YOUR WETLAND
hydrology guidelines

RIVER MURRAY SOUTH AUSTRALIA

Report DWLBC 2002/19

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If you would like more information, two complementary documents are available:

Your Wetland: Supporting Information and
Your Wetland: Monitoring Manual.

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Foreword

Your Wetland: Hydrology Guidelines is the first of three documents developed for managers of the wetlands that enrich the River Murray of South Australia. These documents consolidate the findings from research, monitoring and experiences of managers to create an ecologically-based decision making framework for guiding wetland management.

The River Murray is facing a number of challenges, not least of which is river regulation. These challenges are drivers of fundamental changes in the hydrology of the river and its adjoining wetlands.

Over the past decade, motivated individuals in the Riverland community have been managing wetlands by simulating the conditions of flooding and drying cycles. As a result of their experiences, much has been learnt about what can be achieved when these relatively simple tools are applied to wetland management. Although we still cannot explain all of the responses of wetlands to these management protocols, we now have a framework for future management activities that is based on documented experiences. Our collective tasks in the coming years are to extend this knowledge in order to refine further our capacities to manage and enhance the wetlands of the River Murray. These wetlands are worthy of our best efforts.

The Australian Landscape Trust and the South Australian Government are committed to addressing the declining condition of biological communities in the lower River Murray. Broad scale wetland management has the best chance of success through collaboration and innovation by community members, government agencies and the private sector. This project demonstrates how the private sector and government benefit from working together to build community capacity. Community capacity is essential for taking the next big steps in the management of River Murray wetlands to achieve a vision we share for their well being, for wildlife and other biodiversity they support and for their ecosystem services on which we all depend.

This document, *Your Wetland: Hydrology Guidelines,* is intended to assist wetland managers through the process of developing rehabilitation projects for wetlands. It highlights the importance of knowing the particular characteristics of your wetland, understanding where your goals and efforts are headed and how you can achieve success through adaptive management. The key feature of this document is the decision-making framework that outlines how managers can use the manipulation of water regimes to achieve key outcomes for the recovery and ongoing health of wetland habitats.

The Guidelines are supported by two complementary documents - *Your Wetland: Supporting Information* and *Your Wetland: Monitoring Manual.* The former collates current ecological knowledge about wetland biota which was used to develop the Guidelines presented here. It will help managers understand the effects of their water regime on wetland ecosystems and give them tools to interpret changes in their wetland. The latter document contains details for managers on how to monitor their wetland, an essential requirement for adaptive management.

Foreword

It is with great pride that we present these documents. They are a demonstration of the values and commitment that provided the foundation for the Natural Heritage Trust and an example of benefits realised from the partnership formed between the Australian Landscape Trust, River Murray Catchment Water Management Board, and the South Australian Government. They form a record of the success that is possible when community volunteers and scientists combine their resources to achieve shared goals. We hope that the energy, commitment and discipline that carried this work forward will continue to drive a process that will recover much of the past magnificence of our wetland heritage.

Neil R Clark, AO
Chairman, Australian Landscape Trust

John Hill
Minister for Environment and Conservation
Minister for River Murray

Contents

GOLDEN RULES

These Golden Rules should override all other decisions you make about managing your wetland.

THEY SHOULD NEVER BE BROKEN!

Don't kill long lived vegetation

Understand the water stress tolerances of species such as lignum (*Muehlenbeckia florulenta)* and red gums *(Eucalyptus camaldulensis)* to ensure that their survival is not compromised by your water regime management. Maintaining established red gums requires an average flood frequency of 1-3 years, not lasting for more than 18-24 months [1,2]. Experiences in the Barmah Forest have shown shallow flooding over hot summer months resulted in moisture stress and death of mature red gums [3]. Lignum require an average flood frequency of 1-8 years, not lasting for more than 3-5 months [2]. Complete drying between flood cycles is required for both of these species [2].

Don't salinise your wetland

Ensure that you understand the ground water processes under your wetland before you embark on an extended drying. Ensure there is a freshwater lens (layer of freshwater under a dry wetland) and monitor its integrity through a number of dry stages.

Let big floods through. This will ensure that the hydraulic pressure created during flooding will not cause saline regional ground water to rise to the surface in and at the edges of your wetland.

Don't destroy threatened communities or habitats of threatened species

Get to know your wetland before you change anything. Learn about its flora and fauna to ensure that changing the water regime will not compromise the habitats of threatened species and communities (Section 1).

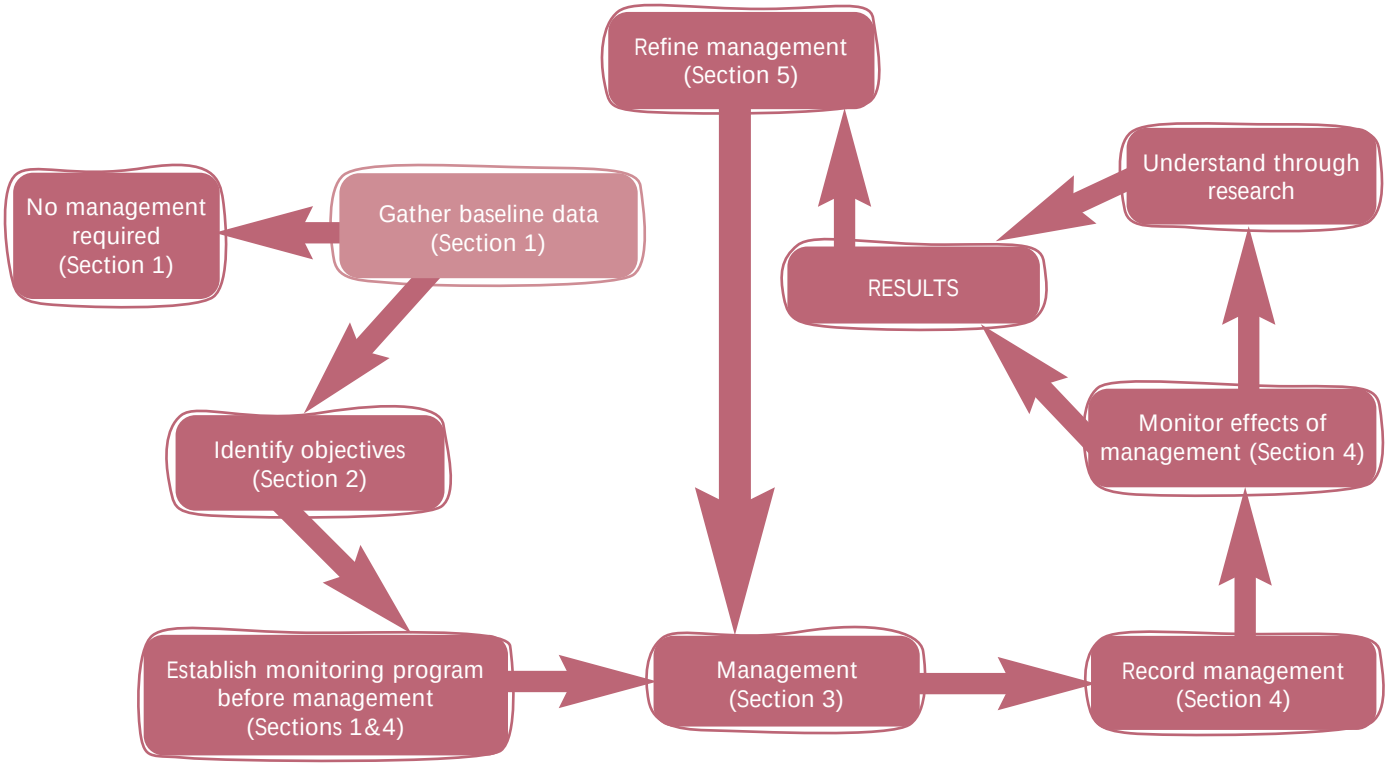
Wetlands are complex. Through the management of lower River Murray wetlands over the last decade we have learnt a lot about what can be achieved [18]. While we cannot necessarily explain all of the responses of wetlands to management actions, we can now provide a framework for management based on our experiences and continue to build on it to further refine management and enhance the wetlands of the lower River Murray.

The Hydrology Guidelines presented in this document have therefore been put together with two main ideas in mind – to record and share the knowledge we have accrued and to provide a framework for you to build on from your own experiences. The Guidelines are not prescriptive, but are intended to set you in the right direction and help you focus your monitoring efforts. They will bring you up to date with the latest research findings, but have been written with the understanding that all wetlands differ and that the day-to-day management of your wetland will depend on the ecological responses you observe.

Just as importantly, these Guidelines advise you on what not to do. Rules are rules: if you break them, you and your wetland could be in big trouble! Our experience has highlighted three Golden Rules (see opposite) that should be followed at all times and considered above all other guidelines presented.

While some general guidelines can be applied to managing wetlands, each wetland is unique. Therefore, the Guidelines have been put together based on the adaptive management model (see Figure 1), requiring you (the manager) to make key management decisions based on the results of monitoring. Intuitively, we all learn from our experiences and fortunately we also learn from our mistakes. Learning and applying the knowledge we gain is the key to adaptive management.

FIGURE 1: ADAPTIVE MANAGEMENT MODEL



These Guidelines are divided into four sections.

Section 1 – *Getting intimate with your wetland: Baseline surveys*
This section helps you to become intimate with your wetland: to learn about its strengths and weaknesses, to decide if it should be managed, and to identify the options for management.

Section 2 – *Setting your objectives: A focus on habitats*
Managing wetlands is not as easy as turning the tap on and off. You need to know where you are headed (your objectives) so that you can use current knowledge to move in the right direction. Focusing your management objectives to support a range of plant habitats in your wetland will provide the ecological infrastructure that will also support a range of wildlife.

Section 3 – *Achieving your objectives: Hydrological management*
Plants respond rapidly to changes in water management. You will need to turn the tap on and off, BUT do so with careful consideration of all parts of your wetlands water regime: timing, duration, frequency, rate and depth of filling and drying (Table 2).

Section 4 – *Getting results: Recording and refining*
Monitoring ecological responses in your wetland is the key to a successful project. A supporting document, *Your Wetland: Monitoring Manual*, provides the tools to get you started.

Although numbered sequentially, the actions described in each of these sections overlap and should be implemented concurrently, as shown in Figure 2.

FIGURE 2: HOW THE SECTIONS IN THESE GUIDELINES OVERLAP

For example, it is important to become intimate with your wetland (Section 1) before you begin identifying your objectives (Section 2) which in turn will enable you to refine your monitoring (Section 4) before starting to manage your wetland (Section 3). Monitoring and Evaluation (sections 4 and 5) continues throughout the life of your project.

Wetland management equals long-term commitment.

Remember, wetland management equals long-term commitment. These Guidelines will give you an idea of the complexity of managing a wetland, introducing you to the web of monitoring and decision-making that is part of wetland management.

Your wetland.
Fish in it,
Canoe in it,
Wade out in it:
Search out its weaknesses,
Identify its strengths:
Watch the way it changes
Day to day, season to season:
It's all part of getting to know
Your wetland.

Each wetland is unique. While there is no 'silver bullet' solution for managing wetlands, there are some key principles that can be applied to new and existing projects in the South Australian section of the River Murray. If you are 'intimate' with your wetland and you have the most current information about wetland ecosystems, you will be armed with the tools to make the types of decisions critical to successfully manage your wetland.

Getting to know your wetland before it is managed is the first stage. With the information you collect in **baseline surveys** you will be able to:

Step 1. Decide if your wetland should be managed
Step 2. Begin to understand your options for management, and
Step 3. Establish a basis on which to evaluate the success of your wetland management project.

Step 1: Should your wetland be managed?

Fish in it,
Canoe in it,
Wade out in it.

Just as a farmer would not plant crops without knowing about the land (soil nutrients, seasonal changes, plant requirements etc.), you should not try to manage your wetland without knowing about its ecology. Once you know about its ecology you will be able to make informed decisions about whether management will maintain or enhance the wetland through alleviating threatening processes and therefore if the wetland should be managed or not. It is also important to know what the wetlands around yours are like. This will help you understand if the habitats in your wetland are unique or common, and work out how your management may impact on wetland habitats regionally.

... build a picture of its ecology and options for management.

If you undertake general biological surveys before you start managing your wetland, you will have the information to make decisions about the focus and direction of your wetland management project. This information will help you identify your objectives for management. A combination of flora and fauna surveys will provide a good starting point for management. These types of surveys are generally referred to as baseline surveys. (Techniques for baseline surveys are outlined in *Your Wetland: Monitoring Manual*.)

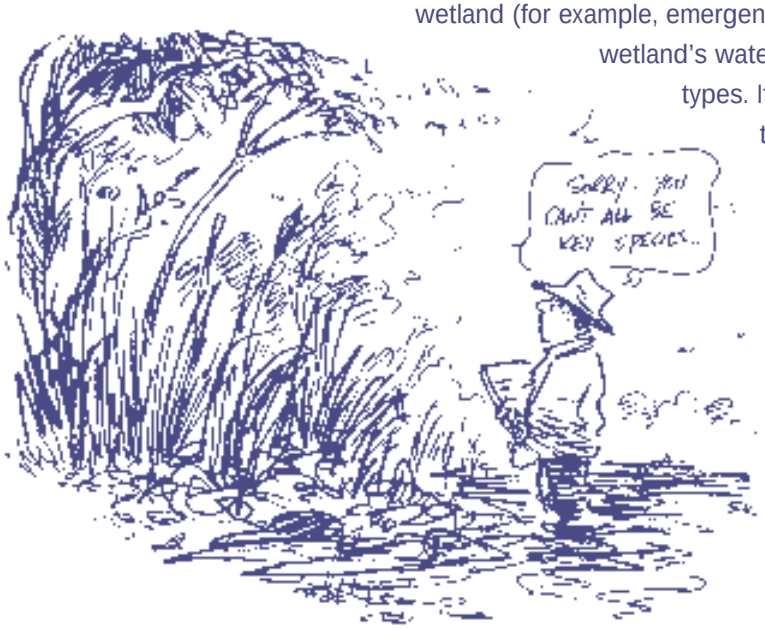
Invite a biologist from the local high school, or from one of the universities, to come along and look at your wetland. They may be able to help you build a picture of its ecology and options for management.

Habitat surveys

Vegetation is the major habitat type that can be changed in wetland management.

Habitats within a wetland include the soil, fallen logs, water and vegetation and combinations of these things. The habitat surveys recommended focus on the habitat provided by vegetation. Vegetation is the major habitat type that can be changed in wetland management. Habitat surveys should involve surveying the distribution and composition of vegetative habitats in your wetland. Techniques for habitat surveys are outlined in *Your Wetland: Monitoring Manual*.

Habitat surveys will help determine your management objectives. If, for example, your objective is to create a range of wetland habitats and the habitat survey indicated there was only one dominant habitat in your wetland (for example, emergent vegetation), you may consider altering the wetland's water regime to support a wider range of habitat types. If, on the other hand, your habitat survey showed that a wide range of habitats already existed in your wetland, you may decide to spend time and resources managing threats to the floodplain surrounding your wetland (for example, carrying out fox and rabbit control).



Habitat surveys will also help you identify any rare habitats or plant species within your wetland. If you find rare habitats or plant species, you must be extremely cautious. You will need to identify and understand the threats to these habitats or species and find

ways to abate the threats. If detailed information about their ecology is available, you may be able to take specific actions to enhance their survival.

Fauna surveys

Surveying for fish, frogs, macro invertebrates and birds will also influence your management decisions. Techniques for conducting fauna surveys are detailed in *Your Wetland: Monitoring Manual*.

A few moments spent peering through a hand lens or, better still, a microscope will persuade you that the unseen world of tiny animals is every bit as bizarre and fascinating as the one to which we are most familiar. Some of these animals (like the snails, for example) have important stories to tell.

Some animals have important stories to tell.

As with habitat surveys, if there are rare species of animals in your wetland you need to be extremely cautious in your management decisions. You will need to identify and understand the threats to these species and find ways to reverse them. If, however, there is detailed information about their ecology you may be able to take specific actions to enhance their survival.

Step 2: Understanding your options for management

Search out its weaknesses,
Identify its strengths.

Understanding the physical and hydrological options and limitations of your wetland is essential for making management decisions and setting objectives. Before you start managing your wetland, it is critical that a detailed record of the wetland's hydrology is collated.

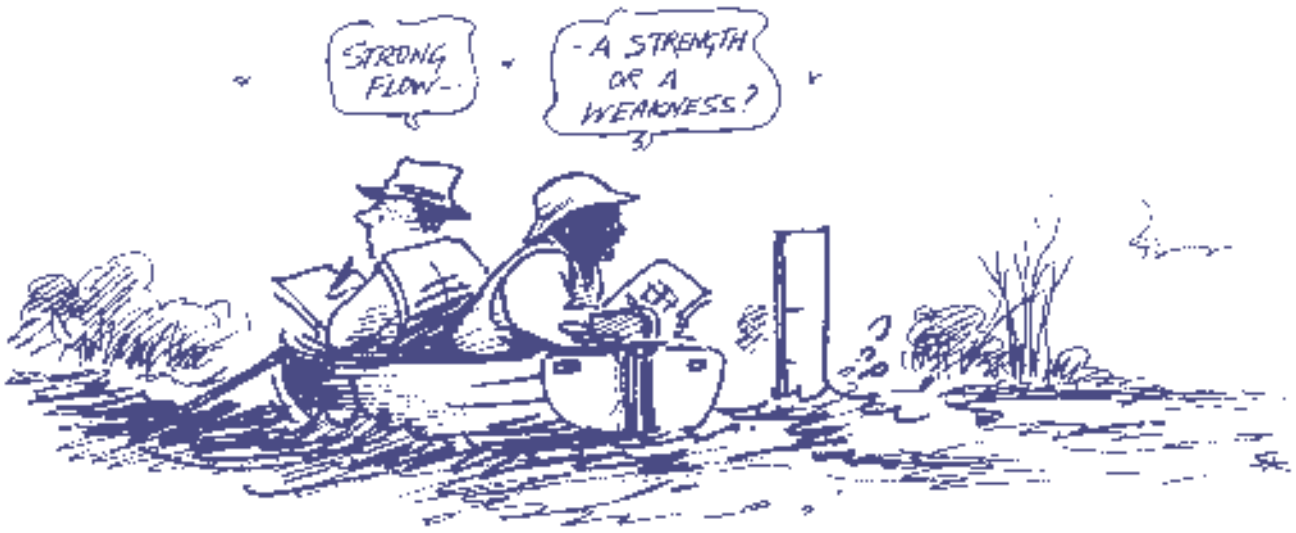
Hydrological and physical surveys will need to include:

- records of the water levels and associated river flow at which the wetland fills and drains, and
- options available for holding water above the basin of the wetland.

The feasibility of completely drying the wetland without causing salt to seep into the wetland bed also needs to be considered.

When you get to the stage of managing the water regime of your wetland (Section 3), the options you have available will be largely determined by the results from hydrological and physical surveys. If, for example, you are interested in managing a wetland that is permanently inundated as a result of the stable weir pools, then you will have a range of options relating to the timing, duration, frequency, rate and possibly depth of filling. On the other hand, if you are interested in managing a temporary wetland, you will have fewer options available because the timing, rate and frequency of filling are predetermined (based on when the river is flooding).

Before starting to manage your wetland, it is critical to collate a detailed record of its hydrology.



The types of sediments will influence the types of plants that will germinate.

Knowing about the sediments of your wetland will also help you build a picture of what outcomes can be achieved from management. If, for example, you have sandy sediment in your wetland the sediments will not become more strongly consolidated as the duration of drying increases [4]. The types of sediments in your wetland will also influence the types of plants that will germinate on the dry wetland bed. Sandy sediments will have little water retention on drying, and therefore plants that require a lot of moisture to germinate and grow will not survive. On the other hand, sediments that are high in clay content are more likely to become increasingly consolidated with length of drying. By increasing sediment consolidation, sediments will not be re-suspended readily when disturbed (or when the wetland is re-filled) [4]. Lower re-suspension rates mean that under-water light conditions will be higher and submerged plants will be more likely to germinate.

Step 3: Establishing a basis on which to evaluate the success of your project

Watch the way it changes
Day to day, season to season.

The benefits of biological surveys prior to management are two-fold. In addition to guiding management decisions, in some cases the data collected can be used to evaluate the ongoing success of the management project.

Detailed monitoring provides a basis for adapting your management and assessing your success.

However, while some data collected during baseline surveys can be used to assess your management objectives, you will need to do more targeted monitoring (prior to management) to ensure you have enough information to assess your objectives and evaluate the success of your wetland management project in the long term. This more detailed information will provide a way of quantifying the changes that are observed, enabling you to continue adapting and improving the management of your wetland (Section 4).

Once you have become intimate with your wetland and have worked out whether your wetland can be managed, you are ready to embark on a wetland management project. The first questions you should ask are:

What is it you want to achieve from your wetland management project?
How will you achieve your objectives?

By answering the 'What?' question, you will clearly define your management objectives, thus providing your project with focus and direction. The objectives will automatically answer the 'How?' question, giving you the direction required to make decisions about the day-to-day management of your wetland (Section 3).

Realistic habitat objectives are essential for the success of your wetland management project.

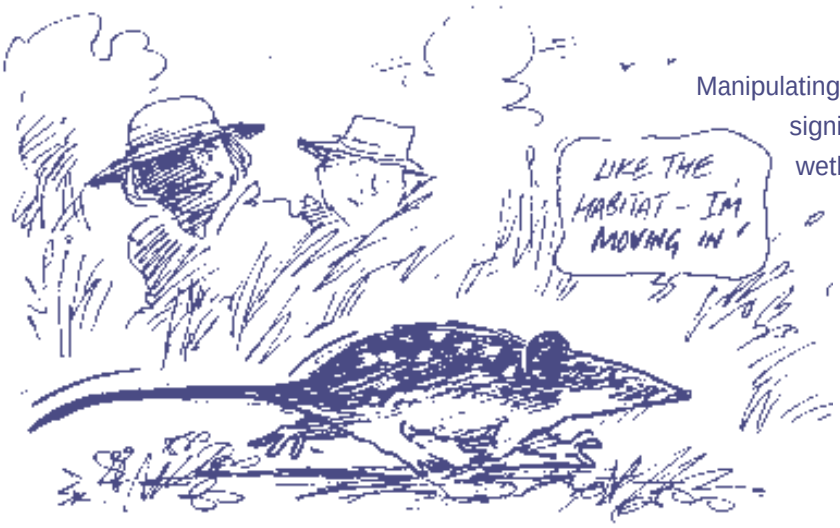
What do you want to achieve?

So you want to see your wetland teeming with native fish, macro invertebrates and birds? Then you will need to focus on supporting the infrastructure of the wetland ecosystem.

Establishing and maintaining a range of vegetative wetland habitats will result in positive effects throughout the system: habitat diversity promotes wildlife diversity. By providing the structures where plants and animals can attach and grow, aquatic vegetation forms the basis for the grazing food web [5]. If, for example, you support a range of submerged plants in your wetland, you will be providing habitats and food resources (biofilms) for a diversity of grazing invertebrates and fish. These invertebrates will then become food for predators such as fish and a number of species of wetland birds. Maintaining these submerged habitats will maintain food availability and support a wide range of wetland fauna.

The types of habitats you are interested in should be the focus of your management objectives. Responses in wetland fauna that result from habitat change are the outcomes of your wetland management project.

Focus on supporting the infrastructure of the wetland ecosystem – vegetative habitats.



Manipulating the water regime is the most significant management tool available to wetland managers: Plant growth, survival and reproduction will respond readily to hydrological change [6, 7, 8]. Your management options will therefore depend on the hydrological options and limitations you identified for your wetland (Section 1, Step 2).

There are four main vegetative habitat types:

- Submerged plants are those with all parts of the plant below the surface of the water, such as ribbon weed *(Vallisneria americana)* and curly pond weed *(Potamogeton crispus).*
- Emergent plants are species that must maintain at least some of their leaves and stems above the surface of the water to survive, and include bulrush *(Typha spp.),* spiny sedge *(Cyperus gymnocaulos)* and three cornered rush *(Bolboschoenus caldwellii).*
- Dry wetland bed plants are those that live on damp mud and colonise the mud flats that are exposed once the water level in the wetland is drawn down. They include knot weed *(Persicaria* spp.) and common sneeze weed (*Centipedia* spp.).
- Riparian vegetation is the group of species that fringe the wetland basin and have a low tolerance for extended periods of inundation, such as red gums *(Eucalyptus camaldulensis)* and lignum (*Muehlenbeckia florulenta).*

These four habitats should not necessarily be considered in isolation. At a single point in time a wetland can be managed to support a combination of these habitats. A wetland could include areas dominated by submerged plants and a mix of submerged and emergent plants as well as areas dominated by emergent plants with enhanced riparian vegetation and dry wetland bed plants (Figure 3). Habitat management is directly tied to the hydrological management of the water regime (Section 3).

The types of habitats you create will determine the types of wildlife you observe in your wetland (Figure 3). In a wetland dominated by submerged plants, for example, biofilms, invertebrates, fish and some species of birds will flourish. Whereas terrestrial invertebrates and reptiles will inhabit a wetland dominated by emergent and dry wetland bed plants.

The types of habitats you create will determine the types of wildlife you observe in your wetland.

Establishing objectives that include maintaining a mix of habitat types through time, will result in a range of wildlife through time. For example, you could promote submerged and emergent vegetation during spring and summer, encouraging biofilms and a range of invertebrates and water birds, and in late summer you can draw the water level down to support dry wetland bed vegetation and terrestrial invertebrates and reptiles. The result is a range of wildlife responses through time.

Supporting a range of plant species within the key habitat types should also be a major consideration for managers. A wide range of plant species will promote greater structural complexity within your wetland (that is, you will ensure the presence of plants with different growth forms within each habitat). By increasing the structural complexity you will have a wide range of microhabitats suitable for different wildlife. Within submerged habitats, for example, the fine structured leaves of watermilfoil (*Myriophyllum* spp.*)* provide suitable microhabitat for bloodworms (Chironomidae) and segmented worms (Oligochaeta), while charophytes (soft structured algae-like plant) may support high percentages of *Hydra* spp. (soft bodied invertebrate which attaches to vegetation, twigs and other debris) [9]. Thus, a mix of these species within a submerged habitat will support a range of different types of invertebrates.

FIGURE 3: insert

A unique habitat may become a focus for your habitat objectives.

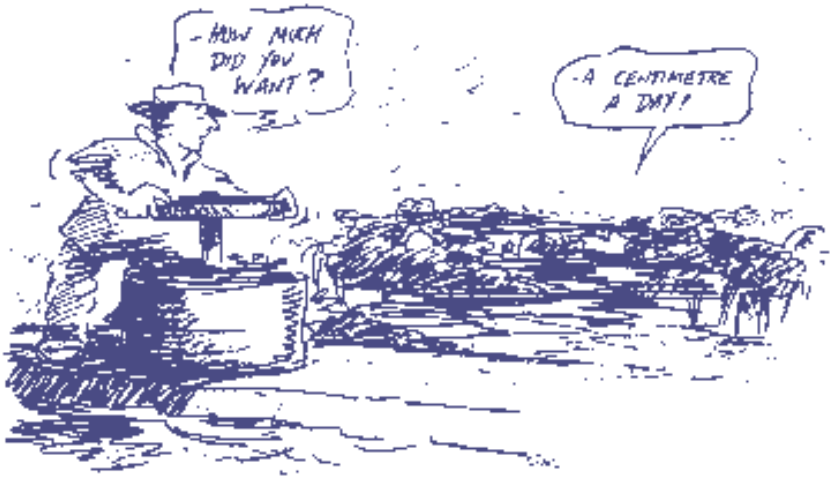
Rare habitats and species should also be considered in your wetland management objectives. If, for example, your wetland has a regionally unique habitat type (such as red gum swamp or dry wetland bed plants), you may consider these habitats as a focus for your habitat objectives (Section 1).

The hydrological management options and limitations of your wetland will also influence your management objectives (Section 1). For example, if it is not possible to completely dry your wetland without risking salt intrusion, it will not be possible to achieve a habitat objective to create dry wetland bed vegetation.

How will you achieve your objectives?

The key management tool is water, but it's about more than just wetting and drying.

To alter the mix of habitats in your wetland, the key management tool is water. Wetland management is more than just wetting and drying. It is an intricate balance of all parts of the wetland water regime because plants respond readily to changes in timing, duration, rate, depth and frequency of filling (Table 1). In other words, the periods between the wet and dry phases are probably the most important of all.



Once you have identified the habitat objectives, Section 3 will guide you on how to manage the wetland water regime to achieve these.

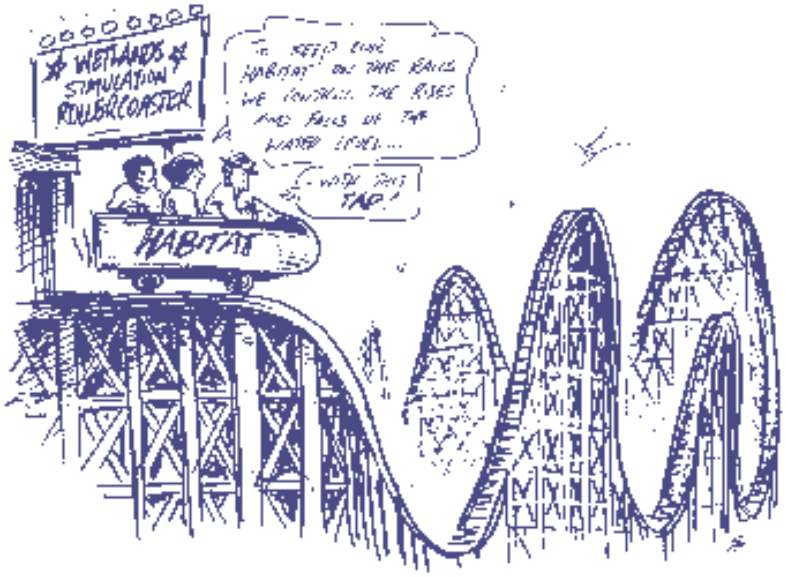
TABLE 1: FEATURES OF THE WATER REGIME IN WETLANDS *(adapted from Boulton & Brock, 1999[10])*

FEATURE	DEFINITION
Timing	The time when water is in the wetland – that is, the season when the wetland fills.
Frequency	How often filling and drying occurs - ranges from zero for permanent wetlands to frequent filling and drying (several times a year) in shallow wetlands.
Duration	Period of inundation or drying – ranges from days to years, varying within and among wetlands.
Rate	The length of time it takes for water levels to increase – for example, 1cm/day.
Depth	The depth of water in your wetland after filling - depth will also influence the extent of flooding (that is, whether the water will fill the wetland basin or extend into the riparian areas).

The Hydrology Guidelines presented in Table 2 are intended to point you in the right direction by outlining options currently available to achieve the objectives you have identified for your wetland. The Guidelines are based on three years of research and monitoring within 11 wetlands in the lower Murray (including PhD research, Honours student research and general wetland monitoring), and are supported by findings of other researchers (see References, page 24, and *Your Wetland: Supporting Information*).

These Guidelines can be applied to temporary wetlands and wetlands that have become permanently inundated as a result of stable weir pools. However, the options for management will be different for these types of wetlands. The options available will be determined by the results of the physical and hydrological surveys (Section 1, Step 2).

There are a number of management actions that could result in the establishment and maintenance of a range of submerged, emergent, dry wetland bed and riparian habitats. The timing of filling and drying is critical for their establishment. Key management actions and the associated ecological responses are outlined below.



Key management actions

Complete dry

The complete drying of the wetland commencing in late summer and lasting until early spring permits the germination of a range of dry wetland bed plants [11]. These plants will, in turn, provide shelter for invertebrates and fish and re-release nutrients to the wetland when it re-fills in early spring. Complete drying for approximately six months may consolidate wetland sediments that are high in clay content and allow dry wetland bed plants to complete their life cycles and contribute to the seed bank [4].

In general, the complete drying of wetlands only needs to occur once the submerged vegetation starts deteriorating and has been allowed to flower and set seed: This decision needs to be based on monitoring results. Drying could also occur if you wish to support dry phase plants as one of the major habitat objectives for your wetland.

Full (weir pool level)

When wetlands are re-filled after a period of drying, nutrients are released [4,12], supporting algae and biofilms. (Biofilms are the slimy growths of algae, bacteria and fungi that you see on submerged rocks, wood, submerged plants and other surfaces.) Re-filling also provides clear, nutrient rich water conditions suitable for the germination of submerged plants [13]. This, in turn, provides habitat and abundant resources for invertebrates and small fish. Thus, they can become food resources for animals higher up the food chain like

water birds and larger fish species. The consolidation of sediments during the dry period will ensure that the sediment is not easily re-suspended on re-filling [4]. Filling wetlands gradually in early spring should provide ideal temperatures and good light conditions for the germination and survival of submerged plants that provide surfaces for biofilms and habitats for invertebrates and fish.

To ensure submerged plants complete their life cycle by flowering and contributing to the seed bank, the wetland should remain full for at least the length of the first growing season (spring through until the end of summer), and preferably until the following growing season (approximately two years). This recommendation should be considered a 'ball park' figure because it is based on observations of a single species, ribbon weed (*Vallisneria americana*) [2]. Such information is currently unavailable for other submerged aquatic species.

It is critical to monitor the life stage and abundance of submerged species to make decisions about changing the hydrology of your wetland.

It is therefore critical that, as managers, you monitor the life stage and abundance of submerged species to make key decisions about changing the hydrology of your wetland. If maintaining submerged habitats is one of the major habitat objectives for your wetland, an option is to dry the wetland (once the submerged vegetation has flowered, set seed and begins to break down). Techniques for monitoring the life stage and abundance of submerged vegetation are outlined in *Your Wetland: Monitoring Manual* [12].

Partial dry

Partially drying wetlands to expose an additional area within the wetland basin can increase emergent vegetation. Exposing additional areas will encourage the germination of emergent species into the wetland basin (down the elevation gradient) and provide a water regime suitable for emergent species that prefer fluctuating water levels.

The species composition in this emergent zone will vary depending on the rate of filling and draw down and the depth of water. This is because different species have different water stress tolerances. In some wetlands, extending the area of emergent vegetation can increase the structural complexity of your wetland once it re-fills. However, in others, there is the potential for species like bulrush (*Typha* sp.) to dominate the emergent vegetation and prevent other emergent and submerged species from becoming established.

Partial drying can also benefit wetlands that are fringed with red gums by removing water from the root zone in late summer each year. Whilst this could promote survival of this species, complete drying of the root zone is needed between flooding cycles [2].

Over bank flooding (natural / enhanced)

To help vegetation survive in the riparian zone, there may be the option in some wetlands to keep water levels above the weir pool level (that is, above the wetland basin), either at times of spring flooding or during normal river levels. Where this is possible, spring floods can be enhanced to mimic natural flooding lengths by extending flood duration in the wetland (average duration 4-7 months) [2]. Flooding the riparian zone vegetation will continue to support red gums, lignum and river coobah (*Acacia stenophylla)*, which rely on periodic flooding.

It is critical, however, to ensure that you understand the water requirements of the key species in the riparian zone to make sure that the duration of flooding will not compromise their survival (see Golden Rules, page 4). Also, complete drying should occur between flooding events to allow for aeration and consolidation of the wetland bed soils [2].

Make sure the duration of flooding will not compromise the survival of key species.

Over bank flooding (managed)

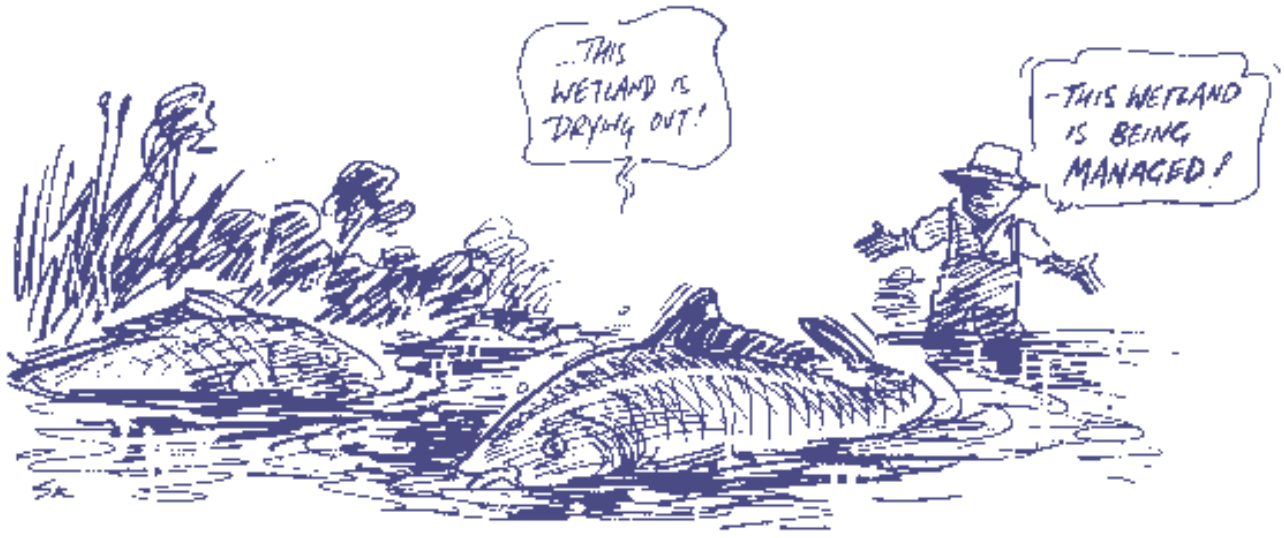
Extending the flooded area of a wetland by filling the wetland beyond the edge of the wetland basin can also be used to increase the area of emergent vegetation. As is the case for partial drying, creating a water regime ideal for the germination of emergent vegetation will encourage emergent vegetation to move away from the wetland basin (up the elevation gradient). If water levels can be raised into the riparian zone, the benefits outlined above for over bank flooding (natural/enhanced) will also apply.

Reducing/excluding carp

One of the consequences of managing the water regime of wetlands is the reduction in carp abundance when you dry your wetland. A complete dry stage will reduce the number of carp in your wetland. If you exclude large fish, by screening the wetland inlet when you re-fill your wetland, you will be able to maintain low numbers of large breeding sized carp for some time.

Carp are known to increase the turbidity of wetlands (which may influence the germination and survival of submerged plants) and uproot submerged vegetation[14-16]. However, carp are not the only threat to wetlands in the lower River Murray. They are as much a symptom of a changed environment as they are a cause of problems, and you can't fix problems by only treating the symptoms. Concentrating on habitat management, rather than managing for a single species (such as carp), will have benefits for a wide range of wildlife in your wetland.

Carp are as much a symptom of a changed environment as they are a cause of problems.



Hydrology guidelines

The Guidelines in Table 2 provide you with details on how to use the management actions described above to establish and maintain the habitats outlined in Section 2. These habitat types can be supported in combination. If, for example, your habitat objective is to 'create a structurally complex wetland with a range of submerged and emergent habitat types', you could:

- completely fill the wetland at the beginning of spring to create conditions suitable for the germination of submerged species,
- partially dry over summer/autumn to encourage emergent vegetation to move down the elevation gradient, and
- increase the duration of flooding in the riparian zone in years when spring flooding occurs in the catchment.

This process can continue for several years until the monitoring for adaptive management (Table 2 and Section 4) reveals a deterioration of submerged species.

...can be used in combination.

Each management stage is interdependent. Responses you'll see in your wetland following a single management event reflect preceding conditions and may even result from several management actions. For example, several dry stages may be needed before a response is observed in submerged species, depending on the types and amount of seeds in the seed bank of your wetland, which in turn is determined by the history of water regime management. Certain species may be absent from the seed bank due to extended periods of flooding, and these would need to re-establish via propagules.

...not prescriptive.

It is important to remember that the Guidelines aim to point you in the right direction for achieving various habitat types - they are not meant to be prescriptive. While the Guidelines suggest water regimes that will favour certain habitat types, this does not mean that these habitats cannot exist outside of these conditions. Each wetland will differ in its response to water regime management and may even respond differently with similar management actions on different occasions (depending on topography, seed bank, quality of the water source, etc.).

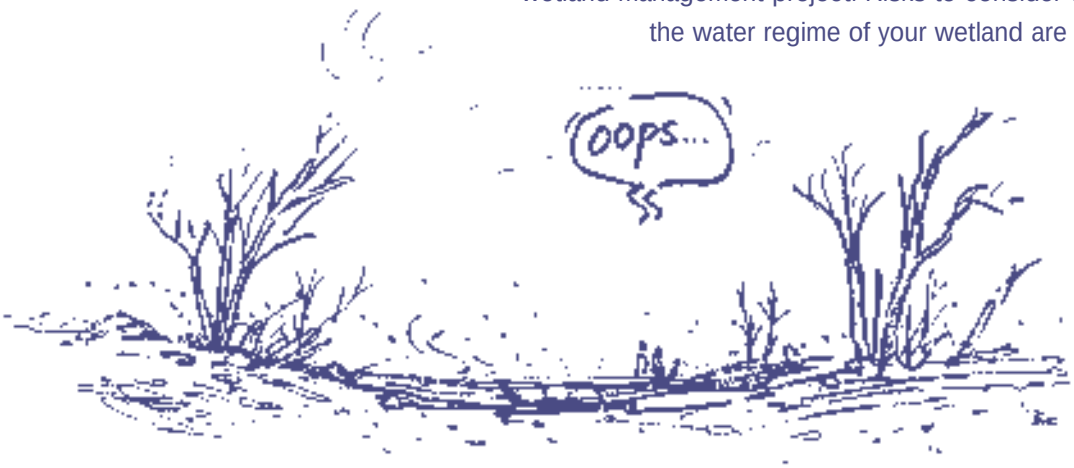
This is why it is critical that as a wetland manager you adopt the adaptive management model. Once you have identified your objectives, you will then be able to monitor the response of your wetland to make decisions about when to change the management. In most habitat types, the frequency of management actions is variable and depends on your monitoring findings. This is because there is little information available to support such decisions, further highlighting the importance of monitoring in making day-to-day decisions about managing your wetland.

Adapt your management based on monitoring results.

Ensure that you seek advice from other managers who have many years of experience and also pass on your own experiences to them. Establishing wetland management in this way will enable you to continue refining management in response to ecosystem changes (Figure 3 and Section 4).

Management risks

In wetland management it is just as important to consider risks and limitations as it is to understand options for management. In most cases, the topography and hydrology of your wetland (Section 1) will limit your management options. While you must always consider the Golden Rules (see page 4) above all of the Guidelines presented here (Table 2), you also need to be mindful of other risks that could be relevant to your wetland management project. Risks to consider when managing the water regime of your wetland are outlined below.



Rapid filling (greater than 3cm/day)

In wetlands that are greater than 50cm deep, rapid filling is likely to limit the germination and consequent survival of submerged plant species. Generally, as water depth increases the amount of light reaching the sediment surface will decrease. Low light conditions resulting from deeper water will limit the germination of this group of species. Filling should be slow (less than 1cm/day) so plants have a chance to grow and stay close to the surface.

Short dry (less than three months)

Few dry wetland bed plants will establish in the basin of the wetland during a short dry period [18]. Dry wetland bed plants that germinate (for example, knotweed *Persicaria* spp.) will utilize some of the nutrients released when the wetland re-fills. If there is limited germination of these species during the dry stage, plants will not readily take up nutrients released from sediments on re-filling and you may create conditions suitable for the abundance of algae.

In wetlands with clay sediments, an increase in the length of drying is likely to result in an increase in sediment consolidation. With greater consolidation, sediments are less likely to be re-suspended on re-filling[4]. If wetland sediments are not strongly consolidated, re-suspended sediments could reduce the amount of light reaching the sediment surface and the low light conditions will limit germination and survival of submerged species [2].

Long dry (more than six months during warm months)

Drying a wetland for more than six months could risk ground water seepage into the wetland, changing groundwater dynamics and allowing saline groundwater intrusion to occur. If you dry your wetland for an extended period you could affect the thickness of the freshwater layer under the wetland (freshwater lens).

Capillary action allows the evaporation of the freshwater layer, depositing salts in the surface soil of the wetland. A similar process could occur more rapidly in wetlands where no freshwater layer is present under the wetland on drying.

In some cases the expansion of dry wetland bed vegetation during extended dry stages may create unfavorable conditions for aquatic fauna once the wetland re-fills. Low oxygen conditions could occur when the dry wetland bed vegetation breaks down after flooding. The expansion of species such as the native water couch can occur in wetlands where drying does not limit their expansion (for example, where ground water remains high during the dry stage). Species such as water couch are of particular concern because they rapidly expand to cover the bed of the wetland during the dry stage. Their soft structure breaks down readily on re-filling, predisposing the wetland to low dissolved oxygen conditions. [4]

Long dry followed by a short wet (months)

Low oxygen conditions resulting from the breakdown of dry wetland bed vegetation will not be improved during a short re-filling. In situations where low oxygen conditions occur, leaving the wetland full will increase the chance of improving oxygen conditions.

Short dry/short wet (edge drying)

Drying the edges of a wetland is likely to encourage the movement of emergent species, such as bulrush, down the elevation gradient. In shallow wetlands (less than 50cm deep) this may be considered a problem when the bulrush expands and colonises areas that are usually, or could be, inhabited by other emergent and submerged species. Short wet periods in shallow wetlands may be a problem because water levels are not held high enough and long enough to stress species like bulrush and therefore restrict their dominance [19]. The benefits of a dry stage will not be fully realised if drying is short in duration. Reducing the length of drying will mean reduced sediment consolidation in wetlands with clay sediments. Short dry stages will also decrease the chance of dry wetland bed vegetation establishing. Further discussion of these risks is provided in the ‘Short dry’ section above.

Long wet (in the riparian zone)

Long-lived vegetation, such as red gums and lignum, have specific water stress tolerances. Red gums can only tolerate flooding in their root zone for up to 18 –24 months before exhibiting signs of stress. Lignum is less tolerant of extended periods of flooding, coping with only 3-5 months of water before dying [2, 1]. Experiences in the Barmah Forest have also shown shallow flooding over hot summer months caused moisture stress and death of mature red gums [3].

Rapid draw down (greater than 5cm/day)

In wetlands where water levels can be managed rapidly, emergent vegetation will not be able to tolerate a draw down of greater than 5 cm/day if their root zone dries out. The plants need to have time to respond to changing water levels by increasing the extent of their root zone or moving down the elevation gradient to follow the changing water level.

TABLE 2: (fold out)

Monitoring

Monitoring is essential in the adaptive management of wetlands. It begins in Section 1 when you collect baseline and pre-management data to assess the feasibility of management and set your objectives (Section 2). Once you have started managing your wetland (Section 3), you will need to begin operational monitoring and monitoring to meet your objectives. See *Your Wetland: Monitoring Manual* for details.

Your monitoring findings will guide your management decisions.

Operational monitoring will help you make day-to-day decisions about managing your wetland and guide you through other management decisions. Since we are still learning about how different wetlands respond to different management regimes, you will need to make decisions about management frequency based on your findings through monitoring. Operational monitoring also includes monitoring the Golden Rules (page 4) to ensure they are being followed when making your management decisions.

Monitoring is part of the evaluation stage in the 'adaptive management model' (Figure 1), and therefore needs to reflect your management objectives. Focusing monitoring in this way will help you work out if you are achieving your objectives, learn from your experiences and make decisions about how you might improve management.

Evaluation

Evaluation in wetland management projects is essential for their success. It basically involves interpreting the monitoring data in relation to your objectives. Not only will it quantify your ability to achieve your objectives, it will also help you refine the management of your wetland and let others learn from your experiences. Evaluation of wetland management projects operates at two levels:

- As the wetland manager, you use the operational monitoring data to make day-to-day decisions about the frequency of each management stage (Table 2).
- Data you collect when monitoring the objectives can be used to determine if the overall approach to managing the wetland is helping you meet your habitat objectives.

Evaluating the results of monitoring can sometimes be difficult. As a manager you need to be careful not to measure short-term responses against long-term goals. In many cases it can take years of management to observe the types of habitat responses you are aiming for in your wetland. As an example, when you turn a permanently inundated wetland into a temporary wetland it could take several drying and re-filling events before you will see a response in submerged vegetation – natural systems generally need time to respond. If this is one of your habitat objectives and you do not record any submerged vegetation germinating in the first year after drying and re-filling, then you should not react by trying a completely different approach to management. Rather, you should continue to monitor your wetland and stick to your predetermined hydrological management plan (Table 2). If after some time you do not achieve your objectives you may need to consider other approaches to management (that is, adapt your management).

It can take years of management to observe the types of responses you are aiming for in your wetland.

When interpreting your monitoring results, it is also important to be up to date with the monitoring findings of other researchers. You need to be able to determine if the short-term responses you are recording are unusual or reasonable for the type of wetland you are working in. Salinity, for example, fluctuates from season to season and increases when you are drying wetlands (evaporative concentration effects), gradually decreasing when your wetland refills. If the salinity of your wetland starts to increase during a dry stage you probably would not switch to re-filling unless the salinities were reaching extremely high levels that are beyond the tolerances of organisms that naturally occur when a wetland is drying. This example also demonstrates the importance of being aware of the tolerances of organisms that inhabit wetlands (see *Your Wetland: Supporting Information*).

At the same time as you are evaluating your long-term goals, you need to monitor the Golden Rules (page 4). Golden Rules should be considered above all other management options. If your short-term monitoring results indicate that you could be compromising one of the Golden Rules, you should react by changing your management actions to reduce the threats.

Never break the Golden Rules.

We know wetlands are complex. Through the management of lower River Murray wetlands over the last decade, we have learnt a lot about what can be achieved [18]. While we cannot necessarily explain all of the responses, we can now provide a framework for management based on our experiences and continue to build on these to further refine management and enhance the wetlands of the lower River Murray.

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Glossary

adaptive management	A management strategy that involves identifying the causes of a problem, trying a management approach, monitoring the outcomes, learning from their success or failure and adapting management accordingly [10].
adaptive management model	Conceptual model of how the adaptive management process occurs [10].
biofilms	Slimy growths of algae and bacteria you see on submerged wood, aquatic plants and other surfaces.
dry wetland bed plants	Those that live on damp mud and colonize the mud flats that are exposed once the water level in the wetland is drawn down - for example, knotweed *(Persicaria* spp.) and common sneeze weed (*Centipedia* spp.).
emergent plants	Species that must maintain at least some of their leaves and stems above the surface of the water to survive - for example, bulrush *(Typha* spp.*),* spiny sedge *(Cyperus gymnocaulos)* and three cornered rush *(Bolboschoenus caldwellii).*
floodplain	An area of relatively flat land covered by water during a major flood [20].
freshwater lens	Layer of fresh groundwater under dry wetlands that is above the regional ground water.
groundwater intrusion	The place where water occurring below the surface comes to the surface.
hydrology	The scientific study of surface and subsurface water [10].
macroinvertebrates	An animal without a backbone that is visible to the naked eye and retained in a 500µm (usually 1-2mm in length) [10].
microhabitats	A small specialised habitat [21].
riparian vegetation	The group of species that fringe the wetland basin and have a low tolerance for extended periods of inundation – for example, red gums *(Eucalyptus camaldulensis)* and lignum (*Muehlenbeckia florulenta).*
riparian zone	Land which adjoins, directly influences or is influenced by a body of water [10].
root zone	The area in the soil where plant roots are located.
seed bank	Reserve of dormant seeds in the soil.
submerged plants	Those plants with all their parts below the surface of the water – for example, ribbon weed *(Vallisneria americana)* and curly pond weed *(Potamogeton crispus).*
topography	All human-made and natural surface features in a geographic area.[21]
turbidity	Often used to describe the cloudiness or ‘muddiness’ of water, it is strictly a measure of scattering of light by suspended particles and can give a quick surrogate measure of the level of suspended solids.
weir pool	The body of water that is created when river water accumulates upstream of a weir.