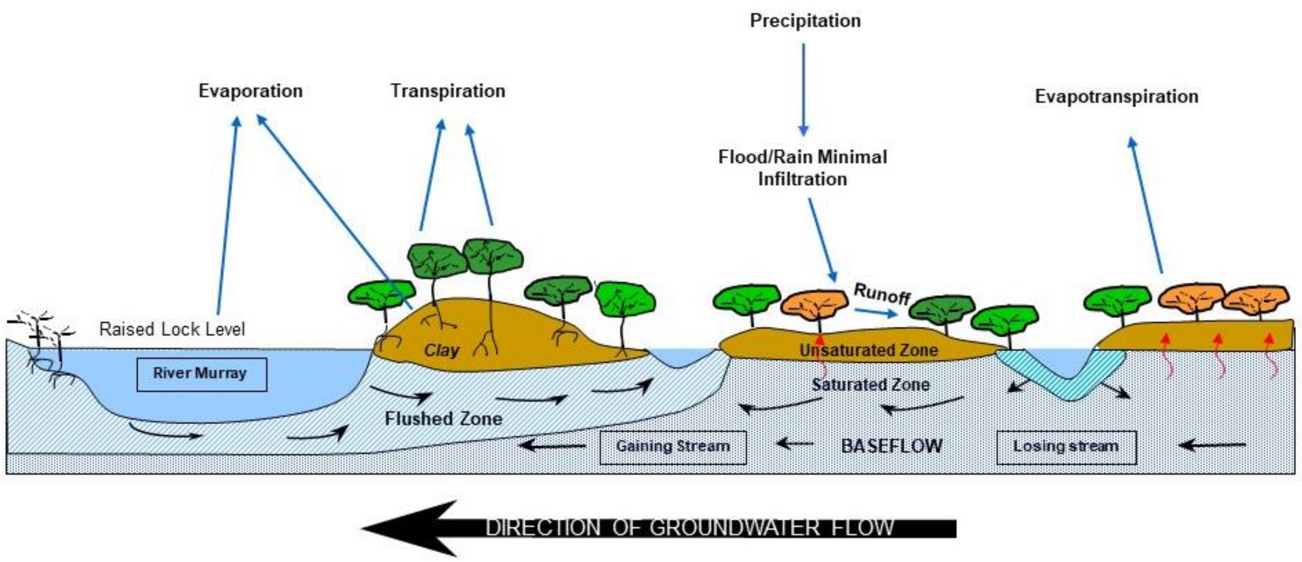


Figure 3-8: Hydrogeological and ecohydrological processes on the River Murray floodplain (Overton and Doody, 2008a)

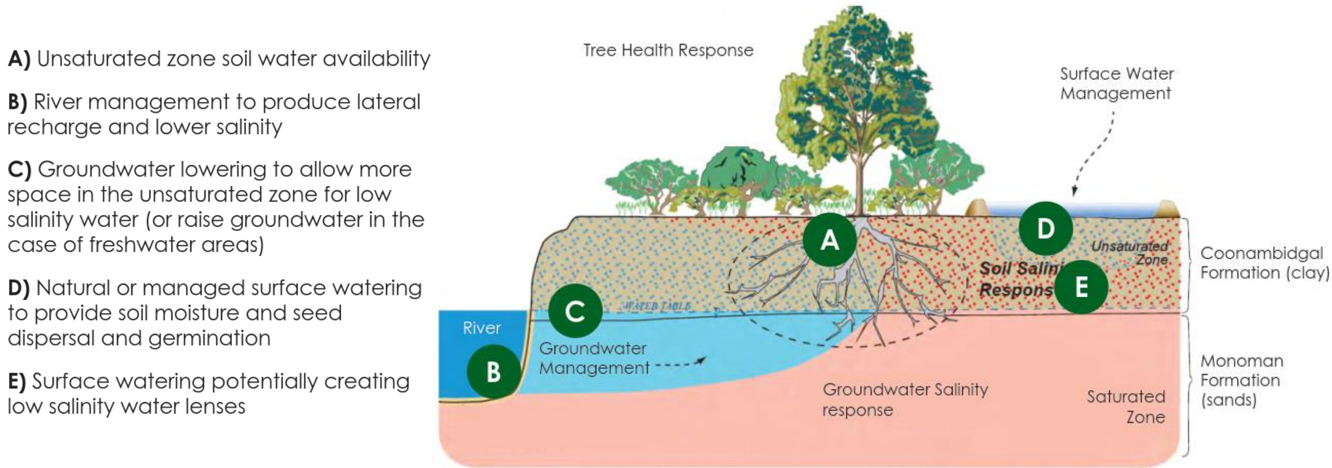


Figure 3-9: Floodplain response to water management (AWE, 2015)

If soil salinisation is regarded as having a role in limiting soil water availability at a site it is recommended that additional data is collected and analysed to provide an empirical basis for defining the interrelationship between these factors.

3.5.1.3 Soil Salinisation Model

The soil salinisation conceptual model depicts a balance between the freshwater going down from flooding and rainfall and the salt water coming up due to evapotranspiration. The balance between these two determines the amount of soil moisture available to the plants. When salt accumulates in the soil profile the amount of water available to the Black Box roots is reduced. Plants uptake water through their roots via a process of osmosis that is driven by salt concentration differences across the plant membranes. When the salt concentration outside the plant exceeds that inside the plant the water in the soil is not available to the plant. The osmotic potential is too great for the plant. Different plant species have different osmotic potentials. This process is similar when there is little actual water in the soil. Extracting water from a dry soil requires matric potential and when the matric potential is too great the plant will wilt. Soil salinisation and hence increased lack of available water has been attributed as a major cause of floodplain vegetation decline in the lower River Murray.

Black Box relies on groundwater for survival when other forms of surface water is not available, provided groundwater is not too saline. Where the salinity of the groundwater is too high for the Black Box to extract sufficient water, the trees must draw their water from the upper soil profile and become affected by salt accumulation in this capillary fringe zone.

A critical depth to groundwater exists and it is dependent upon flood frequency. This was shown to be consistent with soil salinisation processes in that there is a critical depth to groundwater at which there is no vertical movement of salt through the soil profile. As flooding frequency increases, the critical depth to groundwater is decreases. The critical depth is also dependent on the groundwater salinity. Below about 3 metres from the surface the pressure of capillary rise of groundwater to the surface is reduced to the point of no salt accumulation. Vegetation, through transpiration, can increase the rate of salt accumulation. The critical depth of groundwater is deeper for clay than for the coarser sands, hence trees situated on the sands would have more available fresh water in the soil profile (Jolly *et al*., 1993). This change in the balance between shallower groundwater, increased salt accumulation and less flooding has shifted from pre-regulation to current conditions (Figure 3-10). This has combined to create reduced water availability in the soil profile (Jolly and Walker, 1995).

The critical flooding frequency or groundwater depth will differ from site to site. Black Box trees established in an area have grown to adapt to the local conditions. Rather than focussing on universal critical threshold levels it is more important to consider the change in conditions from when the trees originally became established.

In areas of shallow groundwater and high groundwater salinity, soil salinisation can be higher than Black Box tolerance. High flooding frequency must occur to combat this soil salinisation and will be dependent on the soil type. Management needs to address this balance by increasing recharge through flooding or decreasing discharge through lowering groundwater levels or lowering groundwater salinity. Providing an alternative water source is also an option through lateral recharge, for example from a nearby creek, up to approximately 150 metres, however this varies significantly for different sites (AWE, 2015).

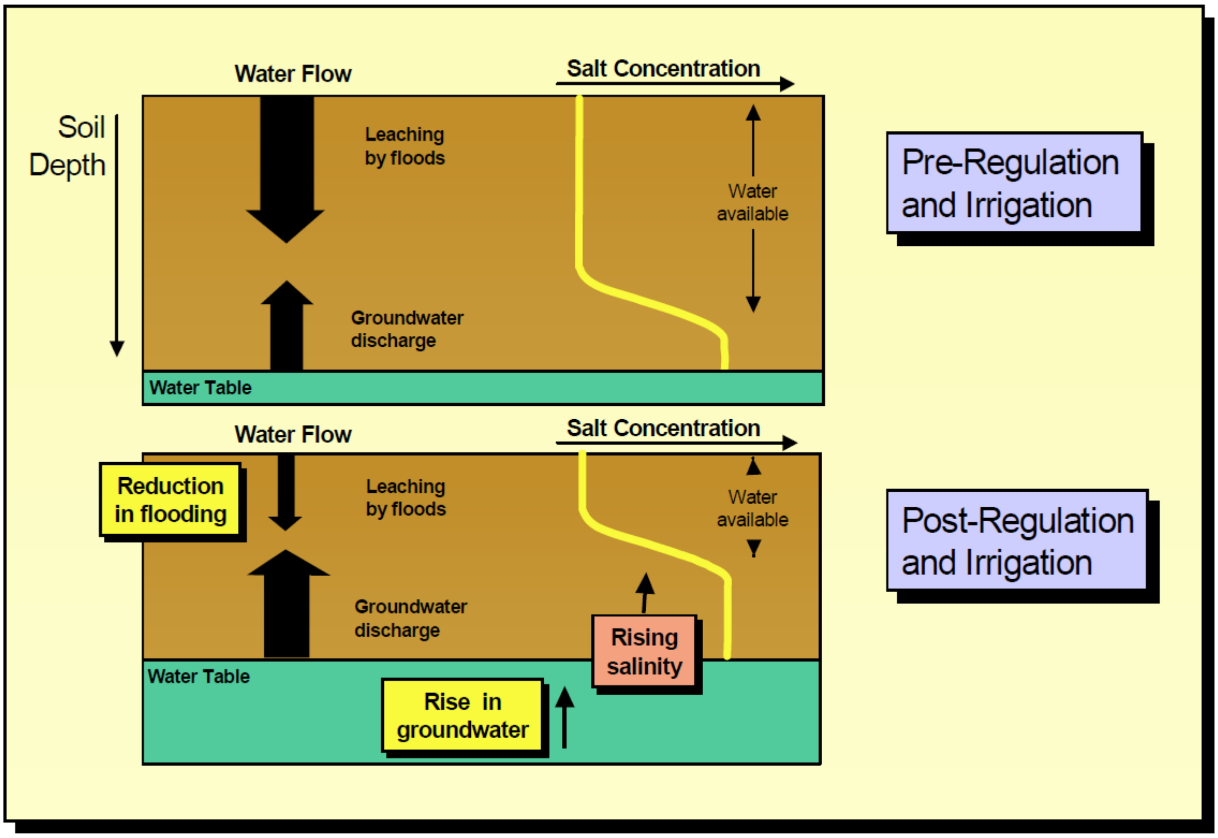


Figure 3-10: Conceptual diagram of the salt accumulation mechanisms in floodplain soils (Overton, 2011).

3.5.1.4 Black Box State and Transition Model

The Black Box Conceptual Model for condition states and their transitions (Transition Model) (Overton *et al.*, 2014) has been developed to predict the rate of decline and recovery of mature trees as a result of changes to watering availability (Figure 3-11 and Table 3-5). As a long-lived and slow-growing tree, mature Black Box takes several years to transition between different condition states in response to water availability.

This conceptual model is based on surface watering requirements (frequency and duration of surface watering events) for mature Black Box and a function of the time in years since the last effective watering event. The model is useful for considering likely timeframes for recording either decline or improvements in Black Box condition however Overton *et al*. (2014) note that these changes may not correlate specifically to flood history rather to changes in soil salinity and/or changes in groundwater.

The model predicts that the decline in Black Box condition from “Good” to “Critical” is predicted to occur over 19 years since the last watering although Black Box is known to be able to survive for longer than this. The pathway to recovery is represented as being staged, slower and occurs across multiple years of management intervention. Improvement from “Critical” to “Good” is estimated to take up to 25 years. It is important to note that these transition pathways do not factor the impact of salinity on Black Box condition that may result in either a more rapid decline or prolonged recovery.

The longer recovery pathway occurs via an “Intermediate” condition. Trees may be observed responding rapidly to a single rainfall or floodplain watering event e.g. epicormic growth, however the sustained improvement to convert this vigorous growth into new woody structures is more energy-demanding and occurs over multiple years. Restoration of a watering regime or soil water availability in a single season does not restore the vegetation to good condition if Black Box trees have experienced severe decline (Overton *et al.*, 2014). The expected response to a watering event at each stage in the conceptual model is described as follows:

1) **Good condition** - Responds to watering by maintaining its vigorous condition, increasing in size (bole diameter, canopy extent) whilst maintaining foliage density as high.
2) **Medium condition** - Responds to watering by producing new leaves from existing twigs and branches, so assessed as returning to "Good" after 1 year.
3) **Intermediate condition** – Responds to watering by developing new leaves on branch tips. Capable of abundant flowering and high reproductive effort once this stage is reached. Assessed as taking 7 years to reach "Good" with ongoing maintenance of conditions that are conducive to recovery.
4) **Poor condition** - Responds to watering by epicormic growth on bole and branches. Assessed as taking ten years of favourable growing conditions (wet years with short dry intervals) to reach "Intermediate" condition and then 7 years after that to return to "Good".
5) **Critical condition** - Responds to watering by epicormic growth, but due to slow growth rate needs repeated favourable growing conditions (optimal frequency and no long dry to cause stress) to re-establish most of the crown. Assessed as taking approximately 18 years to reach "Intermediate" condition. If the tree is not re-watered within a year or two of first watering, this new epicormic growth dies, and the tree remains in "Critical" condition.

Table 3-5: Stress and recovery pathway transition descriptors (Overton *et al.*, 2014.)

Stress transitions	Years since last watering	Recovery transitions	Water requirements
(a) Good to Medium	5 consecutive years	(d) Medium to Good	1 year with single watering event
(b) Medium to Poor	5 consecutive years	(e) Poor to Intermediate	Three or more events in 10 years
(c) Poor to Critical	5 consecutive years	(f) Critical to Intermediate	Five or more events in 18 years
(h) Intermediate to Poor	4 consecutive years	(g) Intermediate to Good	Two or more events in 7 years

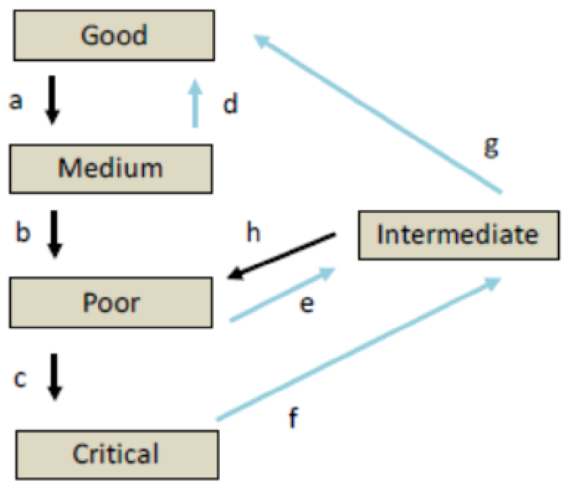


Figure 3-11: Transition between various condition states for Black Box trees (Overton *et al.*, 2014).

Case Study Box 2: Developing and Verifying a Conceptual model for Calperum Station

Calperum Station has developed a site specific conceptual model that tracks salinity through the floodplain, including three smaller sub-models (for surface hydrology, soil water and vegetation). The models convey the current understanding of site conditions and range from simple box and line diagrams to pictorials.

The motivation to develop site specific models came from:

- an observed heterogeneous response of Black Box to environmental-watering (i.e. unexpected responses to surface watering events)
- the need to manage Black Box growing on shallow sand dunes and clay soils (e.g. differences in the rates of water infiltration and soil water availability)
- an observation that a significant proportion of Black Box occurring on shallow dunes are in stable, moderate to good condition (i.e. inundation frequency does not appear to be driving tree condition)
- Black Box in poor / dead condition are observed in clay swales immediately adjacent to the inundated lakes (knowledge gap on the stressors effecting tree health).

The site manager took physical elements, stressors and relationships of a generic floodplain rainfall pulse model and adapted these to reflect site observations and data analysis. The resulting Calperum conceptual models are working versions; still being verified via investigation, testing management options, monitoring and evaluation. The elements of each model and the relationship between models are documented (technical report) so that scientific understanding of key relationships can continue to grow.

The relationships and assumptions in the models are tested through various discrete trial projects where there is relatively low risk. The design and delivery of associated monitoring and evaluation is a key component, providing the manager with an indication of success and thereby informing the validity of relationships in the models and the related management approaches.

For example, the Soil Water Sub-Model (Figure 3.12) describes the following key relationships and stressors for the Calperum Station floodplain:

- most groundwater is from regional groundwater systems and is saline
- depth to groundwater (and associated depth of the unsaturated soil zone) is variable in response to seasonal influences, physical soil characteristics, and flows in adjacent river systems
- soil water is derived from vertical infiltration of surface water or the lateral movement of water through the soil from water bodies (i.e. lakes, river)
- the infiltration of surface water is significantly influenced by soil type (clay / sand)
- for clay soils, water infiltration is enhanced through cracks in the soil matrix but this relationship is dynamic and affected by variances in clay structure (some Calperum clays crack more readily than others), and the duration/frequency of wetting and drying events.

The variance and influence of soil type on watering, and the duration of successive wetting and drying events produces a heterogeneous response to floodplain inundation and Black Box condition at Calperum Station.

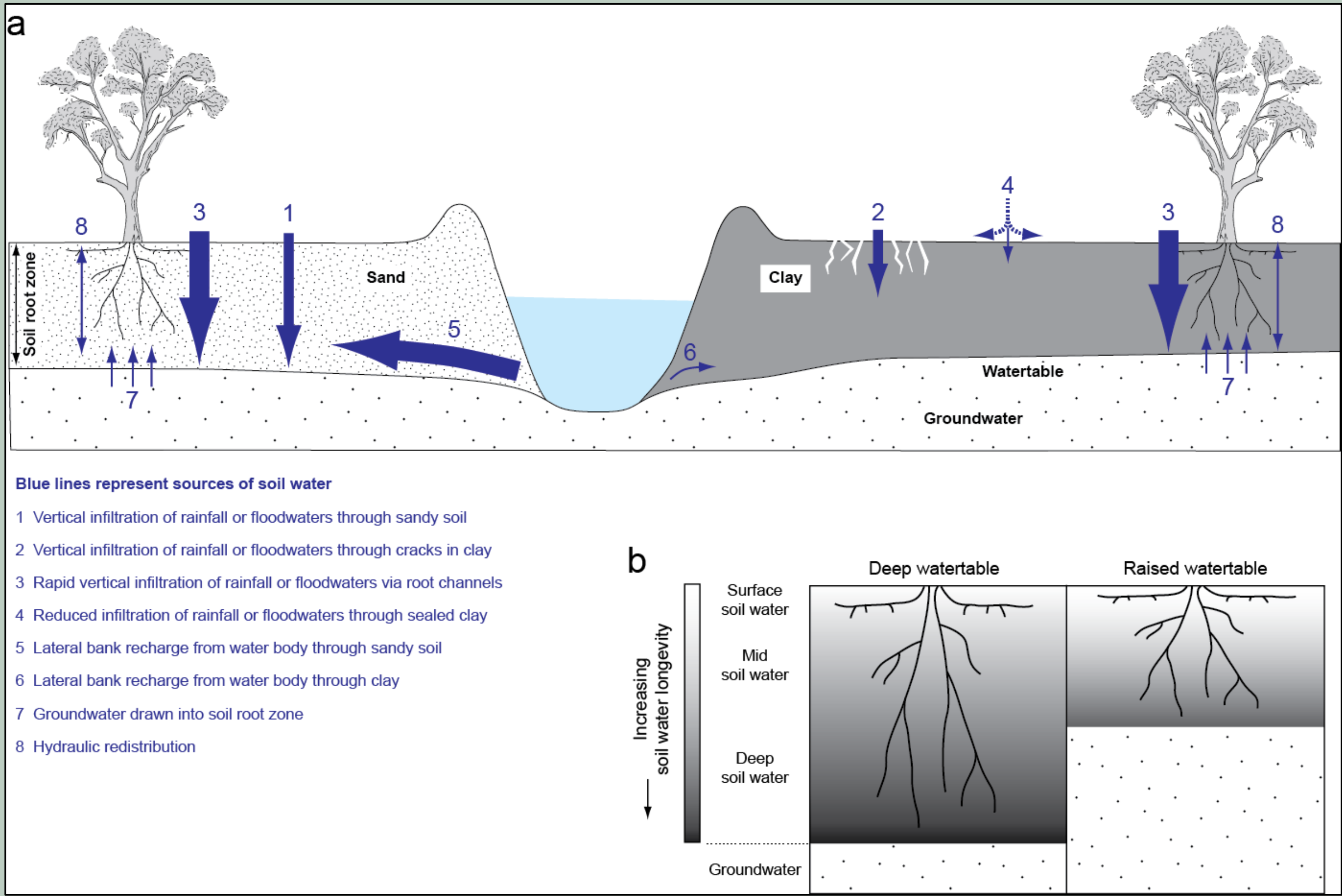


Figure 3.12: Calperum Station soil water conceptual model (Cale and Cale 2011)

3.5.2 Using Conceptual Models to Identify Relevant Stressors at a Site

While the conceptual models are useful in identifying and understanding key stressors to Black Box, they do not provide guidance on the degree to which different stressors are impacting on Black Box. This chapter provides guidance on how observed site conditions can be used to validate a site specific conceptual models and provide additional detail on the influence of stressors and how they might be managed.

Potential stressors of Black Box are listed below. All relevant thresholds relating to these stressors are summarised in chapter 3.5.3:

- **Shallow saline groundwater:** Shallow groundwater decreases the amount of soil in the unsaturated zone, which can lead to waterlogging of tree roots, reducing the oxygen available and affecting nutrient uptake. Shallow groundwater levels can also drive soil salinisation through capillary rise of water from the aquifer, resulting in accumulation of salts at the soil surface/rootzone, and hence the moisture in the rootzone being too saline to be suitable for plant uptake.
- **Deep fresh groundwater:** In the upper River Murray and in the northern parts of the basin, fresh groundwater is a constant supply of water to Black Box trees. With increased groundwater extraction and reduced recharge groundwater levels are falling, reducing soil water availability.
- **High groundwater salinity:** If groundwater salinity is saline (refer floodplain response conceptual model in chapter 3.5.1.2), there will be a lack of available soil water of acceptable quality for Black Box to access.
- **High soil salinity:** If soil salinity in the upper soil layers is high (refer floodplain response conceptual model in chapter 3.5.1.2), there will be a lack of available soil water of acceptable quality for Black Box to access, related to changes in osmotic potential.
- **Lack of soil moisture in the unsaturated zone:** A lack of soil moisture leads to water stress in Black Box vegetation, due to changes in matric potential.
- **Reduced flooding frequency:** Flooding increases the soil moisture availability to Black Box for the period of inundation and causes freshening of groundwater and soils in the areas inundated through recharge, reducing salinity stress. A low frequency of flooding results in stress to Black Box vegetation through lack of soil moisture availability and accumulating salinity in groundwater and soils.

Other key features that influence Black Box condition:

- **Soil structure (related to salt leaching and movement of groundwater (aquitards)):** The soil profile at a site can be used to infer how groundwater recharge and soil leaching processes are likely to occur.
- **Grazing/land disturbance:** Physical disturbance of Black Box vegetation, and soil degradation, due to grazing, pests, or other land affecting activities.
- **Potential for lateral recharge:** Lateral recharge causes groundwater freshening to occur horizontally, to a zone outside areas that are inundated, when the surface water level exceeds the head at the groundwater interface. The potential for lateral recharge influences how far away from the river certain management options may influence Black Box vegetation. Typical maximum extents of lateral recharge have been noted at 150 metres, however this is dependent on soil types.
- **Presence of paleo channels:** Paleo channels are areas where it is likely that groundwater movement will occur, hence they provide opportunities for groundwater freshening to the areas surrounding them.
- **Accumulation of rainfall:** Where rainfall gathers in the landscape, soil moisture availability is likely to be higher, and soil/groundwater salinity are likely to be lower than areas where rainfall does not infiltrate. This is evident at the base of a slope change where runoff accumulates to provide a water source.

Further discussion on stressors, potential indicators, and the ecological attributes or functions that are impacted is provided in Appendix B.

Multiple stressors are likely to apply at any one site (e.g. water availability, salinisation, competition) and these stressors may be acting at multiple spatial and temporal scales. Not all stressors may be able to be actively managed, however an understanding of the relative importance of different stressors should form the basis for choosing appropriate management interventions. Consideration of stressors that have changed since establishment of the trees is needed, such as reduced flooding frequency or rising groundwater levels that can occur due to changes in the environment. Stressors can also change as a function tree growth. For example, as Black Box trees grow their roots progress deeper into the unsaturated zone to stabilise the tree, potentially encountering the soil salinity at depth, introducing a new source of stress.

Many stressors are also likely to impact more than one ecological process or function. For example, water availability will influence growth and condition, as well as reproduction, dispersal and recruitment establishment. Seedlings tend to be more vulnerable to all the listed stressors and additional management intervention is potentially needed if they are to survive over the first 1 to 2 years.

3.5.2.1 Data Collection for Stressors and Confidence Levels

To understand the main stressors that are occurring at a site, a review of existing observational data, or collection of additional data is required. There are a range of data sources and types, ranging from anecdotal information, to measured data sets that can be used to develop an understanding of the stressors acting at a site. Depending on what investigations have taken place at a site, a range of different data sources may be available, which will influence the level of confidence, or uncertainty, in understanding which stressors are relevant to management of Black Box.

Table 3-6 provides a guide to the hierarchy of data sources for providing increasing levels of understanding about the main stressors. This table is intended to provide land managers with a quick reference guide of what they need to understand for their site and the level of effort and technical understanding that might be required for each step.

The criticality of each of these data types in validating a conceptual model for the site should be used to determine whether the confidence level is sufficient, or whether further investigation is required to improve the confidence level. For example, if the conceptual model for the site is heavily reliant on understanding groundwater depth and salinity interactions throughout the site, a moderate/high level of confidence should be provided for those data types. The overall confidence level should be determined in relation to the overall conceptual understanding that is provided throughout the site.

Refer chapter 3.2 for an explanation of the confidence assessment colour coding and explanation of what confidence levels are appropriate for different types of sites.

For larger or more complex sites, or those with many stakeholders, a workshopped process may be helpful for identifying the key defining processes (and stressors) affecting Black Box condition. Technical input from a range of relevant disciplines with knowledge of the site (e.g. ecology, hydrogeology, hydrology, river operations etc.) should aim to build a common understanding of the key processes operating at the site (presented in the form of a conceptual model), the drivers or stressors responsible, the degree to which each of these may influence the site, and where uncertainty and or knowledge gaps (and thus risk) apply.

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Table 3-6: Hierarchy of data sources for providing increasing levels of understanding about the main stressors to Black Box at a site

Confidence level	Confidence Score	Groundwater Depth	Groundwater Salinity	Soil salinity	Soil Moisture in the upper surface	Soil Structure (related to salt leaching and movement of groundwater)	Potential for lateral recharge	Flooding Frequency	Presence of paleo channels	Accumulation of rainfall	Grazing or other land disturbance
Low: Anecdotal or regional level of information, providing a rough estimate of site conditions.	1	Regional groundwater maps: *Provides only a coarse estimate of GW depth at the site* One push tube test at the site	Regional groundwater salinity maps	Regional soil salinity maps	Regional soil moisture maps	Regional soil classification maps: *Provide a coarse estimate of soil profiles at the site*	Assume a zone of lateral recharge, from published literature reporting monitoring at other sites (e.g. 30m, 50m, 100m)	Anecdotal evidence of prior flood event timing and water levels. Water observations from space data	Regional geological mapping	Anecdotal evidence of where runoff pools following large rain events	Anecdotal evidence of grazing/land use history
Low/Moderate: Measured data from local sources, providing a better estimate of site conditions.	2	Groundwater depth map interpolated from local groundwater bores: *Provides a better estimate of GW depth at the site* *Several push tube tests at the site*	Groundwater salinity map interpolated from local groundwater bores	Soil Salinity derived from AEM inversion grids	Anecdotal evidence of soil wetness/dryness at the site	Soil classification map interpolated from local geotechnical testing	-	Historical records of weir pool levels at River Locks, extrapolated to the site	-	Interpretation of remote sensing data	Interpretation of remote sensing data
Moderate: Data measured at the site, but with high level of uncertainty.	3	Groundwater bore at site: *Provides GW depth near to the Black Box unit*	Groundwater salinity measured from a single bore at site, over a short period of time (<1 month)	Soil salinity map interpolated from local soil salinity on-ground testing	Soil core sampling at a low number of locations on the site, at one time	Geotechnical testing of the soil properties throughout the soil profile at a low number of points on site	Estimates of lateral recharge at the site, from observations of prior management activities, such as WPM	Short period of historical records of River flows measured near to the site	-	Inspection of site topography data to identify high and low points and estimate where rainfall is likely to accumulate	One-off physical survey throughout the site, recording observations of any grazing or land disturbance
Moderate/High: measured data at the site, with moderate level of uncertainty.	4	Groundwater pit or measurement of water level as bore is dug: *Provides actual measure of GW depth*	Groundwater salinity map interpolated from measurements of several bores at the site, over a moderate period (2-12 months)	Testing of soil salinity at a small number of locations on the site	Soil core sampling at several locations at the site, at one time	-	Lateral recharge estimate from interpretation of AEM data	Long period of historical records of River flows measured near to the site	Hydro-geochemistry monitoring	-	-
High: Measured data at the site, with low level of uncertainty.	5	Soil pit: *Provides measure of GW depth and any aquitards that may produce freshwater lenses or restrictions of deep GW reaching the surface*	Groundwater salinity map interpolated from measurements of several bores at the site, over a long period of time (>1 year)	Testing soil salinity at a larger number of locations at the site	Soil core sampling at several locations at the site, regularly over a period	Geotechnical testing of the soil properties throughout the soil profile at a higher number of points on site	Geophysics and hydro geochemical sampling and modelling Use of groundwater models that have been calibrated to transient sub plain potentiometric head data	Historical records of River flows measured at the interface of the site and the river Surface water modelling at the site	Geophysics and hydro geochemistry monitoring to understand conductivity of channels	Rainfall runoff modelling, using a terrain model to predict how much runoff is generated, and where runoff flows throughout the site	Repeated surveys throughout the site, recording observations of any grazing pressure or land disturbance

3.5.3 Analysis of Stressors

After collecting information on relevant stressors, it is beneficial to map the stressors throughout the site and analyse them to understand the degree to which they are impacting each Black Box management unit throughout the site. Conceptual models can provide an understanding of the relationship between Black Box condition and stressor impacts. Data analysis is required to test and validate the conceptual models, and to determine a relationship between Black Box condition classes and stressor thresholds.

Some generalised stressor thresholds are summarised in Table 3-7, intended for use by practitioners in analysing the stressor information at their site. These thresholds will vary in different locations depending on soil types, rainfall and the conditions under which the Black Box originally established, hence should be reviewed and updated for site specific conditions.

Table 3-7: Summary of stressor thresholds

Stressor	Threshold
Flood interval period	Maximum up to 19 years (potential for 25 years) (Overton *et al.*, 2014). Note: Black Box can survive on rainwater indefinitely if there is very low salinity in the soil. In cases where there are other stressors the starting condition of the trees influences the maximum flood interval the tree can survive. Overton and Doody (2008b) note that a universal threshold is probably not realistic but the change in flooding from when the tree established is important. Trees were found to be of poor condition when exposed to a flood interval of greater than 3 times the return period. For example, if the tree was used to a 1 in 4 return period, then 12 years is a useful interval to use for predictions of decline.
Flood duration	Natural flooding durations on the Chowilla floodplain were found to be 2-4 months (Roberts and Marsden, 2000). Continuous flooding for 13 months caused acute stress in mature Black Box trees (Briggs and Townsend, 1993), hence a threshold of 12 months could be considered appropriate. For seedlings, flooding of 70 days has been shown to cause stress (Roberts & Marsden, 2000).
Flooding frequency	Black Box typically occur at floodplain elevations with flood frequencies of 1 in 5-10 years. Threshold for stress is a 1 in 10-year return period (Jolly and Walker, 1995). Note that the change in flooding frequency is more important than a single universal threshold.
Groundwater depth	Stress from shallow saline groundwater at depths within 2-4 m of the surface (AWE, 2015) Stress from deep fresh groundwater - >10 metres, depending on depth of roots
Groundwater salinity	Groundwater salinity of 22,000 mg/L (equivalent to 33,850 EC) (AWE, 2015)
Soil salinity	The critical salinity for Black Box has been estimated to be 55,000 EC (Overton and Jolly, 2003). Soil salinity of 39,000 mg/L (equivalent to 60,000 EC or 60,000 µS/cm) (AWE, 2015) is a useful management threshold for salinity stress.

Mapping the area of impact of different stressors could lead to redefining the management units identified from the Black Box condition assessment. The goal of the management units is to map areas of Black Box that will respond similarly from broad management actions. Contiguous areas of similar vegetation condition are likely to be impacted by similar stressors but where there is a clear change in stressor impact across a management unit it should be divided into more than one unit.

Following this analysis, the site specific conceptual models should be updated with the identified thresholds and any other information of relevance.

Case Study Box 3: Analysis of Stressors

An analysis of stressors at Calperum Station was conducted to validate the conceptual models (refer case study box 2), explain variability in Black Box condition, and further break Black Box vegetation patches into management units based upon their primary stressor. The steps undertaken are described below.

1. Data Collection for Stressors Throughout the Site

Data was collected for each of the potential stressor categories shown in Table 3-6. The following datasets (soil salinity, groundwater salinity, and water table elevation), were available from previous site studies, and were provided by the ALT:

- Depth to groundwater: Depth to groundwater was calculated by taking the difference between a water table surface produced by ABARES, and a DEM. Polygons with depth to groundwater <6m were identified as being at a potential risk of stress due to shallow groundwater depth.
- Soil type: A soil classification layer developed by ABARES (2011) was reclassified into a binary sand or clay layer for the purposes of identifying the two major types of soil profiles which impact groundwater recharge and soil leaching. The floodplain on Calperum station is primarily clay soils, with sandy soils and dunes present at high elevations.
- Soil salinity: Soil salinity from the ABARES AEM inversion grids was mapped to identify areas of high soil salinity. Soil salinity derived from the AEM inversion grids is reported in μS/cm. Soil Salinity surfaces reported in the following figures was reported at depths of 0-2m, 2-4m, 4-6m and 6-9m from the surface.
- Groundwater salinity: Groundwater salinity has been mapped using the ABARES data provided. This dataset describes pore water conductivity in the soil 5m below the watertable, and was estimated based on average bulk conductivity from Holistic inversion data from the Calperum AEM survey and assumed soil porosity values for the Calperum region. The greatest groundwater salinity values are between 20,000-27,845 μS/cm. Areas of concern are central Reny Island, south of Woolpolool Swamp, and South of Lake Clover.
- Flooding Frequency: Commence to Fill (CTF) was used from the RiM-FIM (Overton, 2005) to provide the River Murray inflow exceedance to inundate areas within Calperum Station. A map showing the areas under different CTF flows was developed to identify areas of higher and lower flooding frequency.

Since the ABARES and CTF data that was used was specific to the Calperum Station site, a “moderate” confidence level was applied to each data source. This amount of data may not be available at all sites. For each site investigation, practitioners should refer to Table 3-6, find out what data is currently available, complete a confidence assessment, and determine whether collection of additional data is required.

Case Study Box 3: Analysis of Stressors (cont'd)

2. **Analysis of the stressors to determine the degree to which they are impacting and therefore the potential to mitigate these stressors with management options**

The following thresholds for the stressors to Black Box vegetation were determined for Calperum Station, using the conceptual models:

- Areas requiring flows into South Australia greater than 100,000 ML/day were identified as flooding less frequently than 1 in 10 years, resulting in flood stress
- Groundwater salinity > 20,000 EC is the threshold for groundwater salinity stress
- Groundwater depth < 6m is the threshold for stress due to shallow groundwater depth

Maps for areas under stress by flooding frequency, areas under stress by groundwater salinity and areas under stress for shallow groundwater depth were developed, using the information gathered in step 2.

3. **Determination and mapping the key stressors which relate to each of the Black Box management units that were identified during the condition assessment**

Key stressors for each Black Box Management Unit throughout the site were determined through combination of the maps developed in step 3, as shown in the Figure below. These stressor combinations help to identify where a mix of management options are required or where management options that impact multiple stressors should be targeted.

Case Study Box 3: Analysis of Stressors (cont'd)

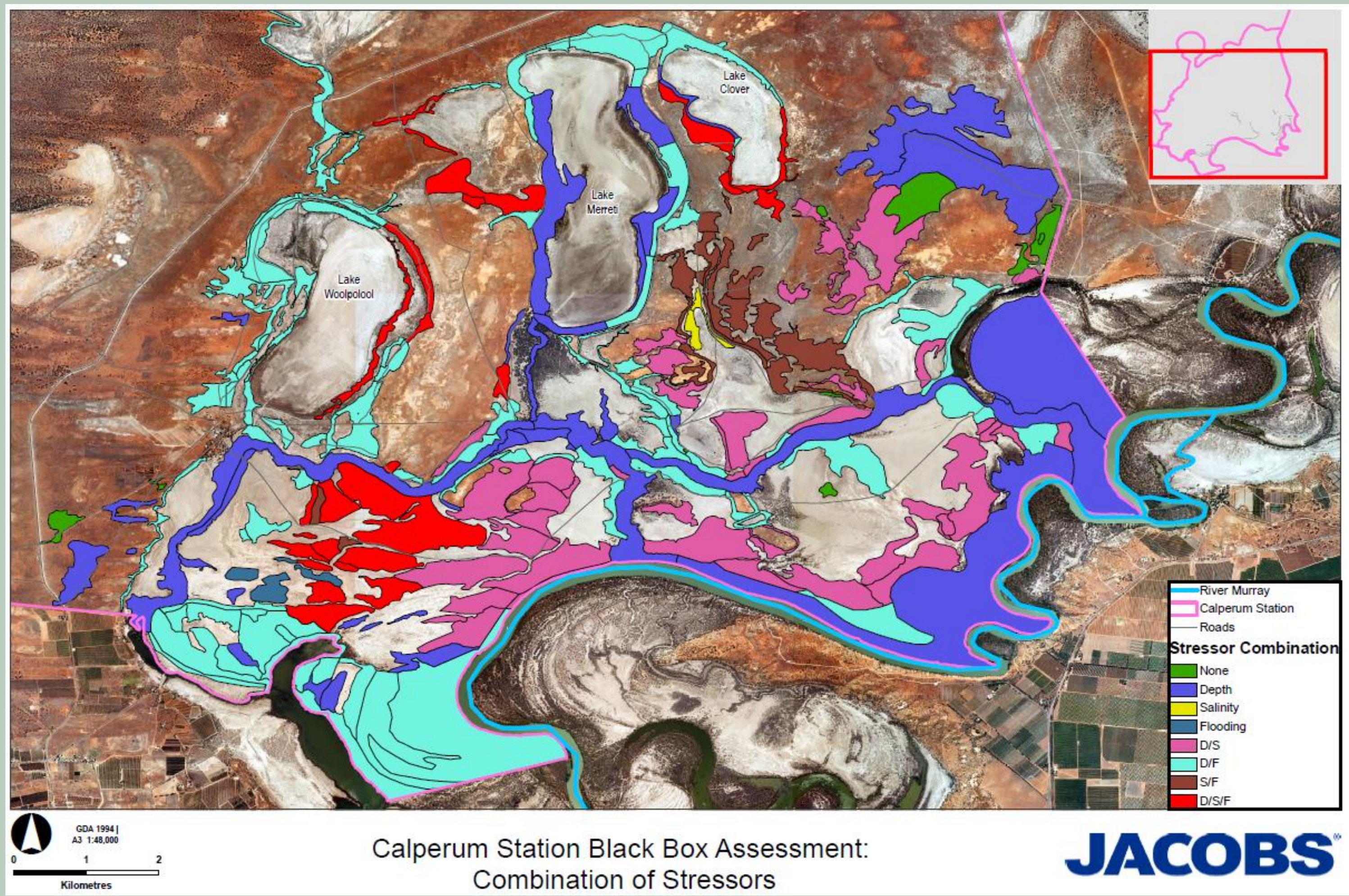

Figure 3-13: Black Box management units at risk by a combination of stressors

3.6 STEP 3: VULNERABILITY ASSESSMENT

To understand the need for, the urgency and the priority of managing one Black Box community over another it is important to assess the vulnerability of a Black Box community. The Framework uses the definition of vulnerability as described by the Intergovernmental Panel on Climate Change (IPCC, 2001). Vulnerability is a function of the sensitivity of a system to change, its exposure to those changes and its capacity to adapt to those changes. The Framework uses the term vulnerability of a Black Box community as a measure of how likely the trees will decline given the condition the trees are in and the level of stress they are exposed to. Risk is often expressed as a function of vulnerability and likelihood. The likelihood of an overbank flow event has been incorporated into the exposure component of the vulnerability assessment of the Framework.

When assessing Black Box vulnerability, the potential impact is a function of external factors and internal factors, as shown on Figure 3-14. A conceptual model can help in identifying vulnerability.

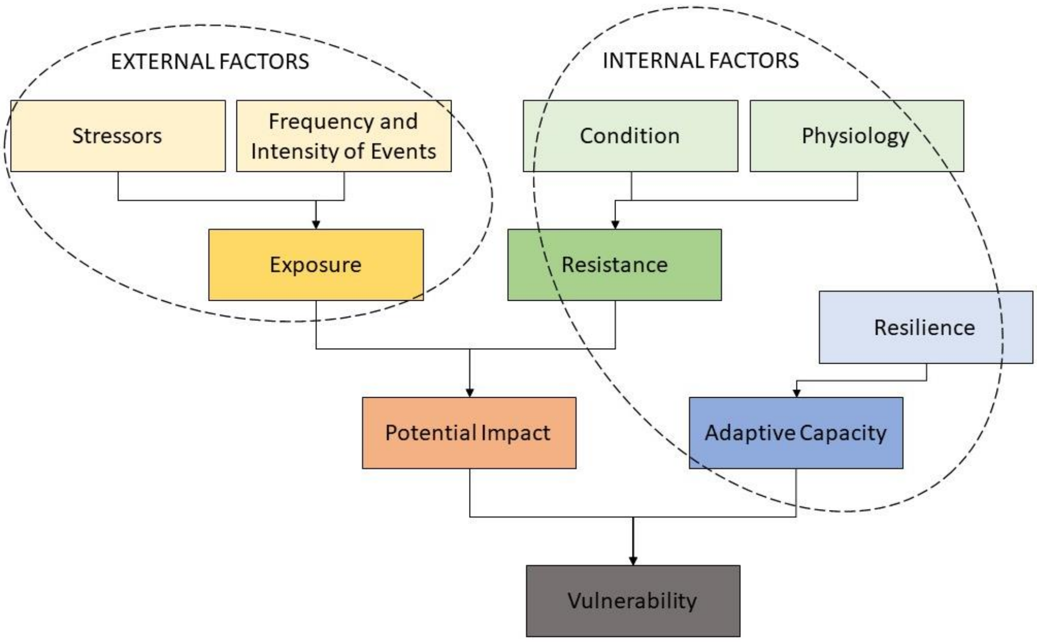

Figure 3-14: Key components of Black Box vulnerability used in the Framework (Modified from IPCC, 2007).

The key components of Black Box vulnerability are:

- **Exposure** or force of change is a function of the external stressors and their severity. These can be long term constant or chronic stressors (e.g. depth of saline groundwater) or acute events (e.g. frequency of droughts);
- **Resistance** to change or sensitivity (e.g. salt and drought tolerance) is a function of the current condition and the nature of Black Box physiology and the community structure (e.g. unit size). The ability of a plant to extract water from a saline source (osmotic potential) and from a dry soil source (matric potential) is dependent on the tree condition and on its physiology. Black Box has a greater osmotic and matric potential than Red Gum for example. Measurements for resistance include vegetation condition assessments as described earlier and physiological assessments from leaf water potential and sap flow;
- Potential impact is therefore the likelihood and severity of Black Box condition decline due to external stressors and is dependent on the current health and the stressors; and

- Adaptive capacity is a function of the ability of a tree or community to recover from impact (**resilience**) and its ability to adapt to new conditions (e.g. growing new roots or establishing in another part of the floodplain). Black Box trees are highly resilient to mild drought impacts and can recover fully, however severe, prolonged and frequent droughts may be too much for the trees in poor condition. Black Box communities have adaptive capacity by releasing seeds that can establish in more favourable environments. Measurements of resilience include long term adaptive capacity such as genetic variation to combat environmental stressors (the Black Box 'Green Variant' hybrid is more salt and drought tolerant), land management arrangements (conservation/tenure), recruitment capacity.

Management actions can address the stressors and their severity and improve the current condition of the trees. Management can also improve the resistance, through planting Black Box hybrids or improving the unit size. Other actions can increase Black Box adaptive capacity by allowing migration across floodplains or up and down stream.

To simplify the assessment of vulnerability for illustrative purposes in the Framework, the following factors are used:

1. What is the likely future exposure to stressors (high, medium, low); and
2. What is the current condition (good, medium, poor).

By measuring these two factors a vulnerability assessment can be made with the categories of extreme, high, medium and low, as shown in Table 3-8. A vulnerability map can be produced which indicates the vulnerability rating of each of the Black Box management units throughout the site. In areas where information on vulnerability is low, two classes of vulnerability, such as 'high' and 'low' can be used.

Table 3-8: Vulnerability Assessment based on combination of exposure to stressors and current condition (Potential Impact)

Exposure \ Condition	Good	Medium	Poor
Low	Low	Low	Medium
Medium	Medium	Medium	High
High	Medium	High	Extreme

Other measures of exposure, resistance, resilience, adaptive capacity should be used when available to increase confidence in the assessment. The rules within the table above can be further refined with the inclusion of these other components which can help manage vegetation stress from different combinations of the components of vulnerability. Assessment of vulnerability can also be used to guide the definition of appropriate management objectives. An example of applying management objectives to the vulnerability assessment is provided in Table 3-9. These should not be used as the only basis for management objectives, for example, it may be more beneficial to improve areas of poor adaptive capacity if it is of high value and low implementation cost. However, the table can be used as part of a broader multi-criteria assessment of management priorities.

Table 3-9: Vulnerability Assessment related to possible management objectives

	Adaptive Capacity		
Potential Impact	Good	Medium	Poor
Low	Maintain / Improve	Maintain / Improve	Protect
Medium	Maintain / Protect	Protect	Avoid damage

High	Protect / Avoid damage	Avoid damage	Avoid damage / may not be sustainable

By using the vulnerability assessment, it is possible to predict what would happen if there was no management intervention to effect exposure to stressors. The 'Do-Nothing' scenario can also be mapped and used in the management plan to support prioritisation. The 'Do-Nothing' scenario has been developed regarding the transition model presented at chapter 3.5.1.4.

Table 3-10 shows the rules that are used to make the 'do-nothing' scenario map:

- Good condition Black Box with low exposure to stressors will remain good;
- Medium condition Black Box with low exposure to stressors will remain as medium;
- Good or medium condition Black Box with high or medium exposure to stressors will eventually decline to dead if no management action is taken. This could be over a very long period of 25 years or more. The most likely action for these areas is to monitor their condition and act if changes occur; and
- Poor condition Black Box with low, medium or high exposure to stressors will decline to dead.

Table 3-10: Rules to create the 'do nothing' scenario map

Exposure \ Condition	Good	Medium	Poor
Low	Good	Medium	Dead
Medium	Dead	Dead	Dead
High	Dead	Dead	Dead

3.6.1 Assessing Vulnerability and Confidence Levels

A confidence assessment is required to appreciate the level of understanding of the vulnerability assessment, and to determine whether currently available data is sufficient for management decisions, or whether further investment in data may be required. A conceptual model will improve the assessment of vulnerability and confidence levels.

The level of confidence that can be placed in a vulnerability assessment depends on the level of confidence with which the condition and stressors to Black Box were determined. Table 3-11 provides a guide to the confidence assessment for the vulnerability assessment. Refer chapter 3.2 for an explanation of the confidence assessment colour coding and explanation of what confidence levels are appropriate for different types of sites.

Table 3-11: Confidence Levels for Vulnerability Assessment

Confidence level	Confidence Score	Data
Low	1	Anecdotal or regional level of information, providing a rough estimate of site conditions. Based on low confidence in stressors and low confidence in condition. Conceptual model does not support vulnerability assessment. Vulnerability is simply classified as not-vulnerable or vulnerable.
Low/Moderate	2	Based on moderate confidence in stressors and low or moderate confidence in condition. Vulnerability based on stressors and condition only.
Moderate	3	Based on moderate confidence in stressors and moderate confidence in condition. Conceptual model supports the identification of vulnerability. Vulnerability based on stressors, condition and adaptive capacity.
Moderate/High	4	Based on moderate or high confidence in stressors and moderate or high confidence in condition. Vulnerability is based on potential impact including physiological measurements and Black Box resistance.
High	5	Measured at site scale with high confidence in stressors and condition, including physiological measurements. Vulnerability is based on potential impact and Black Box resilience.

3.6.2 Establishing the Need for Management at a Site

Prior to progressing with the next steps of the Framework, a decision must be made as to whether there is a need for management at the site, based on the vulnerability assessment.

The need for management at a site can be established through comparison of the ‘Do-Nothing’ scenario with objectives for Black Box at a site, regional, and Basin level. A ‘Do-Nothing’ map is a useful tool for communicating the need and the prioritisation of management actions. The predicted rate of change is critical to prioritising the need for management. Historic data showing the rate of recent decline can be used to predict future decline and therefore the need for management. In cases where there is a lack of historic data, predictions of the rate of decline need to be based on the current condition and the level of stressors above the threshold limits. Visual health of Black Box trees is not a strong indicator of potential to decline or recover. More detailed data is required to increase the confidence in understanding the need for management.

Following the confidence assessment of the vulnerability analysis, it might be determined that more confidence is needed in specific aspects of the condition, stressor or vulnerability analyses prior to deciding on the need for management. If the analysis shows that the ‘Do-Nothing’ scenario is undesirable, then the practitioners should proceed with the remaining steps of the Framework.

Case study box 4: Vulnerability and the need for management

The vulnerability assessment for Calperum Station was undertaken with an approach that was determined to require a ‘moderate’ level of confidence. Firstly, the stressors were simplified to groundwater depth, groundwater salinity and flooding frequency as the assumed three major factors affecting Black Box condition based on the conceptual model. Resistance was then simplified to condition classes to reduce the requirement for physiological data. The adaptive capacity was also simplified to having space in the landscape of suitable environmental conditions to recruit into. Calperum Station is a large conservation area and has the space to allow migration. The key elements of the simplified vulnerability assessment were modified as shown on Figure 3-15.

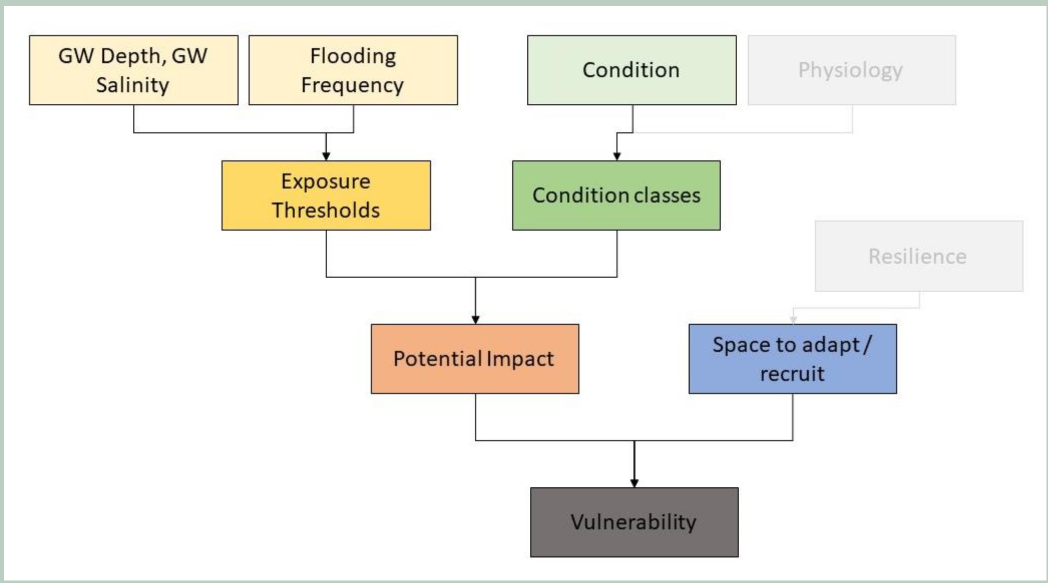

Figure 3-15: Vulnerability assessment for Black Box on Calperum Station.

Spatial analysis was used to map vulnerability of Black Box at Calperum station and establish the need for management (Figure 3-16). Vulnerability was simplified to ‘vulnerable’ or ‘not-vulnerable’ to simplify the mapping, as per confidence class 1.

A second map was developed to provide a ‘Do-Nothing’ scenario map prediction for the next 30 years if only the regional and basin management actions continued, and no direct action was taken on Calperum Station (Figure 3-17). This map is useful to identify priority areas of management. This map was developed using the following rules:

- Good condition Black Box adjacent to the river (or that we’ve judged is rain fed and not pressured by groundwater depth or salinity) will remain good;
- Medium condition Black Box will remain as medium unless they are old/large trees showing signs of decline (the small 100-year-old trees that are the “watch and wait” areas remain as medium);
- Good condition Black Box away from the river which is under pressure by stressors will eventually decline to dead; and
- Poor condition Black Box will decline to dead.

Based on the predicted decline in Black Box condition, it was determined that management action is appropriate. Priority decision making will be supported by the Do-Nothing scenario. For further information on this analysis, refer “*Site Investigation for Black Box at Calperum Station”* (Overton, Boyd and Coff, 2017)

Case study box 4: Vulnerability and the need for management (Cont'd)

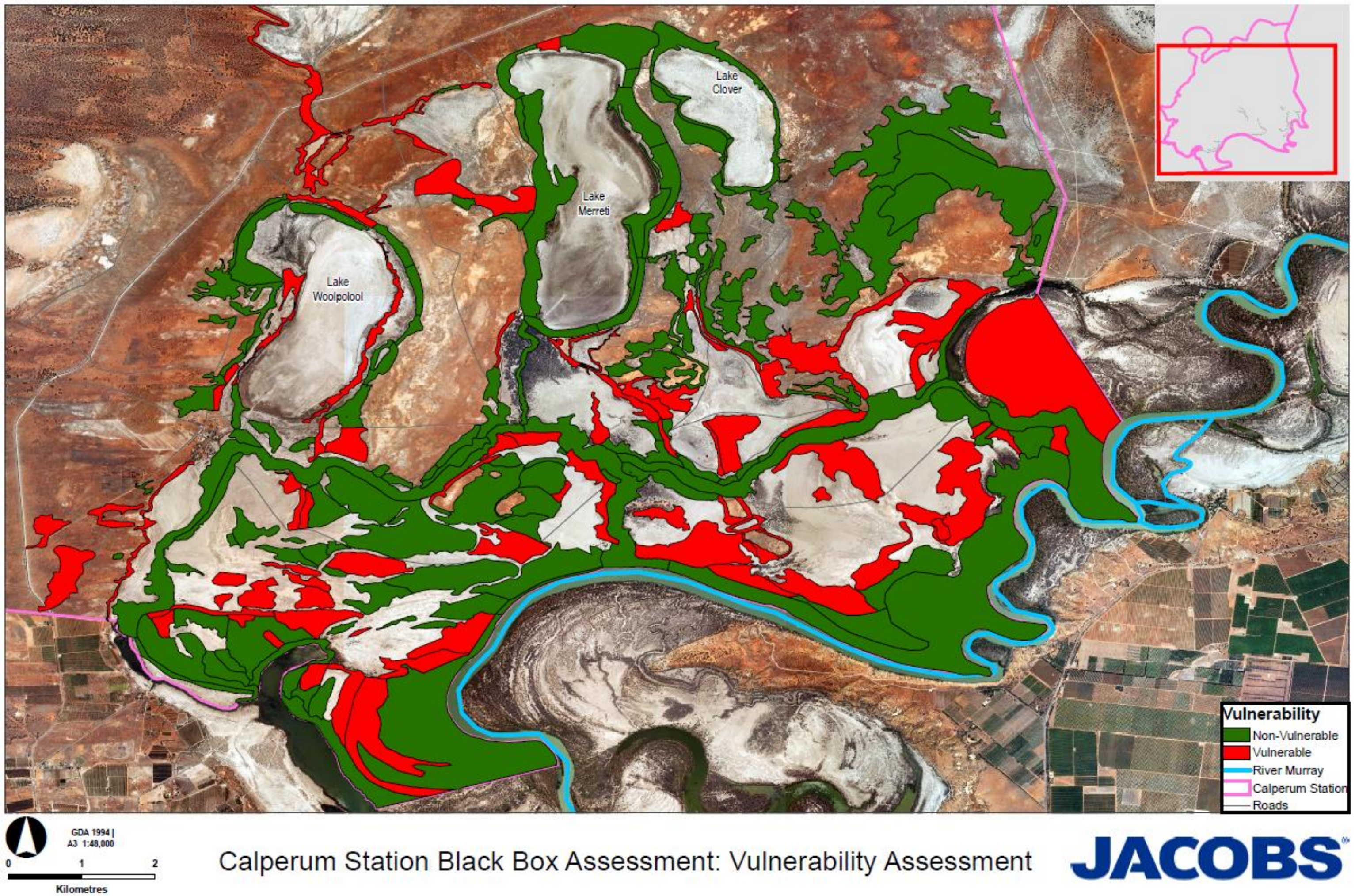

Figure 3-16: Vulnerability map for Black Box.

Case study box 4: Vulnerability and the need for management (Cont'd)

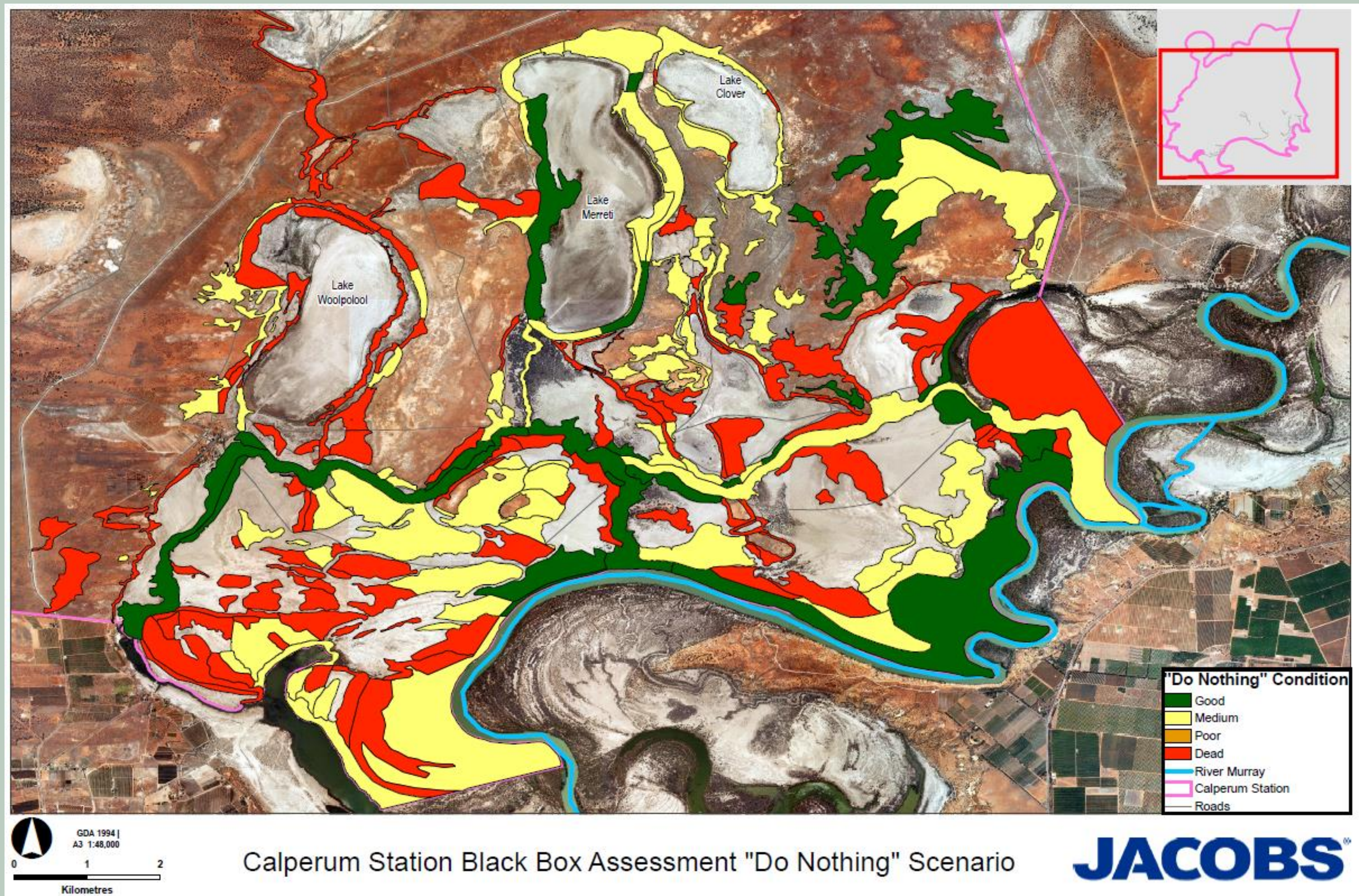

Figure 3-17: Do-Nothing scenario map for Black Box.

3.7 STEP 4: SETTING OBJECTIVES AND TARGETS

The development of site specific ecological objectives and targets is critical for management planning. Management actions, monitoring and evaluation is established based on the objectives and targets set, informing planning and providing a mechanism to track and report progress.

This chapter provides guidance on the development of site specific ecological objectives and targets, and operational objectives for a site. Establishing a clear relationship between site-based objectives and basin scale outcomes and targets (e.g. Basin-wide Environmental Watering Strategy) through a program logic provides context setting and broader purpose. Monitoring and evaluation is established based on the objectives and targets set, providing a mechanism to track and report progress.

3.7.1 Ecological Objectives

Ecological objectives are the high-level outcomes, aspirations and step changes that a practitioner is seeking to achieve at a site over the medium to longer term. They provide a clear, plain language articulation for managers, scientists, stakeholders and the wider community of what planned management actions, including the delivery of environmental water, are intended to achieve.

A simple ecological objective could be to maintain existing Black Box condition to avoid further decline. The Do-Nothing scenario can assist in identifying areas that are likely to decline. Example ecological objectives are provided in Table 3-11 for reference.

3.7.2 Ecological Targets

Ecological targets specify the condition intended to be achieved as a result of an action, often described by a numerical value that allows for assessing and reporting change in condition against a benchmark over time (T. Wallace *unpublished,* 2016).

The timeframe required for achieving the desired change in Black Box condition should be reflected in the ecological targets; refer to Black Box Transition Model (section 3.5.1.4). The introduction of short, medium and long-term targets (Table 3-13) is likely to be necessary to track and report progress on the recovery of Black Box populations. For example:

- *Long term target*: Greater than 50 percent of tree recruits within the actively managed floodplains will survive and establish into adult trees by 2020.
- *Short term target:* Maintain total soil water at greater than -1.5 MPa within a soil depth of 20-50cm for the first two years following seedling germination, to promoting seedling retention and growth.

The long-term target presented above is focused on ecological change, whereas the short-term target is focused on measuring a change in the influence of the stressor. Achieving short term targets which are focussed on managing known stressors is expected to have a direct benefit to achieving the associated ecological objective.

Ecological targets, where practical, should be developed for each site in accordance with SMART principles (Specific, Measurable, Achievable, Realistic and Time bound). Targets for Black Box should:

- define what constitutes a sustainable assemblage or population of Black Box
- be spatially and temporally quantitative (e.g. percentage area, number of trees per ha)
- be time bound and presented as short term (e.g. 5 years) and/or long term (e.g. 20 – 30 years) targets.

SMART ecological targets allow for assessments both during and after management actions have been implemented to determine if the targets (and associated objectives) have been or can be met. Targets should reflect milestone changes in attributes along a transition pathway. Examples of ecological objectives paired with SMART ecological targets are provided in Table 3-12 for further reference.

The selection of ecological targets, as noted by Wallace (2012), should be undertaken with due care for the following reasons:

- *In many cases insufficient baseline data and understanding of ecosystem function exists to set targets that may be ecologically meaningful.* Where possible, it is recommended that a minimum set of baseline data be collected to guide the setting of realistic targets.
- *Targets that are not based on agreed or verified ecological interactions are value judgements that may result in unintended outcomes to other components of the ecosystem*. Where possible a minimum set of baseline data is used to guide the development of a widely accepted conceptual model. Whilst this Framework is focused on the management of Black Box vegetation, the need to take a broader ecological view to consider potential implications across other functional groups is appropriate.

3.7.3 Operational Objectives

Operational objectives describe the short-term management interventions to be applied to achieve the ecological targets and objectives. These objectives are set within the management context of existing operational practices, any flexibility/constraints within these practices and available resources. Operational objectives are set based on achieving the ecological objectives and targets, and reflect management decisions on the suitability of management option(s) to be implemented.

Examples of operational objectives paired with ecological objectives/targets are provided below for reference.

Example 1:

- *Ecological Objective*: Improve the condition and viability of Black Box woodland populations.
- *Ecological Target*: Greater than 75% of trees within the actively managed floodplains will have a crown extent and density score greater than 60% by 2020.
- *Operational Objective*: Floodplain inundation at X locality is augmented to extend the area of inundation to X ha, at an average frequency of 3 events in 7 years.

Example 2:

- *Ecological Objective:* Establish soil conditions conducive to improving vegetation condition.
- *Ecological Target:* Maintain soil water availability, measured as soil water potential at soil depth 20-50 cm, greater than -1.5 MPa, to sustain the recruitment of tree saplings.
- *Operational Objective:* Apply X ML of surface water to a maximum inundation height of Y m AHD across an area of Z ha for a period of 30 days, at an average frequency of 2 events in 3 years.

3.7.4 Linking Objectives, Targets, Stressors and Monitoring

Relationships between Black Box attributes and functionality, stressors and potential indicators are provided in Appendix B. This provides practitioners with a guide to the types of stressors and indicators that may be influencing the condition of Black Box at a site.

Table 3-12 has been prepared as an example linking short term objectives to specific operational targets for the relevant stressors. Table 3-13 then provides linkages between the stressors and some specific monitoring activities that could be used to track success over the short, medium and longer term. These can be taken and adapted by practitioners where relevant for site management planning.

Table 3-12: Example objectives and targets, related to Black Box stressors.

Objectives	Example targets	Potential stressor that the target is trying to address
Establish groundwater conditions conducive to improving vegetation condition[1]	The top one metre of the vertical salinity profile of groundwater is below 22,000 mg/L in areas supporting Black Box[3]	• shallow groundwater salinity • groundwater depth (shallower groundwater may influence soil salinity more and reduce ability to flush salts from soil profile) • soil salinity (unsaturated zone), • soil water availability (unsaturated zone)
	Groundwater salinity does not increase from baseline conditions at site[3]	
	Maintain soil water availability, measured as soil water potential at soil depth 20-50 cm, greater than -1.5 MPa to sustain the recruitment of long-lived vegetation[1]	• soil water availability (unsaturated zone)
	In soil samples taken from the unsaturated zone at intervals to ≥3 metres depth, at least one depth sampled has soil water availability, measured as total soil water potential, greater than -1.5MPa, to maintain or improve mature tree condition[3]	
	The total salt mass (kg/m^3) of the unsaturated soil zone decreases over time relative to baseline conditions at site, to below the threshold of 39,000 mg/L[3]	• soil salinity (unsaturated zone) • soil water availability (unsaturated zone)
	Ensure soil salinity does not increase in those areas where groundwater levels increase in response to managed inundation but are outside the inundated areas (fringe degradation), to above 39,000 mg/L[2]	• shallow groundwater salinity • groundwater depth (shallower groundwater may influence soil salinity more and reduce ability to flush salts from soil profile) • soil salinity (unsaturated zone), • soil water availability (unsaturated zone)

1: adapted from the Operations Plan for Chowilla Floodplain (Wallace & Whittle, 2014).

2: adapted from SARFIIP preliminary Ecological Targets (unpublished, 2015). *Development of ecological objectives and targets for Pike and Eckerts-Katarapko floodplains*.

3: adapted from draft targets currently being developed to improve preliminary targets for SARFIIP (unpublished, 2016).

Table 3-13: Example Black Box stressors and expected outcomes to be monitored over the short, medium and long timescales.

Potential stressors	Monitoring Short Term[1]	Monitoring Medium Term[1]	Monitoring Long Term[1]
shallow groundwater salinity	• groundwater salinity in top 1 m of vertical profile	• groundwater salinity in top 1 m of vertical profile • Black Box crown extent / density • seedling survival • rate of recruitment • percentage of remaining viable trees within responsive condition classes • trajectory of change of condition data or understorey composition as a surrogate (improving, worsening, stable)	• groundwater salinity in top 1 m of vertical profile • Black Box crown extent / density • Black Box age class diversity • percentage of remaining viable trees within responsive condition classes • trajectory of change of condition data (improving, worsening, stable)
groundwater depth	• depth to groundwater	• depth to groundwater • Black Box condition class	• depth to groundwater • Black Box condition class
soil salinity (unsaturated zone)	• soil salinity in unsaturated zone immediately above saturated zone	• soil salinity in unsaturated zone • Black Box crown extent / density • seedling survival • rate of recruitment • percentage of remaining viable trees within responsive condition classes • trajectory of change of condition data or understorey composition as a surrogate (improving, worsening, stable)	• soil salinity in unsaturated zone • Black Box crown extent / density • Black Box age class diversity • percentage of remaining viable trees within responsive condition classes • trajectory of change of condition data (improving, worsening, stable)
Soil water availability (unsaturated zone)	• soil water potential at soil depth 20-50cm, should be > -1.5 MPa • soil salinity in unsaturated zone	• soil water potential at soil depth 20-50cm, should be > -1.5 MPa • soil salinity in unsaturated zone • Black Box crown extent / density • seedling survival • rate of recruitment • percentage of remaining viable trees within responsive condition classes • trajectory of change of condition data or understorey composition as a surrogate (improving, worsening, stable)	• soil salinity in unsaturated zone • Black Box crown extent / density • Black Box age class diversity • percentage of remaining viable trees within responsive condition classes • trajectory of change of condition data (improving, worsening, stable)

1: Short term is classed as 1-5 years, Medium 5-10 years, Long term 10+ years

The definition of objectives, targets, and by association, monitoring is supported by published literature. A literature review of the tree health trends, water needs and salinity thresholds (including requirements for sustaining Black Box tree regeneration and recruitment) is provided in AWE 2015.

Case Study Box 5: Setting meaningful objectives and targets

Objectives and targets for management of Black Box on Calperum Station were developed during the project in consultation with the land manager, through:

- A literature review of current objectives in management plans for Calperum station and similar sites
- Application of the SMART target methodology for developing objectives

The objectives and targets are summarised below. Management actions, monitoring and evaluation at Calperum Station should be established based on these objectives and targets, when a management plan is developed.

Black Box Objectives for Calperum Station

- Maintain populations of Black Box of medium-low vulnerability within the management area, and where possible improve Black Box resistance (condition).
- Improve the adaptive capacity of Black Box by targeting actions that support recruitment and transition into areas of low exposure to stressors.
- Reduce the exposure of stressors from soil and groundwater salinity, to avoid further damage to Black Box vegetation in areas of medium or high vulnerability.

SMART Targets for Black Box on Calperum Station

- Short Term: Greater than 50% of Black Box recruits within the managed area are protected from threats such as grazing, extended inundation or no inundation to maintain their condition and reduce their vulnerability, and survive to 2023
- Medium Term: 40% of poor condition Black Box units improve to good or medium condition by 2028
- Medium Term: 50% of medium condition Black Box units are maintained as medium condition by 2028
- Long term: Improve 50% of medium condition Black Box units to good by 2038
- Ongoing: Maintain at least 80% of good condition Black Box woodland in this state

3.8 STEP 5: IDENTIFYING A RANGE OF ACTIONS AND OPTIONS

A key aspect of a site investigation is to explore the management options that may be available at the site. Following the vulnerability assessment, if it has been determined that active management is required at the site, a range of management options can be explored.

3.8.1 Management History

A detailed understanding of the history of management throughout the site is required. By documenting previous management actions, it is possible to learn from these actions and identify physical constraints to management. This is the starting point for identification of management options.

A history of the management at a site is also important for understanding what actions have been already taken regarding flooding frequencies, changes in flow paths and plantings etc. This can help in identifying the relationships between environmental stressors and Black Box condition.

3.8.2 Overview of Management strategies

Several options and tools are available to assist with achieving ecological outcomes for Black Box through surface water delivery, groundwater management and complementary works/measures within the Murray-Darling Basin. Those which potentially have the greatest ability to impact Black Box are:

- delivery of environmental water through pumping or augmented river flows
- redeveloping surface water flow paths
- complementary operation of river and floodplain infrastructure
- groundwater manipulation
- minimisation of land clearance
- minimisation of other land degradation processes
- minimisation of deep drainage from highland irrigation.
- drip or spray irrigation of Black Box vegetation
- removal of constraints to variations in weir pool levels

The achievement of targeted ecological outcomes may require one or a combination of interventions being implemented. There is potential for maximising possible benefits through considering combining two or more management options within a management strategy, rather than planning management strategies in isolation.

Table 3-14 provides an overview and examples of various management options that could be implemented to address site specific Black Box stressors. A complete description of each of the management options is provided in Appendix E. The options included in this chapter are not exhaustive but seek to provide the practitioner with some guidance on the possible options available from which further refinement, assessment and prioritisation can be undertaken. The final selection rests with the practitioners using this framework, with considerations of the Black Box condition and water requirements, conceptual models and stressors, site specific attributes, vulnerability, risk, and operational and resourcing constraints.

Table 3-14: Management strategies overview

Site stressor	Generalised management option(s)	Objectives / outcomes of management	To what area of the flood-plain could this be applied?
Lack of access to soil moisture caused by reduced frequency and duration of inundation.	Environmental watering via enhanced surface inundation (regulators and blocking banks, aqua dams, pumping to wetlands / recharge basins)	▪ Increase the availability of soil water by providing more frequent and longer duration watering events.	Small – Large depending on infrastructure
	Groundwater pumping (extraction) from the floodplain to create/enhance freshwater lens (where relatively permeable river skin exists)	▪ Increase the availability of soil water through enhanced rate of freshwater lateral recharge from rivers and anabranch creeks to groundwater.	Small – Medium depending on infrastructure
	Removal of constraints to redevelop surface water flow paths, e.g. by removing flow obstructions to allow water to access isolated parts of the floodplain	▪ Increasing the extent of surface water inundation and lateral connectivity ▪ Increase availability of soil water via vertical recharge over a larger area of floodplain.	Small – Large depending on area of floodplain that was isolated and the flows at which these areas become inundated.
	Augment river flows with environmental water	▪ Increase availability of soil water via enhancing the peak and duration of a natural flow event to water a larger area of the floodplain and/or for an extended duration.	Medium – Large depending on operational constraints
	Spray or drip irrigation	▪ Increasing infiltration of water into the soil profile to increase soil water content and availability	Small – Large depending on infrastructure
High unsaturated zone / soil salinity (with saline groundwater not in the capillary fringe)	Environmental watering via enhanced surface inundation (regulator and blocking banks, aqua dams, pumping to discrete wetlands / recharge basins)	▪ Reduce salinity stress in unsaturated soil zone through enhanced floodplain inundation and increased rate of vertical freshwater recharge, leading to: o Flushing of salt from unsaturated soil o Increase in unsaturated zone soil moisture content and availability ▪ Potential to create a freshwater lens.	Small – Large, depending on infrastructure (e.g. Chowilla Floodplain, SA)
	Weir pool manipulation to enhance lateral recharge from surface water bodies (river or lakes) (where relatively permeable river skin exists, as described in AWE, 2015)	▪ Reduce salinity stress in the unsaturated soil zone through enhanced rate of lateral freshwater recharge, leading to: o Creation of freshwater lens via lateral movement of water through the river bank o Freshening of saline groundwater.	Small – Medium depending on depth to groundwater, soils and height/duration of weir raising and lowering

Site stressor	Generalised management option(s)	Objectives / outcomes of management	To what area of the flood-plain could this be applied?
	Removal of constraints to redevelop surface water flow paths, e.g. by removing flow obstructions to allow water to access isolated parts of the floodplain	o Increases the potential for environmental water to reach Black Box vegetation, and the potential variation of river water levels for weir pool manipulation events, to inundate larger areas of Black Box.	Small to large
Shallow high salinity groundwater in the capillary zone (i.e. evaporating from the floodplain)	Weir pool manipulation to enhance lateral recharge of groundwater from surface water bodies (river or anabranches) (where relatively permeable river skin exists, as described in AWE, 2015)	▪ Reduce salinity stress though enhanced rate of lateral freshwater recharge, leading to: o Formation of freshwater lens ▪ Associated freshening of unsaturated soil moisture.	Small – Medium depending on depth to groundwater, soils and height/duration of weir raising and lowering
	Groundwater pumping (extraction / interception, e.g. SIS) from the floodplain to lower water table	▪ Reduced salinity / water logging stress by increasing depth to groundwater table (to below capillary zone) through groundwater extraction (pumping) and offsite disposal leading to: o Reduces rate of salt accumulation via a reduction in rate of capillary rise and evapotranspiration of groundwater o Freshens groundwater via lateral recharge o Increases capacity for flushing of salt from the unsaturated soil profile in subsequent flooding and rainfall events o Increases magnitude of unsaturated zone in which soil moisture can be stored.	Potentially small to large, but dependent on how easy it is to dispose of the highly saline pumped water and cost.
	Groundwater injection to create / enhance freshwater lens	o Reduced salinity stress in groundwater zone through direct creation / enhancement of freshwater lens.	Small
	Groundwater recharge via groundwater recharge basins / infiltration galleries (i.e. where naturally sandy soils occur)	▪ Reduced salinity stress in groundwater zone through direct creation / enhancement of freshwater lens.	Small-Medium
	Removal of constraints to redevelop surface water flow paths, e.g. by removing flow obstructions to allow water to access isolated parts of the floodplain	▪ Increases the potential for environmental water to reach Black Box vegetation, and the potential variation of river water levels for weir pool manipulation events, to inundate larger areas of Black Box.	Small to large
Land clearance	Limit clearance of remnant Black Box populations through voluntary/ legislative means	▪ If meets relevant criteria, establish formal protection for Black Box site through legislative mechanism, for example: o SA: Heritage Agreement under SA Native Vegetation Act 1991 o NSW: Conservation Agreement under NSW National Parks and Wildlife Act 1974	Small – Large

Site stressor	Generalised management option(s)	Objectives / outcomes of management	To what area of the flood-plain could this be applied?
		○ VIC: Wildlife Management Cooperative Areas under the VIC Wildlife Act 1975 and Conservation Forests and Lands Act 1987 ○ QLD: Conservation Agreement under QLD Nature Conservation Act 1992 ○ AUS: Conservation Agreement as under the Environment Protection & Biodiversity Conservation Act 1999 Voluntary agreements put in place.	
	Increase leaf and litter cover and mulch soils to increase water retention	▪ Increase water retention to increase available soil water between flood events	Small areas only
Land degradation	Reduce grazing pressure through animal control measures (temporary fencing of seedlings, restrict grazing access / rates, grazing rotation, rezone land use, targeted capture / eradication / baiting of problematic feral and or native populations)	Reduced grazing pressure particularly for younger life stages of Black Box, leading to: ○ Improved seedling establishment (regeneration) ○ Improved seedling retention (recruitment) ○ Improved age class distribution and therefore sustainability of Black Box population.	Small – Large depending on area protected
	Reduce impact of edge effects through protection of existing at-risk units (blocking unwanted tracks, fencing edges near target or sensitive populations, undertaking regular spot weed control, grazing exclusion around seedling)	▪ Reduced edge effect pressure on Black Box leading to improved stand condition, through: ○ Reduced competition by weeds ○ Enhanced protection to reduce impact to sensitive areas (compaction, trampling, grazing etc.).	Small – Large depending on area protected
	Review and optimisation / improvement of local irrigation industry	▪ Optimise application and use of irrigated ground and surface waters, with the aim to: ○ Minimise seepage of irrigation return flows (including associated agricultural chemicals and salts) to groundwater ○ Minimise water use (drawn from ground and surface water resources) ○ Improve quality and quantity of soil/groundwater sources available to Black Box on the floodplain ○ SIS schemes on the highland to reduce groundwater mound discharging to floodplain and river.	Small – Large depending on irrigation intensity and area

Table 3-15 presents a generalised, hierarchy of management option preferences, based on the current understanding of the effectiveness of different management options at improving the condition of Black Box vegetation, and with regard to the results of management trials and monitoring. This hierarchy is independent of the specific site being investigated.

The Table below assumes that the Black Box vegetation is affected by a lack of soil water availability through a combination of water and salinity stressors. This table is intended to provide a guide to practitioners of the generalised relative benefits of different management options, for consideration in option prioritisation. The specific site conditions will also influence which options should be prioritised at a site. A combination of management options is likely to be required.

Table 3-15: Hierarchy of management options

Hierarchy	Management Option	Comments
Moderately Effective	Environmental watering through pumping to specific wetlands / locations	Closest management option to a natural flood, hence can provides additional benefits in relation to seed dispersal, nutrient dispersal, understorey soil moisture compared with other options. Seeks to improve soil moisture availability
	Augmenting river flows with environmental watering	Augmenting river flows are highly effective but likely to be limited for Black Box as high magnitude floods are needed to reach the upper parts of the floodplain.
	Weir pool manipulation	Weir pool raising provides inundation of vegetation and potential for lateral/vertical recharge. Regimes of raising and lowering seek to address both water and salinity stressors through greater river level variability. Weir pool manipulation is likely to be moderately or least effective on a broad scale as it will only influence Black Box on low parts of the floodplain or close to river banks.
	Removal of constraints to redevelop surface water flow paths	Increases the potential areas of surface inundation and lateral/vertical recharge created through environmental watering or weir pool manipulation.
	Drip or spray irrigation of Black Box vegetation	Provides water to Black Box vegetation, however does not simulate flooding conditions, so does not provide other benefits. Seeks to address stressors.
	Groundwater pumping	Improves soil water availability through lowering saline groundwater table, enabling freshening of the groundwater in the unsaturated zone. However, does not provide surface inundation of vegetation.
	Groundwater injection	
Least effective	Minimisation of deep drainage from highland irrigation	
	Minimisation of land clearance and other land degradation processes	Prevents damage to Black Box vegetation, however does not improve soil water availability.
	Increase in leaf litter and mulching	Reduces soil moisture loss to increase the retention of rain water (Gehrig and Nicol, 2010). Only suitable for small areas.

3.8.3 Developing a List of Management Options

A list of management options that have the potential to influence Black Box vegetation at a site should be developed. For the site investigation, the focus is to determine physically feasible options that have the potential to effectively influence Black Box stressors at the site. There are a range of factors other than physical feasibility which are important to consider in the prioritisation and selection of management actions to implement, however these aspects are considered in *Part B: Developing a Site Management Plan*.

The following steps describe a process that can be used to develop a list of management options for Black Box sites:

1. Inspect the vulnerability maps developed in chapter 3.6. These provide information on the location, condition and stressors relevant to Black Box on the site. They also show the Black Box management units that have been defined.
2. Review the information provided in Table 3-14 and Appendix E to identify the full list of management options that have the potential to be physically feasible at the site.
3. Investigate each management option, including determination of:
    - The suitability of management options for each Black Box management units (based on site conditions/vulnerability of Black Box). Developing a map of the potential locations where each management option can be applied is useful at this stage.
    - The area of Black Box that would potentially be influenced by the management option. Developing a map and conducting analysis of the potential area affected by each management option, relative to the location of Black Box vegetation.
    - A summary of the physical works that would be required to implement the management option (e.g. excavation, installation of pumps, installation of regulators, weir pool manipulation).
    - The approximate volumes of water that would be required.
    - Approximate relative costs to implement each management option. This involves developing an understanding of all resources needed to develop each option and converting those into costs estimates.
4. Summarise the results of the investigation. This summary is a key input to *Part B: Developing a Site Management Plan.*

It is useful to work through this process by developing a series of maps that show the locations for potential management options to be applied, the Black Box management units, locations of physical works, and areas of Black Box potentially influenced.

3.8.4 Management Options and Confidence Levels

A confidence assessment is required to understand the physical feasibility of various management options at the site, and to determine whether currently available data is sufficient for management decisions. The outcome of this assessment will indicate whether further investigation may be required to inform the prioritisation of management options.

Table 3-16 provides a guide to the hierarchy of data sources for providing increasing levels of understanding about the management options. Review of the confidence scores for each data type can be used to determine whether further investigation or work is required to improve the confidence of any specific data type. An overall confidence score for the physical feasibility of management options can be determined through averaging the confidence scores for each of the data sources. Refer chapter 3.2 for an explanation of the confidence assessment colour coding and explanation of what confidence levels are appropriate for different types of sites.

Table 3-16: Hierarchy of data sources for providing increasing levels of confidence about physical feasibility of management options for Black Box at a site

Confidence level	Confidence score	Land area inundated	Area of Black Box affected by the management option	Works required	Volume of water required
Low: Anecdotal or regional level of information, providing a rough estimate of site conditions.	1	Estimate based on regional topographic map	Anecdotal information of the locations where Black Box are found	Expert advice on what works are needed	Volumes estimated based on regional topographic map
Low/Moderate: Measured data from local sources, providing a better estimate of site conditions.	2	GIS mapping of site using low resolution LIDAR to estimate inundation extent	Estimate of locations where Black Box are found from visual inspection of aerial photography	Estimate of the works based on similar management options applied at other sites	Volumes estimated using GIS mapping of the site using low resolution LIDAR
Moderate: Data measured at the site, but with high level of uncertainty.	3	GIS mapping of site using high resolution LIDAR, showing inundation management actions	GIS mapping of where Black Box are found, based on past site investigations	Estimate of the works based on similar management options applied at the site in the past	Volumes estimated using GIS mapping of the site using high resolution LIDAR
Moderate/High: measured data at the site, with moderate level of uncertainty.	4	Surveyed levels at the site for a specified management action	GIS mapping of where Black Box are found, based on current site investigations	Concept design of options at the site	Surveyed levels at the site for a specified management action
High: Measured data at the site, with low level of uncertainty.	5	Records of previous management interventions at the site Surface water modelling	GIS mapping of where Black Box are found, based on current site investigations of the entire site Groundwater modelling of changes to the water table	Detailed design of options at the site	Records of water used for previous management interventions at the site Surface water modelling

Case Study Box 6: Identifying a range of management options

The set of potential management options investigated for implementation at Calperum Station include:

- Redeveloping surface flow paths (channel opening
- Pumping water into wetlands
- Drip or spray irrigation
- Weir pool raising
- Groundwater freshening
- Groundwater lowering

For each management option, a summary was provided of any relevant investigations or management activities that have occurred at Calperum Station in the past, potential future management activities. Potential future works are provided with associated works and approximate costs, and a physical feasibility assessment for each management option.

Management Option 1: Channel Opening

The investigation into one of the options, reconnecting existing floodplain channels for inundation at raised weir pool levels is included below. Similar investigations were completed for all other management options listed above.

Past Management Activities: Channel opening has not been conducted at Calperum Station in the past. While the potential has been identified by the land manager, resources have not been available for excavation works needed to lower channel sill levels and reconnect existing channels to the River.

Potential Future Management Activities

Throughout Calperum Station, there are several floodplain channels that have over time become disconnected from the River by raised embankments. There are several locations where minor earthworks, such as lowering embankments, could result in increased inundation of floodplain channels and lateral recharge. These earthworks, in combination with weir pool raising could improve the effectiveness of environmental watering.

The normal operating level for Lock 5, which dictates water levels at the River at Calperum Station, is 16.3mAHD. During recent weir pool raising events, a level of 16.8mAHD was achieved.

Through analysis of the Digital Elevation Model (DEM), several locations were identified where minor earthworks could result in inundation of existing channels for a raised weir pool level of 16.8mAHD. The potential areas influenced by this option are shown in Figure 3-18. The potential impact areas include a 150m buffer zone surrounding the inundated areas assumed. Additional details, including the area of Black Box vegetation inundated, excavation requirements and costs, are provided in Table 3-17. Approximate costs have been estimated based on a rate of $\$50/m^3$ excavated, however will need refinement during site plan development.

Following earthworks, Calperum Station's existing environmental water allocation could be used to inundate these channels at raised weir pool levels. This would serve to increase the area inundated, without requiring pumping (long term cost efficiency).

Table 3-17: Potential Channel opening locations at Calperum Station

Site #	Area Inundated (Ha)	Area impacted (150m buffer), Ha	Area of Black Box impacted (Ha)	Vol Excavation required (m3)	Approx. Excavation Costs
1	3.5	51	30.9	3,000	$ 150,000
2	1.7	31.7	23.8	2,520	$ 126,000
3	0.6	17.2	14.4	375	$ 18,750
4	2	24.1	20.6	2,723	$ 136,125
Total	7.8	124.0	89.7	8617.5	$ 430,875

Case Study Box 6: Identifying a range of management options (Cont'd)

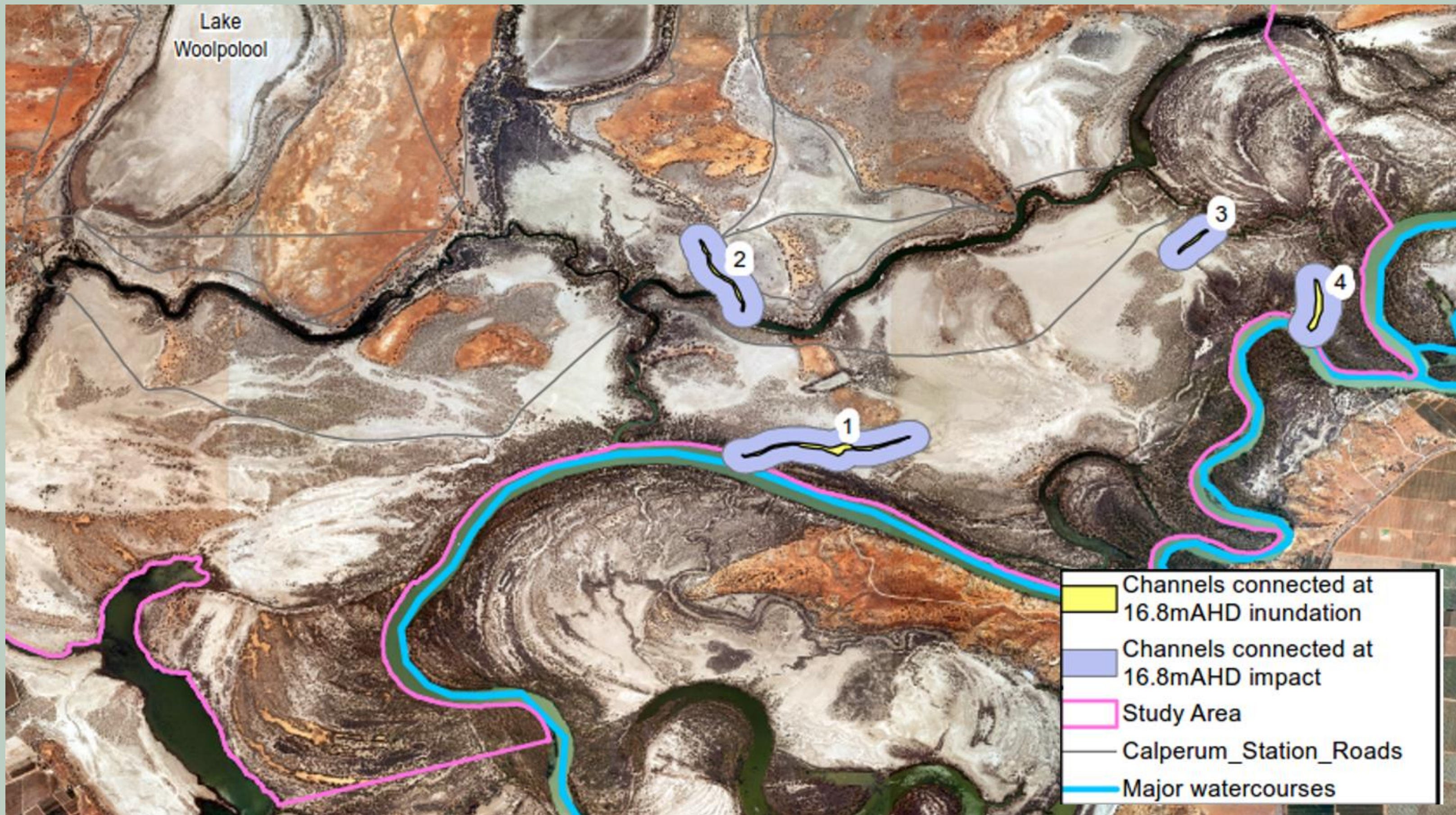

Figure 3-18: Potential channel opening locations

Following investigation of all potential management options in a similar way as described above, a long list of potential management options was developed by combining potential options. This information should be used as the first inputs to prioritising the management options (Part B)

3.9 Overall Confidence Assessment for the Site Investigation

Four confidence assessments have taken place as part of the following key steps to the site investigation:

- Condition assessment
- Identification of stressors
- Vulnerability assessment
- Developing management options

For each of these steps, an average/overall confidence score was developed. At this stage, the results of these progressive confidence assessments can be combined to provide an overall measure of confidence in the site investigation. Table 3-18 provides an example format into which the average confidence level scores can be input for each step, and from which an overall confidence score for the site investigation can be calculated. This can be used to determine whether additional investigations or data collection should take place to increase the confidence in the condition assessment, prior to progressing to *Part B: Site Management Plan*. Refer chapter 3.2 for an explanation of the confidence assessment colour coding and explanation of what confidence levels are appropriate for different types of sites.

Table 3-18: Overall Confidence Assessment – to be populated with the average confidence scores from each step of the site assessment process

Confidence level	Confidence score	Condition Assessment	Identification of Stressors	Vulnerability Assessment	Management Options	Overall Confidence score
Low: Anecdotal or regional level of information, providing a rough estimate of site conditions.	1					
Low/Moderate: Measured data from local sources, providing a better estimate of site conditions.	2					
Moderate: Data measured at the site, but with high level of uncertainty.	3					
Moderate/High: measured data at the site, with moderate level of uncertainty.	4					
High: Measured data at the site, with low level of uncertainty.	5					

PART B: SITE MANAGEMENT PLAN

4. Part B: Site Management Plan

The purpose of *Part B: Site Management Plan* is to use the information and analysis completed in Part A to prioritise the Black Box management units and available management options and develop a plan of action for management at the site. The process for developing a site management plan is outlined in Figure 4-1, and each of the steps of the process are described throughout this chapter.

Figure 4-1: Process for Part B Developing a Site Management Plan

Part B involves collation of information required for the option prioritisation that was collected during Part A, as shown in Figure 4-2. This involves:

- Objectives: How each listed option contributes to objectives for the site, region, and Basin. These objectives will have been defined as part of *Step 4: Setting Objectives and Targets.* An assessment of the extent to which each listed option would achieve these objectives is required.
- Option Outcomes: The outcomes that could be realistically achieved through each listed option, and the extent to which they relate to the operational objectives. This is based on the feasibility of each option, the vulnerability of Black Box in the relevant management units, and the uncertainty associated with the options. This information will have been collected as part of *Step 5: Identify a range of management options*.
- Resources: These are the physical resources that would be required to implement each listed option. Both capital and ongoing operational costs should be considered. Ongoing monitoring requirements should be included in these costs. This information will have been collected as part of *Step 5: Identify a range of management options*.
- Impacts: A consideration of the potential impacts (both positive and negative) of the each of the listed management actions on other site objectives or species.

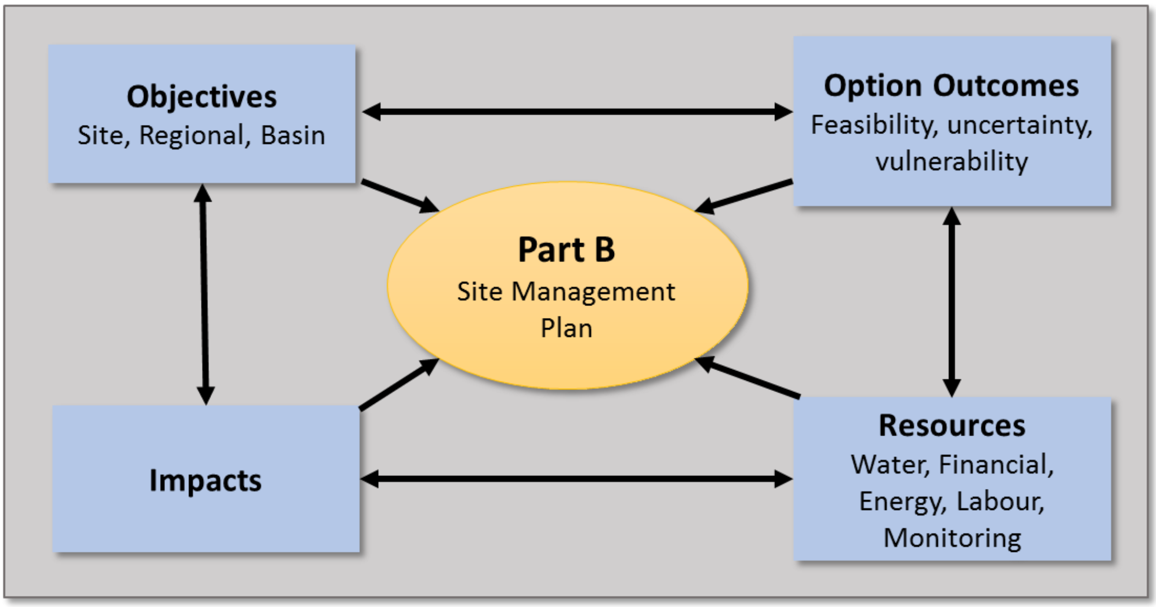

Figure 4-2: Inputs required for the prioritisation of management units and management options

It should be noted that the site management plan is likely to consider management for a range of outcomes, not solely focused on Black Box. This chapter provides guidance on feasibility and prioritisation for Black Box outcomes only, consideration of other outcomes is outside the scope of the Framework.

4.1 STEP 6: PRIORITISE BLACK BOX MANAGEMENT UNITS AND MANAGEMENT OPTIONS

Environmental managers are faced with a limited pool of resources from which to deliver the “best” possible ecological outcomes. This chapter provides guidance to support practitioners in prioritising the management units and management options, and in demonstrating that a range of options have been considered for both selection of management units and management options.

A suggested high-level approach to prioritising Black Box management units and management options is provided in Figure 4-3. Throughout the prioritisation process, there are a range of choices practitioners can make so that the process is suitable for their situation. Guidance on each of the steps of the approach are provided throughout this chapter.

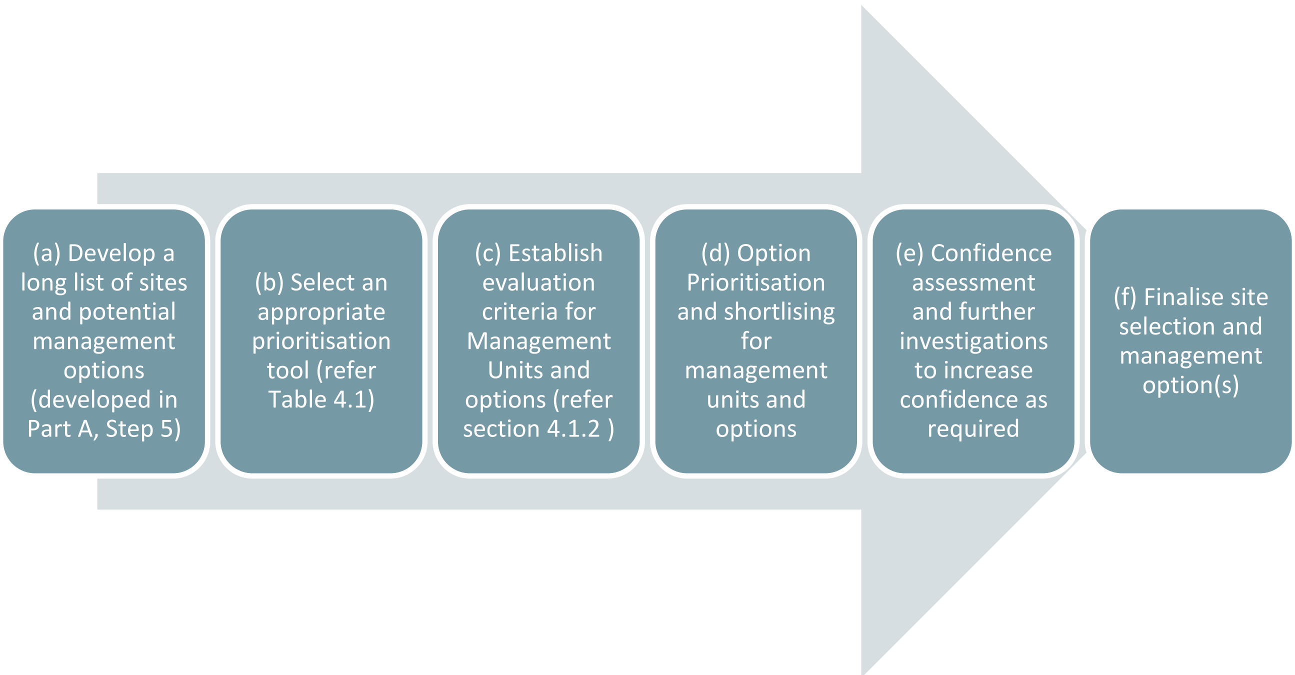

Figure 4-3: Overview of Step 6: Prioritise Black Box management units and management options

4.1.1 Overview of Prioritisation Tools and Confidence Assessment

Various methods and tools can be used to prioritise management units and management options. The selection of an appropriate method will be determined by the range of potential management options, time and resources available for the prioritisation, and the scale of investment that is likely to be sought for the site. Table 4-1 provides a description of a range of methods along with a guide to a hierarchy of prioritisation tools, for providing increasing levels of confidence in the prioritisation process. This table is intended to provide land managers with a quick reference guide from which they can select the most appropriate method depending on their situation.

Refer chapter 3.2 for an explanation of the confidence assessment colour coding and explanation of what confidence levels are appropriate for different types of sites.

Table 4-1: Guide to a hierarchy of methods for prioritising Black Box management units and options

Confidence level	Prioritisation Tool
Low:	**No formal prioritisation process**: selection based on "intuition alone"
Low/Moderate:	**Rapid Prioritisation Method:** Uses a qualitative comparison of multiple criteria to compare potential management options, however does not include detailed scoring and weighting of criteria. This method is appropriate for relatively small sites, where the investigation of management options (Step 5 in Part A of the Framework) shows a small number of feasible management units and options, and where the level of investment being sought for management is low. It is recommended this process be completed as part of a workshop with key stakeholders, so that all relevant knowledge is captured and included in the prioritisation. Refer Appendix F for a description of the Rapid Prioritisation Method.
Moderate:	**Multi-Criteria Analysis (MCA):** MCA is a decision supporting tool that is commonly used to assess a list of sites and options, through a robust and transparent process that compares potential options against an agreed set of weighted criteria. Refer Appendix G for a description of MCA.
Moderate/High:	**Cost-Benefit Analysis (CBA):** CBA involves quantifying all costs and benefits involved with the management units and the management options. The benefits and costs are adjusted for the time value of money, so they can be expressed as their net present value. Where a selected site requires comparably large works for implementation, the CBA method may be required in seeking investment from project sponsors.
High:	**Cost Effectiveness Analysis (CEA):** CEA is another framework style assessment tool, which could be used to compare the intended outcomes or effects of each management site / option with the relative associated costs. A CEA would likely only be of value for management options requiring significant funding investment.

4.1.2 Criteria for Prioritising Black Box Management Units and Management Options

Selection of an appropriate set of criteria through which the management units and management options will be assessed is an important step in preparing to prioritise. This chapter presents some example criteria as a starting point for practitioners. The specific criteria set that will be most appropriate will depend on site specific factors, and on which prioritisation process is selected.

The suggested parameters to assist with the prioritisation of the sites/management options are provided in Appendix H and Appendix I.

Example Criteria: Black Box Management Units

As part of the development of the assessment framework, a set of suggested criteria have been created to aid the selection and prioritisation of Black Box management units for management. These are described fully in Appendix H and include:

a. Environmental factors:
   - likelihood of achieving the targeted and long-term outcome
   - biodiversity values at the unit (e.g. unit size, refuge value)
   - environmental context which the site contributes too (e.g. connectedness or isolation of Black Box in the landscape).

b. Economic:
    - potential positive impacts on tourism and local communities (third party benefits)
    - infrastructure presently available/required at the site to assist in implementation (establishment cost)
    - operational cost and capacity to keep managing into the future
    - funding / resource availability.

c. Cultural factors:
    - support from, and alignment with cultural objectives of Aboriginal groups
    - social factors such as the level of stakeholder/land owner/community interest and support.

d. Implementation factors:
    - logistics of delivering management measures at the unit
    - implications for ability to deliver water to other units
    - compatibility with land tenure
    - risk assessment.

Each criterion for site selection is supported by a set of parameters that can guide the use of available information for assessing and prioritising sites. By collecting the available information at each site related to these parameters, the differentiating factors can be identified and used to determine priorities. The intent of the parameters is to enable a flexible approach, which can be applied to a wide range of management units, that have different attributes and condition, and with varying levels of available information.

Example Criteria: Management Options

A range of criteria have been developed to distinguish between management options (refer Appendix I which provides suggestions). These include:

a. Environmental factors:
    - area of Black Box affected by proposed intervention
    - current condition and trajectory of Black Box
    - responsiveness of key stressors affecting Black Box condition e.g. soil water availability, groundwater salinity and/or soil salinity conditions
    - long term sustainability of outcomes
    - any possible negative impacts outside the management area
    - potential for management options to effect matters of national environmental significance.

b. Economic factors: a cost-benefit assessment (including with consideration of pre-existing services available to assist with the management options) for the site enables economic comparison.

c. Social factors: including potential for impacts to third parties such as existing users of the floodplain, upstream or downstream water users and irrigation communities.

d. Cultural factors:
    - potential for management options to impact matters of cultural heritage
    - alignment with goals of Aboriginal groups.

e. Political factors: including the prioritisation of resourcing different outcomes due to social perceptions / preference, and the willingness to fund management options over the long term given the time frames for Black Box recovery and regeneration.

f. Implementation factors: practicality of management options, complexity of ongoing operations and maintenance, and implementation/operational risks.

For each option it is important to document how these interventions aim to manage, reduce and or mitigate the key stressors and/or address the objectives and targets formulated in Chapter 3.

4.1.3 Management Combinations to Increase Potential Benefits

The prioritisation process involves ranking the Black Box management units and management options to develop a prioritised list of potential individual management actions. It is important to consider whether additional benefits can be achieved through combining various management options at a site.

Table 4-2 provides a summary of some potential management combination scenarios, which should be considered when determining the site management plan. This is not an exhaustive list, and land managers are encouraged to consider other combinations which have the potential to increase benefits at their site, with respect to site based conceptual models.

Table 4-2: Example management combinations

Management Option Combination	Purpose / Potential Benefits
Weir pool raising combined with pumping water to areas further from the river	Much of the Black Box vegetation throughout the Basin grows on higher sections of floodplain, outside the zone of influence achievable by weir pool manipulation. By pumping water to wetland areas that lie outside the range of weir pool manipulation while water levels are raised, a greater area can benefit from inundation. The pumping head and infrastructure required to deliver water to the wetland is reduced during weir pool raising, as opposed to pumping when the river is at normal pool level.
Weir pool lowering and raising regime	Benefits of weir pool manipulation increase through implementation of a raising and lowering regime over several years, rather than isolated events. Recommended vegetation inundation frequencies and groundwater monitoring can be used to determine the frequency and magnitude of a weir pool manipulation regime.
Removal of operational constraints in combination with weir pool raising	Much of the Black Box vegetation throughout the Basin grows on higher sections of floodplain, outside the zone of influence achievable by weir pool manipulation. Removing operational constraints can either increase the allowable amplitude of weir pool raising, or increase the areas inundated when the weir pool is raised.
Environmental watering, in combination with groundwater pumping	Groundwater pumping, such as Salt Interception Schemes, reduce the depth of the saline groundwater. Environmental watering enables freshening of the soil water, and in combination with lowering of the groundwater table provides an effective method for increasing soil water availability.

4.2 STEP 7: BENEFIT AND RISK ASSESSMENT

Following prioritisation of the management scenarios, the impacts (both positive and negative) to other site objectives, species, or other unintended consequences should be considered for the shortlisted management scenario(s) prior to any decision on implementation of management actions.

The assessment of risks should be undertaken in accordance with AS/NZS ISO 31000: 2009, incorporating the following principles:

- **Communicate and Consult** – with internal and external stakeholders at each stage of the risk management process. Ongoing consultation will be undertaken throughout the risk management process.
- **Establish the Context** – establish the external, internal and risk management procedures against which risk will be evaluated.
- **Identify the Risks** – where, when, why and how events could prevent, degrade, delay or enhance the achievement of the Program objectives.
- **Analyse the Risks** – consider the existing controls, the range of potential consequences, the likelihood of the risk occurring and therefore, the level of risk involved.
- **Evaluate the Risks** – consider the balance between potential benefits and adverse outcomes to determine priorities, and the extent and nature of treatments required.
- **Treat the Risks** – develop and implement strategies and action plans for increasing benefits and reducing potential risks.
- **Monitor and Review** – monitor the effectiveness of all steps of the risk management process. This is important for continuous improvement.

There are a range of risk assessment tools available. Appendix L presents a risk assessment matrix that can be used to explore the risks, likelihood and consequences for managing Black Box at a site. Some potential risks that could apply for each type of management option are included in Table 4-2. This is intended to provide a starting point only, as the specific risks and benefits, and the extent to which they apply, will be unique for each site.

Table 4-3: Potential risks and benefits associated with management options

Management Options	Potential Benefits	Potential Risks
• Augmenting river flows with environmental watering • Environmental watering • Weir pool manipulation (both weir pool raising and lowering) • Removal of constraints to redevelop surface water flow paths • Drip or spray irrigation of Black Box vegetation • Groundwater pumping • Groundwater injection	• Increased inundation of other sites, greater connectivity flows for fish passage etc. • Improving Black Box forest and woodland understorey • Improved condition, coverage and recruitment of red gum and other floodplain vegetation • Improved cycling of nutrients through the floodplain • Greater distribution of water plants • Improved algae diversity, benefiting macroinvertebrates and fish • Can provide beneficial cues for fish movement and breeding	• Over watering of other sites • Water quality risks - sediments, turbidity, dissolved oxygen, salinity • Bank erosion and slumping (weir pool lowering only) • Impacts of changed flow velocities to fish • Physical risk for operators from infrastructure management • Physical risk to community members posed by variable water levels • Property risk to infrastructure within zone of inundation

4.3 STEP 8: DEVELOPING A SITE MONITORING PLAN

An important aspect of developing a site management scenario is to develop a plan for ongoing monitoring of the site, to record changes and outcomes of the management activities.

Ongoing monitoring of Black Box condition should be consistent with the condition assessment methodology undertaken in Step 1, so that direct comparisons can be made before and after implementation of site management. Monitoring should be undertaken at an appropriate frequency to capture variation and trends in Black Box condition over time. Black Box vegetation can take several years to respond to management actions, and changes in condition can be delayed (refer state and transition conceptual model, chapter 3.5.1.4). Given the long timeframe, it is important to plan management and monitoring activities over a long-term period (5 – 10 years), if relevant changes are going to be detected. When developing a site monitoring plan, the level of resources required to provide adequate monitoring over the long term must be considered.

Key outcomes of the site monitoring include:

- Validating or updating the conceptual model. New information provides a means to update the conceptual model so that observed impacts are within the explanatory capacity of the conceptual model.
- Updating the condition mapping and to bring in temporal data to better understand the trajectory of change and therefore the vulnerability of the Black Box. Black Box recruitment should be monitored so that a better perspective on the stressors impacting different life stages can be incorporated into vulnerability assessments and management objectives.
- Updating the stressor mapping so that old and new stressors can be identified and changes over time can provide a better understanding of the intensity of the stressors. Factors such as flooding frequency and groundwater changes after flooding events require temporal data.
- Updating the objectives and targets. As areas of the floodplain improve from management or potentially decline further from stressors, it is important to revise the objectives and targets to make them relevant. Operational targets should be refined to achieve the best outcomes from the resource investment.
- As a basis for adaptive management, whereby past management actions are evaluated for their effectiveness and new strategies and management actions can be improved.

As changes occur, it may be appropriate to revisit the site investigation phase and update the management plan based on the monitoring outcomes. In this way, site investigations and management plans will continue to be refined over time.

4.4 STEP 9: DEVELOPING A SITE MANAGEMENT PLAN

The priority management scenarios and monitoring plan should be documented in a site management plan. This plan should outline:

- the investigations that informed the choice of the priority management scenario
- the expected outcomes of the management scenario
- infrastructure works, timeline, and investment required to implement the management scenario
- risk and benefit analysis of the management scenario
- monitoring plan.

The site management plan is required to ensure that the ongoing management of the site:

- achieves the relevant objectives identified by the landholder, the regional plan and the Basin Plan (BWS)
- is consistent with other related environmental legislation and policies, for example Threatened Species Conservation Act 1995, the Noxious Weeds Act 1993 the Water Management Act 2002, and guidelines such as the Rural Fire Services Planning for Bushfire Protection 2006
- ensures that resources are deployed in an efficient and effective manner
- that outcomes are monitored, and an adaptive management approach is used to improve future outcomes
- provides a mechanism for communicating the objectives and for seeking support for resources
- provides a strong evidence-based approach that can be compared to other plans in the prioritisation of funding at a Basin scale.

A site management plan should be developed that incorporates all the Framework steps including background information and maps. The site management plan forms part of the business case for the investment of resources, for example environmental water or funding to undertake earthworks or infrastructure development.

PART C: MANAGING FOR BASIN SCALE IMPROVEMENT

5. Part C: Managing for Basin Scale Improvement

Chapter 5 applies the steps of the Framework to a regional and a basin scale. These analyses are intended as case studies to investigate the Framework's applicability at different scales, to demonstrate how the Framework can be used to inform decision making on Black Box management and prioritising the investment of resources. The regional and basin scale analyses provide results of Black Box location, condition, influence of stressors and vulnerability, based on currently available spatial datasets. These results will provide resource managers with a good basis for assessing basin wide strategies for Black Box management, and land managers a broader context for site-based interventions. A discussion of the applicability of the Framework to multiple scales ranging from patch, floodplain, reach, region and basin is also presented.

5.1 Applicability of the Framework to Different Scales

Approaching the issue of Black Box management at different scales provides insights and issues that differ when considering a small patch of trees, for example, from when considering the entire Murray-Darling Basin. The terms used for different scales below are not prescriptive and do not have distinct threshold sizes that classify areas into specific scales.

5.1.1 Small Scales: Patch and Floodplain

The Framework process has been applied at a site scale (Calperum Station, Chapter 3). In this case, local knowledge and detailed site investigations could be used to identify the condition, stressors and management options on small patches of trees (management units). The concept of the management unit needs to be expanded beyond a cluster of trees (a few hectares) to something more appropriate for the scale being considered for interventions.

This scale allows Black Box management to focus on:

- Small patches of trees (the framework does not encourage condition assessment or management actions targeting individual trees).
- Site specific management actions, for example individual environmental watering actions, groundwater bores, channel earthworks, etc.

The Framework provides guidance on managing patches of Black Box and developing a site management plan based on prioritising management actions.

The previous chapters have focussed on the small floodplain scale, so this will not be discussed further. The following discussion on reach, region and basin scales provides a framework for supporting evidence-based decision-making to strategically target interventions and prioritising multiple floodplain/site investment proposals.

Figure 5-1: Example of a floodplain scale (Chowilla/Calperum Floodplain)

5.1.2 Medium Scales: Reach and Region

In the case of a reach or region, the management unit is best considered as a much larger area of Black Box vegetation that is impacted by regional processes such as groundwater depth and salinity. Even these stressors can change in very small distances leading to changes in tree health in neighbouring patches due to local differences in soil properties or infrastructure, for example. Flooding frequency is influenced by topography and this has a very local dynamic nature. Broad flooding frequency patterns are determined by weir pool levels with local variation within that area.

Reach and regional scales allows Black Box management to focus on:

- Large patches of trees and groups of patches. This means that areas of Black Box are treated in a similar way.
- Connectivity of Black Box forests and woodlands to allow flora and fauna exchange.
- Composition of reaches to ensure representation of different Black Box communities (including understorey types).
- Distribution of Black Box protected in the reach.
- Broad management actions such as salt interception schemes and weir raising events.

The Framework, although targeted at site investigations, still provides guidance at a reach scale by considering the vulnerability of Black Box and the range of management options required to protect given areas. Refer chapter 5.2 for an application of the Framework to the reach scale.

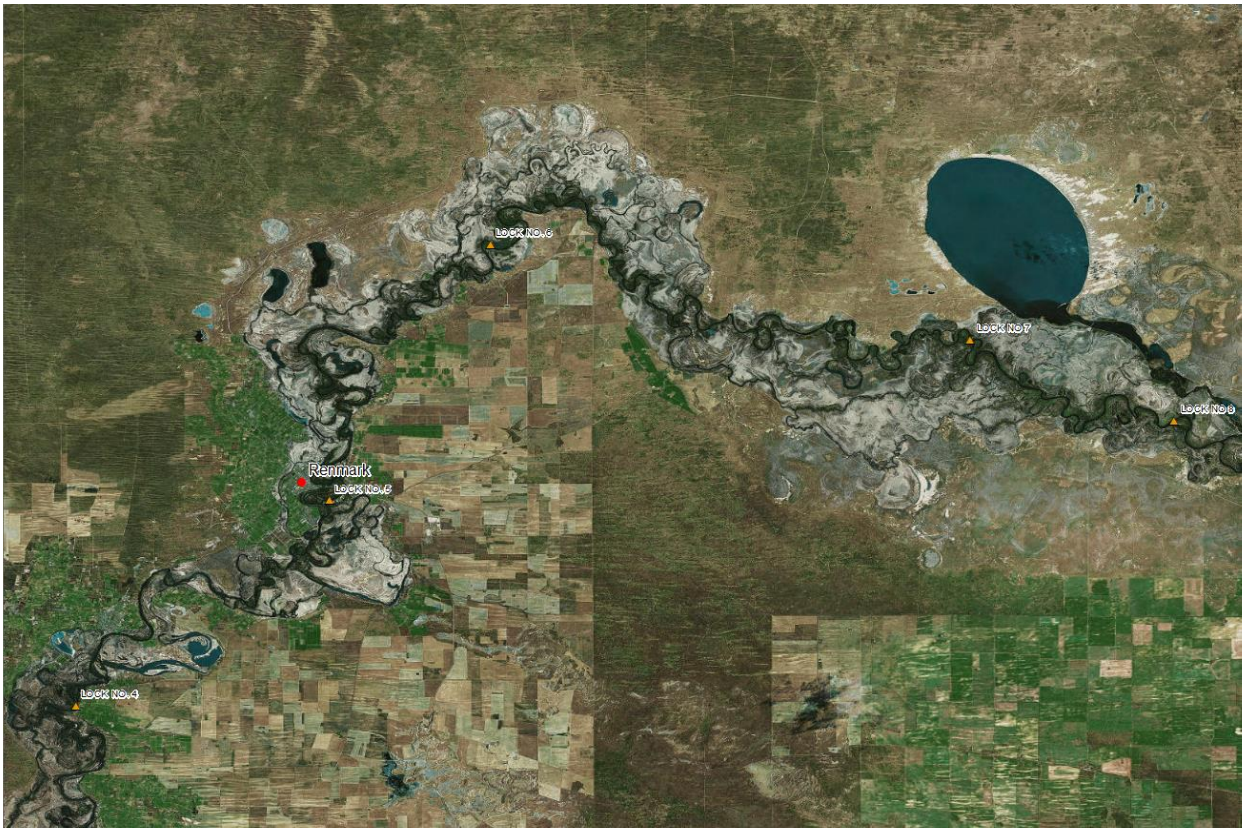

Figure 5-2: Example of a reach scale (River Murray from Lock 4 to Lock 8)

5.1.3 Large Scales: Large Regions and Basin

When considering the Framework at a large reach or region scale it is also important to bring in other management options that consider connectivity of Black Box patches. At the basin scale, the key considerations include representation of different Black Box communities, as well as distribution of the community across a broad geographic area.

This large scale allows Black Box management to focus on:

- different reaches having representation of Black Box to ensure basin wide distribution
- Black Box communities distributed across environmental variables such as rainfall, temperature, groundwater salinity, groundwater depth, so that shifts in climate can be buffered within the range of Black Box tolerances
- distribution of resources to strategically target across the basin
- broad management actions to ensure sustainable Black Box communities across the basin.

The Framework, although targeted at site investigations, still provides guidance at a basin scale by considering the vulnerability of Black Box and the range of stressors that act on local scales and large scales across the basin. The basin scale use of the Framework is to provide a transparent approach to prioritising investment proposals across the basin to ensure that vulnerability, geographic distribution and ecological processes are considered. Refer chapter 5.3 for an application of the Framework to the basin scale.

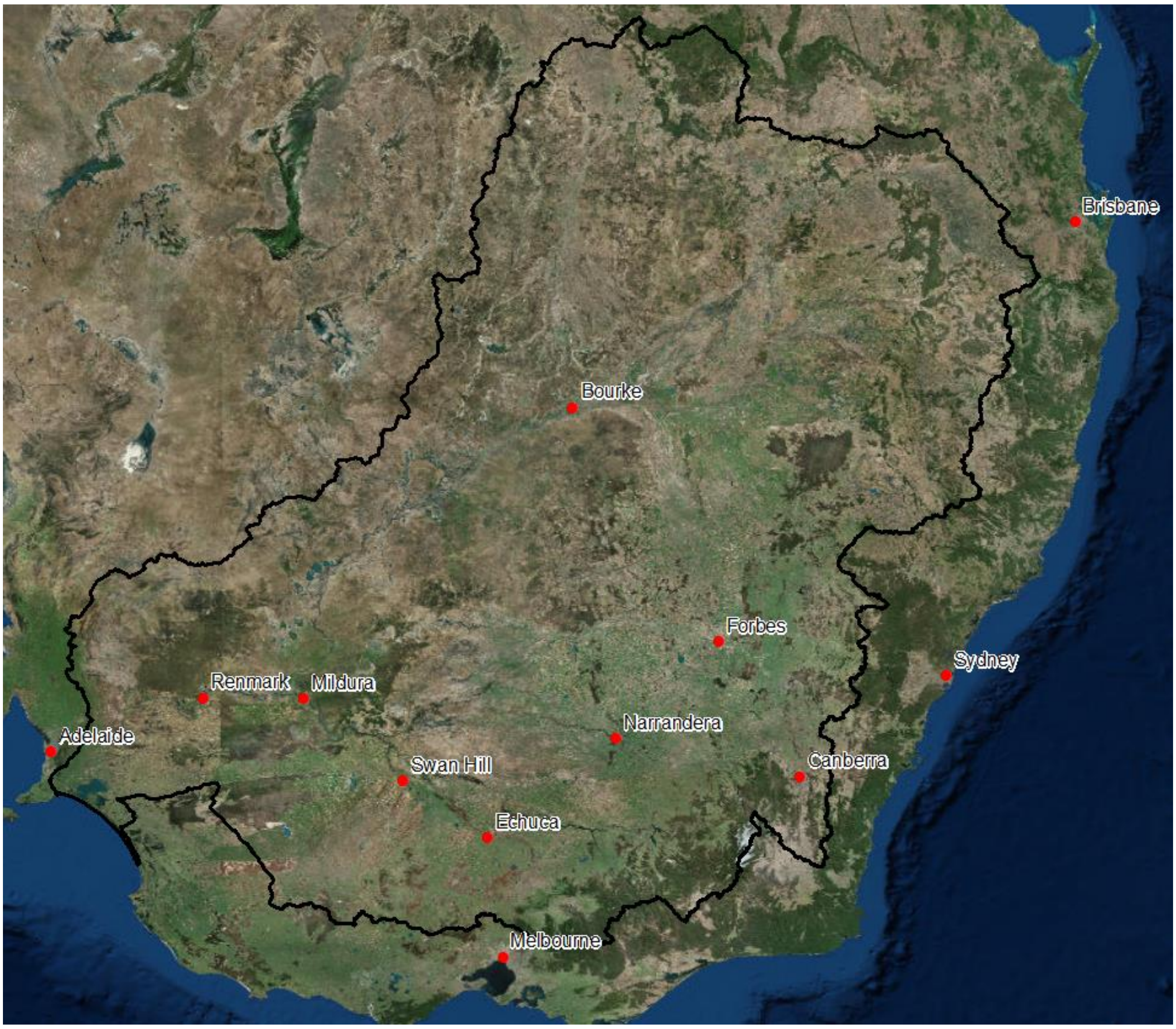

Figure 5-3: The Murray Darling Basin

5.2 Application of the Framework to a Reach or Regional Scale

This section extends the application of the Framework beyond the floodplain/site scale, to a regional scale. The analysis provides a spatial overview of predicted Black Box extent and condition, flooding frequency and soil salinity. It also provides some further analysis on the varying importance and/or interaction of each of these factors. A short discussion of how the outputs of the spatial analyses can be used to inform basin scale management of Black Box, with associated assumptions, is also provided.

The Framework is applied using regional level data for river reach zones defined by River Murray Floodplain Inundation Model (RiM-FIM) data along the River Murray. Usually, a regional analysis would be applied to one or several of these zones, however the analysis in this chapter has included all zones for which all key data sets (Black Box extent and predicted condition, flooding frequency, inundation maps and soil salinity) are available. These data sources provide a lower level of detail than the data used for the floodplain scale analysis at Calperum Station but are more detailed than the data used for the basin scale analysis (Chapter 5.3).

The 22 reaches of the River Murray below Hume Dam, taken from the BWS (MDBA 2014), are presented in Figure 5-4. Reaches 7 to 18 inclusive have been adopted for the following spatial analysis of flow and salinity stress as only these reaches have all the key data sets available.

Table 5-1 provides a summary of the data used for the reach scale analysis, including a confidence assessment score for each data source. Refer chapter 3.2 for an explanation of the confidence assessment process. Confidence assessment at a reach or regional scale differs from the small floodplain scale as it is generally not possible to collect detailed field data for such large areas, and as such, there is likely to be an increased reliance on remotely collected data when compared to small floodplain scale site investigations. This is even more the case for data available at the basin scale.

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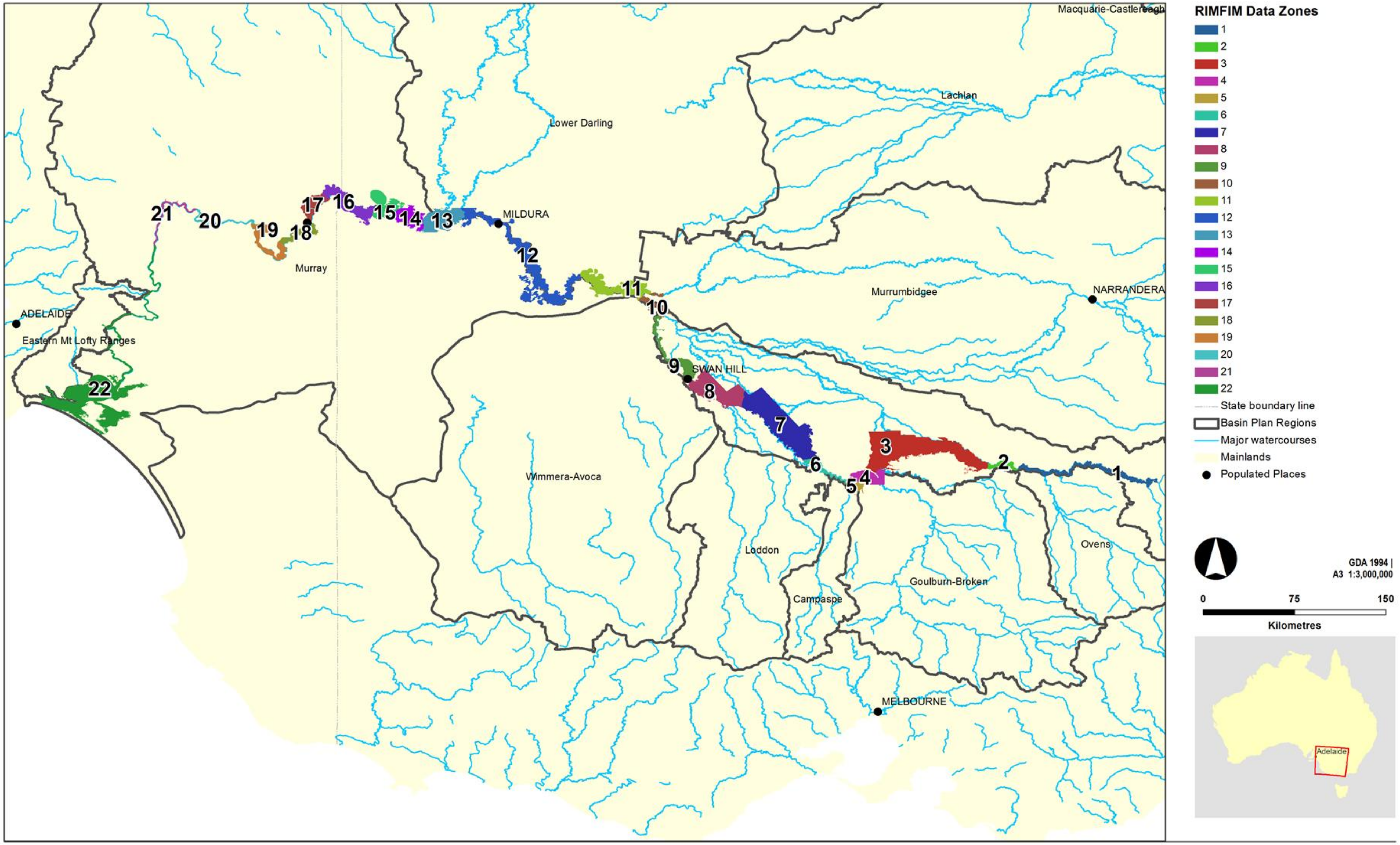

RIMFIM (v2.0 CSIRO) is a data layer based on River Murray Floodplain Inundation Model (RiM-Fim v2) modelled output provided by the Commonwealth Scientific and Industrial Research Organisation.

The data was provided to Jacobs by the CSIRO in November 2016, under the terms of a Licence Agreement, valid to 31 December 2020.

Figure 5-4: Regional scale analysis: extent of River Murray RiM-FIM zones

Table 5-1: Summary of data used in the regional analysis

Data Name	Source	Description	Coverage	Level of Confidence
Extent and condition of Black Box vegetation	MDBA	The MDBA commissioned a vegetation condition assessment model (as at 2013) of water-dependent trees for the development of the BWS. Vegetation extent and condition mapping using remote sensing was combined with the modelled inundation extent to determine the area of River Red Gum, Black Box and Coolibah across the managed floodplain. A remote sensing approach was used to map vegetation extent and condition to provide a consistent set of metrics across the Basin.	Basin Wide for extent (data used for both regional and basin scale analysis) Southern Basin only for condition.	Low/Moderate Remote sensing approach introduces uncertainties, condition data missing for many regions
Inundation frequency (RiM-FIM)	MDBA and CSIRO	To determine the extent of the total and managed floodplain a toolkit has been developed consisting of: ▪ Water resource models that include representation of: - the natural system (i.e. no-development scenario) - water resource development pre-Basin Plan (consumptive use, operational rules and water sharing arrangements as at 2009) - water resource management under the Basin Plan (2,750 GL water for the environment with the operational rules as at 2009) ▪ Inundation model(s) are used to relate a river flow rate to the extent/area of the local floodplain that is inundated. The River Murray Floodplain Inundation Model (RiM-FIM) was used for the lower River Murray (Overton, 2006). The tool kit was used to predict the difference in the inundation extents, frequency and durations for each scenario in the water resource model.	Basin Wide for water resource models. River Murray, Lower Darling, Edward-Wakool and upper Murrumbidgee for inundation models.	Moderate/High Data accurate for the reaches that it covers
Soil salinity in the unsaturated zone.	Geoscience Australia, DEWNR	Airborne Electromagnetic (AEM) surveys along the length of the River Murray have been used to characterise the salinity of the soil in depth slice intervals relative to the natural surface.	River Murray from Barmah in Victoria to Katarapko Island in SA	Moderate/High Data accurate for the reaches that it covers

5.2.1 The Concept of the Managed Floodplain

The reach scale analysis uses the concept of the **managed** floodplain, which is presented within the BWS as a basis for quantifying the targeted environmental outcomes. The concept was introduced to differentiate between the extent to which river flows can be *actively* managed to create broad scale inundation of the floodplain, verses those areas which are out of scope for active flow management and reliant on other forms of management intervention or natural processes.

The area of managed floodplain documented in the BWS (2015) is an estimate of the area of the floodplain which could be feasibly watered with river operations and using environmental water, within the existing operational constraints across the Basin. The area of the managed floodplain for the River Murray also includes those areas that can be inundated using floodplain infrastructure constructed under The Living Murray ‘environmental works’ (channels, levees, flow regulators and pumping stations). The ‘managed’ floodplain will vary over time and between rivers depending on the current operating rules and practices for managing water, and the establishment of new options (infrastructure) for enhancing the use of water for the environment.

The **unmanaged** floodplain under the BWS includes the floodplain area beyond the scope of environmental watering (augmenting river flows) and is generally reliant on large-scale natural events to inundate this part of the floodplain. These events occur only during very wet years and cannot be actively managed (surface water management). The floodplain can still be actively managed using alternative strategies to environmental watering such as groundwater management, grazing control, and the installation of new regulating infrastructure that extends the area that can be inundated at low-medium flows.

The MDBA have developed a toolkit (MDBA 2014b) to differentiate between the managed and unmanaged floodplain from an environmental watering perspective. This consists of:

- hydrologic models of the basin
- inundation model(s) for the floodplain
- predicted vegetation extent and condition layers.

The hydrology and inundation models of the toolkit can be used to predict the difference in the inundation extents for flow related management activities compared to a “do nothing” scenario. This can be translated into a change in the area of managed floodplain. Through combining the inundation model with the vegetation model, the area of vegetation types that are able to be inundated can be determined. The frequency and duration of watering can also be compared with the water requirements for that vegetation type to determine the potential for improvement (or decline) in vegetation condition.

Different attributes of environmental watering can be applied within the models, providing a range of river flow scenarios with floodplain inundation regimes of different extents, frequencies and durations. Each flow scenario results in a change in the managed floodplain area and therefore presents different ecological outcomes in the model outputs.

Figure 5-5 shows the change in area of vegetation inundated under different river flow conditions, as measured along the South Australian River Murray at different flow rates (MDBA, 2015). Average daily river flow rates of 60,000 ML/day and 80,000 ML/day are highlighted within the graph as they represent key markers for river operations. As flows are increased from 60,000 ML/day to 80,000 ML/day an extra 30,000 ha of floodplain is inundated and the proportion of the wetlands, waterbodies and flood dependent vegetation inundated in this section of the River Murray increases from ~40 per cent to ~75 per cent.

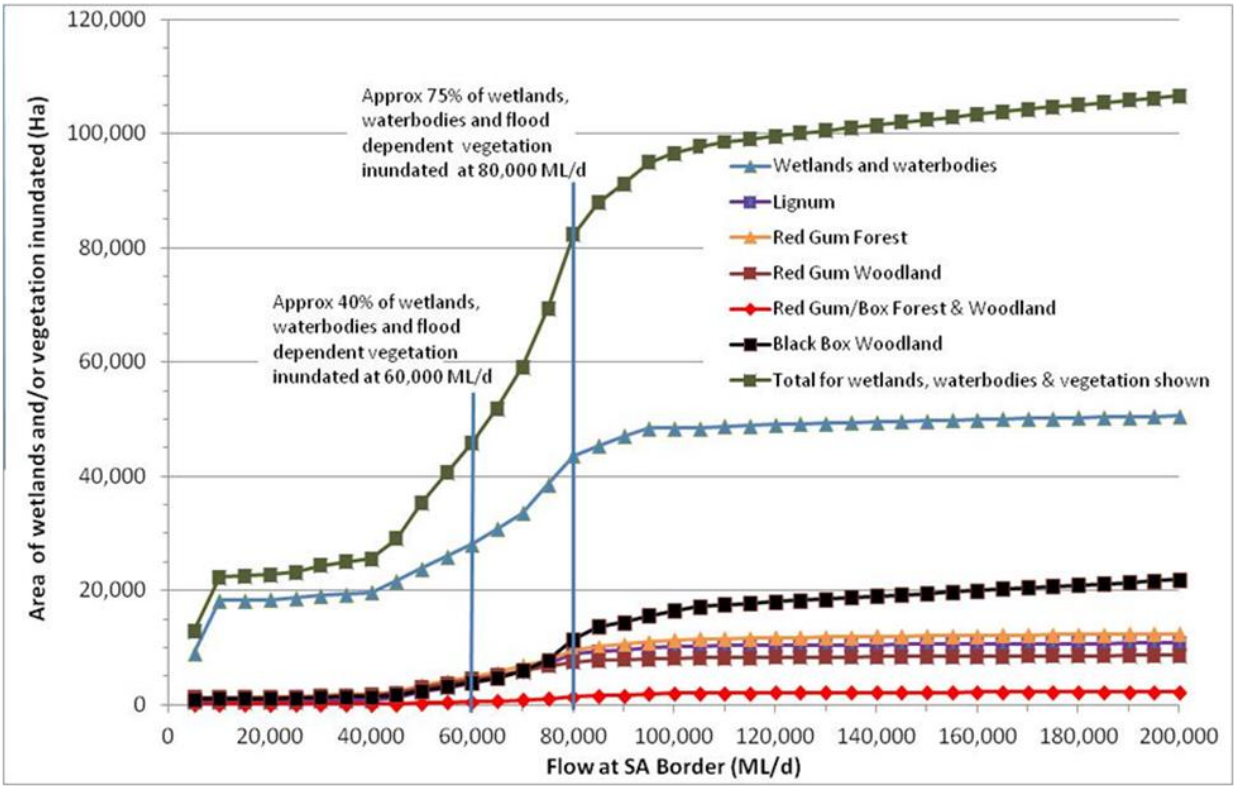

Figure 5-5: Change in the inundated area of floodplain on the River Murray relative to increasing flows measured at the South Australian border (MDBA 2015)

5.2.2 Regional Analysis of Flow Stress for the River Murray

To assess the effect of changes in river flow rates on Black Box vegetation, daily flows at a reach scale along the River Murray have been modelled by the MDBA for the following three scenarios: natural (no development); pre-Basin Plan; and Basin Plan.

The percentage of time a flow rate (ML/day) is exceeded at the South Australian border based on the modelled daily flows is presented in Figure 5-6. This shows that the occurrence of river flow rates up to 60,000 ML/day are increased under the Basin Plan scenario compared with pre-Basin Plan. Between 60,000 ML/day and 80,000 ML/day there is only a marginal increase in the occurrence these flows. Flows greater than 80,000 ML/day are reliant on infrequent large natural events.

The frequency of river flows exceeding 60,000 ML/day and 80,000 ML/day under the Basin Plan scenario is 1 in 3 years and 1 in 6 years respectively at the South Australian border; refer to Table 5-2 and Table 5-3.

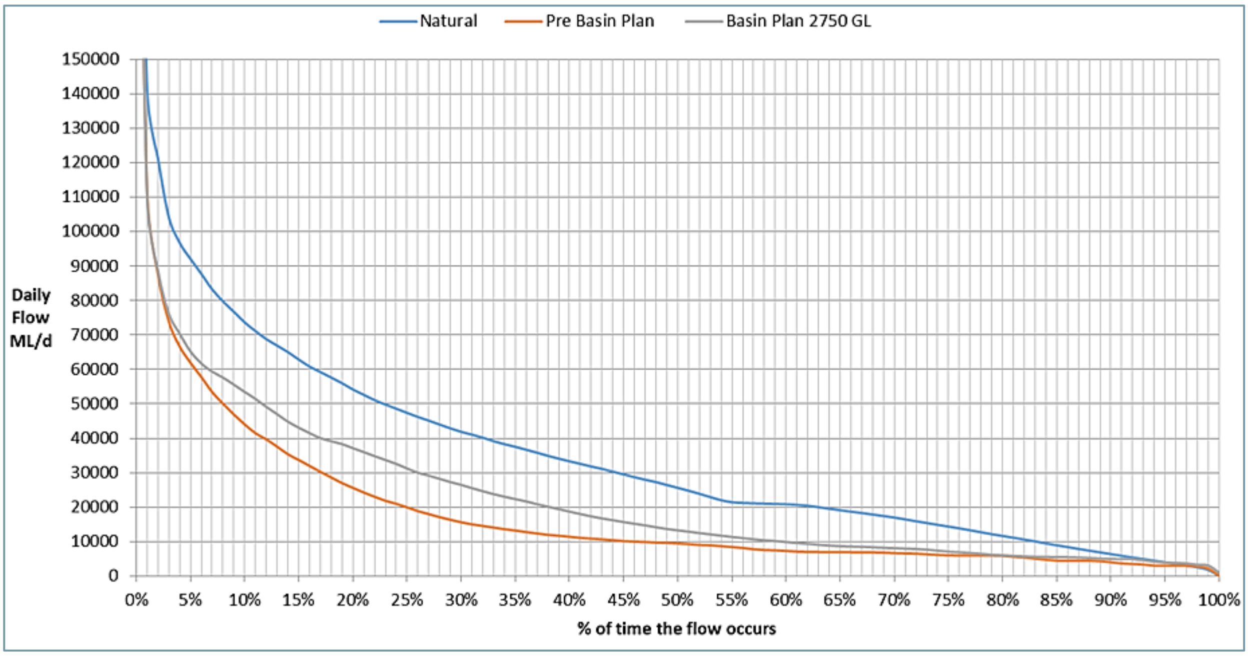

Figure 5-6: Percentage of time that a daily flow occurs at the South Australian border for three scenarios (natural, pre-basin Plan and Basin Plan).

5.2.2.1 Area of Black Box Inundated by Reach

The area of inundation for reaches 7 to 18, relative to river flows of 60,000 ML/day and 80,000 ML/day at the South Australian border, have been analysed using the Basin Plan model scenario and the results are presented in Table 5-2 and Table 5-3, respectively.

The flow rates being targeted at the South Australian border (reach 16) are generated from a combination of tributary flows from the Goulburn and Murrumbidgee rivers, and storage releases from Hume Dam, Lake Victoria and Menindee Lakes. The river flows presented in the following tables for the upstream River Murray reaches (refer to column 5) vary from the targeted flow rate due to this combination of tributary inflows, flow attenuation, river losses, and off-stream diversions.

Table 5-2: Regional analysis of Black Box inundated and flow frequency for 60,000 ML/day flow at the South Australian border based on spatial datasets and flow time series supplied by MDBA.

Reach #	Reach name	Total areas of Floodplain within the reach (ha)	Total area of Black Box within the reach (ha)	Flow rate for the reaches along the River Murray (ML/day) (A)	Flow frequency under Basin plan scenario (years)	Longest period where flows did not exceed (A) (years)	Area of floodplain inundated (ha)	Area of Black Box inundated (ha)
7	Lock 26 (Torrumbarry to downstream of Gunbower forest)	88,244	17,495	20,000	1 in 1.2	3	10,048	1,656
8	Downstream of Gunbower forest to Swan Hill	40,254	4,462	48,000	1 in 2.4	12	8,934	1,062
9	Swan Hill to Murray/Wakool junction	25,139	3,815	22,000	1 in 2.0	8	2,721	211
10	Murray/Wakool junction to Murray/Murrumbidgee junction	13,287	7,126	47,000	1 in 2.7	10	2,510	948
11	Murrumbidgee/Murray junction to Lock 15	47,532	23,864	63,000	1 in 3.0	12	4,435	1,127
12	Lock 15 to Lock 10	92,590	47,154	63,000	1 in 3.2	12	11,314	3,345
13	Lock 10 to Lock 9	38,199	22,080	68,000	1 in 3.3	12	4,067	1,332
14	Lock 9 to Lock 8	21,422	12,270	60,000	1 in 3.0	10	2,636	648
15	Lock 8 to Lock 7	30,732	9,410	60,000	1 in 3.0	10	12,791	626
16	Lock 7 to Lock 6	35,398	16,601	60,000	1 in 3.1	10	9,391	3,052
17	Lock 6 to Lock 5	19,655	6,786	60,000	1 in 2.8	10	12,206	3,349
18	Lock 5 to Lock 4	14,643	4,611	60,000	1 in 2.9	10	5,456	721
Total		**467,095**	**175,674**				**86,509**	**18,077**

Table 5-3: Regional analysis of Black Box inundated and flow frequency for 80,000 ML/day flow at the South Australian border based on spatial datasets and flow time series supplied by MDBA.

Reach #	Reach name	Total areas of Floodplain within the reach (ha)	Total area of Black Box within the reach (ha)	Flow rate for the reaches along the River Murray (ML/day) (A)	Flow frequency under Basin plan scenario (years)	Longest period where flows did not exceed (A) (years)	Area of floodplain inundated (ha)	Area of Black Box inundated (ha)
7	Lock 26 (Torrumbarry to downstream of Gunbower forest)	88,244	17,495	21,000	1 in 1.2	3	10,824	1,727
8	Downstream of Gunbower forest to Swan Hill	40,254	4,462	52,000	1 in 3.2	12	11,123	1,230
9	Swan Hill to Murray/Wakool junction	25,139	3,815	25,000	1 in 3.3	12	3,014	252
10	Murray/Wakool junction to Murray/Murrumbidgee junction	13,287	7,126	75,000	1 in 6.3	21	3,010	1,257
11	Murrumbidgee/Murray junction to Lock 15	47,532	23,864	92,000	1 in 6.0	17	7,551	2,408
12	Lock 15 to Lock 10	92,590	47,154	92,000	1 in 6.7	21	26,615	11,940
13	Lock 10 to Lock 9	38,199	22,080	98,000	1 in 6.7	21	11,282	4,999
14	Lock 9 to Lock 8	21,422	12,270	80,000	1 in 6.0	21	6,159	2,447
15	Lock 8 to Lock 7	30,732	9,410	80,000	1 in 6.3	21	17,057	2,080
16	Lock 7 to Lock 6	35,398	16,601	80,000	1 in 6.3	21	23,825	9,221
17	Lock 6 to Lock 5	19,655	6,786	80,000	1 in 6.3	21	13,748	3,861
18	Lock 5 to Lock 4	14,643	4,611	80,000	1 in 6.3	21	10,581	2,105
Total		**467,095**	**175,674**				**144,789**	**43,527**

The analysis demonstrates that the area of Black Box inundated by the targeted flow rates is small in comparison to the total area of Black Box for each reach. This highlights the importance of implementing a broad range of complementary management options, particularly options that provide alternate sources of water accessible for Black Box trees.

A summary of key findings from the analysis are listed below based on the Basin Plan model scenario:

- For a flow of 60,000 ML/day at the South Australian border:
  - ~18,000 ha (10 percent) of Black Box is inundated out of a total area of ~176,000 ha in reaches 7 – 18 combined.
  - this flow corresponds to an inundation frequency (maximum extent) of approximately 1 in 3 years
  - the longest period where river flows did not exceed this flow rate in the 114-year modelled period was 12 years. Based on the Transition model (Overton *et al.,* 2014) this period is likely to result in significant stress for mature Black Box and a reliance on access to other suitable sources of water.

- For a flow of 80,000 ML/day at the South Australian border:
  - ~44,000 ha (25 percent) of Black Box is inundated out of a total area of ~176,000 ha in reaches 7 – 18 combined.
  - this flow corresponds to an inundation frequency (maximum extent) of approximately 1 in 6 years
  - the longest period where flows did not exceed this flow rate in the 114-year modelled period was 21 years. Based on the Transition model (Overton *et al.,* 2014) this period is likely to result in critical condition for mature Black Box unless it can access to other suitable sources of water i.e. rainfall and groundwater.

5.2.3 Areas of flow stress only, flow and salinity stress, salinity stress only and low stress

For each of the 3 River Murray reaches, the area of inundated Black Box has been divided into one of the following four categories, for determining the appropriateness of management options to address key stressors:

1) flow stressed only (inundated less frequently than 1 in 5 years and soil salinity <39,000 mg/L)
2) salinity stress only (inundated more frequently than 1 in 5 years and soil salinity >39,000 mg/L)
3) flow and salinity stress (inundated less frequently than 1 in 5 years and soil salinity >39,000 mg/L)
4) low stress (inundated more frequently than 1 in 5 years and soil salinity <39,000 mg/L).

Note: The use of long term inundation frequencies to assess flow stress at a locality must be done with due caution as this will not predict either the current level of flow stress or the longest period without flood inundation experienced by Black Box vegetation.

These categories have been assessed for a 60,000 ML/day and an 80,000 ML/day flow at the South Australian border using the Basin Plan model scenario. The derivation of the salinity threshold is discussed in section 3.2.2. The detailed results of the GIS analysis are provided in Table K.1 and Table K.2 (Appendix K), respectively for reaches 7 to 18. Figure 5-7 illustrates the outcome of this analysis for Zone 13.

In its most simplistic form, the GIS analysis presented below can be used to:

- infer those areas that are potentially “flow stressed” only, and within which viable Black Box could be reasonably expected to respond positively to an increased frequency of watering
- infer those areas that are potentially “salinity” stressed only, and within which active salinity management is required to increase the viability of Black Box
- infer those areas that are potentially “flow and salinity stressed,” where increased environmental watering may have a limited impact on viable Black Box unless salinity stress is also actively managed
- infer those areas that have “low flow and low salinity stress”, and where poorer condition trees in these locations are most likely to be linked to factors other than salinity and soil water availability.

A summary of key findings from the analysis in Table K.1 and Table K.2 are listed below (river reaches 7-18).

For the total floodplain inundated by a 60,000 ML/day flow measured at the South Australian border:

- The frequency of inundation of a 60,000 ML/day flow (1 in 3 years) is likely to maintain the condition of the limited area of Black Box i.e. 18,000 Ha (10 percent of the total Black Box area).
- A total of 9,957 ha (55 percent) has been assessed as likely to have both “low flow and low salinity stress” and the proportion of Black Box in moderate/good condition (66 percent) is higher than the proportion in poor condition (34 percent) within the limits of the data (since only 38 percent of the 9,957 ha has condition data).
- The Black Box is however expected to experience significant stress where the maximum period between inundation events extends up to 12 years.
- A total of 3,392 ha (19 percent) has been assessed as potentially being “salinity” stressed. The proportion of Black Box in poor condition (75 percent) is significantly higher than the proportion in moderate/good condition (25 percent) within the limits of the data (since only 11 percent of the 3,392 ha has condition data). The majority of the “salinity” stressed Black Box (being 2,214 ha) is in reaches 16 and 17 (i.e. from Lock 7 to Lock 5).
- A total of 4,728 ha (26 percent) has no salinity data (predominantly in reaches 7, 8 and 12) and cannot be classified at this time and therefore a confidence score of “Low” can be attributed to this undefined area of floodplain.

For the additional 25,468 ha of floodplain inundated between a 60,000 ML/day and an 80,000 ML/day flow at the South Australian border:

- The frequency of inundation of an 80,000 ML/day flow (1 in 6 years and a 21-year period where flows did not exceed this amount) is unlikely to maintain the condition of the Black Box without having access to other sources of low salinity/ “fresh” water.
- A total of 4,646 ha (18 percent) has been assessed as potentially “flow” stressed and the proportion of Black Box in moderate/good condition (72 percent) is higher than the proportion in poor condition (28 percent) within the limits of the data (since only 9 percent of this area has condition data)
- A total of 3,849 ha (15 percent) has been assessed as likely to be “salinity” stressed and the proportion of Black Box in poor condition (86 percent) is significantly higher than the proportion in moderate/good condition (14 percent) within the limits of the data (since only 5 percent of this area has condition data)
- A total of 3,278 ha (13 percent) has been assessed as being potentially both “flow and salinity” stressed and the proportion of Black Box in poor condition (64 percent) is higher than the proportion in moderate/good condition (36 percent) within the limits of the data (since only 2 percent of this area has condition data)
- A total of 8,413 ha (33 per cent) has been assessed as likely to have “low flow and low salinity stress” and the proportion of Black Box in moderate/good condition (70 percent) is higher than the proportion in poor condition (30 percent) within the limits of the data (since only 16 percent of this area has condition data)
- A total of 5,264 ha (21 per cent) has no salinity data (predominantly in zone 12) and cannot be classified at this time.

For the remaining 334,000 ha of floodplain in reaches 7 to 16 that are inundated at flows above 80,000 ML/day at the South Australian border under the Basin Plan (2,750 GL) scenario:

- there is an additional 132,000 ha of Black Box vegetation on the floodplain
- 52,000 ha has been assessed as being “flow stressed” only
- 32,000 ha has been assessed as being both “flow and salinity” stressed with the bulk of the area (24,000 ha) being located between reaches 13 to 18
- 50,000 ha of floodplain has no soil salinity data and cannot be classified at this time

The analysis suggests that the assessment of salinity stress (and the salinity thresholds) is a reasonable predictor for increasing amounts of Black Box in poor condition (despite the analysis being limited by relatively low coverage of Black Box condition data particularly for higher floodplain areas). For example, for the 4,534 ha of Black Box that are predicted to be “salinity stressed” for a flow of 60,000ML/day at the South Australian border, only 517 ha had condition data available, and the remaining 4,017 ha had no condition information. As provided in Table 5-1, the condition data has a confidence rating of “low/moderate”, partly because it is based on a remote sensing/modelled technique which has identified uncertainties, and partly because there are many reaches for which the data is missing. As further calibration and modelling of the remotely sensed data improves, and the data is extended to other areas, the confidence in the condition dataset will be increased.

5.2.4 Summary of Reach Scale Analysis

The reach scale analysis has estimated that there is a total of 175,674 ha of Black Box within the floodplain across reaches 7 to 18, however the area of Black Box inundated is estimated to be 18,077 ha for a 60,000 ML/day flow at the South Australian border and 43,527 ha for an 80,000 ML/day flow at the South Australian border.

Strategies for achieving outcomes within the 18,077 ha of Black Box floodplain inundated by a 60,000 ML/day should include:

1. Where there is low salinity and low flow stress has been identified, promoting management strategies that reduce grazing pressure is expected to enhance an estimated 3,400 ha of Black Box that are in poor condition and maintain an estimated 6,600 ha currently in moderate/good condition.

2. In areas where salinity stress is determined, implementing complementary management interventions targeting salinity and groundwater processes is required to ensure the long-term effectiveness of environmental watering actions; this combination of interventions is estimated to enhance an estimated 2,500 ha of Black Box that are currently in poor condition and maintaining an estimated 800 ha of Black Box in moderate/good condition.

Strategies for achieving outcomes for the additional 25,450 ha of Black Box floodplain inundated between the 60,000 to 80,000 ML/day flows should include:

1. Where low salinity and low flow stress has been identified, promoting management strategies that reduce grazing pressure is expected to enhance an estimated 2,500 ha of Black Box that are currently in poor condition and maintain an estimated 5,900 ha of Black Box in moderate/good condition.

2. Environmental watering to address areas identified as flow stress only, is estimated to maintain approximately 3,300 ha in moderate/good condition and enhance an estimated 1,300 ha of Black Box currently assessed in poor condition.

3. Implementing management interventions targeting salinity and groundwater processes is required to address areas identified under salinity stress but with low flow stress, is expected to enhance an estimated 3,300 ha of Black Box that are currently in poor condition and maintaining an estimated 500 ha of Black Box in moderate/good condition.

4. Addressing areas that are experiencing both flow and salinity stress, require **both** environmental watering and complimentary salinity management options are needed to be effective and sustainable; enhancing an estimated 2,100 ha of Black Box that are currently in poor condition and maintaining an estimated 1,200 ha of Black Box in moderate/good condition.

The spatial analysis presented in this Framework identifies the river reaches framed by Locks 4-7; Lock 8-9; and Lock 9-10 as experiencing highest salinity risk and therefore require strategies that seek specifically to mitigate this stress; including but not exclusive to environmental water management.

The reach scale analysis highlights the need for complementary/alternative management options in realising long term outcomes for Black Box vegetation particularly for the large proportion (>75 percent) of the Black Box that is outside the managed floodplain. Confidence in the reach scale analysis could be improved through expanding the Black Box condition data to represent a larger proportion of the Black Box. This is currently limiting the analysis for reaches where the data is incomplete.

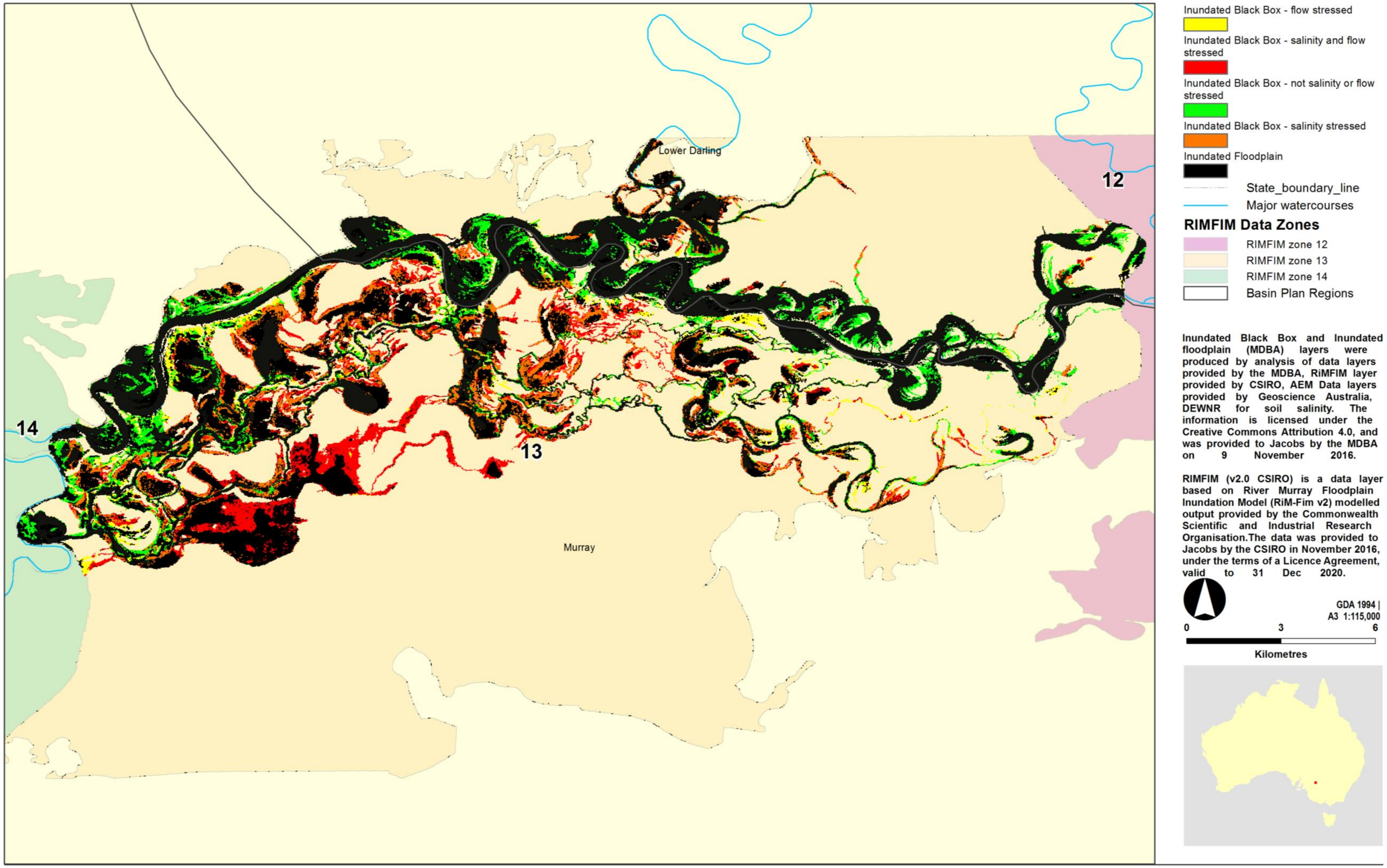

Figure 5-7: The four categories of stress for Zone 13 for 80,000 ML/day flow at the South Australian border.

5.3 Application of the Framework at the Basin Scale

In this section, the steps of the Framework are applied at the Basin Scale. This analysis is intended to demonstrate how the Framework can be used to inform decision making on Black Box management and on prioritising applications for resources at the Basin Scale. Figure 5-8 shows the entire basin and the regions it is broken down into for the analysis. Table 5-4 summarises the data used for the basin scale application of the Framework.

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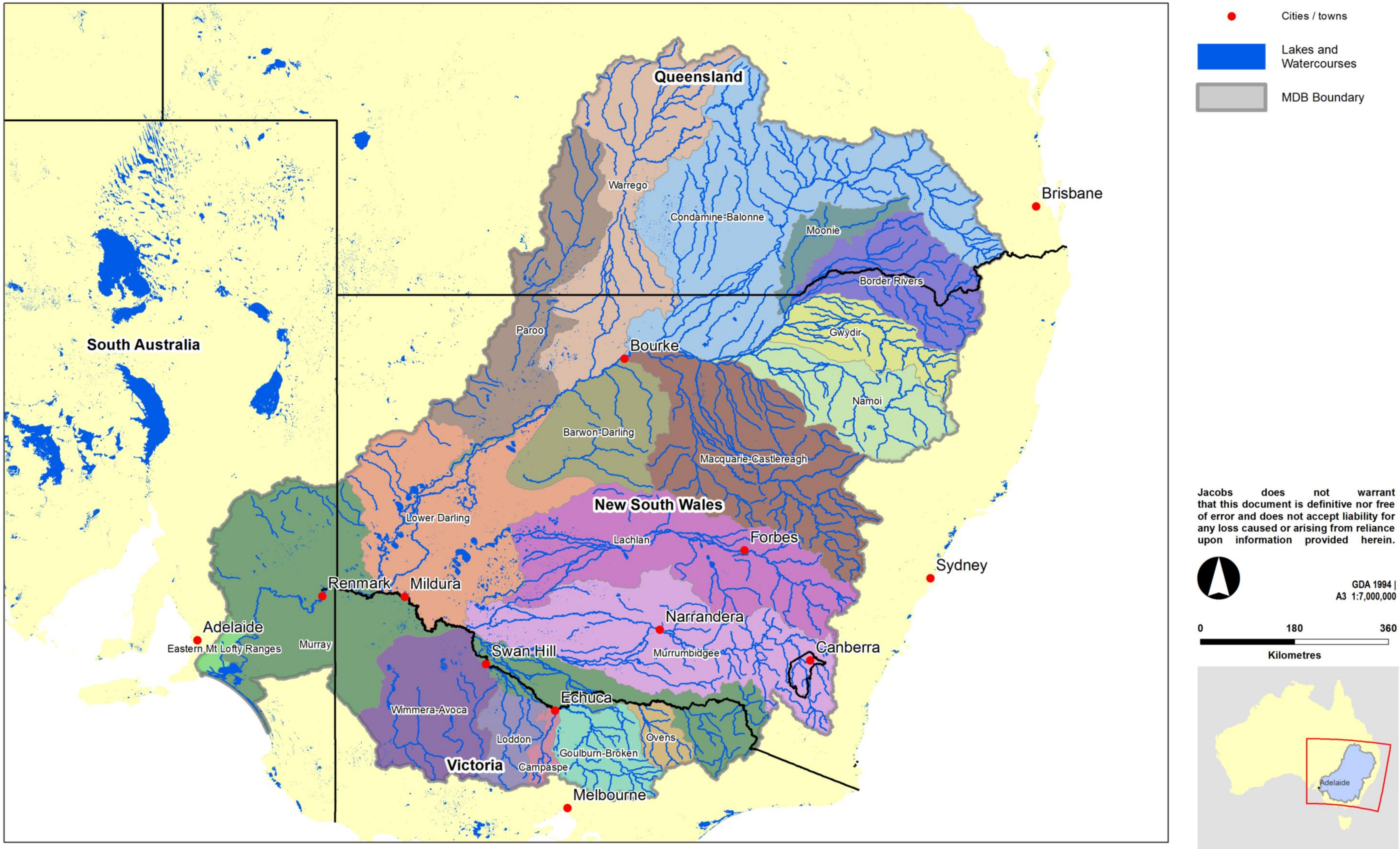

Figure 5-8: Locality map for the Basin and Basin Plan regions

Table 5-4: Data used in the basin scale application of the Framework

Data Name	Source	Description / Reference	Coverage	Confidence Level
Extent and condition of Black Box vegetation	MDBA	The MDBA commissioned a vegetation condition assessment model (as at 2013) of water-dependent trees for the development of the BWS. Vegetation extent and condition mapping using remote sensing was combined with the modelled inundation extent to determine the area of River Red Gum, Black Box and Coolibah across the managed floodplain. A remote sensing approach was used to map vegetation extent and condition to provide a consistent set of metrics across the Basin.	Basin Wide for extent Southern Basin only for condition.	Low/Moderate No condition score available for 86% of Black Box in basin Those areas that are mapped have a Moderate confidence level
Inundation frequency	MDBA and CSIRO	Murray Darling Basin Frequency of Inundation Model (MDB-FIM) was developed by CSIRO. It provides a historical account of floodplain inundation produced from satellite imagery and other available floodplain and wetlands inundation mapping. It is a predictive tool for mapping floodplain inundation under different river flows and wetland connectivity. Overton IC, Doody TM, Pollock D, Guerschman JP, Warren G, Jin W and Wurcker B (2010) The Murray-Darling Basin Floodplain Inundation Model (MDB-FIM). Water for a Healthy Country Flagship Technical Report. CSIRO, Adelaide.	Basin Wide	Low/Moderate All of basin is included. Coarser level of accuracy than RiM-FIM.
Groundwater Salinity	MDBA	Groundwater salinity throughout the basin, provided by the MDBA from their Basin in a Box dataset.	Basin Wide	Low/Moderate Covers basin, but data is not continuous and provides limited information at Black Box stressor threshold.
Groundwater depth	MDBA	Groundwater depth throughout the basin, provided by the MDBA from their Basin in a Box dataset.	Basin Wide	Low/Moderate Covers basin, but data not continuous and provides limited information at Black Box stressor threshold level (6m depth).

5.3.1.1 Black Box Condition Across the Basin

MDBA modelled Black Box extent and condition data (Cunningham et al., 2016) was used to gain an understanding of the current Black Box condition throughout the Basin. As outlined in Table 5-5 and Figure 5-9, only a small proportion of the total area of Black Box throughout the Basin has been assigned a condition category, which limits the ability to interpret the results at a Basin Scale. As a result, the data is assigned a “Low” confidence score, as shown in Table 5-4. To increase the confidence score and improve the ability to interpret the Black Box condition throughout the Basin, a more complete Basin Scale condition layer should be developed.

Table 5-5: Proportion of Black Box of different condition classes throughout the Basin

Black Box Condition	Area (Ha)	%
Good	67,291	5%
Poor	128,004	9%
Not measured	1,202,197	86%
Total	1,397,492	100%

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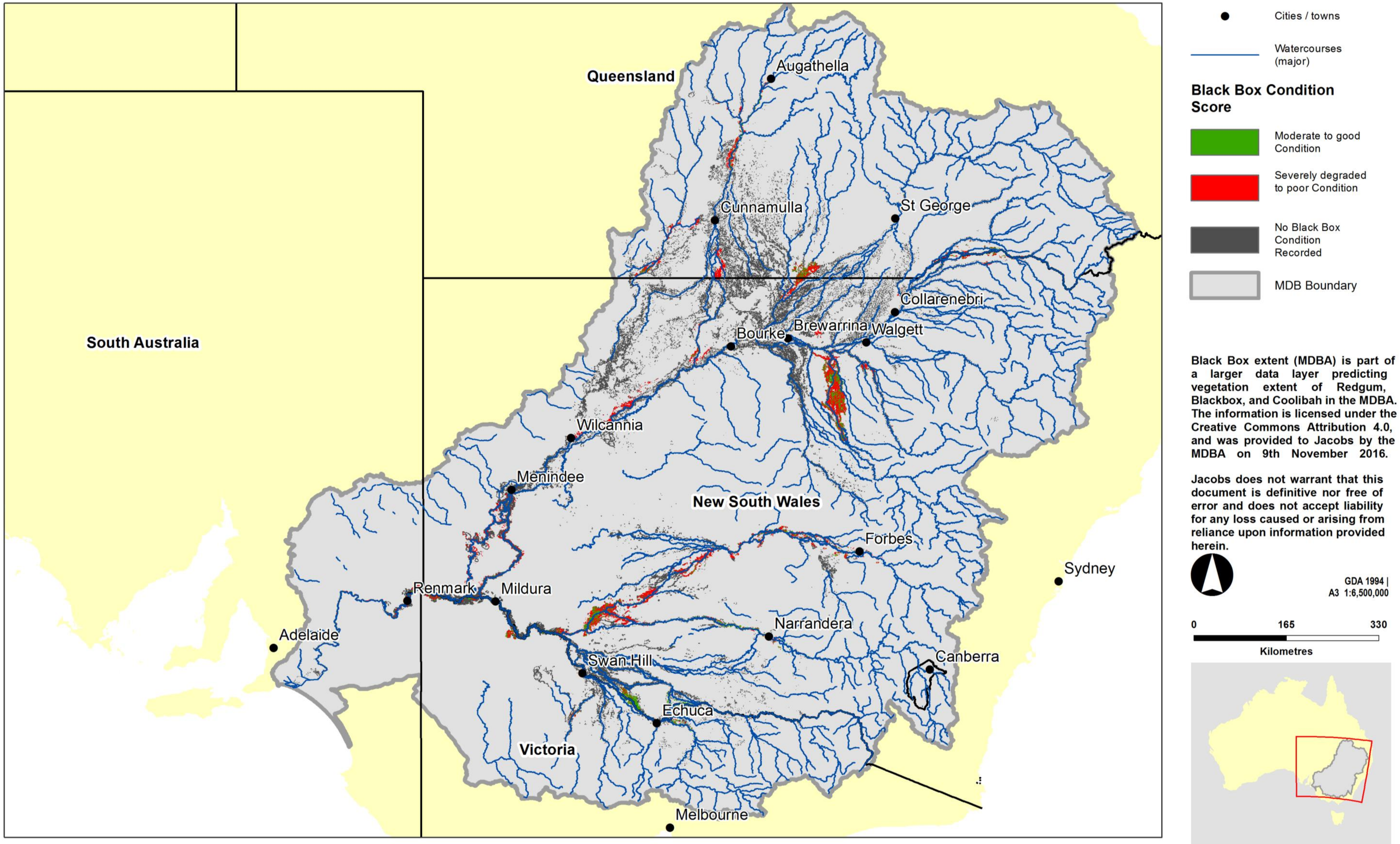

Figure 5-9: Black Box extent and condition throughout the Basin

5.3.1.2 Black Box Stressors across the Basin

As outlined in Chapter 3.5, there are a range of stressors that impact on Black Box vegetation. At a Basin scale, the key stressors of:

- Flooding frequency
- Groundwater salinity
- Groundwater depth.

These stressors have been assessed throughout this sub-section to develop an understanding of the distribution and severity of stressors throughout the Basin.

Flooding Frequency

The Murray-Darling Basin Floodplain Inundation Model (MDB-FIM) (Overton *et al.*, 2016) was used to produce a series of flooding extent maps throughout the Basin. Figure 5-10 shows the basin extent, and two maps showing a greater level of detail in selected areas of the Murray and Darling systems are provided in Appendix M Data from MDB-FIM version 2 was provided by the CSIRO. These provide an indication of the areas of inundation of the floodplain and wetlands for different frequencies.

The threshold value for flooding frequency used in the analysis was 1 in 10 years. Jolly and Walker (1995) used a 1 in 10-year regime as the threshold for Black Box health. A 1 in 2-year regime has been used as well to indicate the areas of the floodplain that are low lying and therefore potential areas of being influenced by weir raising, channel modification or small environmental pumping actions.

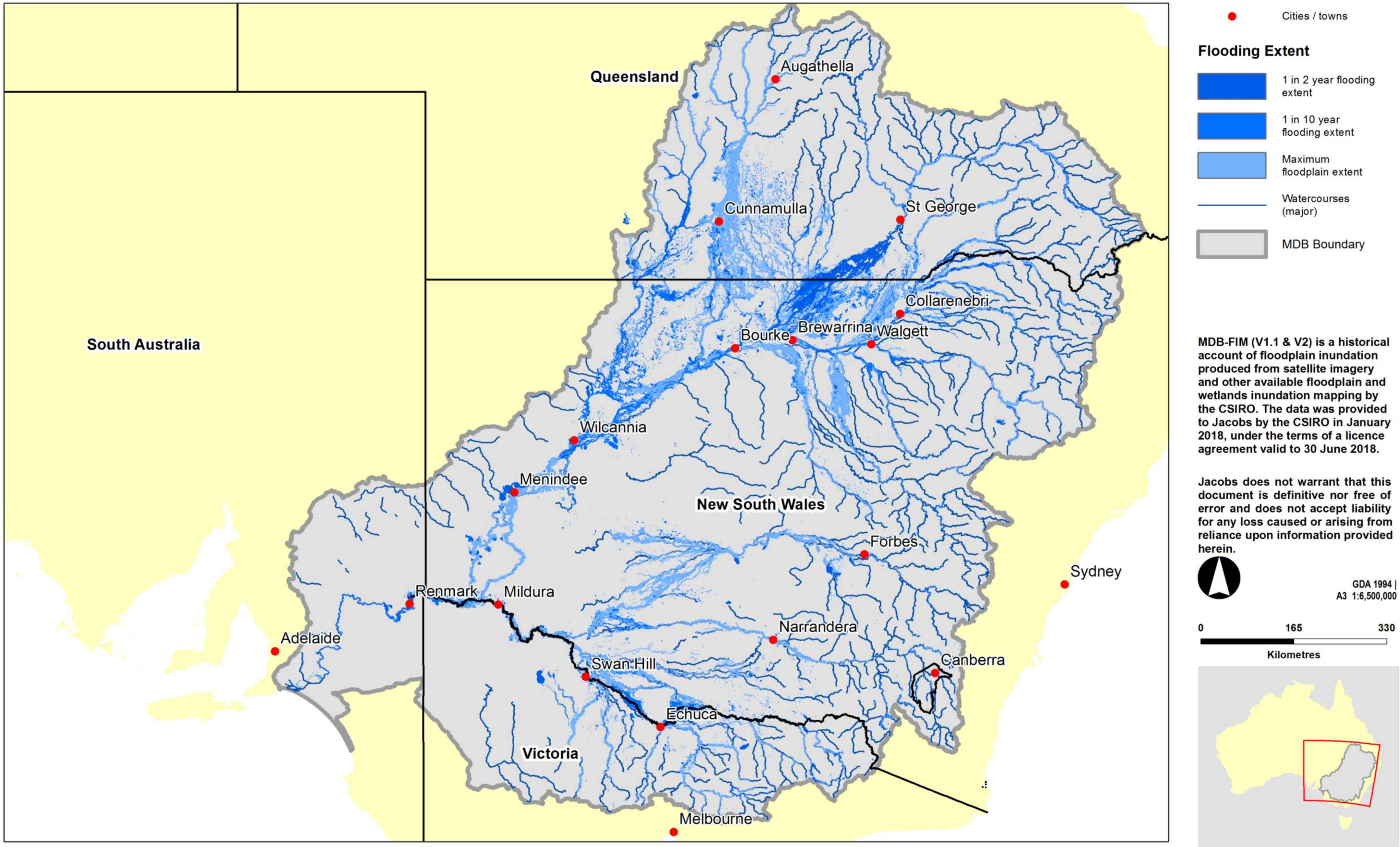

Figure 5-10: Flood frequency map: Basin Scale

Overlaying the flooding frequency data with the extent of Black Box vegetation throughout the Basin provides an analysis of how frequently Black Box are likely to be inundated based on their location relative to the flood extent layers.

Table 5-6 and Figure 5-11 provide the proportion of Black Box throughout the Basin that are:

- Within the 1 in 2-year flood extent. These areas of Black Box are manageable using environmental watering and other management measures, within the current constraints. They are not considered at risk from flooding frequency (as Black Box can survive with inundation as infrequently as once per 10 years).
- Between the 1 in 2 years and 1 in 10-year flood extents. These areas of Black Box are considered outside the areas that can be readily managed, however they are not considered at risk from flooding frequency (as Black Box can survive with inundation as infrequently as once per 10 years).
- Outside the 1 in 10-year flood extent, but within the total floodplain area. For this analysis, these areas of Black Box are considered at risk from flooding frequency (as Black Box that are inundated less frequently than once per 10 years are considered water-stressed, unless the trees have access to other sources of water).

Additional maps showing a greater level of detail in selected areas of the Murray and Darling systems are provided in Appendix M.

Table 5-6: Proportion of Black Box in areas of different flood frequency for each region of the Basin

Basin Plan Regions	Black Box within 1 in 2 Flood Frequency zone		Black Box between the 1 in 2 and 1 in 10 Flood Frequency Zones		Black Box outside the 1 in 10 Flood Frequency Zone	
	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%
Barwon-Darling	4,420	7%	31,190	50%	26,250	42%
Moonie	370	4%	1,420	17%	6,610	79%
Campaspe	0	0%	10	3%	290	97%
Macquarie-Castlereagh	4,220	2%	22,060	12%	160,940	86%
Lachlan	5,400	7%	20	0%	73,050	93%
Eastern Mt Lofty Ranges	100	25%	0	0%	300	75%
Murrumbidgee	5,390	7%	9,120	12%	60,940	81%
Loddon	250	4%	110	2%	5,320	94%
Lower Darling	14,650	7%	14,680	7%	180,990	86%
Gwydir	970	10%	490	5%	8,360	85%
Border Rivers	2,140	19%	1,340	12%	7,830	69%
Namoi	1,020	9%	2,420	21%	8,140	70%
Murray	38,610	17%	43,190	19%	150,170	65%
Condamine-Balonne	76,430	28%	51,480	19%	145,900	53%
Paroo	17,000	36%	17,670	37%	12,750	27%
Warrego	10,420	6%	26,590	16%	129,990	78%
Wimmera-Avoca	1,770	15%	970	8%	9,030	77%
Goulburn-Broken	880	20%	580	13%	3,040	68%
Ovens	0	0%	0	0%	210	100%
TOTAL BASIN	**184,030**	**13%**	**223,350**	**16%**	**990,120**	**71%**

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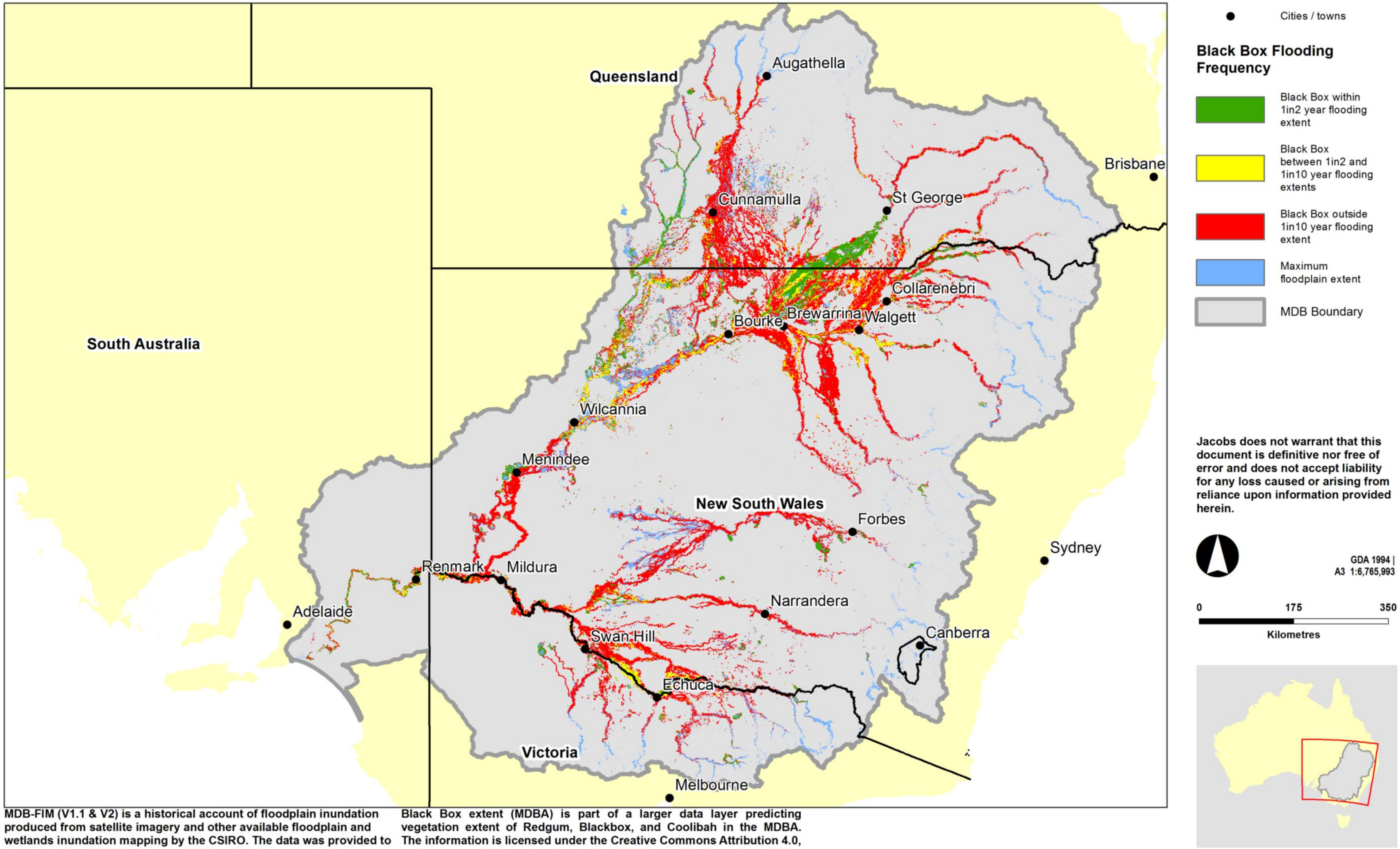

MDB-FIM (V1.1 & V2) is a historical account of floodplain inundation produced from satellite imagery and other available floodplain and wetlands inundation mapping by the CSIRO. The data was provided to Jacobs by the CSIRO in January 2018, under the terms of a licence agreement valid to 30 June 2018.

Black Box extent (MDBA) is part of a larger data layer predicting vegetation extent of Redgum, Blackbox, and Coolibah in the MDBA. The information is licensed under the Creative Commons Attribution 4.0, and was provided to Jacobs by the MDBA on 9th November 2016.

Figure 5-11: Frequency of inundation of Black Box: basin scale

Groundwater Salinity

Groundwater salinity layers from the MDBA *Basin in a Box* dataset were used to produce a series of groundwater salinity maps throughout the Basin. Figure 5-12 shows the basin extent, and two maps showing a greater level of detail in selected areas of the Murray and Darling river systems are provided in Appendix M. These provide an indication of the areas throughout the Basin where groundwater is saline or not saline. As described in chapter 3.5.3, the threshold for groundwater salinity stress for Black Box is 22,000 mg/L. The basin wide data available for groundwater salinity was not a continuous series but provided suitable groundwater salinity intervals. The closest two intervals to the 22,000 mg/L threshold were 7,000-14,000 mg/L and 14,000 – 35,000 mg/L. Due to this constraint in the data, the threshold of 22,000mg/L could not be used and a threshold of 35,000 mg/L was selected for this analysis. As discussed in Table 5-4, the limitations associated with this data result in a “Low/Moderate” confidence score. Provision of basin wide groundwater salinity data in a continuous scale, so that the threshold of 22,000 mg/L can be used in the analysis would improve the level of confidence of the following analysis.

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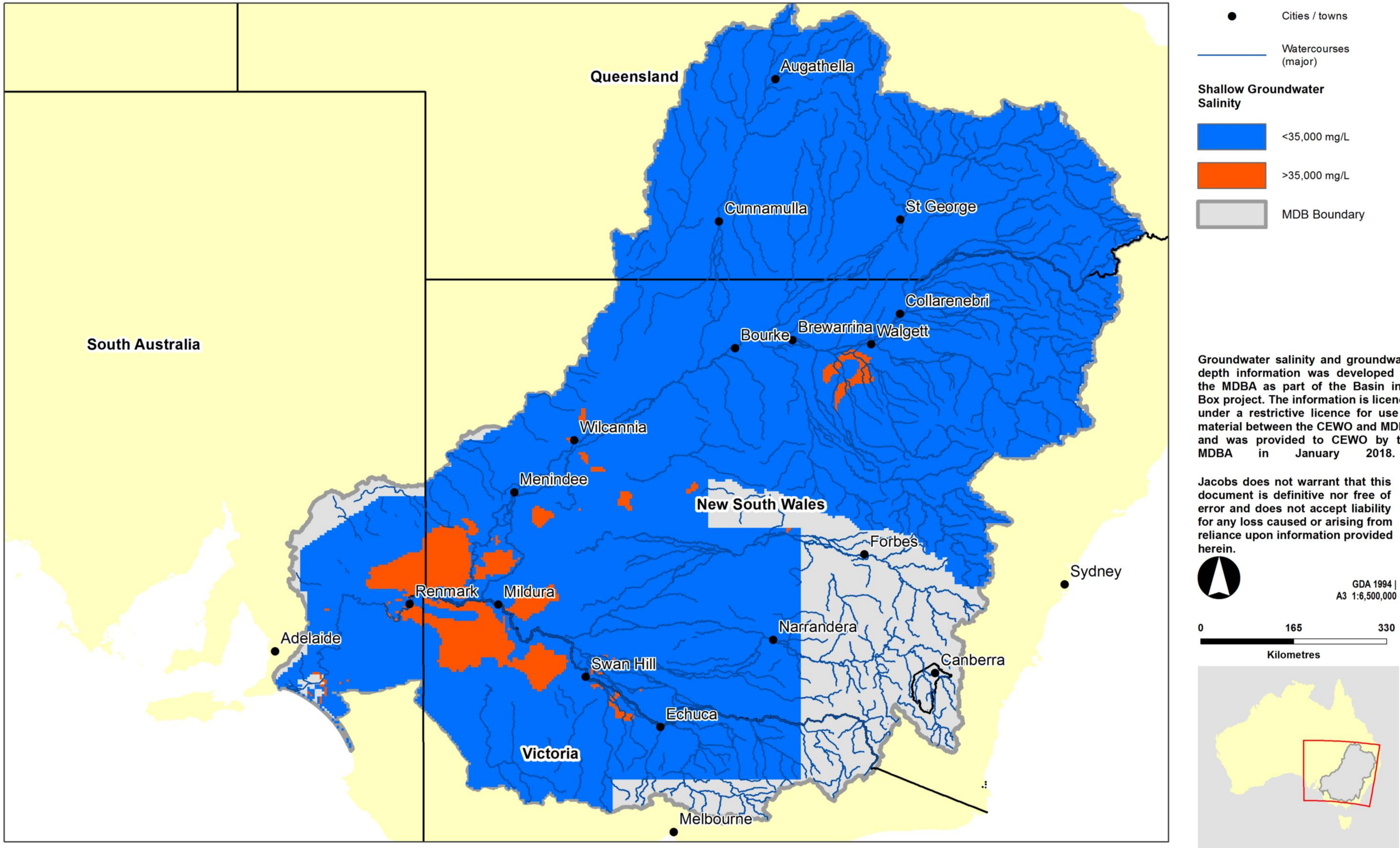


Groundwater salinity and groundwater depth information was developed by the MDBA as part of the Basin in a Box project. The information is licenced under a restrictive licence for use of material between the CEWO and MDBA, and was provided to CEWO by the MDBA in January 2018.

Jacobs does not warrant that this document is definitive nor free of error and does not accept liability for any loss caused or arising from reliance upon information provided herein.

Figure 5-12: Groundwater salinity: basin scale

Overlaying the groundwater salinity data with the extent of Black Box vegetation throughout the Basin provides an analysis of which areas of Black Box are in areas exposed to saline groundwater. When paired with groundwater depth information, the groundwater salinity information contributes to the understanding of whether Black Box are likely to be stressed.

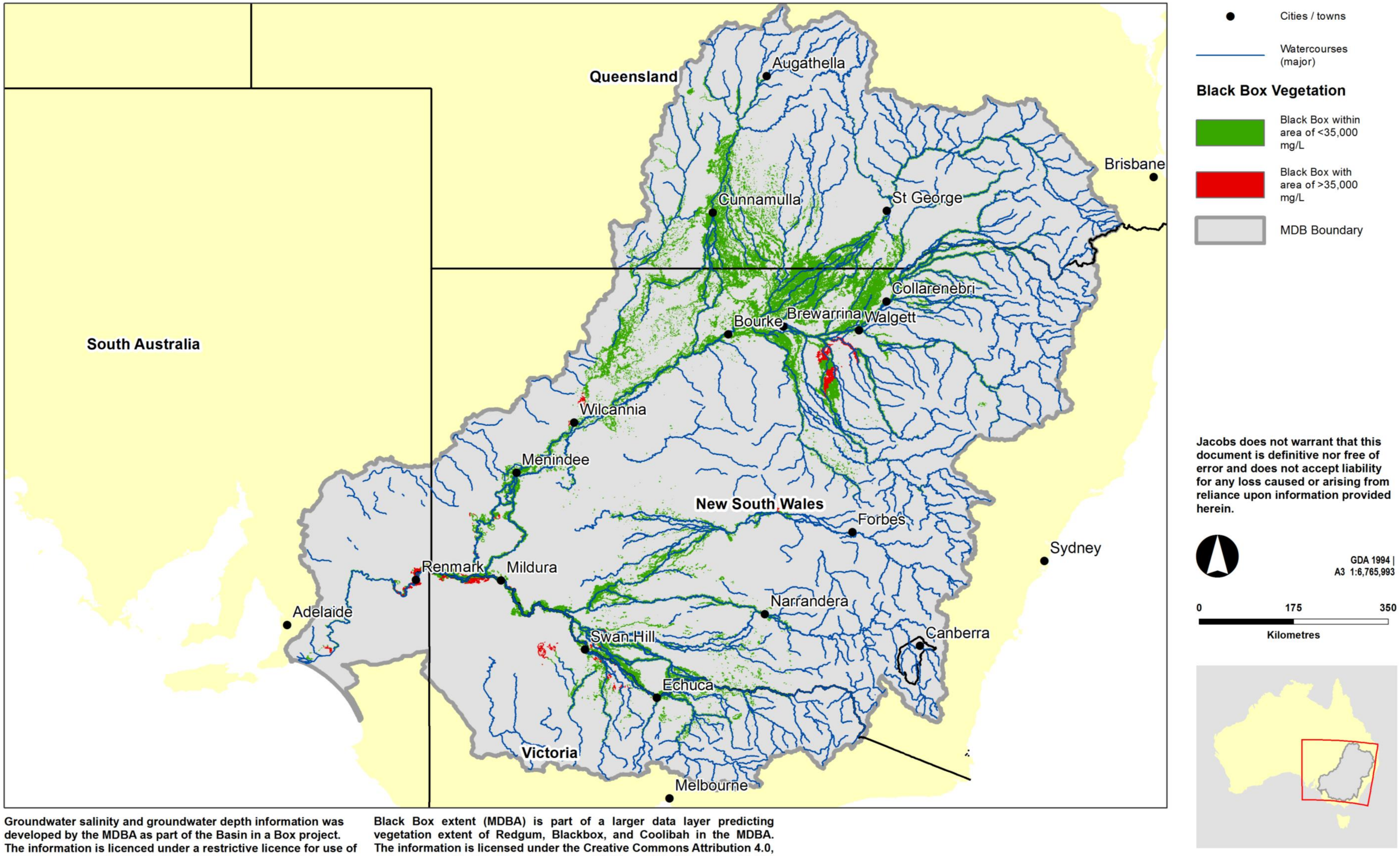
Table 5-7 and Figure 5-13 illustrate the proportion of Black Box throughout the Basin that are:

- in areas of saline groundwater (>35,000mg/L). If the groundwater is saline and shallow, the Black Box is considered to be at risk from salinity
- in areas of non-saline (or tolerable) groundwater (<35,000mg/L). These Black Box are not likely to be at risk from salinity.

Additional maps showing a greater level of detail in selected areas of the Murray and Darling systems are provided in Appendix M.

Table 5-7: Proportion of Black Box in areas of saline and non-saline groundwater

Basin Plan Regions	Black Box in areas of Fresh (<35,000mg/L) groundwater		Black Box in areas of Saline (>35,000mg/L) groundwater		Missing data	
	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%
Barwon-Darling	61,850	100%	0	0%	0	0%
Moonie	8,390	100%	0	0%	0	0%
Campaspe	310	100%	0	0%	0	0%
Macquarie-Castlereagh	159,140	85%	28,070	15%	0	0%
Lachlan	71,280	91%	350	0%	6,830	9%
Eastern Mt Lofty Ranges	380	97%	0	0%	10	3%
Murrumbidgee	75,150	100%	20	0%	280	0%
Loddon	5,180	91%	500	9%	0	0%
Lower Darling	206,850	98%	3,470	2%	0	0%
Gwydir	9,820	100%	0	0%	0	0%
Border Rivers	11,310	100%	0	0%	0	0%
Namoi	11,580	100%	0	0%	0	0%
Murray	200,590	86%	30,720	13%	670	0%
Condamine-Balonne	273,810	100%	0	0%	0	0%
Paroo	47,080	99%	330	1%	10	0%
Warrego	167,000	100%	0	0%	0	0%
Wimmera-Avoca	9,920	84%	1,850	16%	0	0%
Goulburn-Broken	4,240	94%	0	0%	250	6%
Ovens	210	100%	0	0%	0	0%
TOTAL BASIN	1,324,110	95%	65,310	**5%**	8,070	**1%**



Groundwater salinity and groundwater depth information was developed by the MDBA as part of the Basin in a Box project. The information is licenced under a restrictive licence for use of material between the CEWO and MDBA, and was provided to CEWO by the MDBA in January 2018.

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Figure 5-13: Groundwater salinity and Black Box: basin scale

Groundwater Depth

Groundwater depth layers from the MDBA *Basin in a Box* dataset were used to produce a series of groundwater depth maps throughout the Basin. Figure 5-14 shows the basin extent, and two maps showing a greater level of detail in selected areas of the Murray and Darling systems are provided in Appendix M. These provide an indication of the areas throughout the Basin where groundwater is shallow or deep. Ten metres depth was selected as the threshold for ‘shallow’ or ‘deep’ groundwater, as it is the depth threshold under which the groundwater may pose a risk to Black Box. Ten metres was chosen as the threshold as the data was classified and not continuous. The other option was five metres and that was considered too low for meaningful classification of risk. This limitation in the dataset is one reason that the data scored a low/moderate confidence score (refer Table 5-4). To improve the confidence in the data, it is recommended that an improved dataset on groundwater depth is developed and a threshold of six metres (as per the Calperum Station case study) is used.

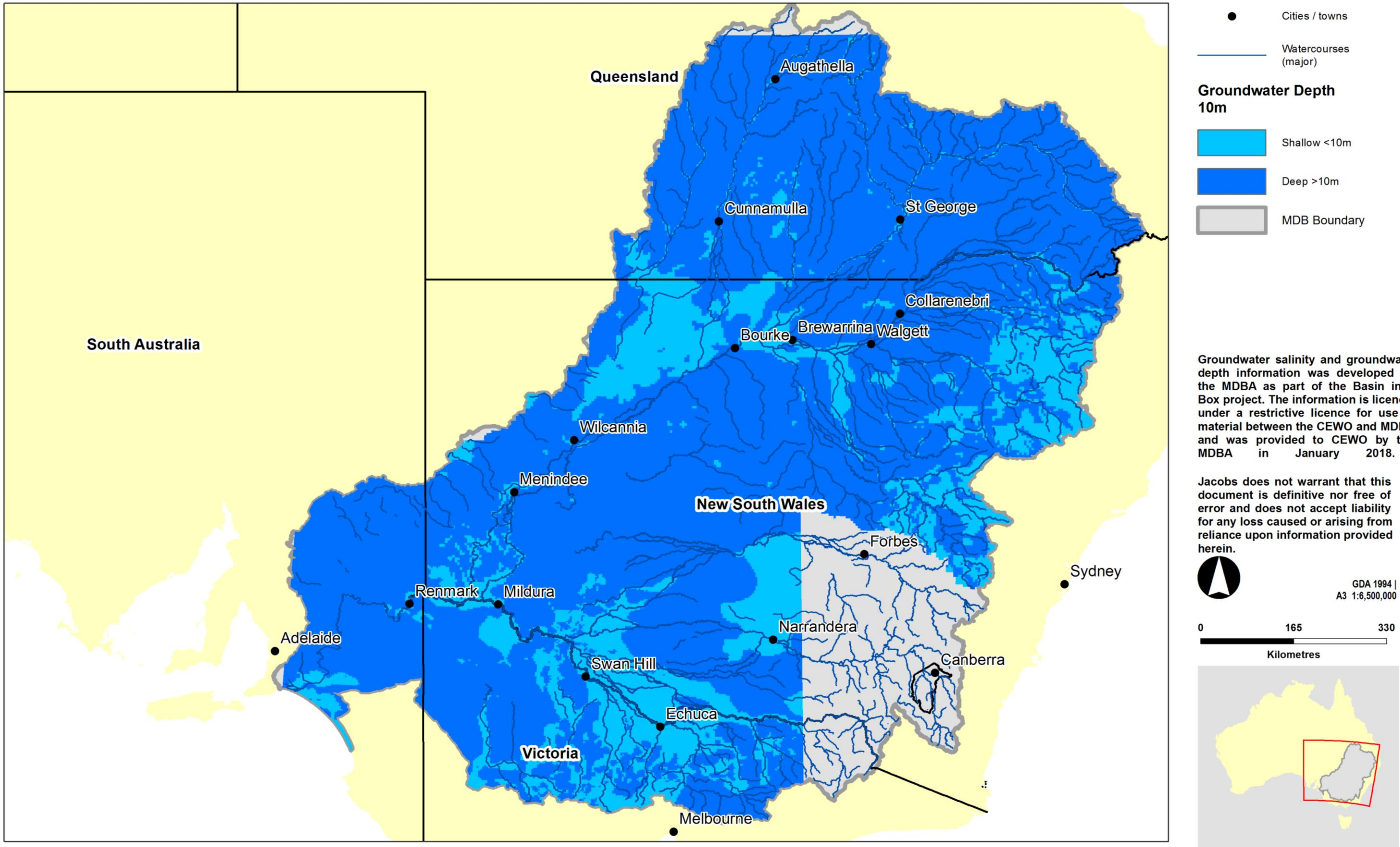

Figure 5-14: Groundwater depth: basin scale

Overlaying the groundwater depth with the extent of Black Box vegetation throughout the Basin provides an analysis of which areas of Black Box are in areas of shallow or deep groundwater. When paired with groundwater salinity and flooding frequency information, the groundwater depth contributes to understanding of whether Black Box are likely to be stressed.

Table 5-8 and Figure 5-15 provide the proportion of Black Box throughout the Basin that are:

- In areas of shallow groundwater (<10m). If the groundwater is shallow and saline, the Black Box is considered to be at risk from salinity. However, if the groundwater is not saline, there is no risk posed as the groundwater can provide a viable water source.
- In areas of deep groundwater (>10m). If the groundwater is deep and the Black Box is also in areas of flooding stress, then the Black Box will be at risk.

Additional maps showing a greater level of detail in selected areas of the Murray and Darling river systems are provided in Appendix M.

Table 5-8: Proportion of Black Box in areas of shallow and deep groundwater

Basin Plan Regions	Black Box in areas of shallow (<10m) groundwater		Black Box in areas of deep (>10m) groundwater		Missing data	
	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%
Barwon-Darling	21,570	35%	40,280	65%	0	0%
Moonie	0	0%	8,390	100%	0	0%
Campaspe	310	97%	10	3%	0	0%
Macquarie-Castlereagh	121,380	65%	65,840	35%	0	0%
Lachlan	17,090	22%	54,570	70%	6,820	9%
Eastern Mt Lofty Ranges	120	31%	270	69%	0	0%
Murrumbidgee	39,320	52%	35,870	48%	270	0%
Loddon	5,560	98%	120	2%	0	0%
Lower Darling	139,640	66%	70,680	34%	0	0%
Gwydir	260	3%	9,560	97%	0	0%
Border Rivers	900	8%	10,410	92%	0	0%
Namoi	3,940	34%	7,640	66%	0	0%
Murray	197,700	85%	33,750	15%	520	0%
Condamine-Balonne	45,500	17%	228,310	83%	0	0%
Paroo	25,610	54%	21,800	46%	0	0%
Warrego	40,820	24%	126,180	76%	0	0%
Wimmera-Avoca	8,960	76%	2,810	24%	0	0%
Goulburn-Broken	3,730	83%	760	17%	0	0%
Ovens	140	67%	70	33%	0	0%
TOTAL BASIN	672,560	**48%**	717,330	**51%**	7,600	**1%**

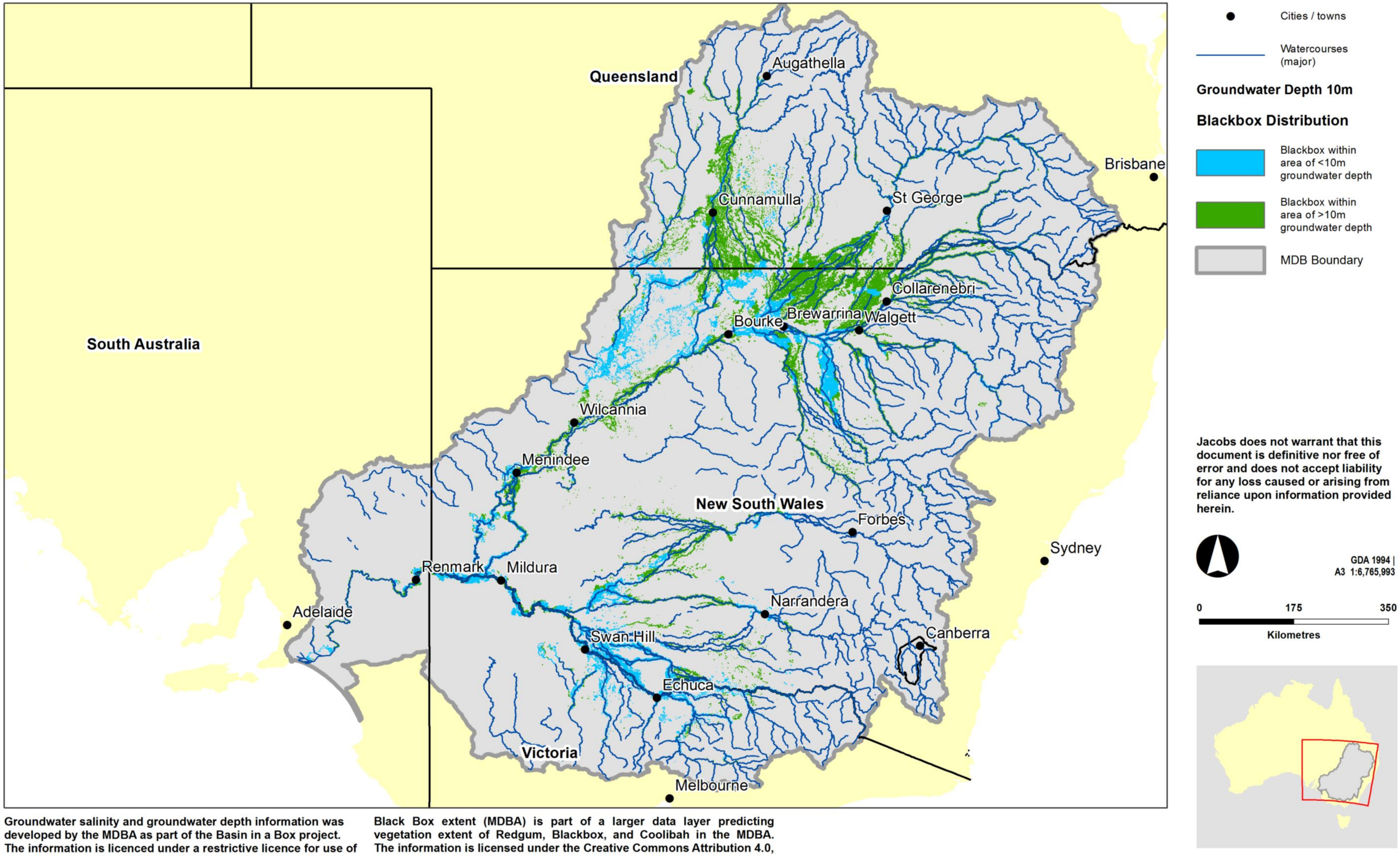

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Figure 5-15: Groundwater depth and Black Box: basin scale

5.3.1.3 Black Box Vulnerability Assessment

Through combining the analysis of stressors at the Basin Scale (refer 5.3.1.2), an assessment of the overall vulnerability of Black Box throughout the Basin can be made. The approach taken follows the rapid assessment method described in chapter 3.7. Basin wide datasets for flooding frequency, groundwater depth and groundwater salinity were available to develop a map of exposure thresholds using the known threshold limits. The available Black Box condition data did not cover the whole basin; however, an improved version could be used in future refinements of the vulnerability assessment. Resilience factors such as connectivity and space to establish in new favourable conditions was also not available at the basin scale. Therefore, the vulnerability assessment was modified to be purely based on exposure thresholds (Figure 5-16). Although this provides a useful reference at the basin scale, it can be considered to have a “Low” level of confidence due to lack of data availability. Improved confidence in the basin scale vulnerability assessment could be achieved following the development of a basin wide condition map, and once the space to recruit is modelled.

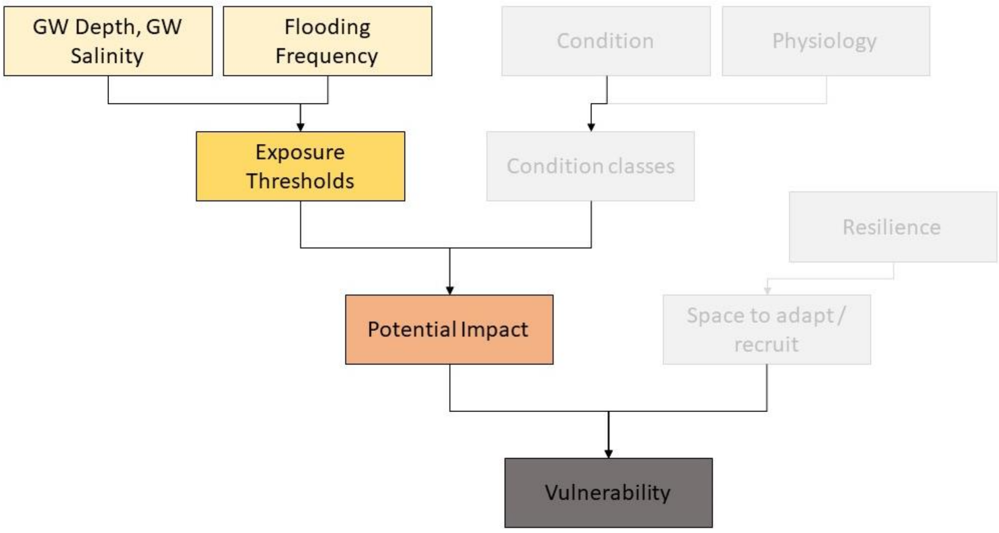


Figure 5-16: Components of the vulnerability assessment for Basin scale.

Vulnerability maps were produced by combining the GIS information on flood frequency, groundwater salinity and groundwater depth based on the rules outlined in Table 5-9. Figure 5-17 shows the vulnerability map for the Basin, while additional maps showing a greater level of detail in selected areas of the Murray and Darling systems are provided in Appendix M.

Areas of vulnerable Black Box vegetation throughout the Basin are summarised in Table 5-10 and Table 5-11.

Table 5-9: Conditions for vulnerability assessment at the Basin Scale

Salinity >35,000mg/L (saline) or <35,000mg/L (fresh)	Depth <10m (shallow) or >10m (deep)	Flooding Frequency >1 in 10 (infrequent) or <1 in 10 (frequent)	Risk
Saline	Shallow	Infrequent	At Risk
Saline	Shallow	Frequent	At Risk
Saline	Deep	Infrequent	At Risk
Saline	Deep	Frequent	Not at Risk
Fresh	Shallow	Infrequent	Not at Risk

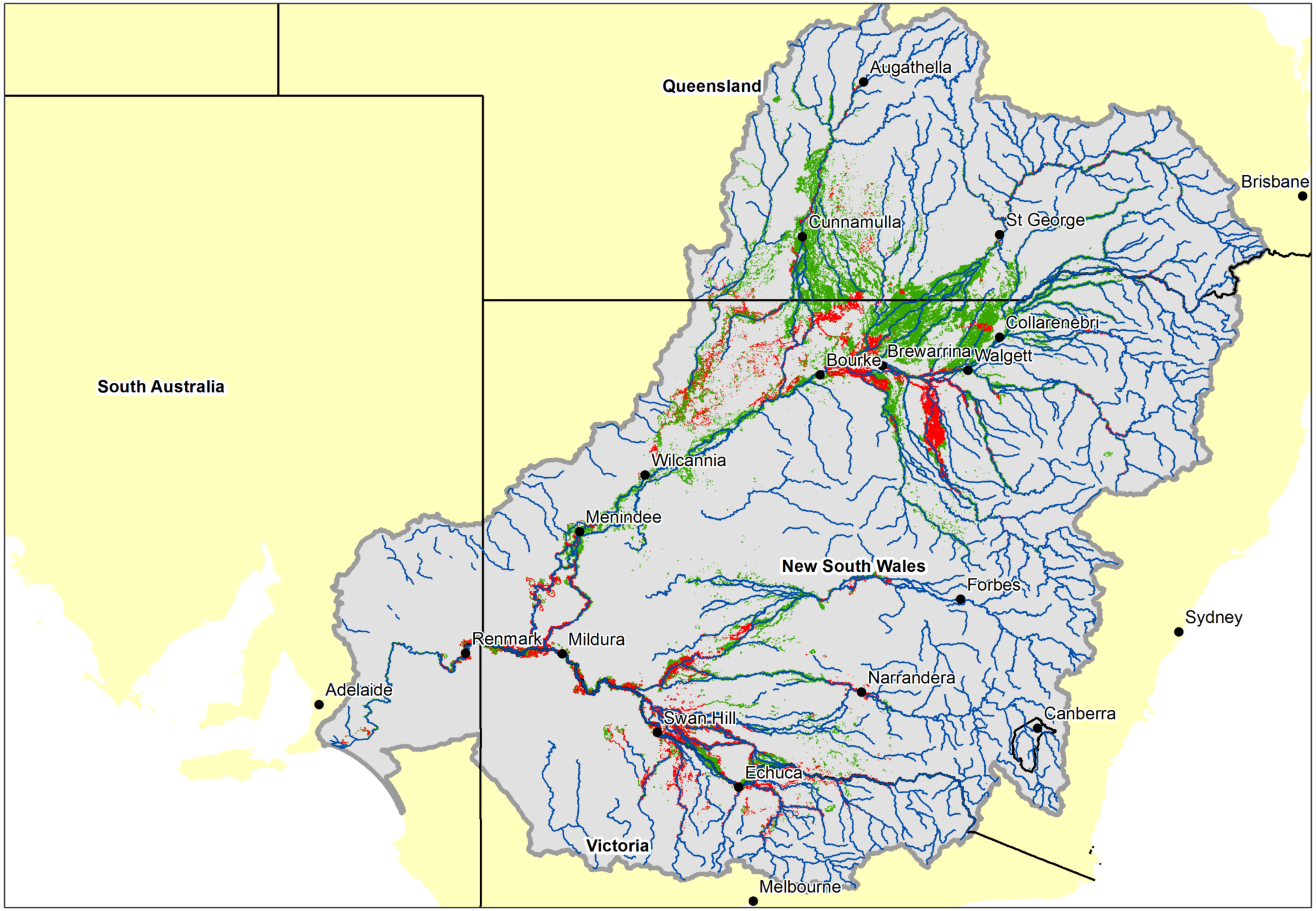
Salinity >35,000mg/L (saline) or <35,000mg/L (fresh)	Depth <10m (shallow) or >10m (deep)	Flooding Frequency >1 in 10 (infrequent) or <1 in 10 (frequent)	Risk
Fresh	Shallow	Frequent	Not at Risk
Fresh	Deep	Infrequent	At Risk
Fresh	Deep	Frequent	Not at Risk

Table 5-10: Areas of vulnerable Black Box throughout the Basin

Combination of Stressors	Area (Ha)	%	Risk
Fresh, Deep, >1in10	461,025	33%	Total at Risk: 37%
Saline, Deep, >1in10	38,444	3%	
Saline, Shallow, >1in10	7,139	1%	
Saline, Shallow, <1in10	9,290	1%	
Fresh, Shallow >1in10	478,908	34%	Total not at Risk: 63%
Fresh, Deep, <1in10	162,328	12%	
Fresh, Shallow <1in10	221,852	16%	
Saline, Deep, <1in10	10,440	1%	

Table 5-11: Proportion of Black Box throughout the Basin that is vulnerable (due to any combination of the stressors above)

Basin Plan Regions	Areas of Vulnerable Black Box		Areas of Not Vulnerable Black Box		Missing data	
	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%
Barwon-Darling	8,900	14%	52,960	86%	0	0%
Moonie	0	0%	8,390	100%	0	0%
Campaspe	290	94%	20	6%	0	0%
Macquarie-Castlereagh	118,230	63%	68,990	37%	0	0%
Lachlan	17,020	22%	54,620	70%	6,830	9%
Eastern Mt Lofty Ranges	90	23%	290	74%	10	3%
Murrumbidgee	30,630	41%	44,540	59%	280	0%
Loddon	5,220	92%	460	8%	0	0%
Lower Darling	122,090	58%	88,230	42%	0	0%
Gwydir	240	2%	9,570	98%	0	0%
Border Rivers	760	7%	10,550	93%	0	0%
Namoi	2,760	24%	8,820	76%	0	0%
Murray	140,640	61%	90,660	39%	670	0%
Condamine-Balonne	24,700	9%	249,110	91%	0	0%
Paroo	5,340	11%	42,070	89%	10	0%
Warrego	28,810	17%	138,190	83%	0	0%
Wimmera-Avoca	7,440	63%	4,330	37%	0	0%
Goulburn-Broken	2,600	58%	1,640	37%	250	6%
Ovens	130	62%	80	38%	0	0%
TOTAL BASIN	515,900	**37%**	873,530	**63%**	8,070	**1%**



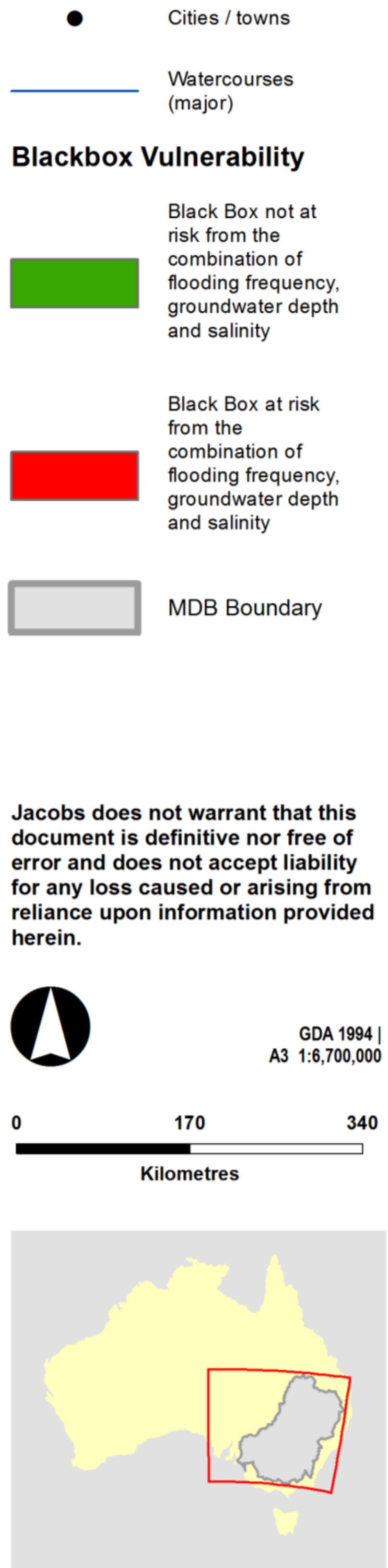


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Figure 5-17: Vulnerability of Black Box: basin scale

5.3.1.4 Black Box Do-nothing Scenario

In a similar method to that used in the site investigation (Chapter 3.7.2) it is useful to consider a ‘do-nothing’ scenario for Black Box condition across the Basin. This not only considers the maintenance or decline in Black Box communities because of continuing pressure from known stressors, but it should also consider the impacts of climate change. Impacts of climate change can be:

- Lower or higher, or variability of rainfall;
- Increase or decrease in the magnitude and frequency of flooding events; and
- Increases in temperatures which drives evapotranspiration and evaporation from water bodies.

Overton *et al.* (2009) used flow predictions from the CSIRO Murray-Darling Basin Sustainable Yields project to predict flooding regimes in the Murray-Darling Basin. A 1 in 10 flood return internal was used as a regime that Black Box would respond to. The areas that are marked historic in Figure 5-18 show those parts of the floodplain that used to have a 1 in 10 return period and no longer have this flooding frequency, indicating that they are likely to be exhibiting drought stress. Those marked as current still have this flooding frequency but are predicted to not have this in the future. The areas marked as future are predicted to maintain a 1 in 10 inundation regime. An additional map showing a greater level of detail in an area of the Murray is provided in Appendix M.

This future prediction map is another way at considering vulnerability into the future. A do-nothing map of Black Box condition would have all areas outside of the “future” class as dead in the future, as they would have inundation less frequently than once every 10 years.

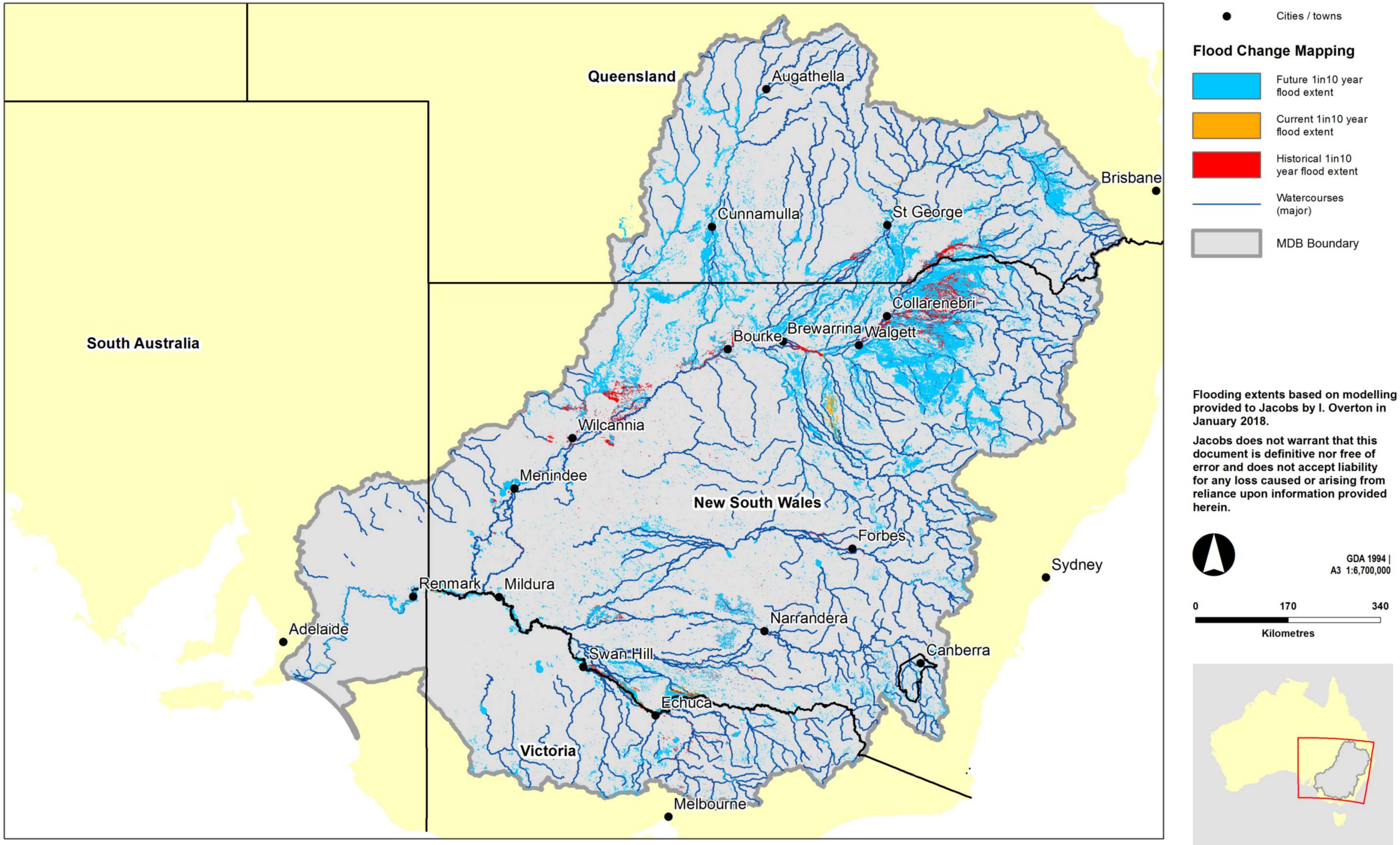

Figure 5-18: Flood change map for the Murray-Darling Basin under historical, current and future modelled climate scenarios for a 1 in 10 year flood regime (Overton *et al.*, 2009).

5.3.1.5 Management Objectives and Targets

This section outlines the desired outcomes that are specified in the BWS (MDBA, 2014) for Black Box vegetation.

The BWS was established under the Basin Plan and includes quantitative environmental outcomes designed to guide environmental water planning to achieve the longer-term objectives for Black Box, as well as specific outcomes for each Water Resource Planning area (i.e. regions shown on Figure 5-8). These outcomes are:

1) maintain the current extent of 409,000 ha of Black Box
2) no decline in the condition of lowland floodplain forests and woodlands across the Basin for Black Box
3) by 2024, improved recruitment for Black Box.

The BWS outlines several strategies to achieve these outcomes, including overbank river flow events at appropriate frequencies, timing and duration to support the character of water dependent vegetation on the managed floodplain as well as for other regionally significant sites. Other strategies necessary to complement overbank watering events to specifically address the key stressors of Black Box, including, infrastructure built on the floodplain, flow augmentation, groundwater manipulation, weir pool manipulation, and salt interception scheme operations.

5.3.1.6 Prioritising Investments Across the Basin

Figure 5-19 shows how the Framework is used to support resource prioritisation decisions across the basin. The components are:

- Consider basin scale objectives
- Consider basin scale assessment of condition and vulnerability
- Consider available resources including financial, political and environmental water availability
- The range of site plans submitted for consideration of financial and environmental water investment.

These four aspects could be integrated to determine a priority list of site investments. The first three aspects can also be used to determine a priority list separate to the development of submitted site proposals, for strategic investment to achieve basin wide objectives.

The method used for the prioritisation of resources is the responsibility of those accountable for the decision-making, however the principles of this Framework provide for evidence-based approach to resource investment in Black Box outcomes.

The use of the Framework for the assessment of investment proposals will allow direct comparison in terms of potential impact, urgency and confidence of the proposal.

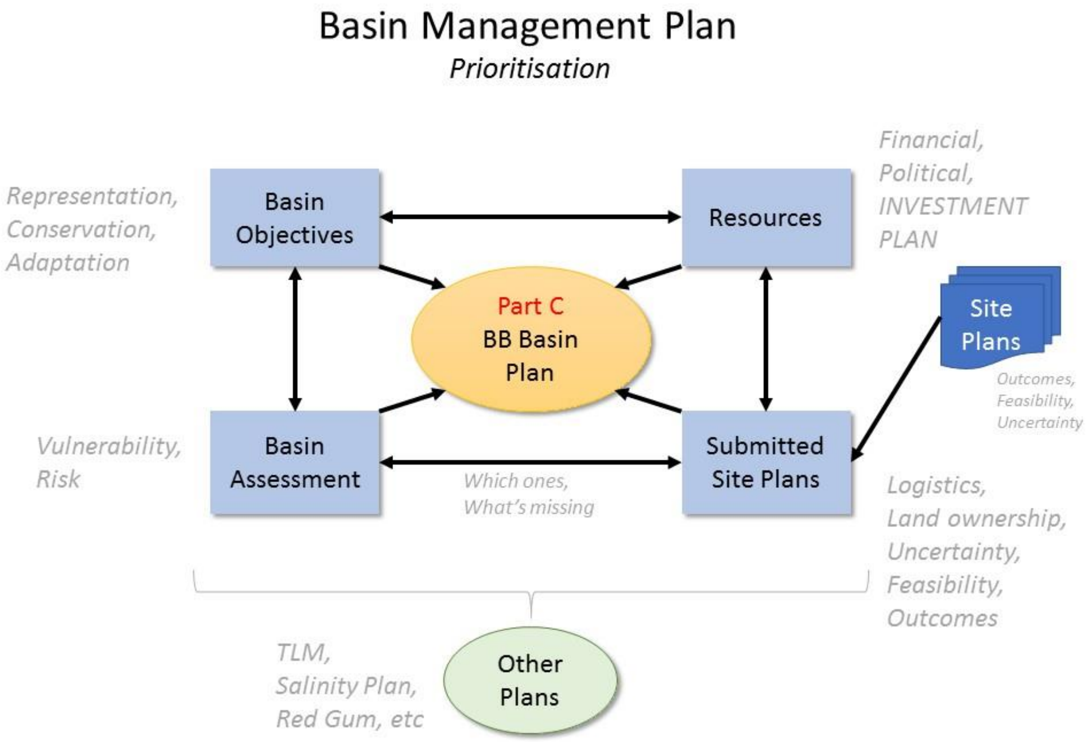

Figure 5-19: Black Box Management Framework – Prioritising Investments

5.3.1.7 Basin Wide Monitoring

Tracking the condition of Black Box under the Basin Plan's implementation is crucial for understanding whether expected environmental outcomes are being achieved. An analysis of progress against Black Box outcomes in the context of the management applied will also inform any adjustments needed to maximise environmental benefits. The program for monitoring and evaluation of Black Box condition at the Basin scale is outlined in Chapter 13 of the Basin Plan.

A summary of the various monitoring activities, and the parties involved in delivering these is provided in Table 5-12**.** This is not intended as a prescriptive or comprehensive list of roles, but rather to give an indication of the areas in which parties are involved.

Table 5-12: Involvement of stakeholders in measuring outcomes of environmental watering at different scales

Party	Involved with	Scale
MDBA	▪ analysis of Basin Scale outcomes and reporting of achievement of environmental objectives of the Basin Plan and associated strategies at a Basin Scale ▪ monitoring and evaluation at The Living Murray icon sites	Basin
Environmental water holders	▪ account for volume and use of environmental water to achieve environmental objectives set by the Basin Plan ▪ ecological monitoring and evaluation for selected water delivery areas; inferring the effects of watering actions in other parts of the Basin	Basin and sites
States	▪ condition and intervention monitoring at the asset scale ▪ reporting on the achievement of environmental objectives of the Basin Plan at the asset scale	Sites
Local government / natural resource management bodies	▪ collection of data used by state and commonwealth reporting agencies	Sites

This framework does not prescribe an approach to monitoring and evaluation for practitioners, rather it suggests adopting appropriate monitoring and evaluation to reduce uncertainty and better inform management decisions, and where possible, to use accepted methods that are commonly used at the site or within the broader region (thereby potentially improving the power of analyses between sites in a region). The confidence assessment process described throughout the Framework provides a guide for how evaluation and collection of new information can build confidence in decision making.

Information reported by a practitioner for a site in the short, medium and long term will contribute ultimately to the periodic Basin scale evaluation of progress against the Black Box objectives of the BWS.

5.4 Principles for Management of Black Box

The decline in Black Box populations has occurred over many decades, influencing hydro-geological processes that take comparatively similar timeframes to reverse the current trajectory in the observable ecological condition. This section presents the principles and high-level strategies for targeting the long-term outcomes of the Basin-wide environmental watering strategy. These represent the outcomes of the analysis conducted for both the regional/reach and basin scales.

Principles for targeting Black Box outcomes:

- Environmental water is likely to be effective where there are viable Black Box trees identified as “flow” stressed”, but less effective where the floodplain is subject to salinity stress.
- The achievement of sustainable outcomes for Black Box populations is dependent on complementary land and water management interventions.
- The recovery of Black Box populations requires multi-year commitments of sustained intervention to achieve long term Black Box outcomes.

Environmental watering provides one management strategy that can be applied to improve the condition of Black Box vegetation. As outlined in section 5.3.1.2, 13% of the Black Box throughout the Basin is within the 1 in 2-year flooding frequency, 16% is between the 1 in 2 and 1 in 10-year flooding frequency, and 71% is outside the 1 in 10 flooding frequency zone.

Strategies for achieving outcomes for the 13% of Black Box vegetation which is within the 1 in 2-year flooding frequency, and hence is not considered flow stressed, include:

1. Where there is low salinity and low flow stress has been identified, promoting management strategies that reduce grazing pressure or other land degradation is expected to enhance the condition of Black Box.
2. In areas where salinity stress but low flow stress is determined, implementing complementary management interventions targeting salinity and groundwater processes is required to ensure the long-term effectiveness of environmental watering actions and sustainability of Black Box populations.

Strategies for achieving outcomes for the 16% of Black Box vegetation which is between the 1 in 2-year flooding frequency and the 1 in 10-year flooding frequency, and hence is not considered flow stressed, include:

1. Where low salinity and low flow stress has been identified, promoting management strategies that reduce grazing pressure or other land degradation is expected to enhance the condition of Black Box.
2. Implementing management interventions targeting salinity and groundwater processes is required to address areas identified under salinity stress but with low flow stress. Since these areas are not considered to be readily managed through weir raising, channel modification or small environmental pumping actions due to their distance from the main River channel, alternative management measures that increase recharge and promote lower salinity water available in the unsaturated soil should be considered.

Strategies for achieving outcomes for the 71% of Black Box vegetation which is outside the 1 in 10-year flooding frequency, and hence is considered flow stressed, include:

1. Where low salinity and low flow stress has been identified, promoting appropriate land management strategies is required to maintain the existing Black Box populations. On-going monitoring should be conducted to determine trends in condition, changes in the exposure to stressors and justify additional options as required.

2. Where both high salinity and flow stress has been identified, **both** environmental watering and complimentary salinity management options are needed to provide effective and sustainable management of Black Box.

The spatial analysis presented in this Framework identifies the Basin Plan regions of Macquarie-Castlereagh, Lower Darling, and Murray have the largest areas of vulnerable Black Box vegetation, and therefore strategies that seek specifically to mitigate this vulnerability should be considered. Environmental water management will be a key management option in these regions, however to be effective complementary options to address salinity stressors is required.

Implementing the strategies require a multi-year management commitment to see improvement in Black Box condition.

The need for complementary/alternative management options will be critical to realising long term outcomes for Black Box vegetation particularly for the large proportion (>85 percent) of the Black Box that is outside the area of the floodplain that can readily be influenced by environmental water ('managed floodplain'). Examples of alternative or complimentary strategies that could be implemented in an integrated way across larger scales (i.e. not just site based) include:

- environmental flow augmentation via additional floodplain infrastructure
- enhancing the effectiveness of rainfall on the floodplain (e.g. by constructing bunds to retard runoff and pool water)
- salt interception schemes (SIS) - whilst originally developed to manage instream salinity, changes in the operations of existing SIS may present an opportunity to provide enhanced benefits for some floodplain vegetation
- groundwater manipulations e.g. recharge galleries, managed aquifer recharge (high value assets), etc.
- reduced grazing pressure from native, feral and agricultural animals (e.g. native animal management, sustainable sheep and cattle stocking rates, at a regional scale).
- management of recreation and other activities such as land clearing, fragmentation, cropping and irrigation across the floodplain (via state and regional planning processes).

6. Conclusion

This Black Box Management Framework was developed to *"assist practitioners in the assessment, planning and implementation of management practices, working towards sustainable ecological outcomes for the condition and extent of Black Box."*

The Framework has presented a broad, adaptable set of processes, tools and management options that can be applied to Black Box growing on the floodplain and near wetlands. The Framework provides a guided decision-making process to support the achievement of the ecological outcomes for Black Box, with advice on how to:

- Assess the need for management through an assessment of vegetation condition and vulnerability. This is developed by conducting a site investigation, to provide an evidence base for the understanding of stressors and management objectives (Part A).
- Develop a range of management options available at a site. This requires gathering and synthesising information through a combination of field and desktop research (Part A).
- Develop a Site Management Plan, which involves prioritisation of management options for a site through considering the vulnerability and the feasibility of various management actions to meet site objectives, available resources, and assessment of risks and benefits (Part B).
- Prioritise management actions across the Basin through transparent and evidence-based assessment, including the assessment of site scale plans in consideration of the Basin objectives, available resources, and the Black Box vulnerability across the Basin (Part C).

A series of further resources are provided in Part D to assist the practitioner in applying the Framework.

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PART D: RESOURCES

Appendix A. Resources

This appendix provides a summary of references and materials which may be of use to practitioners in understanding more about Black Box science and management.

Assessing Black Box Condition

Reference	Description
Overton, I.C., Boyd, A. and Coff, B. (2017). Site Investigation for Black Box at Calperum Station South Australia: Trial Implementation of the Draft Black Box Management Framework. Report prepared by Jacobs Pty Ltd for the Commonwealth Environmental Water Office, Adelaide, South Australia.	Case study of the Framework at the Calperum floodplain, South Australia.
Souter, N, Cunningham, S, Little, S, Wallace, McCarthy, B, Henderson, M and Bennets, K, 2010, Ground-based survey methods for The Living Murray assessment of condition of river red gum and black box populations; Version 12, Murray-Darling Basin Authority.	Provides a description of the TLM Black Box tree and stand condition assessment methodology
Overton IC (2013) Methods to Assess Environmental Flow and Groundwater Management Scenarios for Floodplain Tree Health in the Lower River Murray. PhD Thesis, Department of Soil and Water, University of Adelaide. pp. 355.	Provides a range of methods to map Black Box condition on the Chowilla floodplain, South Australia

Assessing Black Box Stressors

Reference	Description
Overton IC, Jolly ID, Slavich PG, Lewis MM and Walker GR (2006) Modelling Vegetation Health from the Interaction of Saline Groundwater and Flooding on the Chowilla Floodplain, South Australia. Australian Journal of Botany, 54(2): 207-220.	Describes decline in floodplain vegetation at Chowilla as a result of salinisation of floodplain soils. Provides modelling of groundwater depth, groundwater salinity, soil type and flooding to recommend management options for improved health of floodplain vegetation.
Overton IC, Doody TM and Siggins A (2008) Salt Accumulation and Tree Vegetation Response to Surface Water–Groundwater Interactions in the Mallee Region of the Lower River Murray. CSIRO Water for a Healthy Country Interim Report prepared for the Victorian Mallee Catchment Management Authority and the New South Wales Lower Murray-Darling Catchment Management Authority.	
Doody TM and Overton IC (2008) Riparian Vegetation Changes from Hydrological Alteration on the River Murray, Australia – Modelling the Surface Water-Groundwater Dependent Ecosystem. In: 'From Headwaters to the Ocean – Hydrological Changes and Watershed Management'. Eds: Taniguchi M, Burnett WC, Fukishima Y, Haigh M and Umezawa Y. Taylor and Frances Group, London, England. pp 395-400.	Describes the tools available for modelling floodplain vegetation health and discusses management options to conserve floodplain health.
Doody TM, Llewelyn A, Pritchard JL, Overton IC and Holland KL (2016) Influence of Environmental Water on Black Box (Eucalyptus largiflorens). Report for the South Australian Murray-Darling Basin Natural Resource Management Board.	
Doody TM and Overton IC (2008) Tree Health Assessment of the Gol Gol Lake, Swamp and Creek: River Murray Floodplain, Mildura. CSIRO Water for a Healthy Country Technical Report prepared for the New South Wales	

Reference	Description
Lower Murray-Darling Catchment Management Authority.	
Overton IC (2013) Methods to Assess Environmental Flow and Groundwater Management Scenarios for Floodplain Tree Health in the Lower River Murray. PhD Thesis, Department of Soil and Water, University of Adelaide. pp. 355.	Investigates the major causes of floodplain tree decline and develops methods for predicting the spatial impacts on floodplain tree health from a range of management scenarios. Addresses surface water and groundwater changes at the regional scale of the lower River Murray.

Developing Management Objectives and Targets

Reference	Description
Murray-Darling Basin Authority (MDBA), 2014, Basin-wide environmental watering strategy, MDBA on behalf of the Commonwealth of Australia, Canberra, ACT.	Provides the basin scale objectives and targets for Black Box, as well as other Basin indicators such as red gum, fish, birds https://www.mdba.gov.au/sites/default/files/pubs/Final-BWS-Nov14_0816.pdf
Johns C, Reid CJ, Roberts J, Sims N, Doody TM, Overton IC, McGinness H, Rogers K, Campbell C and Gawne B (2009) Native Trees of the River Murray floodplain: Literature Review and Experimental Designs to Examine Effects of Flow Enhancement and Floodwater Retention. Report prepared for the Murray-Darling Basin Authority by the Murray-Darling Freshwater Research Centre.	Reviews the effects that management interventions (particularly flow enhancement and retaining water on floodplains) will have on creation and maintenance of habitat suitable for germination, growth, health, and recruitment of native trees and weed species.
Overton IC and Jolly ID (2004) Integrated Studies of Floodplain Vegetation Health, Saline Groundwater and Flooding on the Chowilla Floodplain South Australia. CSIRO Division of Land and Water, Technical Report No. 20/04. pp.169.	Describes options for environmental flow management and groundwater manipulation in addressing issues of the health of native floodplain vegetation and salt loads to the river. Describes various modelling techniques to determine soil salinisation processes and its impact on vegetation health and predicts impacts from future scenarios on vegetation health.
Overton IC (2013) Methods to Assess Environmental Flow and Groundwater Management Scenarios for Floodplain Tree Health in the Lower River Murray. PhD Thesis, Department of Soil and Water, University of Adelaide. pp. 355.	As above
Clarke, I. Stokes, Z. and Wallace, R., 2010, Habitat Restoration Planning Guide for Natural Resource Managers, Government of South Australia, through Department of Environment and Natural Resources, Adelaide	Provides description of SMART goals, for habitat restoration projects. This information can be applied to developing objectives and targets for Black Box management.

Developing Management Options

Reference	Description
Overton IC, Slarke S and Middlemis H (2006) Chowilla Management Options. Report prepared for the South Australian Department of Water, Land and Biodiversity by URS Pty Ltd, CSIRO Land and Water and Aquaterra Pty Ltd. pp. 141.	Provides a range of management options, design and costings for a lower River Murray floodplain
Overton IC and Jolly ID (2008) Vegetation Health Predictions from Management Options on the Murtho, Pike, Gurra and Bookpurnong Floodplains, River Murray. CSIRO Water for a Healthy Country Technical Report prepared for the South Australian Department of Water, Land and Biodiversity Conservation.	Provides health assessment outcomes from a range of management options in the lower River Murray
Roberts J and Marston F (2011). Water regime for wetland and floodplain plants: a source book for the Murray–Darling Basin, National Water Commission, Canberra.	A source book which presents information on how water regimes affect the growth, survival and capacity for

Reference	Description
	reproduction of wetland and floodplain plants in the Murray Darling Basin.

Prioritising Management Options

Reference	Description
Overton IC, Freebairn A, Joehnk K, Mirza F, Barma D, Rahman J, Eaton JD, Gibbs M, Fuller JA, Sims CL, Turnadge C, Cuddy S, Pritchard J, Penton D, Podger G, Blakers RS, Woods JA, Gao L and Adams G (2016) River Murray Decision Support System: Prototype, Goyder Institute for Water Research Technical Report Series No. 16/x, Adelaide, South Australia.	Describes a decision support system for analysing and prioritising management scenarios for the River Murray.
Overton IC and Doody TM (2007) Flooding Frequency and Vegetation Health Relationships for Environmental Flows in the River Murray in Victoria. CSIRO Water for a Healthy Country Technical Report prepared for the Victorian Environmental Assessment Council.	A flood index has been developed annually for the whole floodplain which scores the number of 'natural return periods' since the last flood. This has been linked to vegetation decline and risk to areas of floodplain vegetation.
Richardson S, Haworth D, Overton IC and Pritchard J (2007) Summary of Floodplain Processes and Possible Changes to Groundwater Conditions and Salt Loads Associated with Floodplain Flow Options. Report prepared for the Mallee Catchment Management Authority by REM Pty Ltd.	Summary of processes and management options
Overton IC (2013) Methods to Assess Environmental Flow and Groundwater Management Scenarios for Floodplain Tree Health in the Lower River Murray. PhD Thesis, Department of Soil and Water, University of Adelaide. pp. 355.	Tree health processes and management options on the River Murray floodplain
Colloff MJ, Lavorel S, Wise RM, Dunlop M, Overton IC and Williams KJ (2015) Adaptation Services of Floodplains and Wetlands Under Climate Change. Ecological Applications 26(4): 1003-1017, DOI: 10.1890/1815-0848.1891.	Presents a case study from the Murray-Darling Basin, for operationalizing the adaptation services concept for floodplains and wetlands, predicting large changes to floodplain ecosystems as a result of climate change induced changes to flow and flood regimes.

Appendix B. A Summary of Black Box Needs, Stressors and Indicators

Table 7-1 summarises the needs of Black Box together with associated stressors and potential indicators. Elements of this table were compiled in the review by Casanova (2014), and this information has been provided with linked references to facilitate further investigation.

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Table 7-1: A summary of Black Box needs and example indicators

Attribute / function	Comments	Potential stressors	Potential indicators
Health and condition (mature trees)	▪ Trees take 20-30 years to reach maturity[7], management timelines for this species need to be longer. ▪ *For vigorous growth*; Flood frequency every 3 to 7 years, depth not critical, duration 3 to 6 months, timing probably not important (natural paradigm[2] should be followed if possible) ▪ *For recovery*; Following a flood in spring-summer additional moisture in first or second year likely to be beneficial ▪ *To maintain critical health*; Trees may survive 19 years without flooding, but will be in poor condition with diminished capacity to recover ▪ Water source for Black Box trees is soil moisture from the unsaturated zone[3] ▪ Water regime requirements to transition between condition states are complex. ▪ A soil salinity of 39,000mg/L, and a groundwater salinity of 22,000mg/L, which if exceeded result in the majority of trees (75 percent) being unhealthy[3]	▪ Water availability ▪ Soil salinisation ▪ Competition ▪ Herbivory / pathogens ▪ Land degradation processes (weeds, grazing, trampling, clearance) ▪ Land use / adjacent land use (e.g. agricultural grazing, irrigation)	▪ **Stand condition indicators** (canopy extent and canopy density). ▪ **Watering indicators** (e.g. soil moisture, frequency and duration of flooding events, rainfall, evapotranspiration, depth to groundwater, and distance from surface water sources). ▪ **Salinity indicators** (e.g. salinity of soil / groundwater) ▪ **Land degradation / competition indicators** (e.g. land clearance rates and areas, weed infestations, proximity to other Black Box units). ▪ **Land use indicators;** zoned land use for region
Reproduction (flowering, seed production, dispersal, germination)	▪ Can flower more than once a year in response to flooding, irrespective of the season although the amount of flowering / viability of seed is dependent on tree condition ▪ Timing of flowering and seed fall varies across the Basin; nominally August to January but has been reported May to October at Chowilla, SA[5] ▪ Capable of abundant flowering and high reproductive effort once restored to intermediate condtition[6] ▪ Seed production is dependent on tree condition and prior seasons watering ▪ Black Box seed is stored in the canopy for up to two years but what triggers capsule dehiscence is unknown[7] ▪ Peak release is summer[4] (southern Basin) ▪ Soil seed bank not generally formed[8] ▪ Seeds die if submerged for >10 days[9] ▪ Natural flooding events needed to trigger mass germination events[4,10], although this response not always consistently observed across the Basin[11].	▪ Water availability ▪ Soil salinisation ▪ Flooding regime (depth and duration, sediment / turbidity when seeds and seedlings present) ▪ Antecedent tree condition ▪ Temperature and Shading (seeds / seedlings) ▪ Soil oxygen / nutrients ▪ Herbivory / pathogens ▪ Land degradation processes (competition from weeds, grazing, trampling, clearance)	▪ **Stand Condition indicators** as described above (unlikely to respond unless classed as Intermediate or above) ▪ **Water indicators** as described above. ▪ **Land degradation / competition indicators**; particularly proximity to other Black Box units, grazing pressure (native and agricultural), weed infestations (type, density, invasiveness)

Attribute / function	Comments	Potential stressors	Potential indicators
	▪ More work required to understand the differences between natural and induced (anthropogenic) flooding events, and the mechanisms driving germination. Vulnerable to grazing[12]		
Seedling establishment / growth to sapling and pole stage	▪ Observed 'Goldilocks-zone' of ideal hydrological conditions (not too wet, not too dry) results in a naturally low mortality of seedlings[13] ▪ Soil moisture of 10-25 % appears to be critical for seedling survival[4] ▪ Intolerant of drought[14], but also slower growing when flooded to 5cm[15] ▪ Requires 85,000 ML/day^{-1} for successful recruitment at lower elevations, and >100,000 ML/day for successful recruitment at higher elevations on the floodplain[16] ▪ Slow growth rate due to low transpiration rates. ▪ Natural flooding events needed to trigger mass germination events[4,10], although this response not always consistently observed across the Basin[11] ▪ Seedling establishment rarely associated with induced flooding	▪ Water availability ▪ Flooding regime (depth and duration, sediment / turbidity when seeds and seedlings present) ▪ Temperature ▪ Shading (seedlings) ▪ Herbivory / pathogens ▪ Land degradation (grazing, trampling, competition from weeds)	▪ **Water indicators** as described above**;** ▪ **Land degradation / competition indicators;** particularly weed infestation (type, density, invasiveness), grazing pressure (native and agricultural) ▪ **Condition indicator;** herbivory / insect damage
Extent of Black Box population	▪ Difficult to further manage extent of Black Box directly, with protection of current extent (through conservation agreements and parks systems), prevention of loss (through clearance policies), and protection of significant communities (through listing under state and national Acts) controlled mostly through legislative policy and regulation. ▪ Assumption that if condition is managed, and protections are in place, that maintenance of Black Box extent will follow.	▪ Land degradation processes (edge effects, clearance, trampling, compaction, regional agriculture and irrigation) ▪ Competition ▪ Water availability ▪ Isolation / position on floodplain	▪ **Land degradation / competition indicators** (e.g. land clearance rates and areas, weed infestations (type, density, invasiveness), average Black Box unit size, proximity to other Black Box units). ▪ **Protection indicators**; (e.g. area of community under voluntary conservation agreements, area of community protected by parks system), ▪ **Water availability indicators** (e.g. inundation extent and frequency)

1 Represents best available knowledge in 2011, as described by Roberts and Marston (2000) and further summarised by Casanova (2014), from studies that are largely based in the southern Basin. 2 'Natural paradigm' refers to the unmodified, pre-European water regime. 3 AWE (2015) review. 4 Jensen *et al.* 2008b. 5 Roberts and Marston 2000. 6 Overton *et al.* 2014. 7 Casanova 2014. 8 Jensen *et al.* 2008a, 9 Jensen 2009. 10 Holland *et al*. 2013. 11 Capon and Balcombe 2015. 12 Duncan *et al.* 2007. 13 Doody and Overton 2012. 14 Lamontagne *et al.* 2012.

Appendix C. Rapid Black Box Condition Assessment

The following is the methodology for a rapid condition assessment that can be used when there is little previous knowledge about the condition of Black Box at a site. This methodology was developed as part of the Calperum Station Case Study, specifically with the purposes of the Framework in mind. This new condition assessment methodology was designed to support management planning and was driven by management actions affecting large areas. The methodology was also developed to be easy and quick to apply, allowing landholders to conduct surveys over large areas within reasonable timeframes.

The condition assessment methodology has been designed to allow landholders to identify and prioritise areas of Black Box which require immediate or long-term management. Although it can provide a simple method of monitoring, the classes are broad and are unlikely to appropriate to detect short term and small changes in condition from management actions. The assessment is conducted at a unit scale, as individual variability within Black Box units would not allow consistent management planning decisions. The method supports the identification of Black Box management units and possible management actions.

The rapid condition assessment methodology is comprised of the following elements:

- Condition class based on canopy cover and epicormic growth (growth of leaves on the tree trunks rather than on outer branches which is a response to water stress);
- Growth form based on height and trunk diameter; and
- Density, the number of trees per hectare in the management unit.

Further validation could be undertaken using:

- Condition verification via satellite imagery analysis, to support the field assessments of Black Box condition.

The final step is to map contiguous areas of Black Box that would all be affected in a similar way by broad management actions. These are designated as management units as they are areas that can be treated as a single unit for the purposes of condition assessment and management options.

Condition Class

Black Box management unit condition classes are assessed on the visual indicators outlined in Figure 7-1**.** Condition is assessed using a qualitative approach considering a combination of dieback, crown cover, and epicormic growth. Visual inspection is conducted at a unit scale, estimation of condition taking into consideration the overall condition within a unit. Examples of each condition class are shown below in Table 7-2**.**

Table 7-2: Black Box condition classification

Class	Description - Observed elements	Possible/recommended actions, considerations, management strategy
C1 – Good	>75% Canopy Cover, relatively non-stressed when compared to other black box	No action required, black box may be stressed but not in need of immediate attention
C2 – Medium	75-40% Canopy Cover, made up of original canopy and/or epicormic growth	Stressed black box - Monitoring recommended to determine condition trajectory (improve or decline), experimental watering to determine response to watering
C3 – Poor	<40% Canopy Cover, made up of original canopy and/or epicormic growth	Stressed black box in poor or critical condition, immediate action recommended
C4 – Dead	0% Canopy, tree is dead and will not recover	No watering action required, consider replanting action taking current stressors into consideration

C1 – Good

C2 - Medium

C3 – Poor

C4 - Dead

Figure

Figure 7-1: Black Box condition assessment. Top left: C1 Good - >75% original canopy; Top right: C2 Medium – 75-40% original canopy and/or strong epicormic growth; Bottom left: C3 Poor - <40% original canopy and/or small amount of epicormic growth; Bottom right: C4 Dead.

Growth Form

Growth form is indicative of a combination of nutrient and water availability, and age. Black Box are divided into three growth form classes of size, and by mallee or non-mallee form as shown in Table 7-3 and Figure 7-2. **Error! Reference source not found.**G1/2 are the largest and oldest while G4/5 are small to medium mature trees. Classes G1/3/5 are single stem while G2/4/6 are mallee form. Note that classes G5 and G6 describe recent saplings which have also been recorded as recruitment; black box units with the presence of recruitment are then mapped.

Table 7-3: Growth form classification

Class	Physical description	Comment
G1/G2	>3m tall >10cm trunk diameter at chest height	Oldest and largest trees on the property, likely established before 1950.
G3/G4	1.5m – 3m tall 3cm-10cm trunk diameter at chest height	Middle sized trees likely established between 100 to 20 years ago.
G5/G6	<1.5m tall <3cm trunk diameter	Established within the last 20 years, all trees observed in good condition unless effected by grazing.

Note: These height classes were developed on the Calperum Station in the lower River Murray. The class breaks may need to be changed for local conditions.

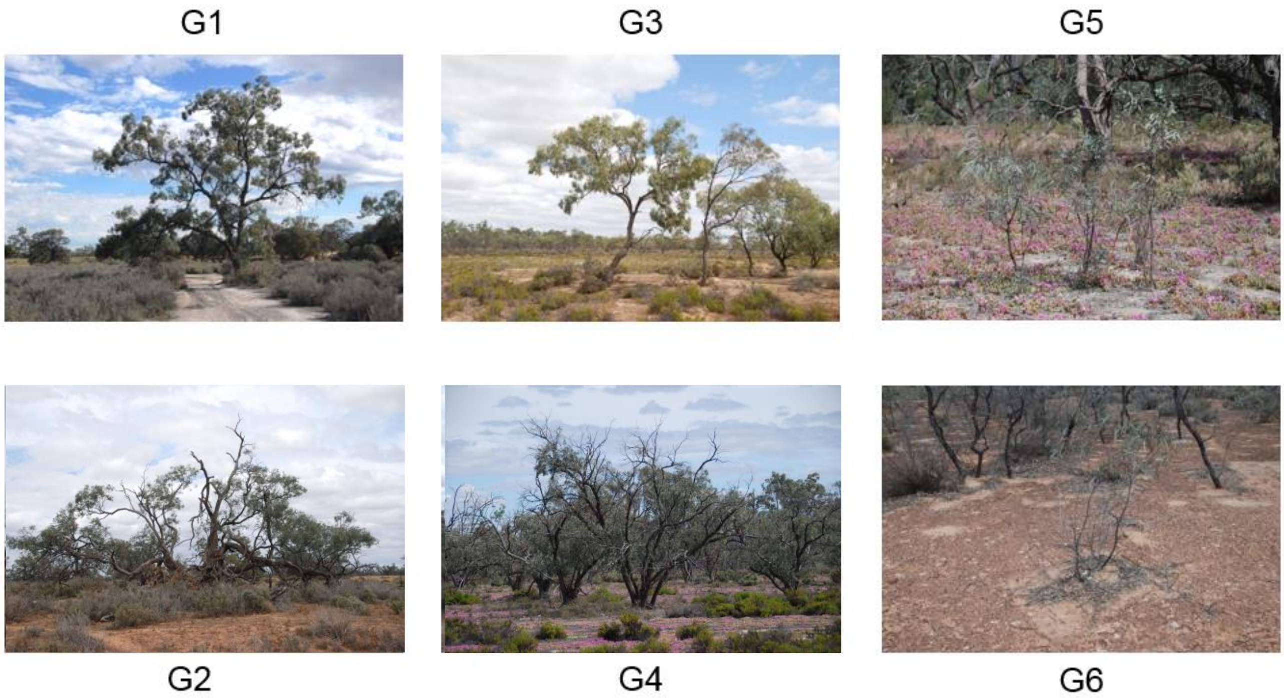


Figure 7-2: Examples of Black Box growth Form

Density

Density is indicative of resource availability of the unit area, or circumstances at time of recruitment and are mapped as per Table 7-4. Examples of density classes are shown in Figure 7-3. It is important to consider the benefit of management actions on sparse woodland as opposed to dense woodland, as fewer individuals can benefit from watering. Density classes were assigned to black box units using aerial imagery as part of the post-field survey digitisation of units.

Table 7-4: Density Classification

Density Class	Description
D1	>40 trees per hectare, Closed forest with canopies touching to open forest
D2	10-40 trees per hectare, Woodland to Open woodland
D3	<10 trees per hectare, Open/Sparse woodland and isolated trees

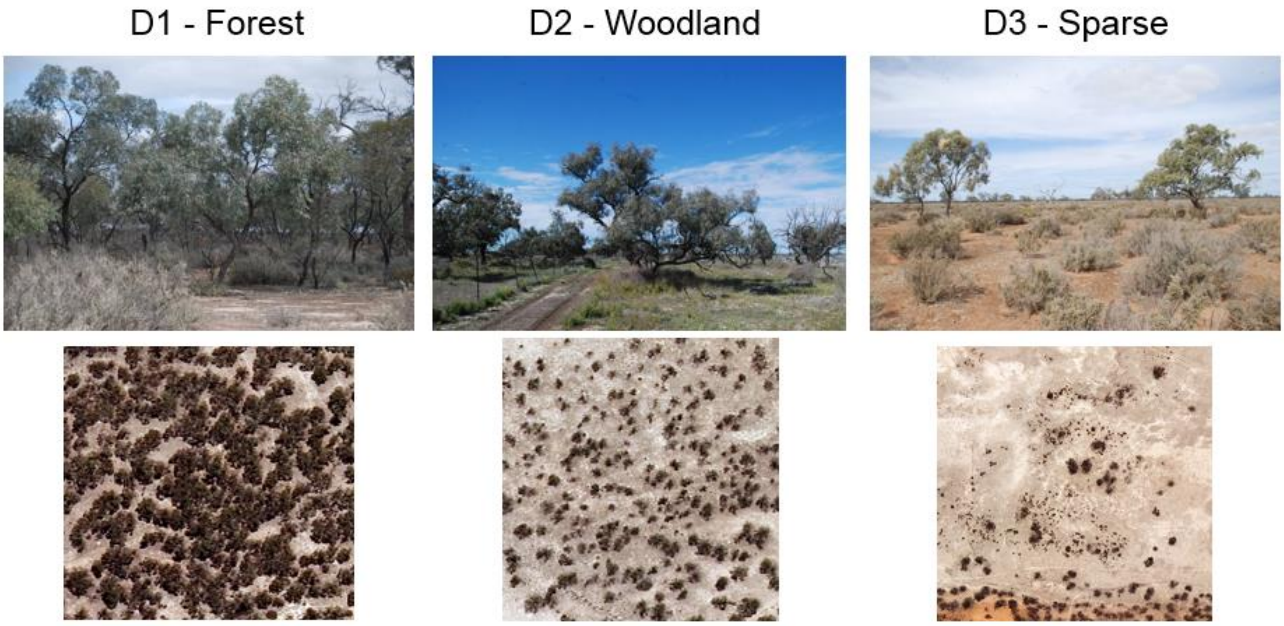


Figure 7-3: Examples of Black Box unit density with aerial imagery

Appendix D. The Living Murray Condition Assessment

The Living Murray (TLM) method, is widely employed across icon sites in the Basin and as such has a documented, tested monitoring and evaluation approach (Souter *et al.,* 2010). The TLM method is a detailed approach, which can be adopted in part or in full to provide indicators tailored to the objectives and targets of a project.

Souter *et al*. (2010) relate the direct TLM measures to stand and tree condition as shown in Figure B.1 and provide methodologies for the survey, analysis and generation of each indicator. For example, epicormic growth and new tip growth are indicators of recovery, whereas bark cracking and leaf die-off are indicators of decline. The balance of indicators of recovery with indicators of decline provides a condition trajectory; i.e. is the overall site in decline or improvement, but need to be interpreted with caution and consideration of when the survey was undertaken and or recent climatic events which may confound results (e.g. (i) peak leaf fall for eucalypts occurs in summer which can result in survey's returning lower scores if surveys are undertaken in summer v's spring, and (ii) crown can respond rapidly to episodic conditions such as heavy rain) Similarly, trees with crown that have a high representation of epicormic growth are a long way from being in "good" condition, and a substantial proportion of trees that generate epicormic growth in response to watering do not sustain the response (i.e. they don't successfully recover as a result, pers. comm. Todd Wallace, November 2016)) . Souter *et al.* (2010) describes an interpretation of the balance between indicators of recover and decline:

> *"Trees producing new tip growth suggest either maintenance in condition for healthy trees or recovery from stress and a possible future increase in condition (if suitable environmental conditions are maintained) in unhealthy trees. Trees producing epicormic growth suggest a recovery from stress and a possible future increase in condition (if suitable environmental conditions are maintained) in unhealthy trees. In contrast, trees that have leaves dying off, and/or deeply cracked bark may be under stress and may continue to decline in condition."*

Measures of Diameter at Breast Height (DBH) together with an assessment of the number of live/dead trees can be used to generate an indicator of percentage live basal area (LBA) per site. Representative hemispherical photos are used to generate the Plant Area Index (the area of leaves and stems per unit ground area). A measure of crown extent (or the percentage of assessable crown in which there are live leaves) is reported in alignment with scaled categories. A stand condition score (SCS) can then be calculated from the average score of the three condition indicators (plant condition index, live basal area and crown condition).

A recommended measure, as relevant to the achievement of the MDBA (2014) Environmental Watering outcome for improved Black Box recruitment, is gaining an understanding of the age class distribution of trees at any site. For the Black Box population to be sustainable, this distribution needs to cover all age classes including seedlings which are required to replace senescent trees and renew existing populations.

Noting that biophysical responses may be slow to occur and be detectable, surrogate physical measures may also be appropriate to indicate a trajectory of change linked to the abiotic conditions known to influence healthy Black Box condition. For example, these may include soil salinity, soil moisture availability, groundwater salinity, depth to groundwater etc. A response in these measures to an applied management regime would be expected to occur more rapidly than the ecological response that follows and could be used as a surrogate demonstrating a short-term change which is linked to the long-term restoration goals of the project. These indicators link to the operational objectives identified in Chapter 3.

Figure 7-4: TLM indicators of Black Box condition (Souter *et al.,* 2010)

Direct ecological indicators of Black Box stand condition:

- Average crown extent (percentage of the assessable crown in which there are live leaves)
- Crown density (amount of skylight blocked by the foliated portions of the crown)
- Diversity and distribution of age class (i.e. seedlings through to senescent trees).
  a. Ratio of live to dead Black Box on site
  b. Distribution of Diameter at Breast Height (DBH)
  c. Seedling counts
- Leaf condition:
  a. New tip growth
  b. Leaf-die off
  c. Dominance of epicormic growth
- Mistletoe dominance
- Insect damage (leaf and bark / trunk)
- Live Basal Area % for trees (i.e. with DBH ≥ 10 cm)

Direct ecological indicators of condition as relevant to reproductive fecundity:

- Flowering / seed-set frequency
- Seedling establishment
- Seedling / sapling growth rate

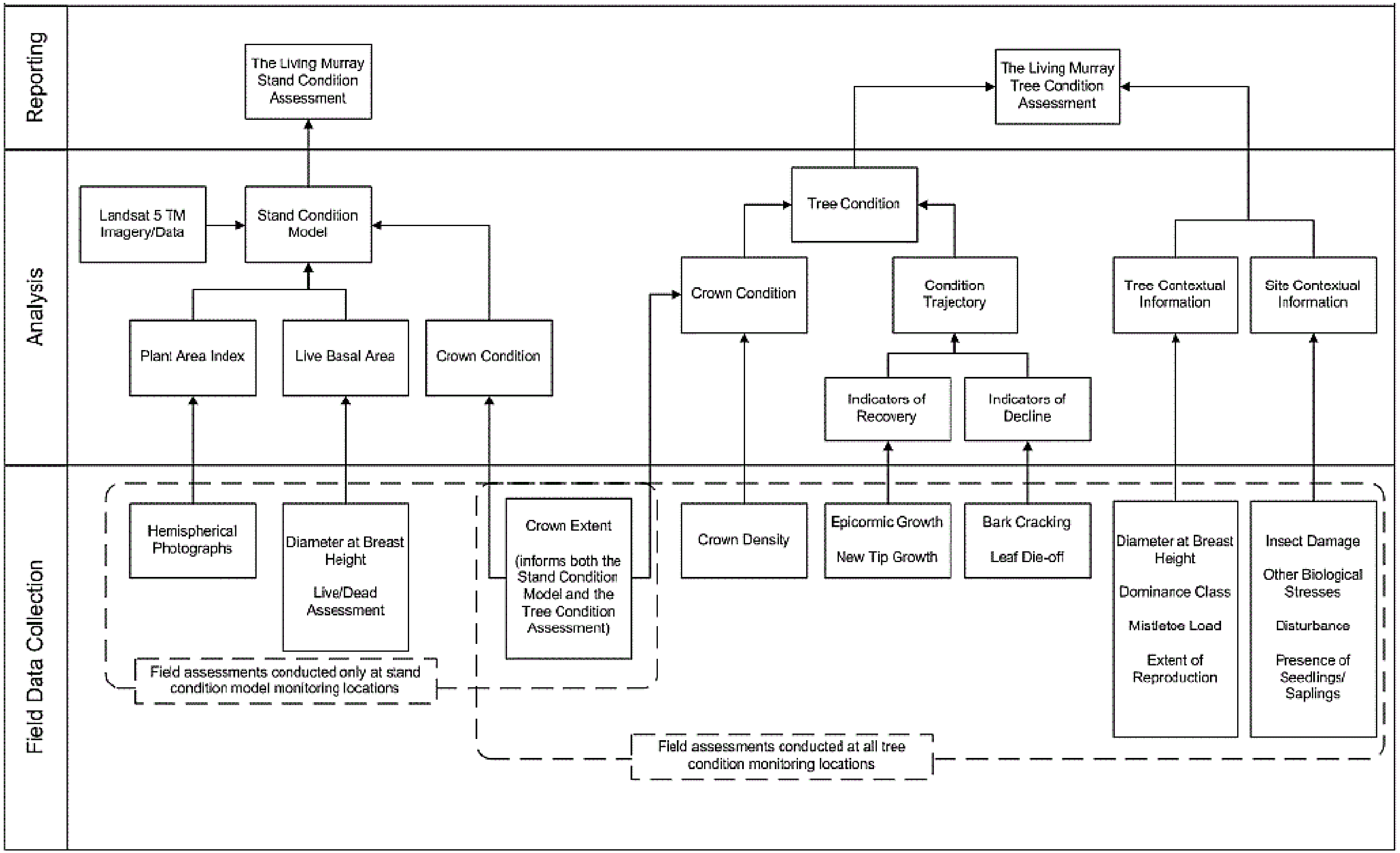


Figure 7-5: TLM measures as indicators and their relationship to analysis and reporting

Appendix E. Potential Management Actions

Environmental watering

Cost / ha	Moderate –High depending on infrastructure	Applied area	Small – Large depending on infrastructure

Environmental watering by surface inundation occurs where water is applied directly to the surface of the floodplain and ponded or retained for some period. These actions target increased infiltration of water into the soil profile to increase soil water content and hence total soil water potential (availability). Environmental watering has been routinely applied to floodplain/wetlands using a range of methods to improve the condition of floodplain vegetation, particularly on the lower floodplain terraces that are more easily accessible. Water may be applied and held on the floodplain for varying periods of time by using purpose-built infrastructure (e.g. regulators, blocking banks, aqua dams etc.). It may also be possible to pump water into discrete wetlands or depressions which are known to function as groundwater recharge basins (i.e. infiltration galleries).

With respect to soil salinisation stress, surface inundation may be used, to varying effect, to flush salts from the unsaturated soil profile over an extended period. This can only be achieved where groundwater is at depth and soil texture sufficiently permeable. If the groundwater is shallow i.e. within the capillary fringe, there is less scope to flush salt out of the root zone and salt will continue to accumulate in the unsaturated soil profile over time. Flushing of salts from the managed section of floodplain may result in the transference of impact to: (i) zones fringing the inundation area, (ii) the adjacent river, or (iii) to the groundwater zone below which may or may not pose a risk to other stakeholders or assets. These potential impacts need to be considered in the risk assessment and managed accordingly. The management of salinity at a Basin scale and the obligations around this are described in Appendix H.

The timing of environmental watering would preferentially occur during winter to early summer, aligned with natural hydrological signals. However, the timing of watering events may be determined based on a broader range of site objectives and critical requirements. Black Box watering requirements generally cover multiple years to achieve a change in condition (refer to chapter 3.2.3 Transition model).

Groundwater pumping

Cost / ha	High	Applied area	Small – Large depending on infrastructure

In its simplest form, groundwater pumping can be used to draw down the water table and increase the depth of the unsaturated zone (increasing the distance between the top of the saturated zone (groundwater) and the soil surface). Groundwater pumping such as for salt interception schemes and floodplain groundwater management, remove saline groundwater from the target aquifer for transport to and disposal at an offsite location. In some locations the removal of groundwater can encourage the formation of a freshwater lens through the creation of losing stream conditions, resulting in enhanced lateral recharge from the river or anabranch channels to the floodplain. Further study is required to better characterise and optimise the potential of groundwater pumping to facilitate freshwater lens formation (e.g. to explore the influence of groundwater gradients between the regional system and rivers, the hydraulic properties of the aquifer and river skin etc.).

Groundwater pumping is focused on the management of the symptom, rather than the cause. The costs associated with groundwater pumping and disposal are very high. The area affected is limited by the size and physical properties of the targeted aquifer, the volumes of extracted water, and the ability to dispose of extracted groundwater. This approach would require access to electricity or diesel generator power source and multiple bores for extraction and monitoring. There are also potential ecological impacts of clearance for pipelines and maintenance tracks plus the carbon footprint of construction and pumping. However, groundwater pumping may be viable where existing infrastructure is already present or where Black Box is located close to areas of high social / economic / environmental value (i.e. multiple potential benefits associated with the intervention).

Removal of constraints to redevelop surface water flow paths

Cost / ha	Low	Applied area	Small – only for Black Box areas adjacent the refurbished reach

The potential exists to restore tributary flow paths where these have been blocked or impaired by natural blockages or man-made infrastructure that is no longer required, or simply to improve operational flexibility. Reinstatement of the natural flow path is often relatively simple and cost effective but can be more complex in proximity to established roads and levies. It may also be possible to landform the flow path so that the passage of water is slowed and/or to lower commence to flow thresholds, thereby maximising the effectiveness of flows at strategic locations for the adjacent floodplain. The flow path must be assessed as being a losing system if an enhanced rate of lateral recharge (i.e. through the bank wall) is to be achieved.

This management option requires prior agreement from the land owners and relinquishment of the impeding infrastructure before works can be undertaken; in addition to standard regulatory requirements. Further negotiation may be required with upstream users and operators to secure water access or finalise management planning.

Augmenting river flows with environmental watering/other river operations

Cost / ha	Moderate (additional cost associated with delivery method at the specific location)	Applied area	Moderate – Large depending on operational constraints

Regular river flows may be enhanced through the timely and coordinated release of environmental water from the major storages and the implementation of appropriate operating strategies for river / floodplain infrastructure e.g. weirs, regulators. These operations seek to maximise the effective height, duration and extent of inundation. The timing of water releases from river storages will need to be coordinated with natural high river flows to achieve the effective flow rates required to inundate areas inhabited by Black Box vegetation (see Chapter 5 for more information).

Weir pool manipulation

Cost / ha	Low	Applied area	Small – Large depending on reach and infrastructure

Lowering a weir pool will increase the discharge of groundwater to the river but once the weir is raised the hydraulic gradient may reverse with fresh river water flowing laterally into the river bank. A program of weir pool raising and lowering has the potential to create a freshwater lens, flush salts from the unsaturated zone, and/or freshen the adjacent groundwater. Note that greater benefits are realised through a regime of weir pool manipulation lowering and raising over several years, rather than singular events.

The distance from the river that experiences this freshening will depend on the head difference created by the weir pool raising and lowering (magnitude of change in water level), the hydraulic conductivity of the soils, and the duration and frequency of raising and lowering cycles. The effectiveness of weir pool manipulation may also be enhanced by cycles of raising and lower in combination with flow augmentation (either to add to the surface of the floodplain or to dilute saline water discharge into the adjacent river. This management option may be more challenging for community to accept due to the temporary impact on associated infrastructure and change in historic practice. The approach will require buy-in from multiple stakeholders and managers across multiple reaches/jurisdictions, achieving broader area of benefit (i.e. beyond the primary site) but a potential for third party impacts.

Groundwater injection

Cost / ha	High	**Applied area**	Small – Large depending on size of target aquifer and volumes of injected water

Injection and storage of freshwater within aquifers is an established method employed across Australia, often to temporarily store excess surface water flows such as storm water runoff and then harvest this water later for irrigation or industrial uses (known as Managed Aquifer Recharge or MAR). The creation of a freshwater lens, or a shallow layer of water with comparatively low salinity lying on top of a relatively high salinity groundwater layer, could provide Black Box with a fresher alternative water source where salinity stress is a key issue. AWE (2015) note that this method has not yet been employed in a floodplain environment on a broad scale but suggests that this approach may be possible depending on the presence of suitable aquifer and soil characteristics at any given site. This approach is likely to have more technical complexities compared to other management options that will require detailed investigation and design.

The costs associated with groundwater injection are likely to be high, with the area affected limited by the characteristics of the targeted aquifer and the volumes of injected water. This approach would require access to permanent or diesel generator power sources and multiple bores for injection and monitoring. A trial study in Bookpurnong (SA) by Berens *et al.* (2009, as referenced in AWE 2015) highlights the importance of injecting filtered water with low biological and particulate matter to limit aquifer clogging. Pre-filtration could also be required to attain necessary water chemistry parameters (i.e. free of contaminants, compatible water chemistry). A successful trial project would require further investigation to increase confidence in its application for the desired site targets/operational objectives.

Minimisation of land clearance

Cost / ha	Low	**Applied area**	Small – Large

To avoid land clearance there are two options: 1) formal protection for Black Box site through legislative mechanisms; and 2) leveraging additional support from landholders for management of Black Box through voluntary agreements and market-based instruments. Pathways of this type will take time to navigate and require significant commitment from the land owner and support from state regulatory and regional authorities but can open additional avenues for assistance to help manage the Black Box on a site.

Minimisation of other land degradation processes

Cost / ha	Low	**Applied area**	Small – Large depending on infrastructure and resource investment

Land degradation covers a range of stressors associated with human activity. Activities can be grouped largely into agricultural, recreational and social. Salinisation is a significant land degradation issue particularly relevant for the southern Basin and is dealt with separately by multiple management options in this chapter.

Agricultural land degradation processes may include land clearance, inefficient water resource extraction and use, erosion, off target pesticide / herbicide drift, indiscriminate browsing and soil compaction by sheep and cattle, and contamination and spread of agricultural weeds. In many cases, the existing evidence of land degradation is a relic of past practices but nevertheless presents an enduring impact on vegetation condition.

Recreational impacts particularly on a floodplain are localised and tend to include off-track driving leading to more tracks, compaction and loss of vegetative cover and greater fragmentation of remaining habitat (with associated greater edge effects), introduction and spread of weeds, and inappropriate resource use (e.g. burning native wood for campfires).

Grazing pressure by native, introduced pests and farmed agricultural animals can be significant on Black Box (Horner *et al.,* 2016), and has contributed to an age class distribution of trees that is skewed towards mature and senescent trees.

Minimisation of deep drainage from highland irrigation

Cost / ha	Low-High (multi-layered potential impact)	**Applied area**	Small – Large depending on size of local irrigation industry

Leaching of salt below the root zones in an irrigation area is sometimes required to maintain a salt balance. This can lead to the development of groundwater mounds on top of the regional groundwater under irrigation districts, which increases the rate of saline groundwater discharging to the floodplain and the river. The height of groundwater mounds can be reduced by optimising water application to minimise the leaching fraction and/or using salt interception schemes to reduce the rate of groundwater discharge to the floodplain/river.

Drip or spray irrigation of Black Box vegetation

Cost / ha	High (installation of irrigation infrastructure and operational costs for pumping)	**Applied area**	Small – Large depending on size of infrastructure

Drip or spray irrigation counters stressors to Black Box vegetation through increasing infiltration of water into the soil profile to increase soil water content and availability. In some very specific conditions, surface inundation can also be used to target salinity stressors by flushing salts from the unsaturated soil profile over an extended period. Generally, drip or spray irrigation is most appropriate for Black Box trees that are located in the higher margins of the floodplain, and so are not affected by inundation through weir pool raising. The area of Black Box that can be watered at one time is quite limited without significant infrastructure spread throughout the floodplain.

Appendix F. Rapid Prioritisation Method

This appendix provides guidance on a rapid prioritisation method that could be used for prioritising Black Box management units and management options and shortlisting management scenarios. This method should be used for relatively small sites, where the investigation of management options (Step 5 in Part A of the Framework) shows a small number of feasible management units and options, and where the level of investment being sought for management is low. This process uses a qualitative comparison of multiple criteria to compare potential management options, however does not include detailed scoring and weighting of criteria.

It is recommended this process be completed as part of a workshop with key stakeholders, so that all relevant knowledge is captured and included in the prioritisation.

Step 1: Summary of Benefits, Dis-benefits and Risks

The first step in this process is to summarise the key benefits, dis-benefits and risks of each of the options, using the information gathered in Step 5 of Part A of the Framework (Identifying a range of management actions and options). When the benefits, dis-benefits and risks have been summarised for each option, each option can be assigned a ranking, based on which is shown to be preferable. No quantitative assessment of the relative importance of each benefit and dis-benefit is proposed for this assessment, however it is recommended these are discussed with a stakeholder group to come up with defendable rankings. The Table below suggests an example format for completing this process:

Option	Option A	Option B	Option C	Option D
Benefits				
Dis-benefits				
Risks				
Ranking (1-5) – 1 is preferred				

Step 2: Assessment of Options Against Objectives

Next, an assessment of the extent to which each of the potential options is likely to contribute to achieving the objectives for Black Box at the site is undertaken. This assessment can provide a semi-quantitative assessment through scoring each option out of 5 for each of the main objective areas. A score of 5 means that the option is expected to deliver 100% of the outcomes targeted for that objective, while a score of 0 means that the option is expected to deliver none of the outcomes targeted for that objective. In this way, the expected progress toward achieving the Black Box objectives can be compared for each option. The table below provides an example of the format for this assessment.

Objectives	Option A	Option B	Option C	Option D
Objective 1	Score from 0-5 (0 means option provides no outcomes for Objective, 5 means option provides 100% of outcomes for objective)			
Objective 2				

Objectives	Option A	Option B	Option C	Option D
Objective 3				
Objective 4				
Total score				

Step 3: Discussion and Selection of Priority Option/s

The tables populated in steps 1 and 2 are intended to provide a basis for discussion and agreement of the priority options. Key stakeholders should be included in this discussion.

Appendix G. Multi Criteria Assessment

MCA is a decision supporting tool that is commonly used to assess a list of sites and options, through a robust and transparent process that compares potential options against an agreed set of weighted criteria. The process allows for additional review of the outcomes of the assessment, if required, as the knowledge base for a site is expanded.

In the context of prioritising sites and selecting suitable management options, the benefits of using an MCA style approach are:

a. Multiple criteria can be included in the assessment, including criteria that are specific to the sites and/or available management options.
b. The analysis uses qualitative measure and so can be completed based on preliminary desktop assessment and information within the constraints of limited data and uncertainty. More detailed technical studies are likely to be required at a later stage.
c. Assessment outcomes can be generated relatively quickly, and sites and options compared on both total scores and on individual criteria.
d. Criteria and weightings used for the assessment are selected and refined by practitioners or a reference group of project leaders or specialists. They are not bound by a prescriptive method.
e. Sensitivity analyses of the outcomes can be completed quickly through varying criteria scores or weightings. This is particularly useful where there is uncertainty around condition assessment, site stressors and or the likely response to different management options (refer to chapter 3.5).

A potential limitation of using an MCA approach is that unreasonably large financial costs or other “pass/fail” criteria can be hidden since the score for each criterion may only make a small contribution to the overall ranking. For this reason, when using an MCA approach a sensitivity analysis should be undertaken by varying the weightings of the different criteria to test the influence of any one criteria (including the estimated cost of a management option) on the assessment outcome.

The MCA described within this Framework includes six broad assessment categories including:

1) environmental
2) economic
3) social
4) cultural
5) political
6) implementation

The following chapters describe steps in a generic MCA process.

Development of evaluation criteria

The first step in an MCA, as a common example of a framework analysis tool, is to develop a set of decision criteria and then weight these according to their importance to the project. This forms the basis of the site or options comparison, and will be used in selection of a preferred site and option. It is suggested that the development of evaluation criteria be carried out early within the site selection and management options identification process, so that identification and development of options for each site are carried out in accordance with how the options are likely to be evaluated and compared. Examples of suggested criteria for site assessment are provided in Appendix C, and for management options assessment in Appendix D, which can be taken by the framework practitioner and applied or adapted to the suit the project.

There are several critical elements required to ensure the MCA process provides a robust outcome, i.e. transparency and consistency in application. The key attributes of effective decision-making evaluation criteria include:

- Criteria with clear definitions
- Criteria that reflect the agreed project objectives and would realistically affect the decision of one or more stakeholders
- Criteria that are measurable (either directly or using surrogate indicators)
- Criteria that are mutually independent (minimising overlap)
- Criteria for which data / information are available and which are independent of each other (i.e. there is no "doubling counting" within criteria)
- A refined list of criteria which adequately differentiate the options

The following table provides a suggested criteria checklist that could be applied when adopting, adapting or developing these for a project:

Requirements for criteria	Description / examples
Comprehensive	Select criteria that cover all important areas of performance for a site and subsequent management options.
Balanced	Select criteria that do not emphasise one benefit at the expense of others, and that avoid double counting. For example, the possible risk of algal blooms and eutrophication are both measures of high nutrient loads (a potential risk of site watering). To use both as criteria would lead to double counting.
Evenly applicable	Apply selected criteria in the same manner for all options under consideration.
Transparent	Developing a clear statement of justification for choosing or excluding any criterion will aid in transparency and communication during the consultation and planning and approvals phases.
Relevant	The chosen criteria need to take account of region specific circumstances. In general, the number of criteria will reflect the complexity of the sites or management options being considered.
Minimum number	The set of criteria should represent the fewest possible criteria that can provide a comprehensive representation of the practitioners / regions objectives. Where possible, merge or remove criteria.
Use high quality data	The use of high quality data, or data with clearly stated uncertainty, is important for the correct interpretation of each criterion.

Option for MCA and short-listing workshop

For site and option screening and shortlisting, the options identified will be developed to provide high level attributes that inform and enable the MCA to take place. Through the options development, each option will be assigned with scores based on the selected evaluation criteria.

This will typically be the relative or quantifiable measures for the selected evaluation criteria such as cost, potential improvement in site metrics (e.g. soil moisture content), implementation risk (e.g. high, moderate, low) etc. For the short-listing purposes, it is envisaged that the options will be developed at a high level, only to sufficiently enable the identification of the options that may be dismissed for any further analysis.

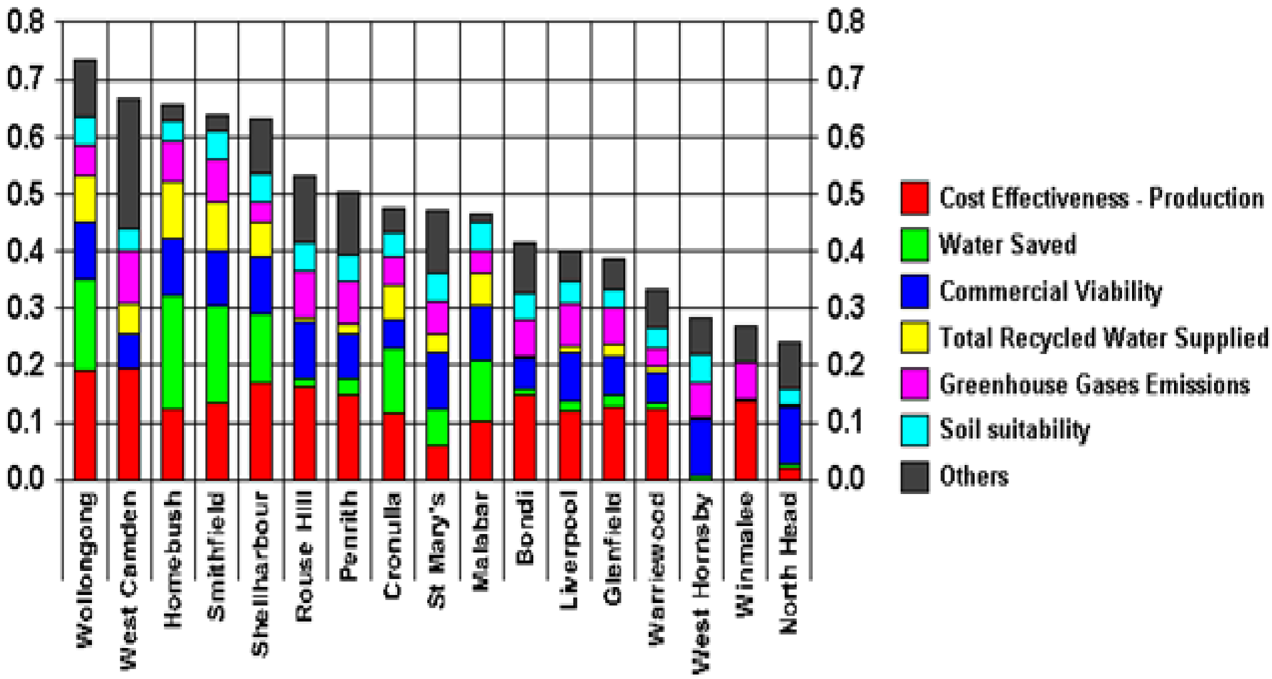
Another input to the MCA is the weighting on evaluation criteria that are used in the analysis to assign relative importance to decision criteria. Each criterion is assigned with a weight obased ontheir importance relative to other criteria selected for the project. Lower level criteria are also given weights based on their relative importance within the relevant criterion or sub-criterion. Weights are typically assigned by the key decision makers for the site – however there are some useful techniques that that can assist with this process (such as paired analysis).

MCA is carried out based on combining the options attributes and the relative weighting under the evaluation criterion. The typical outcome of an MCA is the ranking of options based on the overall rating. Interpretation and sensitivity testing should be made on the findings of the results as well as an understanding of the level of uncertainty that the assessment is based on.

Short-listing workshops or stakeholder forums can be useful to present the long list of sites / options identified and their attributes, and a discussion on how these were reflected into the scores in accordance with the defined and agreed evaluation criteria. The draft outputs of the MCA or related assessments can be presented to broader site or region stakeholders and sensitivities can be checked during consultation, with testing of possible variations in the weighting of the evaluation criteria.

The outcome of this assessment task with could be short-listed sites / options or a clear preferred option. Where a clear preferred option is not evident, the assessment and confidence appraisal can further assist to define what additional investigations or information is required to refine the assessment outcome. The following **Figure E.1** provides an example of an MCA output for a site assessment and prioritisation.

Figure 7-6: Example MCA output



It is noted that practitioners and land managers may have preferred assessment and MCA frameworks and as such, the Framework has not prescribed a specific assessment framework or MCA format. This approach can be used as a check against the current assessment processes undertaken within an organisation, or adopted for organisations that do not yet utilise a formal assessment framework. This approach will ensure flexibility in how site prioritisation and options assessment take place across sites and regions with variable management, objectives, drivers, stressors and site complexities.

Appendix H. Assessment Criteria for Selection of Black Box Management Units

MCA criteria	MCA sub-criteria	Potential parameters that could be used to score
Environment	Potential for recovery / regeneration	- Condition of stand based on percentage of remaining viable trees within responsive condition (i.e. where is it on a scale from recovery to improvement) - Unit size and connectedness of units within the landscape - Condition transition / maintenance targeted by the project (i.e. moderate to good, poor to moderate etc., and linked to ecological objectives and targets) - Level of stakeholder knowledge of site (management history, ecological change, water regime, climatic extremes)
Environment	Site holds important biodiversity values	- Site supports Coolibah - Black Box Woodlands of the Darling Riverine Plains and the Brigalow Belt South Bioregions (EPBC / NSW endangered) - Site provides feeding, shelter, breeding habitat and other resources for rare / threatened species - Site provides important linkages (between adjacent habitats) and/or diversity - Uniqueness / refuge
Environment	Site is part of larger environmental picture / plan	- Site project meets objectives in regional / basin plans, - Site complements agency watering / floodplain management projects - key site stressors may have direct flow on benefits or impact to the environment
Economic	Improved landscape amenity at site will have value for local community / tourism.	- Proximity of associated tourism / recreational facilities to the site - Diversity of tourism / recreational activities known / predicted to occur at the site - Additional destination for visitors which will enhance town community profile / local 'green' image - Supports previous investment
Economic	Existing capacity to deliver project at site	- Capacity to deliver management to site is high with existing or upgradable infrastructure or equipment present on / in proximity to the site (i.e. pumps, regulators, power, wells etc.) - Cost
Economic	Capacity to keep managing into the future	- Capacity to continue delivering management to site across an appropriate time scale to provide meaningful improvement to Black Box condition - Cost
Cultural	Aboriginal partners involved in the project	- Support from indigenous partners for management of environment at the site - Active involvement of cultural groups / representatives with site management
Cultural	Project objectives and cultural objectives aligned at the site	- Management of the site likely to achieve cultural goals which are linked to a healthy / sustainable Black Box community
Social	Level of stakeholder interest / engagement at site	- Number of stakeholders and community groups with active involvement / interest in site
Social	Potential for 3^{rd} party impacts	- Proximity and potential impact to/from associated tourism and recreational facilities - Proximity and potential impact to regional industries - Potential for fringe degradation in areas where depth to saline groundwater is less
Political	Management of the site provides direct opportunity for	- Profile of site in the community / media - Potential for publicity in a variety of multi-media formats

MCA criteria	MCA sub-criteria	Potential parameters that could be used to score
	political coverage / education of Black Box importance / plight	- Potential for project to become example of success story delivered under the framework - Supports previous investment
Implementation	Ease of delivery of any management to the site	- Proximity to resources (e.g. disposal sites, power, water source.) - Ease of access to site for all project phases (seasonal variation in conditions / existing tracks, installation of new equipment, servicing, monitoring and evaluation) - Scope and difficulty of works to get water to upper floodplain and to contain and manage it on the site
Implementation	Compatibility with land tenure	- Willingness of the landholder to participate if on private land, and for anticipated duration of active management - Ease of securing approvals if on public lands (site fits with broader regional plans and strategies, regional management actions and priorities) - If multi-use, all land uses compatible with intent of management proposal (e.g. does not include agricultural grazing). - Site is protected by voluntary conservation agreement (or equivalent)
Implementation	Complexity of hydrology / water regimes	- Capacity for management to address / reverse stressor(s) identified as key to the site e.g. Soil salinization, hydrological regime

Appendix I. Assessment Criteria for Management Options

MCA criteria	MCA sub-criteria (plug these into MCA analysis)	Potential parameters that could be used to score
Environment	Area of Black Box that this measure could be applied to	- Small, medium, large area of Black Box on the floodplain (which the practitioner can define as ha thresholds and/or percent of floodplain unit).
Environment	Location on site that this management option could be applied to	- In close proximity to river / anabranch, to upper reaches of floodplain, multiple (if resources / investment not limited).
Environment	Management regime will restore either or both the water and salt balance required to support healthy / sustainable Black Box	- Does it provide sufficient soil moisture availability to maintain or improve Black Box condition and functionality - Restore soil salinity conditions to a suitable range to complement required soil moisture availability to maintain or improve Black Box condition - Establish groundwater conditions (depth / salinity) conducive to maintaining a healthy Black Box community - Option interferes with natural floodplain hydrological regime
Environment	Likely ability of management option to limit / reverse impacts of stressor(s) to the current and projected life stages of Black Box	- No. of stressors likely to be addressed by the management option - No. of life stages of Black Box that are likely to be benefited by management option
Environment	Potential for offsite salinity impacts	- Potential impact on fringe zones outside of the managed areas; - Possible degradation of freshwater lenses or groundwater mounding; - Potential for salt export to the river
Economic	Cost Benefit Assessment Ratio	- Score from the CBA
Economic	Pre-existing services to deliver project at site	- Capacity to deliver management option is high with existing or upgradable services present on / in proximity to the site (i.e. pumps, regulators, power, wells etc.)
Social	Potential for 3rd party impacts	- Impact to floodplain public existing usage (e.g. access, recreation, public vehicle and boat access, etc.) - Impact to upstream / downstream water users and associated assets - Impact on irrigation communities
Cultural	Potential for impact on matters of cultural heritage / significance	- Impact on Indigenous cultural heritage - Impact on European cultural heritage
Cultural	Indigenous partners involved in the project	- Support of indigenous partners for type of management proposed at the site - Acknowledged contribution to achieving cultural goals
Political	Political willingness to fund long term management options	- Longer-term duration of promised funding / management / operation - Longer term monitoring and evaluation needed to match recovery rates and to quantify the benefit / improvement
Implementation	Constructability of management option	- Options considered stable, serviceable and structurally adequate - Option implementation requires ground disturbance that is dependent on variable/unknown ground/geotechnical conditions - Option presents challenging construction, mobilisation access and requirement for unique construction techniques and installation methods - Expected duration of construction and likelihood of disruption due to seasonal access to site
Operations / Maintenance	The complexity and duration of the ongoing operations / maintenance	- Expected level of ongoing maintenance and frequency of operation as part of the greater system

Appendix J. Managing Salinity from Environmental Watering

This Appendix discusses the active management of mobilisation and transport of accumulated salt from floodplain environments, which can occur as part of environmental watering.

Under Basin Salinity Management 2030 (BSM2030), environmental watering will provide long-term substantial dilution benefits in the river, but it can also mobilise salt from floodplains into the river system. This also an objective of the plan, as it removes salt accumulated at the soil surface and reduces salinity in the unsaturated zone, improving site conditions. The salinity impacts of environmental watering must be explicitly included in the existing Basin salinity accountability framework with the positive and negative salinity impacts associated with environmental water management being included under the different registers. To reduce the overall administrative burden, it has been agreed by all partner governments the credits or debits will be held collectively. In the first instance, they have agreed to be collectively accountable for any salinity impacts associated with:

- the use of environmental water under the Basin Plan environmental watering plan (excluding use associated with the operation of SDL works and measures and where already accounted for under TLM).
- changes to river operations to support environmental outcomes (that are not part of the SDL adjustment mechanism).

There will be a need to monitor and assess the cumulative system-scale salinity impacts arising from environmental watering regimes – including changes to river operations designed to support environmental outcomes. With greater volumes of environmental water available there is greater potential to improve river salinity through increased dilution. Environmental watering can also, in some circumstances, result in temporary increase salinity as salt is mobilised and transported for export through the River Murray, improving site conditions through removal of accumulated salts (export of salt out of the Basin, such as from the floodplain, is a Basin Plan target). Management of this mobilisation and transport of salts needs to be carefully managed. Practitioners should consider the Basin Plan salinity targets for managing water flows, and the potential need to manage off target impacts.

At the site-scale, environmental water holders and managers need to understand the effect of watering at a site on any potential risks arising from the mobilisation of salt to the river, and then seek to appropriately manage potential impacts to third party users and other assets downstream. The management of this risk is strongly tied to ambient salinity conditions (i.e. of less concern when higher flows mean that mobilised salts will be sufficiently diluted). Decisions about watering at high risk sites will require greater efforts to investigate and mitigate risks.

At the system-scale, practitioners need to understand and manage the potential for cumulative (spatial and temporal) salinity risks when multiple sites are being watered – either in series on one river, or in parallel in different tributaries.

The existing 14 jointly managed salt interception schemes have been very successful in reducing base salt loads to the river and continue to be essential to achieving the Basin Salinity Target and for managing in-river salinity peaks during low flow periods. Modelling indicates that there will be no need for further joint capital investment in new schemes for the life of BSM2030. Largely this is because of the dilution benefits associated with environmental water benefiting the river, the lower than expected increase in river salinity associated with the legacy of land clearing and the net salinity credit balances currently held by the partner governments.

BSM2030 will explore the potential to operate SIS to reduce operations and costs during periods of low in-river salinity. Given the uncertainty regarding changing SIS operations, responsive SIS management will initially be trialled for a 3-year period commencing in 2016, with the effectiveness of the trial to be reviewed in 2019. The review will analyse and document the river salinity impacts, third-party impacts, floodplain environmental impacts, benefits and costs. It will also make recommendations on the future operation of SIS to achieve optimal outcomes.

Appendix K. Reach Scale Analysis of Black Box under Flow Stress, Salinity Stress, Flow and Salinity Stress and Low Stress for 60 – 80 ML/day Flows at the South Australian Border

Table 7-5: Areas of flow stress, salinity stress, flow & salinity stress and low stress, and tree condition, for Black Box inundated by a 60,000ML/day at South Australian border.

Reach #	Reach Name	Flow Stressed				Salinity Stressed				Flow & Salinity Stressed				Low stress				Area no salinity data (ha)
		Area (ha)[1]	Cover of condition data (%)[2]	poor condition (%)[3]	mod. /good condition (%)[3]	Area (ha)[1]	Cover of condition data (%)[2]	poor condition (%)[3]	mod. /good condition (%)[3]	Area (ha)[1]	Cover of condition data (%)[2]	poor condition (%)[3]	mod. /good condition (%)[3]	Area (ha)[1]	Cover of condition data (%)[2]	poor condition (%)[3]	mod. /good condition (%)[3]	
7	Lock 26 (Torrumbarry) to downstream of Gunbower	0	0	0	0	46	93	4	4	0	0	0	0	159	86	7	7	1,451
8	Downstream of Gunbower to Swan Hill	0	0	0	0	20	88	6	5	0	0	0	0	239	86	3	11	803
9	Swan Hill to Murray/Wakool junction	0	0	0	0	24	78	16	6	0	0	0	0	106	67	11	22	80
10	Murray/Wakool junction to Murrumbidgee/Murray junction	0	0	0	0	50	37	37	27	0	0	0	0	565	9	32	61	334
11	Murrumbidgee/Murray junction to Lock 15	0	0	0	0	193	88	3	9	0	0	0	0	724	65	6	30	210
12	Lock 15 to Lock 10	0	0	0	0	118	80	10	10	0	0	0	0	1,433	64	14	22	1,794
13	Lock 10 to Lock 9	0	0	0	0	300	94	5	1	0	0	0	0	1023	58	16	25	9
14	Lock 9 to Lock 8	0	0	0	0	81	93	7	0	0	0	0	0	566	76	9	15	0
15	Lock 8 to Lock 7	0	0	0	0	17	85	14	1	0	0	0	0	605	77	7	16	4
16	Lock 7 to Lock 6	0	0	0	0	1,142	87	11	3	0	0	0	0	1,910	43	21	37	0
17	Lock 6 to Lock 5	0	0	0	0	1,072	96	4	0	0	0	0	0	2,243	81	5	14	34
18	Lock 5 to Lock 4	0	0	0	0	329	86	12	2	0	0	0	0	384	68	14	18	9
Total		**0**	**0**	**0**	**0**	**3,392**	**89**	**8**	**3**	**0**	**0**	**0**	**0**	**9,957**	**62**	**13**	**25**	**4,728**

Notes: (1) A zero (0) value in Area (ha) means that there is no area of Black Box that is attributable to the category in the location specified, (2) A zero (0) in Cover of Condition Data means there is 0% (or no) cover of predicted, modelled condition data for the area of Black Box. This column is zero by default if there is no area of Black Box. (3) and (4) Where modelled condition data exists, these columns show the percentage of condition data across two pooled condition classes; poor, or moderate / good. These columns by default are zero if Cover of Condition Data (%) is also zero.

Table 7-6: Areas of flow stress, salinity stress, flow & salinity stress, low stress, and modelled condition, for Black Box inundated between a 60,000ML/day to 80,000ML/day flow at South Australian border.

Reach #	Reach Name	Flow Stressed				Salinity Stressed				Flow & Salinity Stressed				Low stress				Area no salinity data (ha)
		Area (ha)[1]	Cover of condition data (%)[2]	poor condition (%)[3]	mod. /good condition (%)[3]	Area (ha)[1]	Cover of condition data (%)[2]	poor condition (%)[3]	mod. /good condition (%)[3]	Area (ha)[1]	Cover of condition data (%)[2]	poor condition (%)[3]	mod. /good condition (%)[3]	Area (ha)[1]	Cover of condition data (%)[2]	poor condition (%)[3]	mod. /good condition)[3]	
7	Lock 26 (Torrumbarry) to downstream of Gunbower	0	0	0	0	2	80%	0	20	0	0	0	0	10	57	6	36%	59
8	Downstream of Gunbower to Swan Hill	0	0	0	0	40	97%	2	2	0	0	0	0	4	93	2	5%	124
9	Swan Hill to Murray/Wakool junction	0	0	0	0	8	86%	11	3	0	0	0	0	23	85	5	10%	11
10	Murray/Wakool junction to Murrumbidgee/Murray junction	33	74	6	20	18	85%	9	6	2	81	19	0	121	42	19	40%	135
11	Murrumbidgee/Murray junction to Lock 15	81	93	0	6	269	98%	0	2	15	98	0	2	870	93	1	7%	45
12	Lock 15 to Lock 10	968	90	3	7	375	92%	6	2	56	95	3	2	2,461	80	8	12%	4,736
13	Lock 10 to Lock 9	509	95	1	4	989	100%	0	0	1,096	100	0	0	1067	90	1	8%	6
14	Lock 9 to Lock 8	493	89	3	8	202	100%	0	0	108	100	0	0	996	87	2	10%	0
15	Lock 8 to Lock 7	612	91	4	5	94	97%	2	0	168	100	0	0	580	83	4	13%	0
16	Lock 7 to Lock 6	1,720	93	1	6	1,213	88%	11	1	1,516	98	2	1	1,720	84	4	12%	0
17	Lock 6 to Lock 5	22	82	17	1	162	100%	0	0	29	100	0	0	190	95	2	3%	108
18	Lock 5 to Lock 4	208	77	10	13	477	97%	3	0	288	98	1	1	371	79	10	11%	40
Total		**4,646**	**91**	**3**	**6**	**3,849**	**94%**	**5**	**1**	**3,278**	**98**	**1**	**1**	**8,413**	**84**	**5**	**11%**	**5,264**

Notes: (1) A zero (0) value in Area (ha) means that there is no area of Black Box that is attributable to the category in the location specified, (2) A zero (0) in Cover of Condition Data means there is 0% (or no) cover of predicted, modelled condition data for the area of Black Box. This column is zero by default if there is no area of Black Box. (3) and (4) Where modelled condition data exists, these columns show the percentage of condition data across two pooled condition classes; poor, or moderate / good. These columns by default are zero if Cover of Condition Data (%) is also zero.

Appendix L. Risk Assessment Process

For any management scenario, a range of potential benefits and risks should be explored. The impacts (both positive and negative) to other site objectives, species, and third parties should be considered prior to any decision on implementation of management actions.

This Appendix presents a risk assessment matrix that can be used to explore the risks, likelihood and consequences for managing Black Box at a site, to support Step 7 of the Framework.

Process of Identifying Risks

Risk Identification

The aim of the risk identification process is to understand all the key risk events that are relevant to the Management Options; define their cause, identify the nature and extent of potential consequences, and understand their likelihood of occurrence. Risk is a combination of the likelihood of occurrence, and the consequences of an event happening.

A risk event with severe consequences may not necessarily represent a high risk; - because the event or the consequences of the event may have a low probability of occurring. Similarly, a risk event which is highly likely may not necessarily represent a high risk as its consequences may be very small.

Risk Analysis

The objective of risk analysis is to understand risk events, such that the nature and distribution of risk can be evaluated, and to develop appropriate management strategies. The level of risk is determined by the potential consequences of a risk event, and the likelihood that the risk event will occur. The two measures are then considered together to define an overall level of risk.

A summary of the ratings used to define likelihood, consequence and risk are provided below.

Likelihood

A likelihood rating is applied to each of the identified risk events. The likelihood ranges from almost certain, to rare, and a description of the likelihood ratings is provided in Table 7-7.

Table 7-7: Likelihood description guideline

LIKELIHOOD	DESCRIPTION GUIDELINE	
Almost Certain	Consequences is expected to occur in most circumstances	Occurs more than once a month
Likely	Consequences will probably occur in most circumstances	Occurs once every 1 month – 1 year
Possible	Consequences should occur at some time.	Occurs once every 1 year – 10 years
Unlikely	Consequences could occur at some time	Occurs once every 10 years - 100 years
Rare	Consequences may only occur in exceptional circumstances	Occurs less than once every 100 years

Consequence

Five levels of consequence have been utilised for assessing the relative impact, ranging from insignificant to severe, as described in the table below.

CATEGORY	CONSEQUENCE				
	Insignificant	**Minor**	**Moderate**	**Major**	**Severe**
Corporate and Governance	Negligible impact on critical objectives. Minor impact on group objectives. Impact can be managed through routine activities.	Negligible impact on corporate objectives, major impact on group objectives. Impact requires moderate to minor internal management efforts required to manage impact.	Minor impact on corporate objectives. Impact requires management and resources from key areas of business to respond.	Major impact on corporate objectives. Impact requires long term significant management and organisational resources to respond.	Significant impact on critical DEWNR objectives. Impact cannot be managed within existing resources and threatens survival of the department.
Financial	Less than $100,000, negligible impact on overall budget. Assets receive minimal damage and are only temporarily unavailable.	$100,000 - $500,000 financial impact on budget or 2% deviation from corporate budget, or 5% deviation from unit/program budget Several assets unusable but can be replaced within acceptable timeframes	$500,000 - $1M financial impact on budget or 2% → 5% deviation from corporate budget, or 5% → 15% deviation from unit/program budget. A range of assets, including some significant assets, are unusable for weeks.	$1M - $2M financial impact on budget or 5% → 15% deviation from corporate budget, or 15% → 30% deviation from unit/program budget. Significant or critical assets are unusable for weeks.	Significant adverse impact on State budget Greater than $2M, financial impact on budget.
Business Performance	Negligible impact on the effectiveness of the organisation. Isolated partial or short-term service disruption.	Effectiveness and efficiency of elements of the department is reduced. Part service disruption (for less than 2 days). Ability to achieve project objectives or deliver outcomes is affected.	Effectiveness and efficiency of major elements the department are reduced. Full service disruption for 1 day or key services disruption for up to 3 days. One or more projects are significantly impaired.	Continued capability of the organisation is threatened. Full service disruption for up to 3 days or a key service for up to 1 week. One or more critical projects cannot be achieved.	Systemic failure and overall survival of the organisation is threatened. Full service disruption for more than 3 days or a key service for more than 1 week. Majority of critical projects cannot be achieved.
Health and Safety	Incidents with or without minor injury. Dialogue with industrial groups may be required, negligible impact.	Injuries requiring first aid treatment. Urgent dialogue with industrial group require, impact can be absorbed through normal activity. Increase in local staff absentee rate.	Injuries requiring medical treatment. Threats of industrial action, impact can be absorbed, management action required. Increase in department workforce absentee rate.	Single fatality, permanent or partial disabilities, injuries requiring hospitalisation. Industrial action over many months, significant management intervention required. Increase in workforce absentee rate.	Multiple fatalities, permanent or partial disabilities. Collapse of business function, widespread industrial action. Section of the community or workforce harmed.
Environment	Minor temporary damage that normal practice can rectify.	Temporary damage affecting local area. No threat to fauna or flora. No threat to community health.	Severe temporary damage over limited area requiring extensive remediation. Impact on flora or fauna is recoverable over a 6 to 12-month period. Localised threat to community health.	Pervasive and severe temporary damage extending over a large area requiring extensive and lengthy remediation and years of recovery. Damage to flora or fauna requires significant period of recovery (years). Contained threat to community health.	Permanent damage over a wide area, destruction of sites or artefacts of cultural heritage significance. Permanent impact threatens survival of flora and fauna. Widespread threat to community health.

CATEGORY	CONSEQUENCE				
	Insignificant	Minor	Moderate	Major	Severe
Reputation	Isolated local community or individual's issue-based concerns. Legal issues managed by routine procedures. Minor non-compliance and breaches.	Occasional once off negative media attention. Complex legal issues need addressing. Major non-compliance and breaches. Local community impacts and concerns.	Negative media attention (days) Serious incident requiring investigation and legal representation to determine liability, Non-compliance with legislation or report to authority with possible prosecution. Loss of confidence by the community in DEWNR processes. Ministerial concern.	Consistent negative media attention (weeks). Major breach of legislation, major litigation. Considerable and prolonged community impacts and dissatisfaction publicly expressed. Ministerial intervention.	Consistent extreme negative media attention (months). Significant prosecution and fines, major litigation involving class actions, major non-compliance with legislation. Irreconcilable community loss of confidence in the departments' intentions and capabilities. Public Government intervention

Risk

Once the consequence and likelihood of a risk event are determined, an overall risk rating is applied, based on the risk matrix presented in Table 7-8.

Table 7-8 Risk matrix

LIKELIHOOD	CONSEQUENCE				
	Insignificant	Minor	Moderate	Major	Severe
Almost Certain	Low	Medium	High	Extreme	Extreme
Likely	Low	Medium	High	High	Extreme
Possible	Low	Medium	Medium	High	Extreme
Unlikely	Low	Low	Medium	Medium	High
Rare	Low	Low	Low	Medium	Medium

Risk Evaluation

Risk evaluation is to undertake to review the results of the risk analysis and determine whether the risk is acceptable or tolerable. Its purpose is to assist decision making on which risks require further analysis and/or need treatment and the priority for implementation of risk management.

Risk Treatment

Where risks are determined to not be acceptable or tolerable, treatments or management strategies are developed to reduce the risk to a level that is acceptable to the Program. Risk treatment aims to identify and implement the most appropriate action(s) in response to unacceptable risks.

A Risk Register can be developed which provides "controls" for each risk and gives a qualitative evaluation of the likely effectiveness of these controls should they be implemented. Following the application of the identified controls, each risk was re-assigned qualitative consequence and likelihood ratings to determine the level of residual risk.

Appendix M. Basin Scale Analysis – Additional Maps

Australian Government
Commonwealth Environmental Water Office

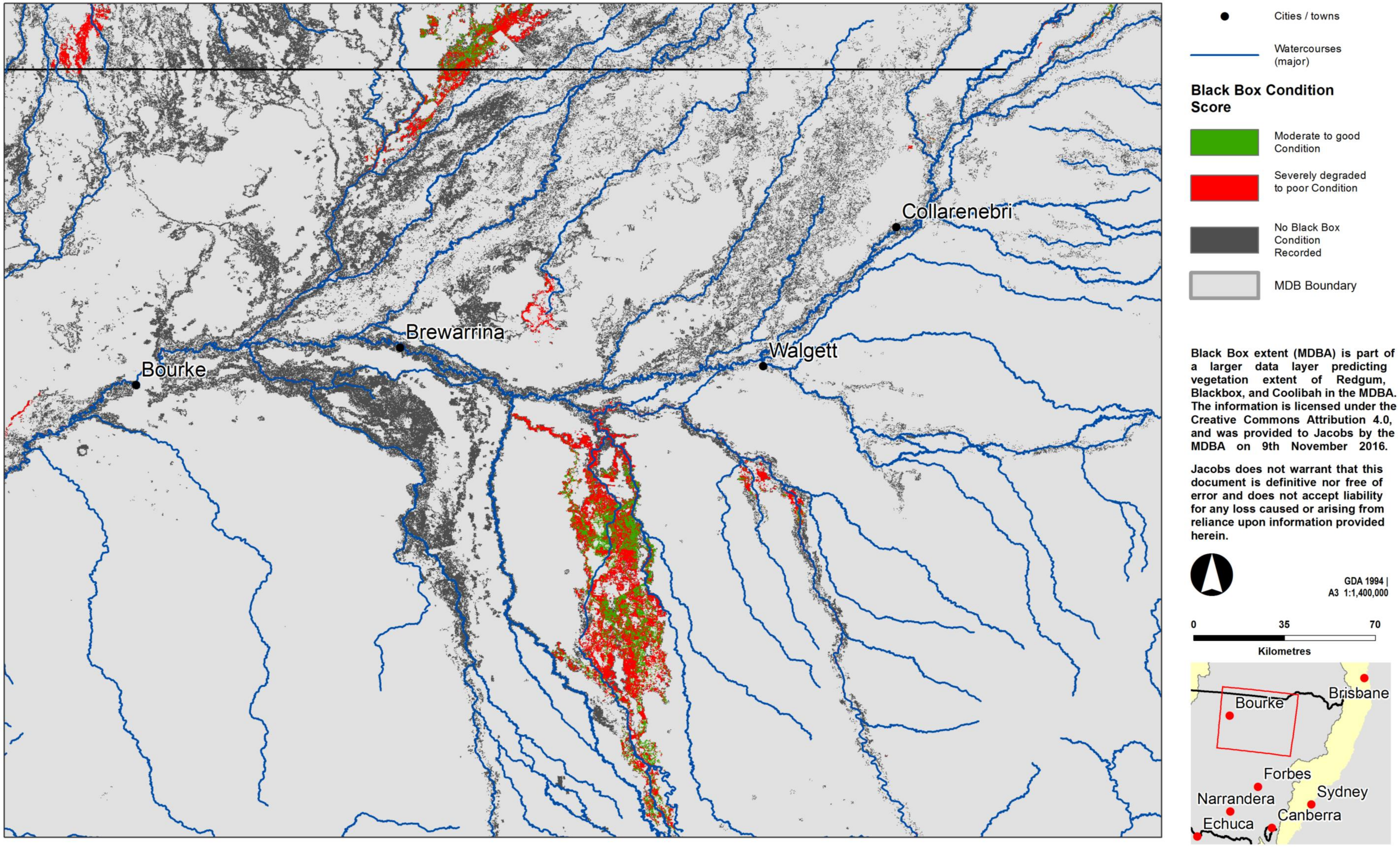


Figure 7-7: Black Box condition map: Darling

Australian Government
Commonwealth Environmental Water Office

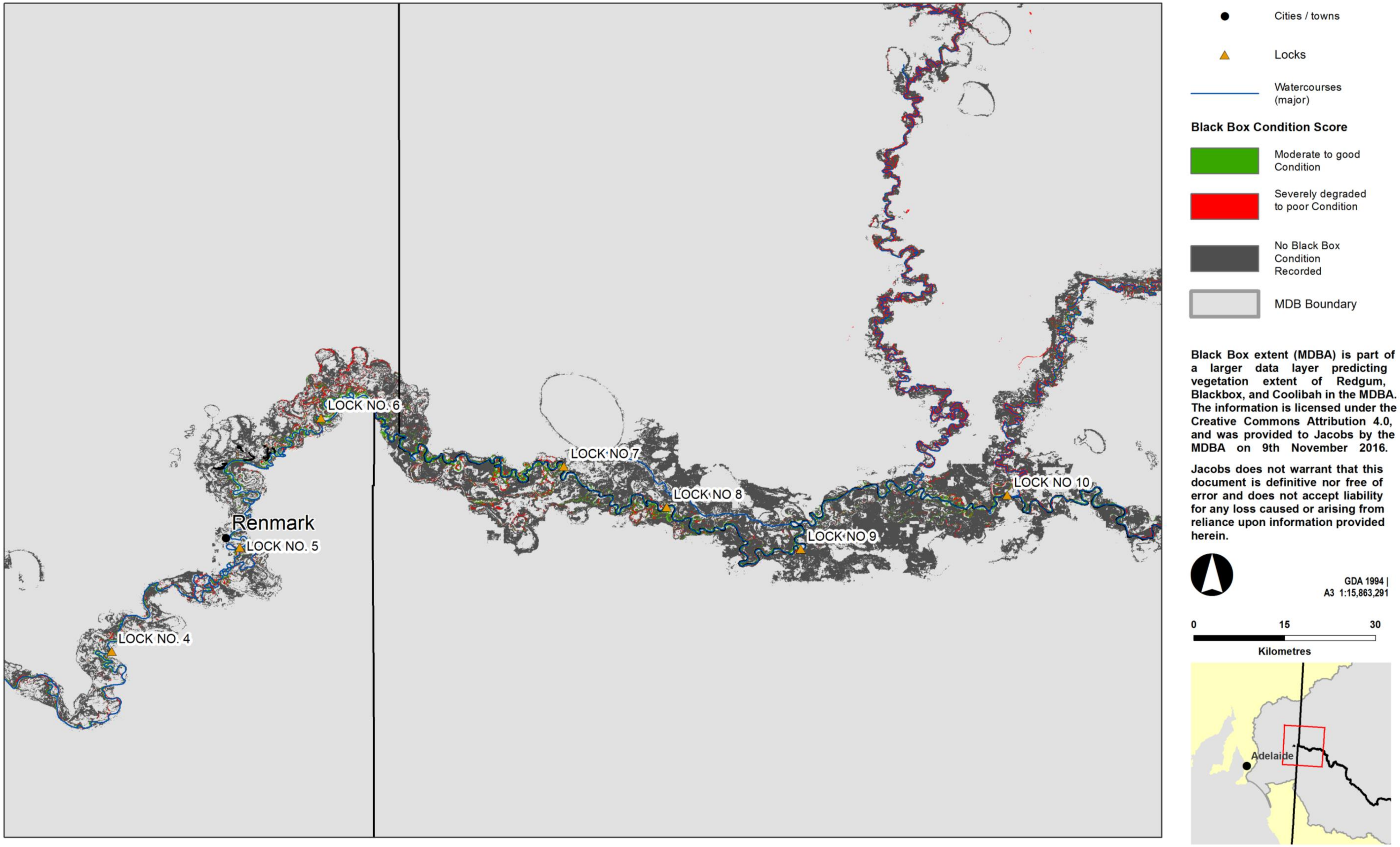


Figure 7-8: Black Box condition map: Murray

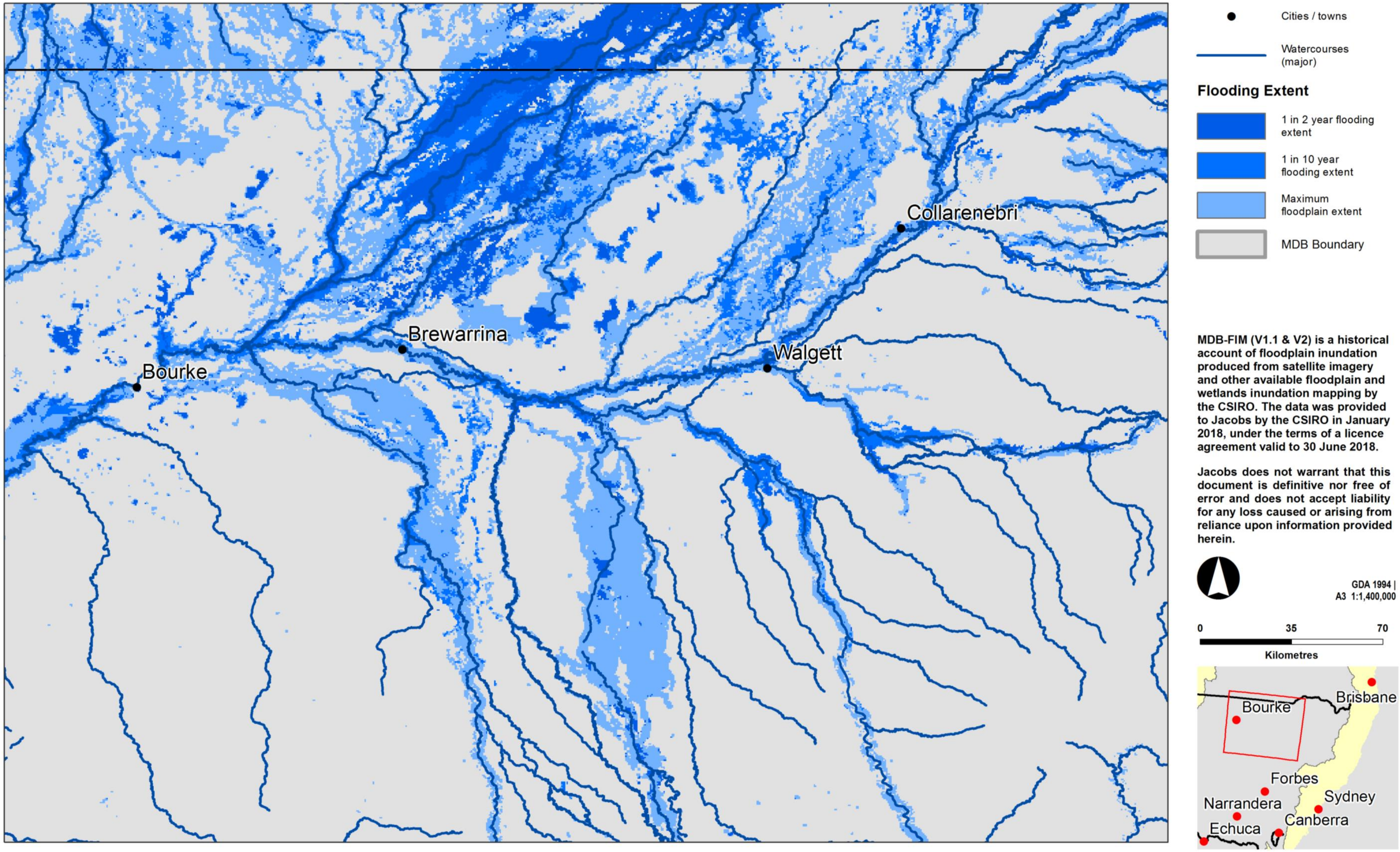


Figure 7-9: Flood frequency map: Darling

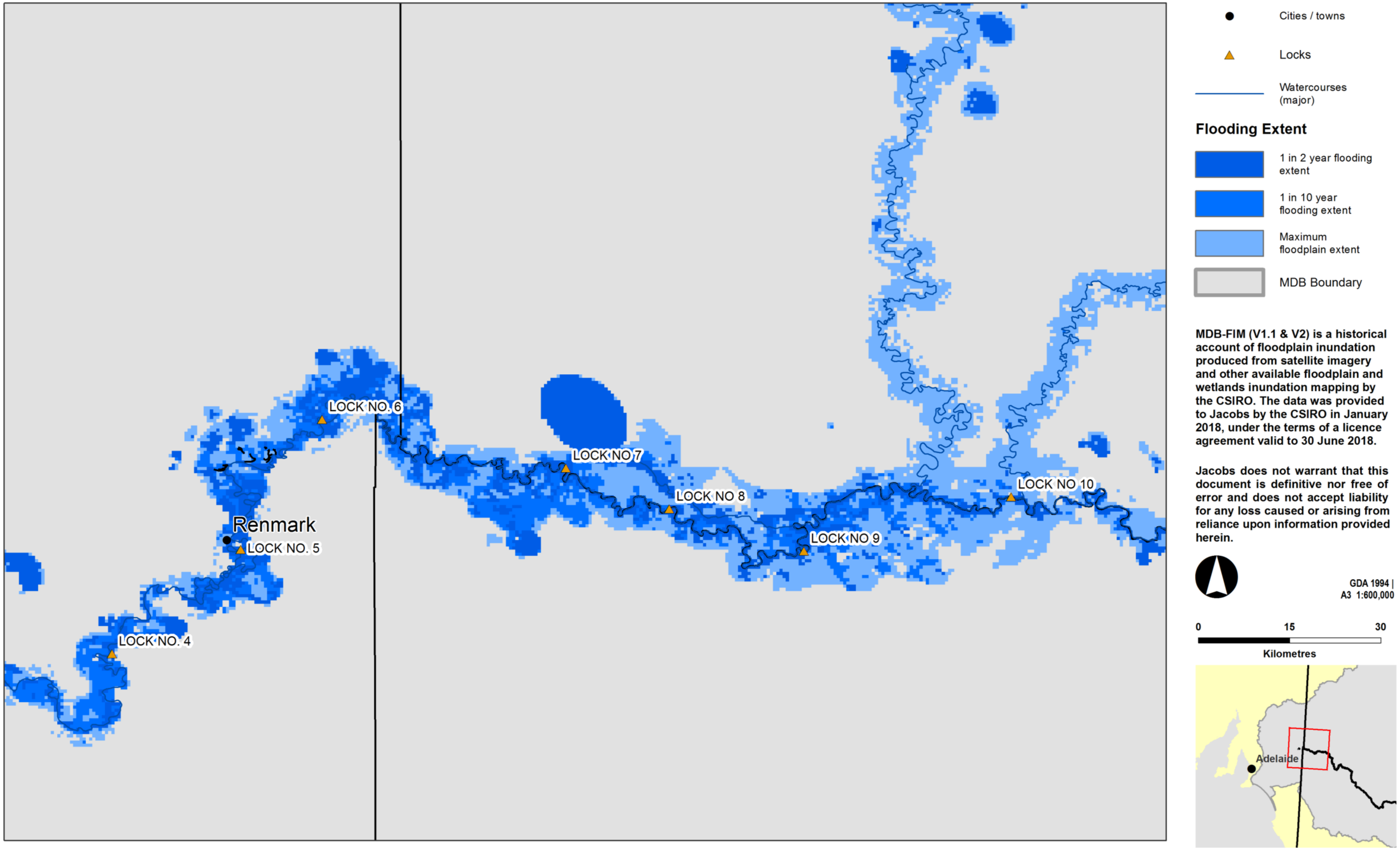
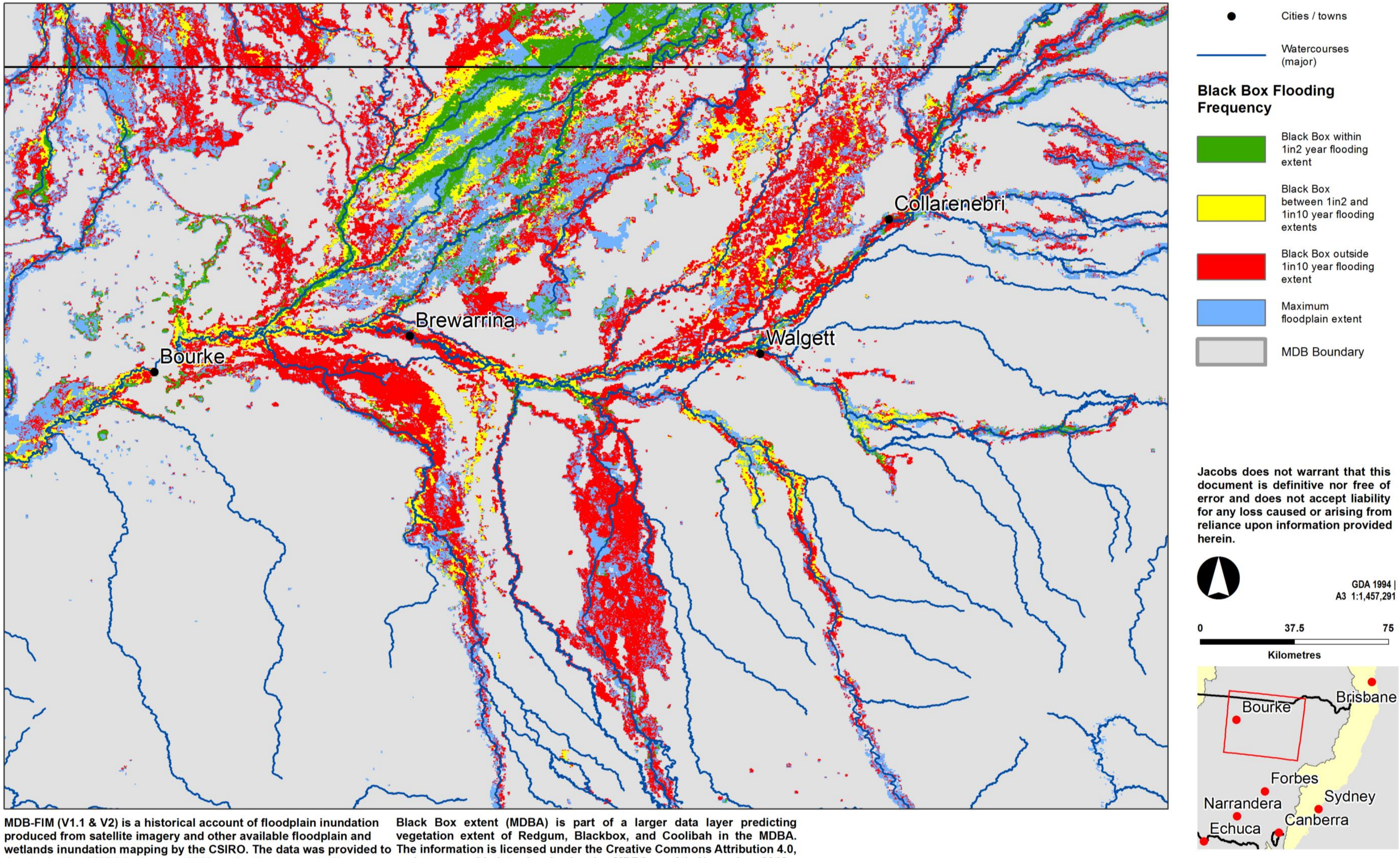


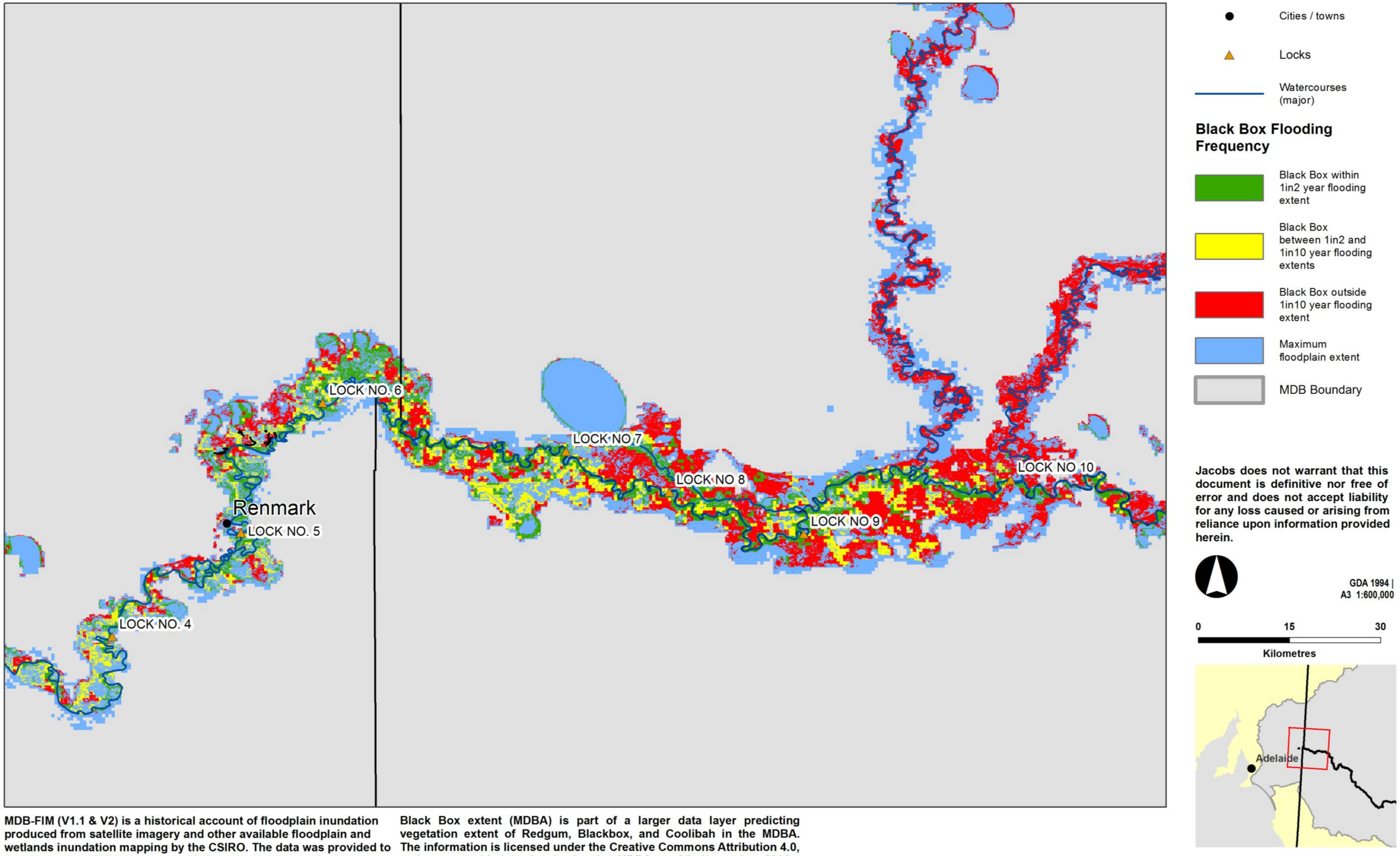
Figure 7-10: Flood frequency map: Murray



MDB-FIM (V1.1 & V2) is a historical account of floodplain inundation produced from satellite imagery and other available floodplain and wetlands inundation mapping by the CSIRO. The data was provided to Jacobs by the CSIRO in January 2018, under the terms of a licence agreement valid to 30 June 2018.

Black Box extent (MDBA) is part of a larger data layer predicting vegetation extent of Redgum, Blackbox, and Coolibah in the MDBA. The information is licensed under the Creative Commons Attribution 4.0, and was provided to Jacobs by the MDBA on 9th November 2016.

Figure 7-11: Frequency of inundation of Black Box: Darling



MDB-FIM (V1.1 & V2) is a historical account of floodplain inundation produced from satellite imagery and other available floodplain and wetlands inundation mapping by the CSIRO. The data was provided to Jacobs by the CSIRO in January 2018, under the terms of a licence agreement valid to 30 June 2018.

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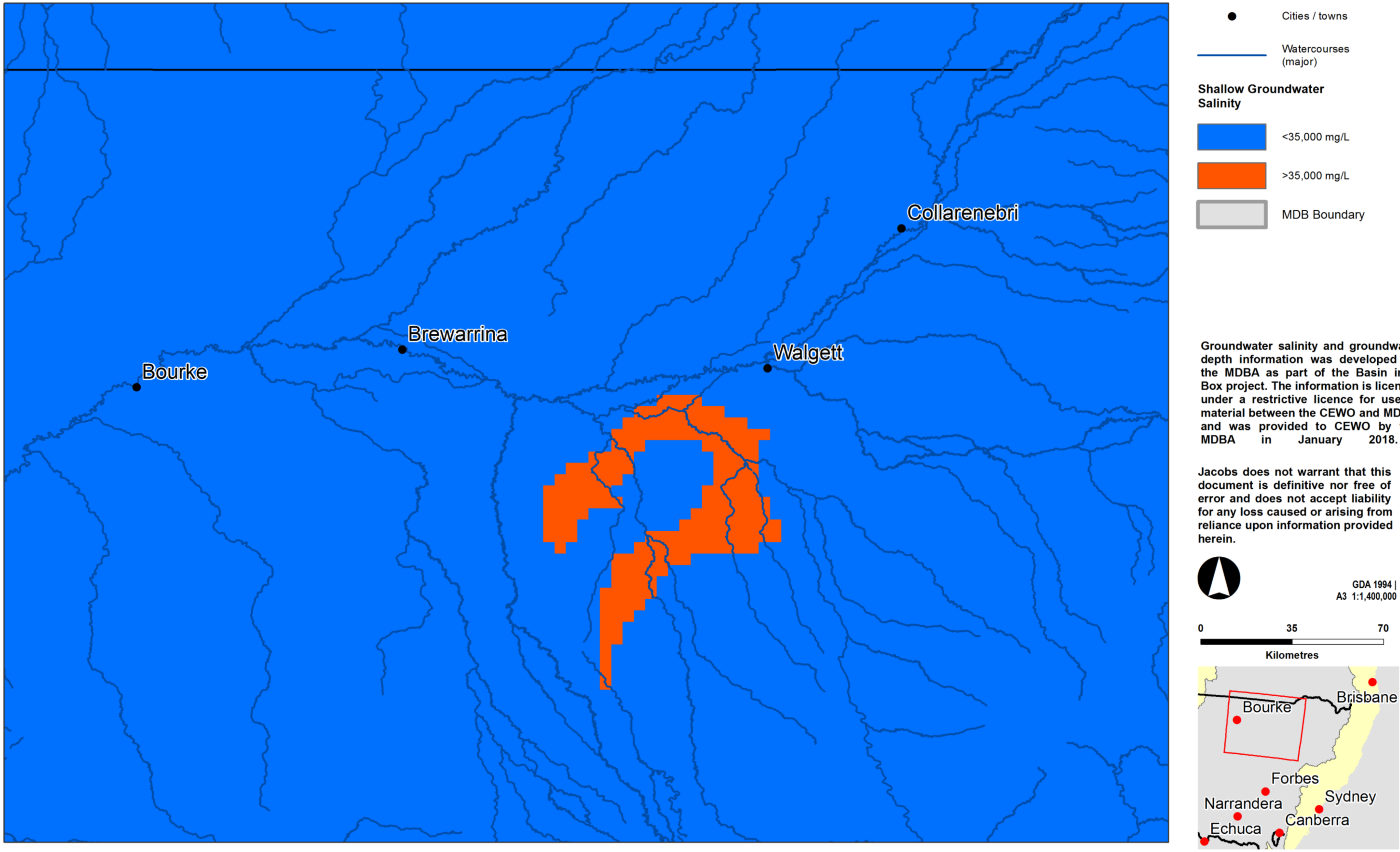
Figure 7-12: Frequency of inundation of Black Box: Murray



Groundwater salinity and groundwater depth information was developed by the MDBA as part of the Basin in a Box project. The information is licenced under a restrictive licence for use of material between the CEWO and MDBA, and was provided to CEWO by the MDBA in January 2018.

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Figure 7-13: Groundwater salinity: Darling

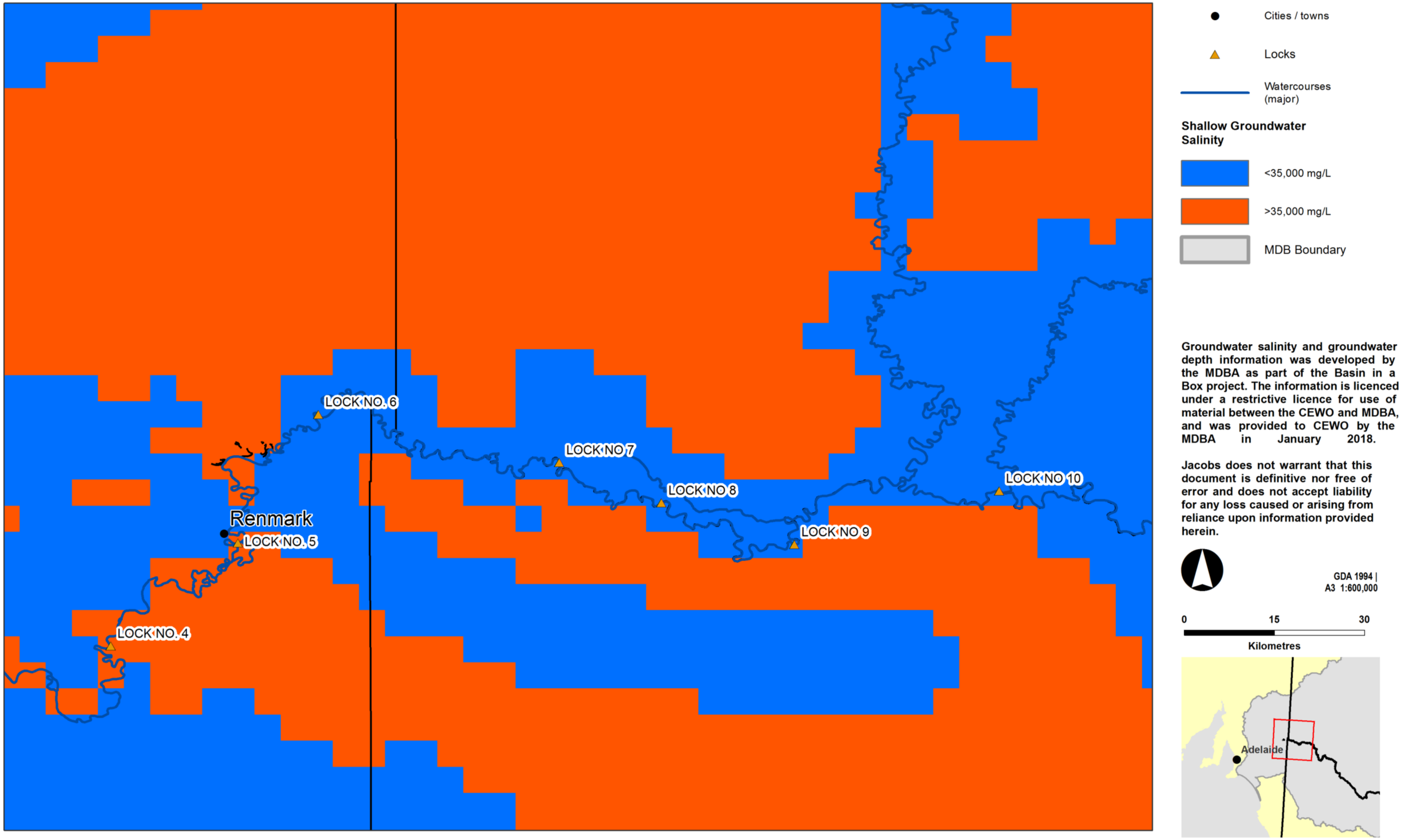

Figure 7-14: Groundwater salinity: Murray

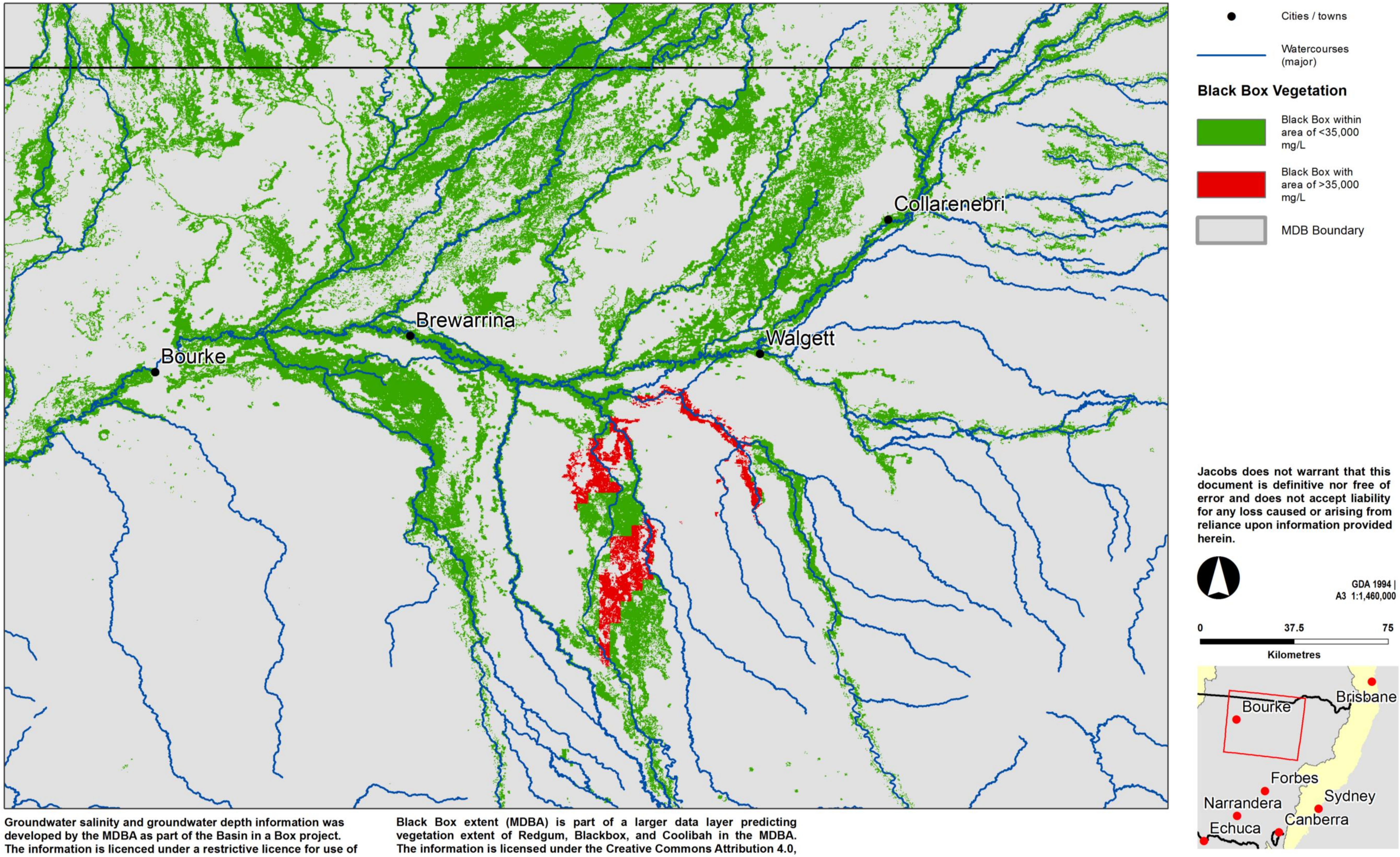

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Figure 7-15: Groundwater salinity and Black Box: Darling

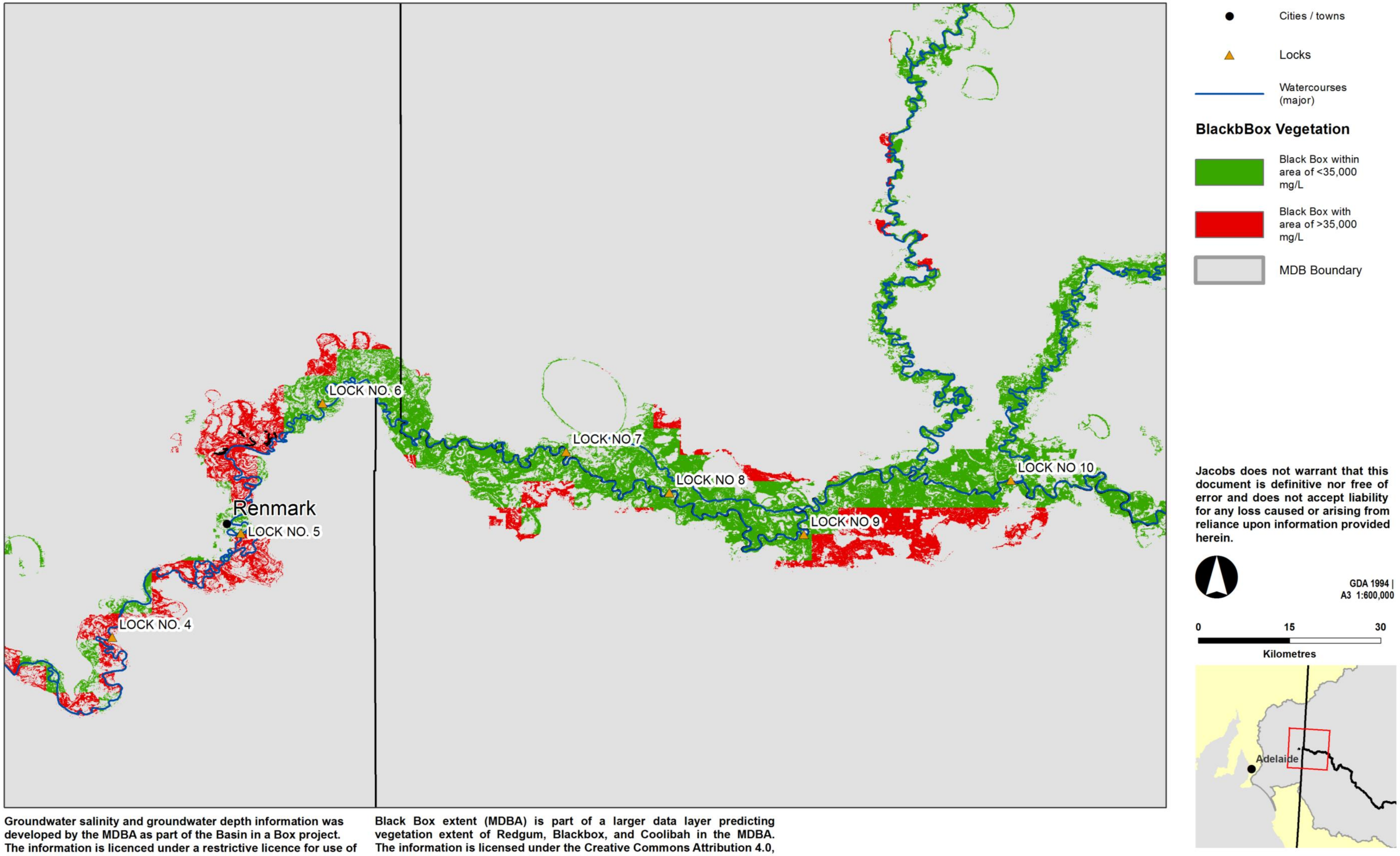

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Figure 7-16: Groundwater salinity and Black Box: Murray

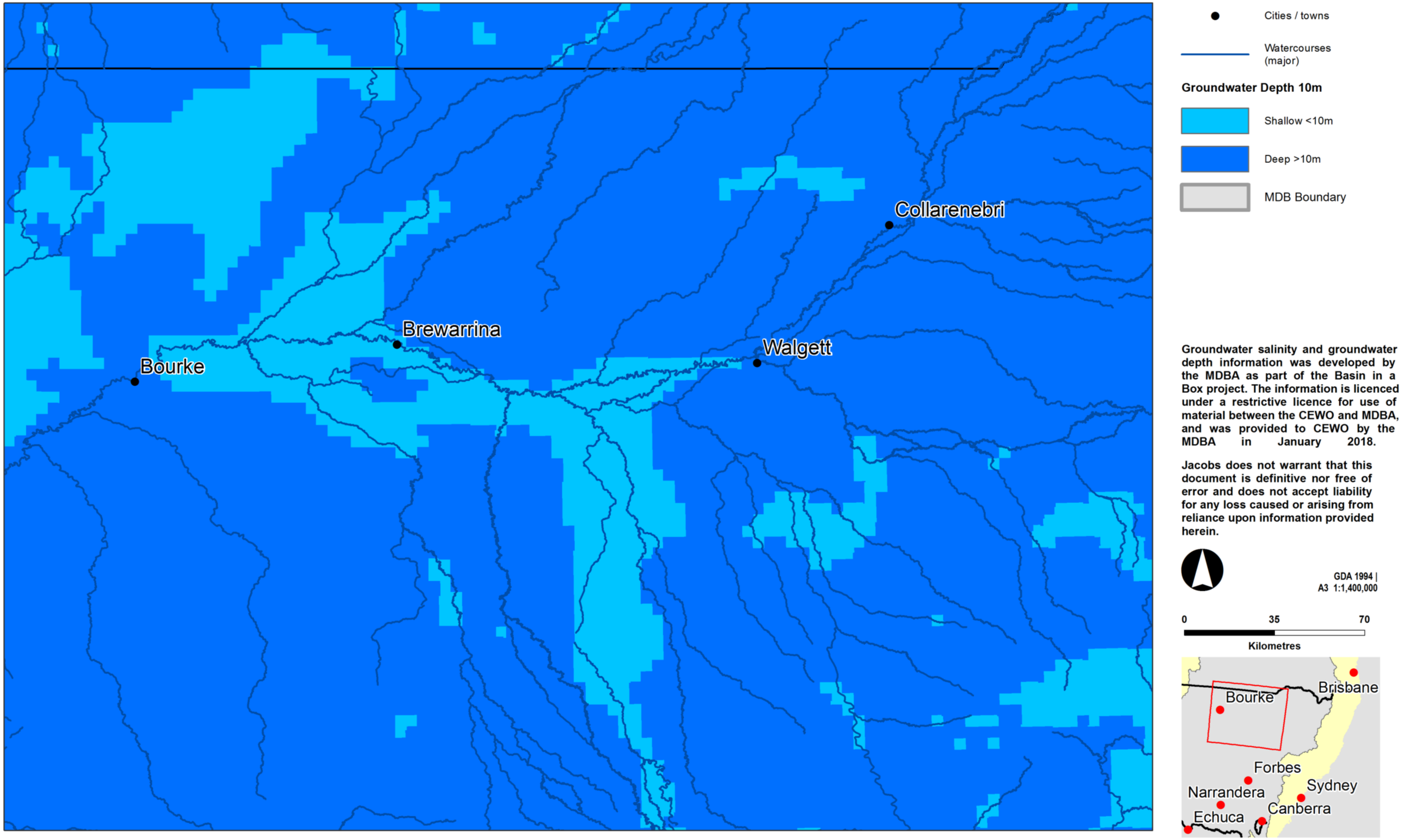

Figure 7-17: Groundwater depth: Darling

Australian Government
Commonwealth Environmental Water Office

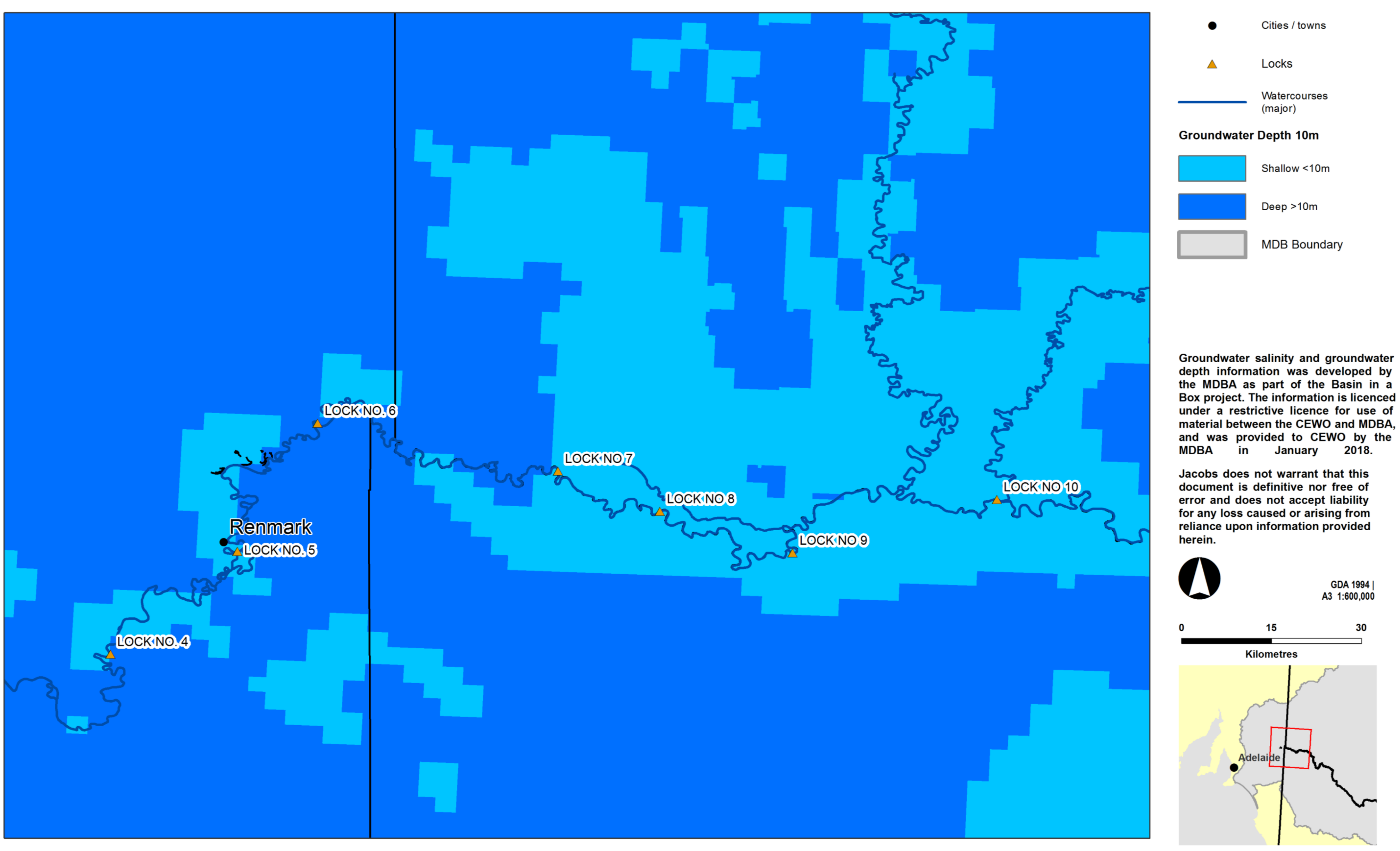

Figure 7-18: Groundwater depth: Murray

Australian Government
Commonwealth Environmental Water Office

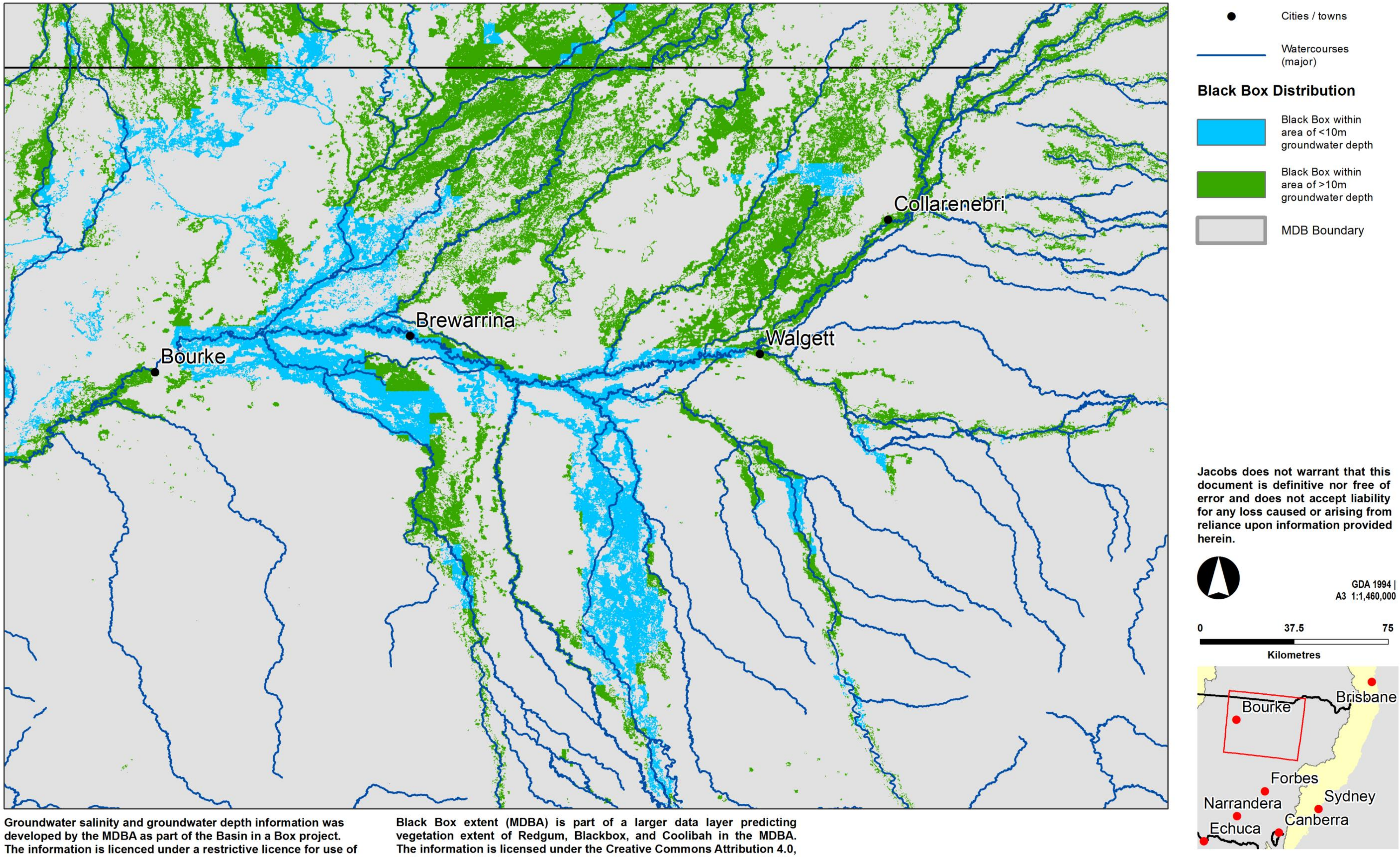

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Figure 7-19: Groundwater depth and Black Box: Darling

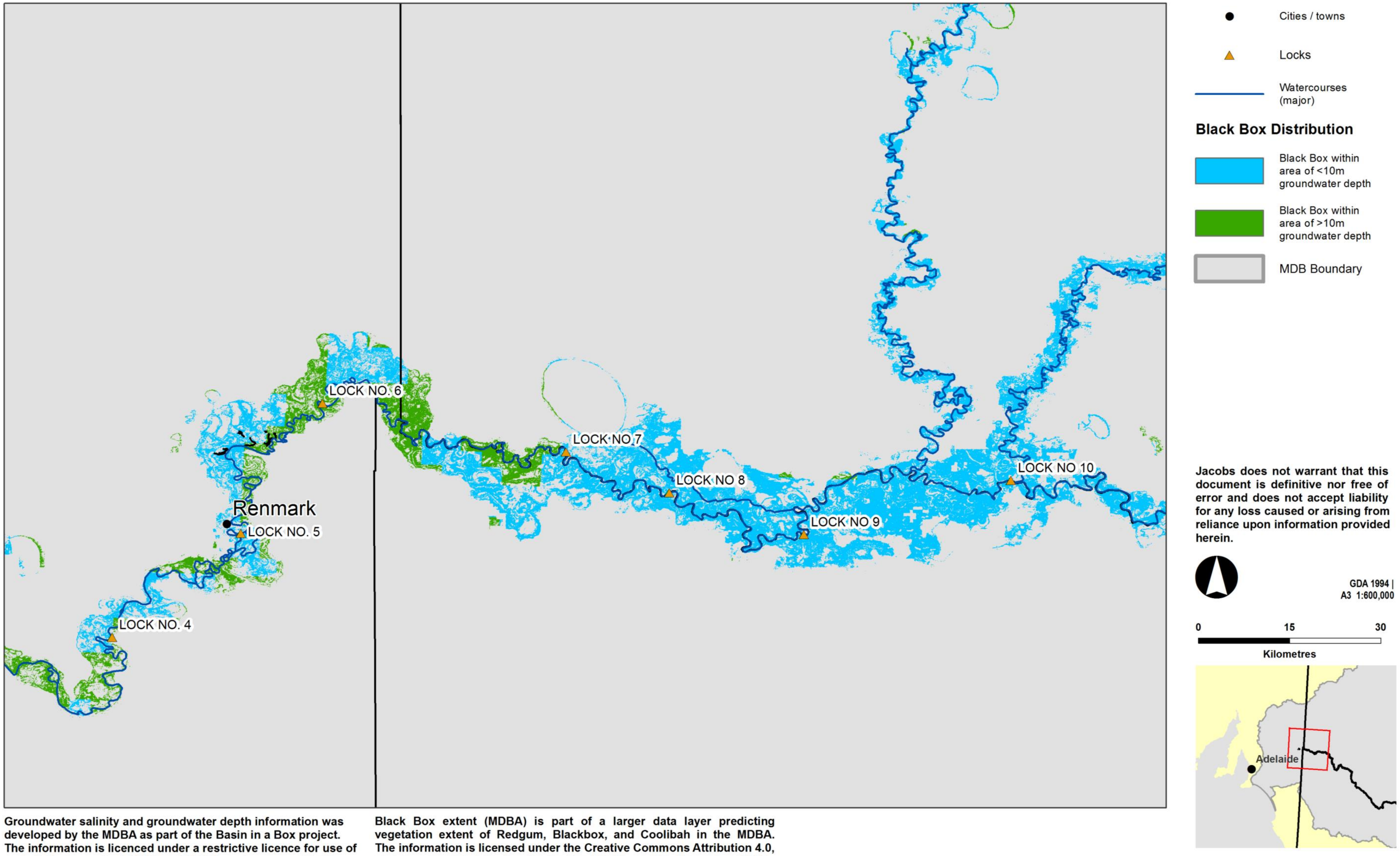

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Figure 7-20: Groundwater depth and Black Box: Murray

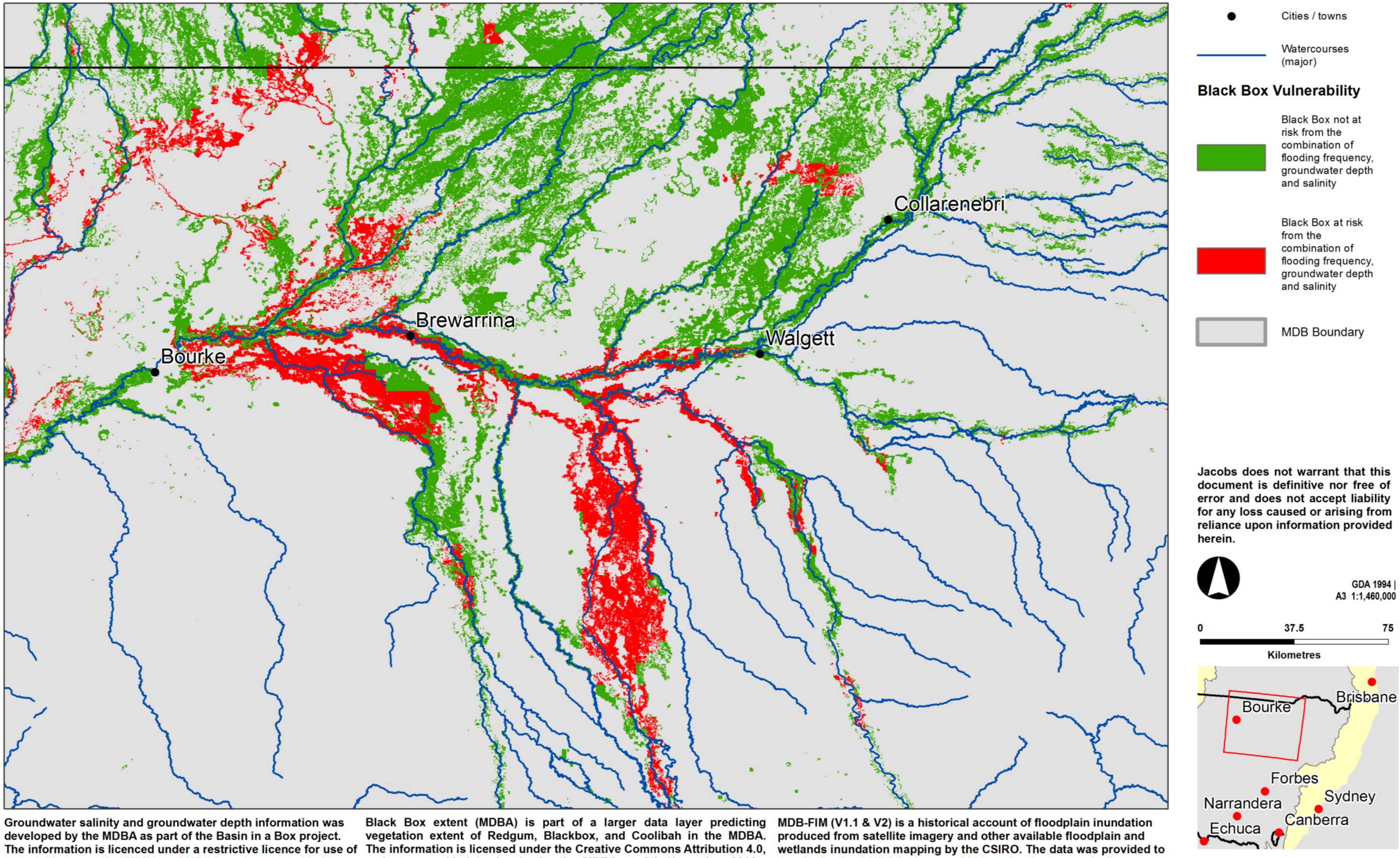

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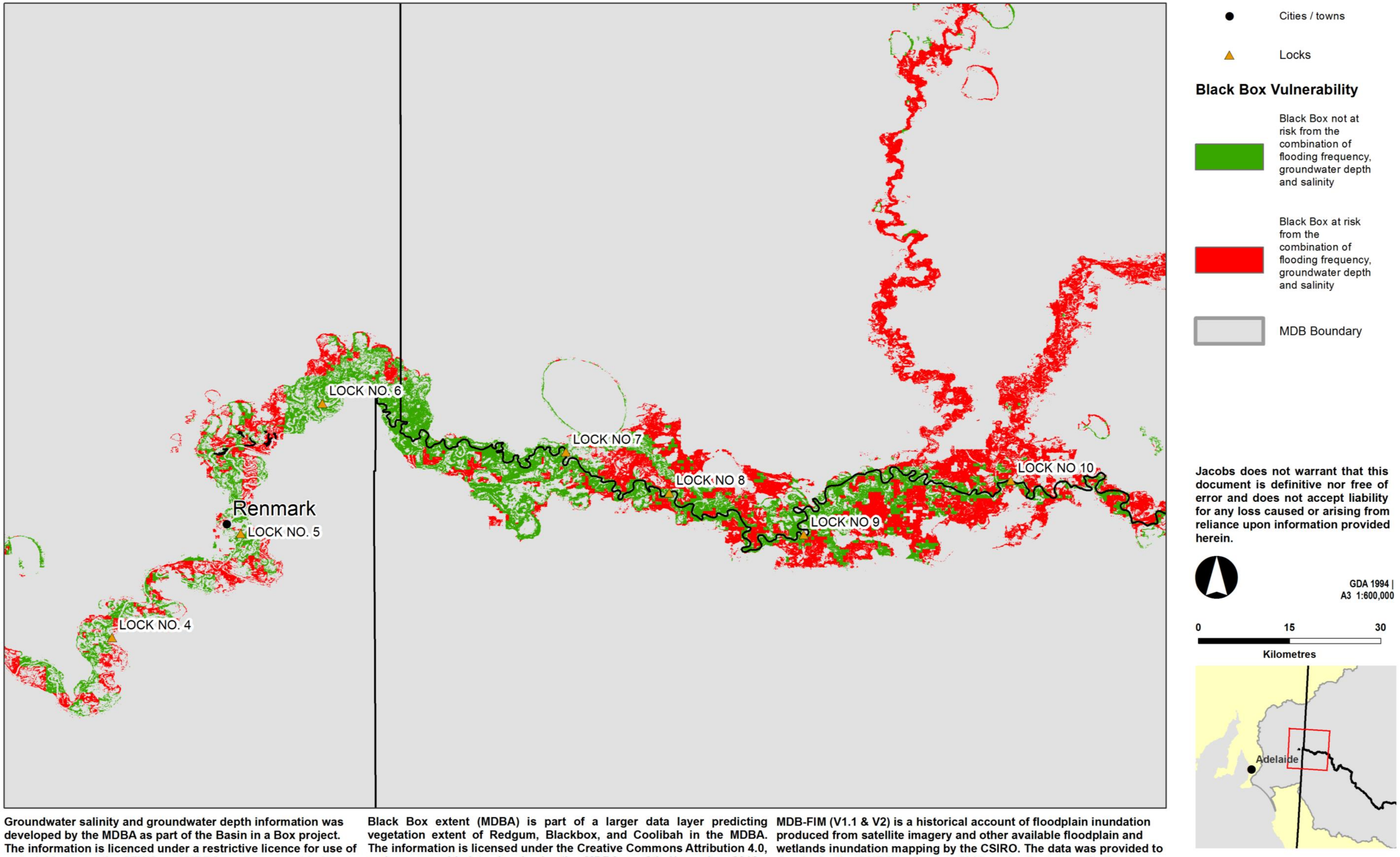
Figure 7-21: Vulnerability of Black Box: Darling

Australian Government
Commonwealth Environmental Water Office



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MDB-FIM (V1.1 & V2) is a historical account of floodplain inundation produced from satellite imagery and other available floodplain and wetlands inundation mapping by the CSIRO. The data was provided to Jacobs by the CSIRO in January 2018, under the terms of a licence agreement valid to 30 June 2018.

Figure 7-22: Vulnerability of Black Box: Murray

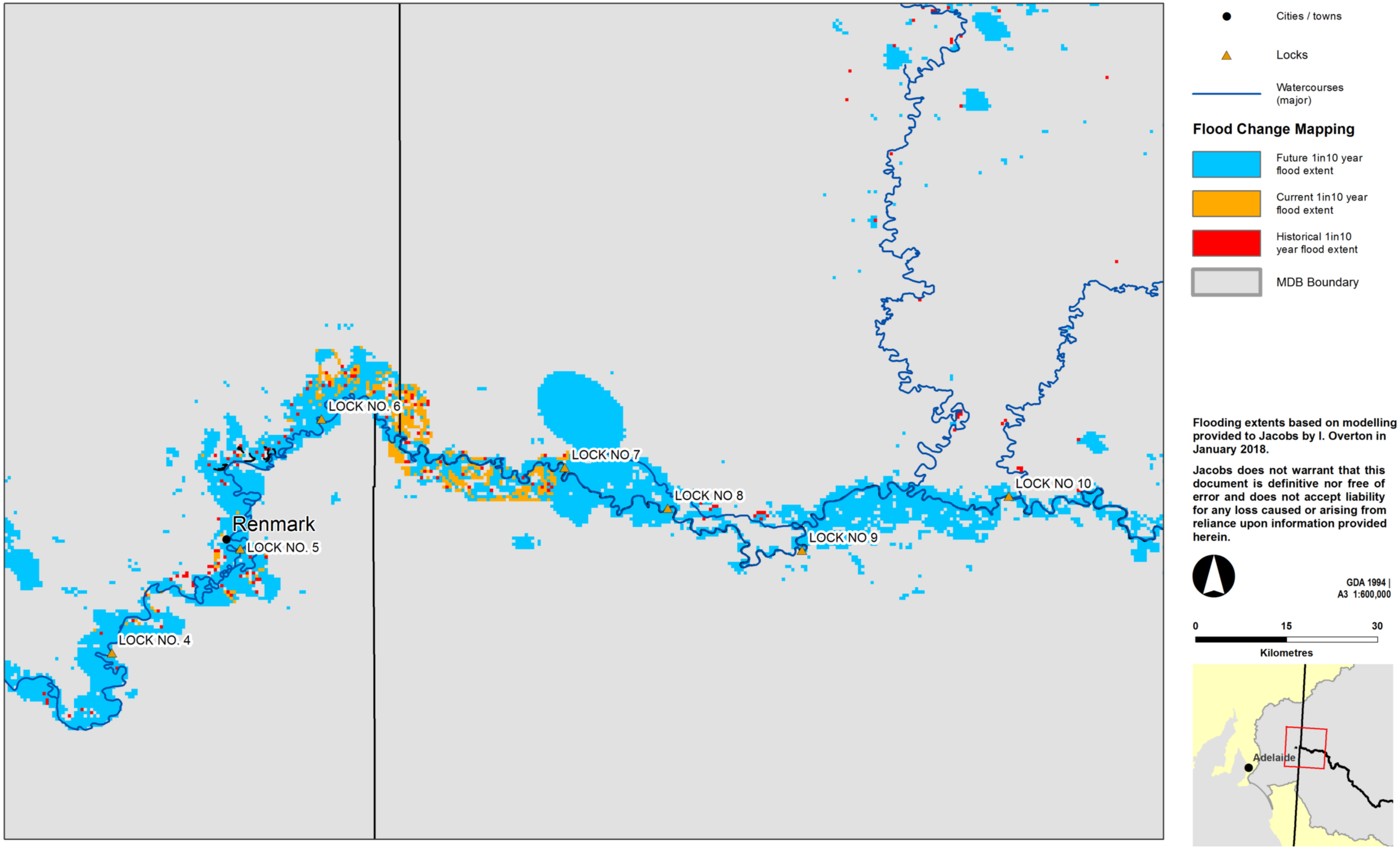

Figure 7-23: Flood change map for the upper area of the lower River Murray in South Australia under historical, current and future modelled climate scenarios for a 1 in 10-year flood regime (Overton et al., 2009).