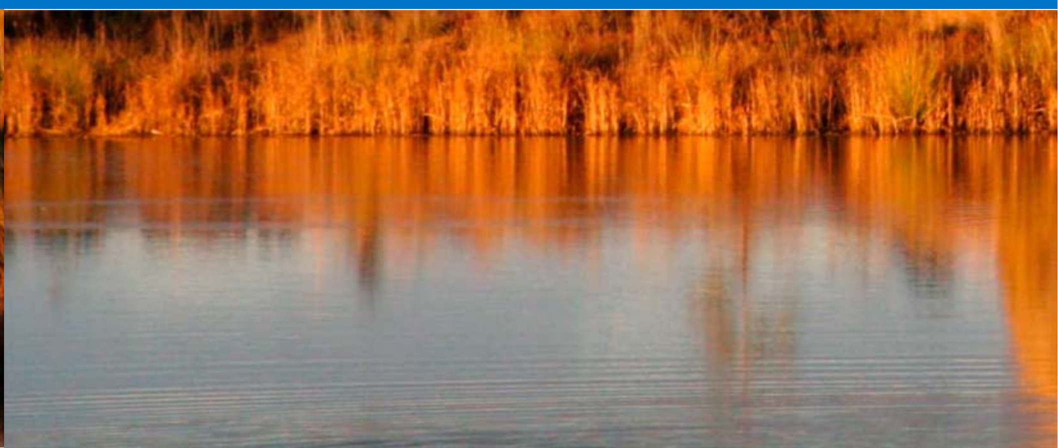
Government of South Australia
South Australian Murray-Darling Basin
Natural Resources Management Board

2007

South Australian Murray-Darling Basin Natural Resources Management Board

SOUTH AUSTRALIAN RIVER MURRAY WETLAND PRIORITISATION

South Australian River Murray Wetland Prioritisation

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For further information please contact:

SA Murray Darling Basin Natural Resources Management Board
Mannum Road, Murray Bridge SA 5253

Phone: (08) 85321432
Fax: (08) 85311843
Email: *enquiries@samdbnrm.sa.gov.au*
www.samdbnrm.sa.gov.au

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SECTION 1: INTRODUCTION

This report documents the development and trial of a prioritisation framework for rehabilitation and conservation of South Australian wetlands along the River Murray from the Victorian South Australian border to the Lake Alexandrina. This report is an evolving document and material covered in initial drafts may be modified and or removed before the final report is completed.

Context

The conservation of wetland areas for the maintenance of biodiversity and ecological functioning has received considerable attention in recent years (e.g. IUCN 2002; Hughes et al. 2004*;* Kingsford et al. 2005) as a clear response to the loss of wetland ecosystems at the global scale. Wetlands are the only ecosystem for which there is an international convention aimed at their protection and conservation; the Ramsar Convention on Wetlands of International Importance (Gopal and Junk 2000). This large-scale loss of wetlands is reflected in Australia, including South Australia, also. It has been estimated that approximately 70% of South Australia's wetlands have been lost since European settlement (DEH & DWLBC 2003). Wetland areas that remain are recognised as nationally and internationally, as well as locally important (e.g. Jensen et al. 1996; Wetland Care Australia 1998).

Governments at all levels now recognize the importance of protecting remaining wetlands systems and the need to make the management of these environments a statewide and regional priority. This is reflected in the State Water Plan (DWR 2000), which clearly states that wetland management is a key platform of integrated water resource management, and its implementation via the Wetlands Strategy for South Australia (DEH & DWLBC 2003).

At a regional level, responsibility for wetland management in the South Australia Murray Valley is the responsibility of the South Australian Murray-Darling Basin Natural Resources Management Board (SA MDB NRM Board). The task of managing wetlands across the Murray Valley is particularly challenging due to the geographic spread of remaining wetlands, the history of land and water use since European settlement, varying condition of remaining wetland systems, and often limited resources from which to protect or improve the condition of existing wetland areas.

The SA MDB NRM Board has taken on the role of South Australian River Murray Environmental Manager (RMEM) to provide clear accountability for delivering environmental flow outcomes for the River Murray in South Australia. As part of this role the RMEM will oversee environmental flow management decisions and determine priorities for state-based environmental watering projects (South Australian River Murray Watering Plan and Annual Watering Plans), which include consideration of wetlands.

The SA MDB NRM Board has to balance often conflicting social, economic and ecological needs, often in a data-poor environment. Thus, a framework that helps to guide decisions on resource allocation to the protection, and importantly the rehabilitation of wetland systems, will provide a valuable tool that will allow the Board to use its resources wisely in meeting its own responsibilities and its contribution to Government policy objectives.

Purpose

This project is aimed at developing a transparent and flexible means of identifying wetland sites along the River Murray for future investment based on their ecological values and potential for rehabilitation. The project does not include socio-economic considerations or values however; the method will be developed in such a way as to allow criteria relevant to these to be added by the SA MDB NRM Board at a later time. This project is based on existing data.

Prioritisation frameworks are scale and data dependent, the scale or spatial unit at which the ranking is undertaken will impact on the results (Schweiger et al. 2002; Whittaker et al. 2005). Data limitations are a significant issue that requires careful consideration when developing prioritisation systems (Heron et al. 2004; Butcher and Hale 2005) as in most cases there is a lack of consistently collected baseline or inventory type data on which to base ranking criteria. Consideration must be given to differences in data arising from variable sampling effort both spatially and temporally and in the type or quality of data collected (inventory, assessment and or monitoring) (Butcher and Hale 2005).

The SA MDB NRM Board has identified a three tiered approach to the prioritisation of the River Murray wetlands for rehabilitation which considers wetland type and representativeness, ecological values and rehabilitation potential (see Figure 1).

As yet there are no standard methods in use for restoration or rehabilitation of aquatic ecosystems, although there are moves towards generating such standards (e.g. Palmer et al. 2005). In designing a prioritisation method for wetland rehabilitation it is necessary to consider the specific aims and how the success of any management activities will be measured. For example river restoration projects which involve stabilisation of banks may be considered a success for valid reasons (ie the bank stops eroding) but this may not include an immediate ecological gain or improvement. Palmer et al. (2005) identify three primary axes of success – stakeholder, ecological and learning success. Whilst this study will focus on the ecological aspects of wetland rehabilitation there is a need to acknowledge that the most successful restoration efforts are those that cross the three axes: ecological success involves a measurable improvement in the system of concern, stakeholder success reflects human satisfaction with the outcome of the restoration efforts, and learning success reflects gain in scientific and management understanding which leads to an adaptive management approach for future restoration efforts (Palmer et al. 2005).

Prioritisation frameworks are decision processes that, in this case, would allow consistent, and scientifically sound, judgements to be made when allocating limited resources towards wetland conservation and rehabilitation. Simple rules and criteria are needed to guide the decision process. The method developed for this study will be used to inform decision making for wetland conservation and rehabilitation along the River Murray valley. Therefore the specific aims are as identified in the project brief:

- Develop a method for prioritising wetlands for rehabilitation,
- Identify any specific data requirements for wetland prioritisation,
- Provide recommendations regarding future data collection needs,
- Trial and refine the method.

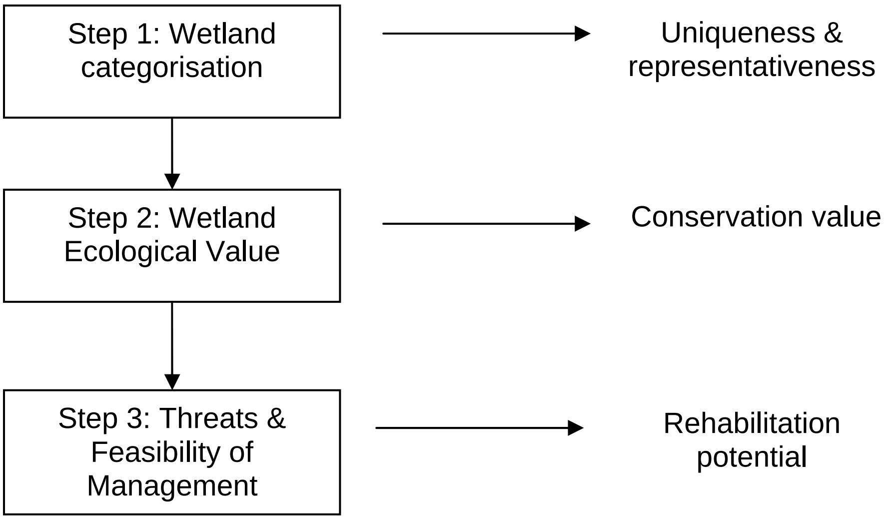

Figure 1: Stepwise approach to wetland prioritisation for rehabilitation (SAMDBNRM Board).

Scope

The study area includes the River Murray valley and wetlands surrounding Lake Alexandrina and Albert and includes all wetlands within the bounds of the 1956 flood. Only discrete wetlands 1 ha or larger will be included as this is the minimum size of wetlands included in earlier studies such as Pressey (1986). Wetlands within the study area are best represented by approximately 2000 polygons (derived from various spatial datasets) and fall within the bounds shown in Figure 2 below. Butcher and Hale (2005) suggested that only natural wetlands be considered for prioritisation for rehabilitation. However, many of the existing wetlands along the Murray valley have been altered, or created though river regulation and irrigation practices, and whilst altered from their original state, many will still retain wetland values and are therefore included in this project. The exception are borrow pits (Pressey 1986) which have been created by excavation rather than altered hydrological regimes. Wetlands referred to as the Goolwa Channel Islands (Jensen et al. 1996) are excluded from consideration in this study area as they are estuarine in nature. Floodplain depressions that do not currently have a polygon assigned to them but have been used for watering trials were also excluded from consideration in the present study.

Some classifications consider floodplains to be wetlands, and a lack of definition can often lead to misunderstandings. Distinguishing between riparian areas along river channels, floodplains and discrete water holding depressions on the floodplain (wetlands) is often quite arbitrary and usually poorly defined. For the purpose of this study wetlands are considered discrete water holding depressions within the bounds of the 1956 flood, and do not include floodplains as a wetland type. Floodplain ecosystems are considered in a separate project (see below).

Figure 2: Map showing boundaries of study area and prioritisation reaches – outer boundary is equivalent to the 1956 flood levels.

Links with other initiatives

The South Australian Wetland Prioritisation project will provide the basis of future management rehabilitation efforts for wetlands along the River Murray in South Australia providing a standard approach for identifying sites at which ecological gains through rehabilitation activities may be possible. This project has links with several other initiatives currently underway, including development of a spatial wetland catalogue by DEH, SA MDB NRM Board and DWLBC; baseline fish and in-stream habitat data collection and assessment for the main channel of the Murray in South Australia by SARDI Aquatic Sciences, and the floodplain prioritisation and environmental water delivery framework being developed by the River Murray Environmental manager Unit of the SA MDB NRM Board.

The undertaking of a baseline fish and in-stream habitat data collection and assessment for the main channel of the Murray in South Australia will seek to determine the present levels of in-stream physical habitat and riparian vegetation within the SA section of the MDB at a sufficient scale that major aquatic habitat types in the main river channel can be identified. Subsequently, a survey of fish communities within these habitats will then be used to determine relationships between fish and major aquatic habitats of the region and improve the outcomes from earlier projects such as identification of barriers to fish passage with SA.

The floodplain prioritisation project is focused on the identification of broad scale floodplain priorities based on floodplain environmental values, the degree to which these values are under threat and opportunities to deal with the threats to values. The Board will use this information to inform the SA River Murray Watering Plan, and in doing so will communicate this information to key stakeholders. This information will also guide annual decision making, ensuring that highest value floodplain systems, or systems where there is the greatest opportunity to deliver environmental outcomes are the focus for environmental flow activities. The wetland prioritisation project is being undertaken at a smaller scale of analysis than the floodplain prioritisation project and it is expected that the wetland priorities will ultimately inform integrated floodplain priorities, and environmental flow decisions (L. Mensforth, pers. comm.).

DEH is assisting in the development of the floodplain prioritisation project by undertaking a pilot investigation aimed at facilitating the development of a policy framework for the floodplain prioritisation process. Broadly, DEH will pilot a method of collating a variety of spatial datasets and information relating to floodplain condition and status for management action which will be able to be fed into the prioritisation method being developed (Miles and Bevan 2006). This pilot project forms what is referred to hereafter as the Wetland Catalogue. This pilot project has rationalised a number of spatial datasets relevant to the SA Wetland Prioritisation project and will form the main source of data for testing the prioritisation method developed. Whilst there is overlap between the Floodplain Prioritisation project and the Wetlands prioritisation projects, the ecosystems and scale of management addressed in each project differ and thus the outputs are also likely to be different.

Also relevant to the current project is the SA Weir Pool Manipulation Project which aims to contribute to the restoration of river health by implementing seasonal weir pool manipulations (raising and lowering) as part of normal river operations within 5 years. Under pre-european conditions flows and water levels in the river fluctuated seasonally and significantly. With river regulation and water use, variation in water level has reduced substantially. The natural fauna and flora communities evolved around this variation in flow and water level, and their health and biodiversity depends upon it. The weir pool manipulation project has direct links to the River Murray Channel and Chowilla Floodplain Asset Environmental Management Plans. Weir manipulation is a key management tool for water delivery and will provide a substantial contribution to meeting the objectives of these plans.

The current project will seek to compliment the other initiatives on wetlands and floodplains outlined above such that the implementation of priority projects for protection and rehabilitation of in-stream and floodplain habitats can then be undertaken for this region in a ‘strategic and integrated’ fashion to maximise resources and ecological benefits, with terrestrial and aquatic components considered together.

SECTION 2: APPROACH TO METHOD DEVELOPMENT

In developing the method for prioritisation several key considerations were made. The scale of application of the prioritisation tool will be at the whole River Murray valley. The prioritisation method was required to be (adapted from Faber-Langendoen et al. 2006):

- Simple to understand and deploy;
- Practical, based on existing data, or data that will be relatively easy or cost-effective to collect;
- Robust, as to include wetlands for which there is little or no survey information (e.g. site specific information on species richness, vegetation type and cover, geomorphic variability etc.);
- Multi-scaled (include site based variables as well as landscape variables)
- Relevant to ecological features of wetlands;
- Relevant and helpful (to stakeholders and decision-makers, not just scientists);
- Comprehensive (for composition, structure and function).

A useful approach to considering the data needed to support the prioritisation method is that used by the Asian Wetland Inventory (AWI) (Ramsar 2005). A central feature of the AWI is the production of hierarchical and map-based outputs at four levels of detail. The level of detail is related to the scale of the maps that are contained within a standardised GIS format with a minimum core data set. The hierarchical approach (Figure 3) comprises a progression in scale from river basins to individual wetlands.

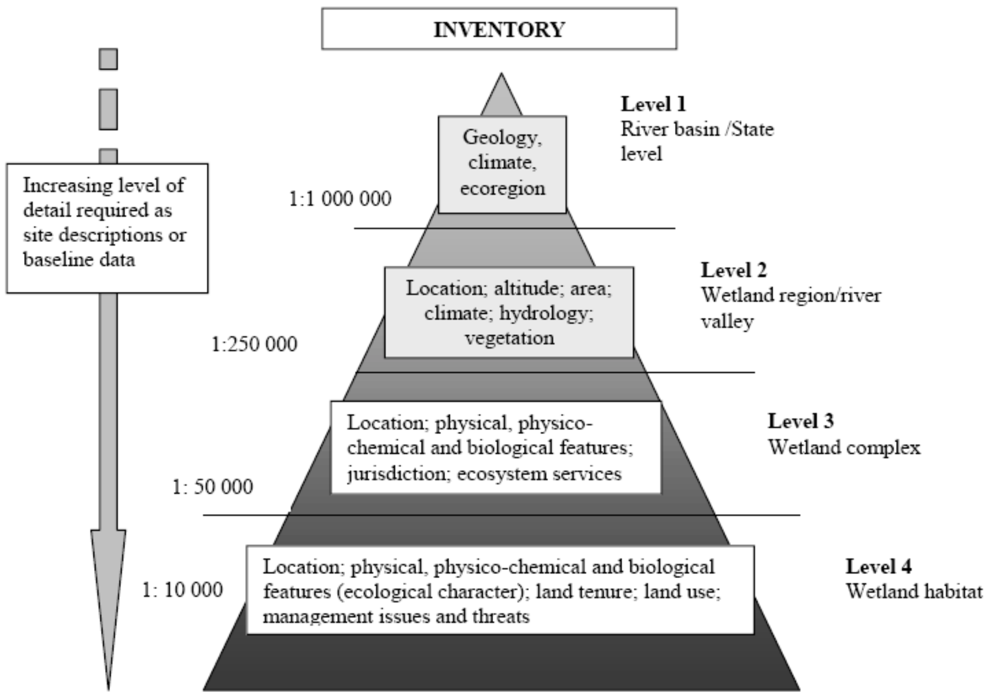

Figure 3: Hierarchical approach to wetland inventory as used in the Asian Wetland Inventory adapted from Ramsar (2005). Level 4 is considered the basic core data level with information stored on a database with a GIS interface.

Drivers of wetland ecology as the basis of criteria selection

This section briefly introduces the key drivers of wetland ecology and ecological values on which the selection of the criteria was based.

There are a number of fundamental or universal drivers (such as hydrology, climate, sediments, hydraulics and geomorphology) that determine the ecological components, processes and functions found at a particular wetland site. While the way these drivers operate and are expressed can vary from site to site, there are commonalities through which it is possible to examine and describe the physical, chemical and biological components and processes of wetland ecosystems. The universal drivers of wetlands are geomorphology and climate (Figure 4). Mitsch and Gosselink (2000a) state that geomorphology and climate "dictate the degree to which wetlands can exist", but that the key attributes are hydrology, the physico-chemical environment and the biota they support.

Climate acts as a driver of wetland ecology primarily through its effects on hydrology. For example, temperature affects evaporation and transpiration, rainfall has a direct influence and solar radiation and day length affect the biological components of wetland systems. In the case of the study area, the climate is semi-arid with hot summers and cool winters. Evaporation exceeds rainfall and so has a major influence on the duration of wetland inundation, with a large proportion of the wetlands on the floodplain being temporary.

Geomorphology refers to landforms and landscape relief and encompasses the shape, size and location of wetlands in the landscape. The morphology of individual basins or wetlands, for example, influences flooding depth as well as frequency and duration of flooding. Geomorphology of the surrounding landscape exerts a strong influence on surface and groundwater connections between the wetland and adjacent terrestrial and aquatic ecosystems. The geomorphic characteristics of wetlands are strongly related to wetland type and as such have been used as a basis for wetland classification in the study area (Pressey 1986).

Hydrology is what distinguishes a wetland from terrestrial ecosystems; it encompasses the source(s) of water for wetlands as well as the inundation frequency, magnitude and duration (hydroperiod). Water source can greatly affect wetland ecology and the wetlands in the study area show marked differences in this regard. For example, the salinity of wetlands on the River Murray floodplain is strongly influenced by the relative contributions of rainfall, overland flow, river and groundwater sources.

The temporal pattern of water level, or hydroperiod, for an individual wetland is part of its ecological signature (Mitsch and Gosselink 2000a). Aspects of hydroperiod that affect wetland ecology include:

- Frequency – how often the wetland receives water
- Magnitude – the amount of water received (which will affect water depth, water velocity and extent of flooding)
- Duration – the length of time that flooding persists
- Timing – when the water arrives

The hydroperiod of a wetland places it along the gradient from permanent lakes and rivers to semi-terrestrial floodplains that may be inundated only once every 20 years.

The variation in hydroperiod and its subsequent effect on the vegetation type that is likely to be present has been incorporated into the DIWA classification system.

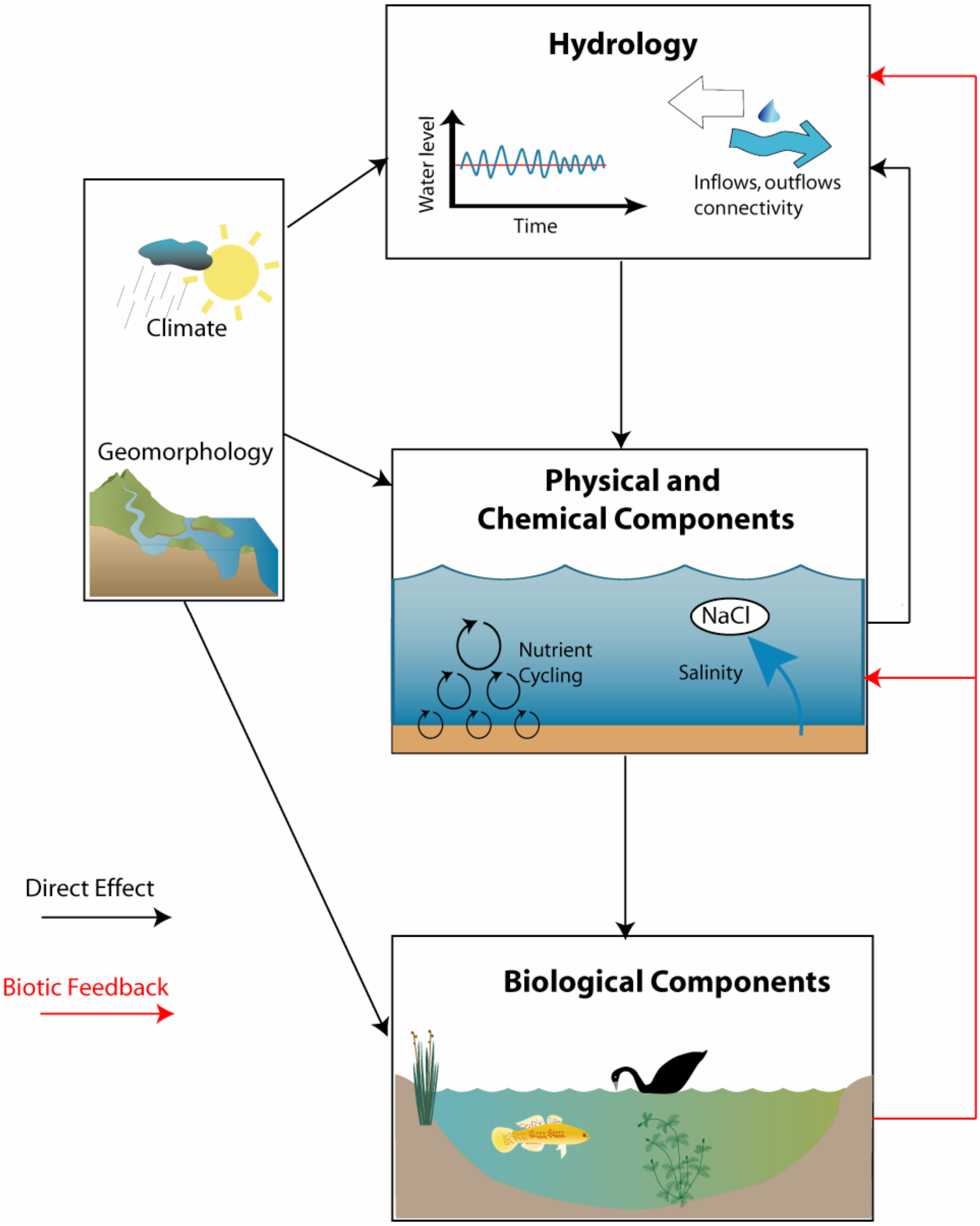

Figure 4: Conceptual model of wetland ecology, illustrating the effects of climate, geomorphology and hydrology on ecological components and the feedback effects of biological components (adapted from Mitsch and Gosselink 2000).

Connectivity

Connectivity is considered a fundamental property of all ecosystems and is of particular importance for floodplain ecosystems (Kondolf et al. 2006; Thoms et al. 2005). The concept of connectivity was introduced as a means of determining the degree to which resource patches or habitats were interconnected and the ease of which biota and material flowed between them (Amat et al. 2005).

Hydrological connectivity is considered a key driver stimulating riverine ecosystems (Tockner et al. 2000; Thoms et al. 2005; Kondolf et al. 2006). Hydrological connectivity has been defined as water mediated transfer of organic and inorganic matter, energy and biota within or between components of an aquatic system (e.g. river channel, floodplain, discrete wetland). It can be modified by disrupting the flow regime and topography of floodplains. Connectivity can also be altered by levee construction, incision of the main river channel and or reduction in flooding brought about by river regulation (Kondolf et al. 2006). Reduced lateral connectivity is a complex issue and is generally considered the main culprit in leading to floodplain degradation; however increased connectivity can also have negative impacts on the ecology of aquatic systems. For example many wetlands along the River Murray have become more permanent in nature, being connected to the river at pool level. This increased hydrological connectivity can often favour exotic species (Kondolf et al. 2006).

Wetlands can be viewed as habitat patches in the landscape providing different resources to different species at different temporal and spatial scales. Connectivity of individual habitats/wetlands, referred to here after as habitat connectivity, is also considered important in determining regional biodiversity patterns. In general, studies of connectivity among habitat patches (wetlands) have largely focused on species specific behaviours (Amat et al. 2005). However, the levels of connectivity required for each species will be different, movement among patches (wetlands) may have different functions, and the timing of movements, and thus reliance on connectivity will also vary. Thus there will be different levels of tolerance to altered connectivity and dependent on the type of movement (e.g. dispersal, feeding) (Amat et al. 2005).

Kondolf et al. (2006) make the point that whilst any change to connectivity will benefit some biota over others, and the desirability of such changes is dependent on our values, restoration of natural connectivity of aquatic ecosystems is considered a key aspect of rehabilitation efforts.

In the case of the wetlands of the River Murray floodplain, a number of key driver attributes, ecological processes and components exert strong influences over wetland values and functions. Specifically, wetland hydroperiod and salinity have been identified as significant contributors to the biological components that wetlands in the region can support (Figure 5 – note not all pathways/connections are shown). As a result, threatening processes that alter hydrology and salinity will result in significant changes in the biological attributes of wetland systems. The prioritisation process has, therefore, been designed with a strong emphasis on these key aspects of salinity and hydrology.

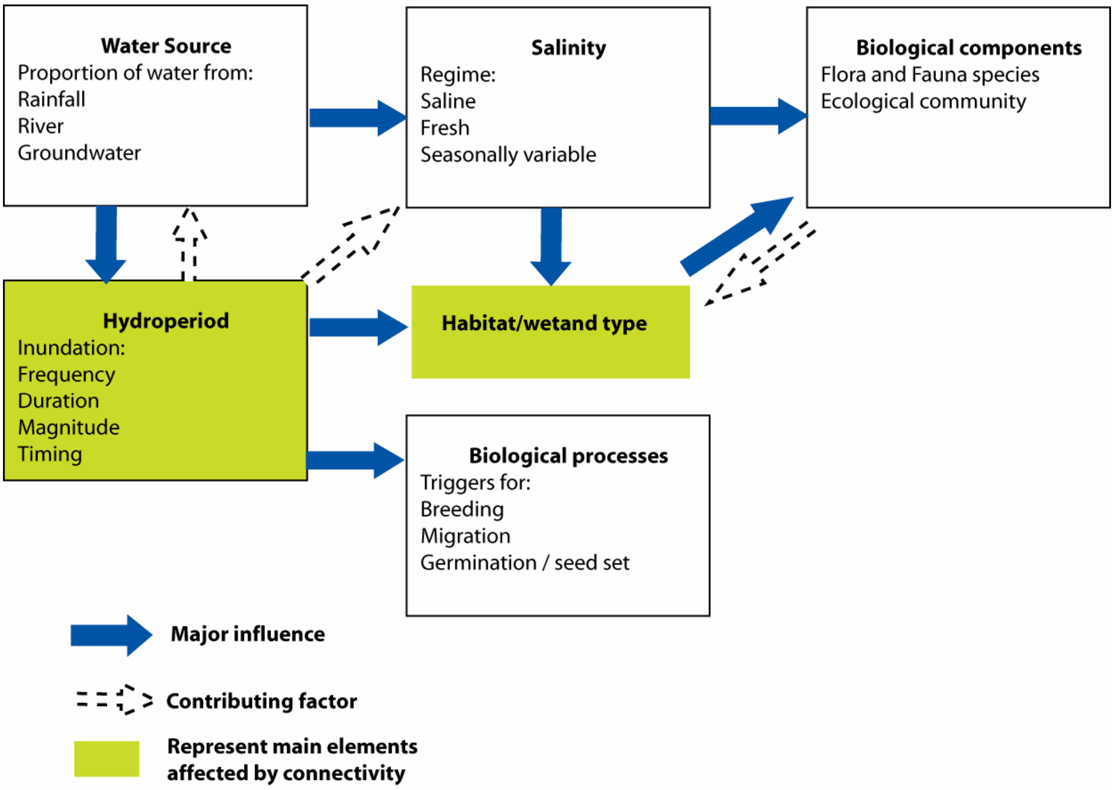

Figure 5: Conceptual model of key elements of wetland ecology on which the prioritisation method was based. Water source and hydroperiod represent the main elements of hydrology, and biological components and processes are key elements of wetlands which are valued. Two elements of connectivity are highlighted, hydrological and habitat connectivity.

Criteria development

The justification and final list of criteria selected are presented in sections 4 -7. The process of developing the criteria was iterative, with several review phases (see Appendix 3) and workshop sessions, including a stakeholder workshop at which draft criteria and approach were presented and feedback received. The main outputs of the stakeholder workshop are presented in Appendix 4.

A distinction is made between ***ecological value*** and ***conservation value***. Conservation value incorporates the concepts of rarity and representativeness as well as ecological value. In this study ecological value relates mainly to species and habitat attributes of a site. This represents a slight variation on the three tiered model presented by the SA MDB NRM Board (Figure 1 above), which was further modified by separating the consideration of threats and feasibility into distinct phases. The approach taken for this project is shown in Figure 6.

The criteria selection was based on key drivers of wetland ecology (Figure 5 above), and the three tiered approach of assigning conservation value, threat ranking and feasibility of rehabilitation. Added to this was the other main constraint: data availability.

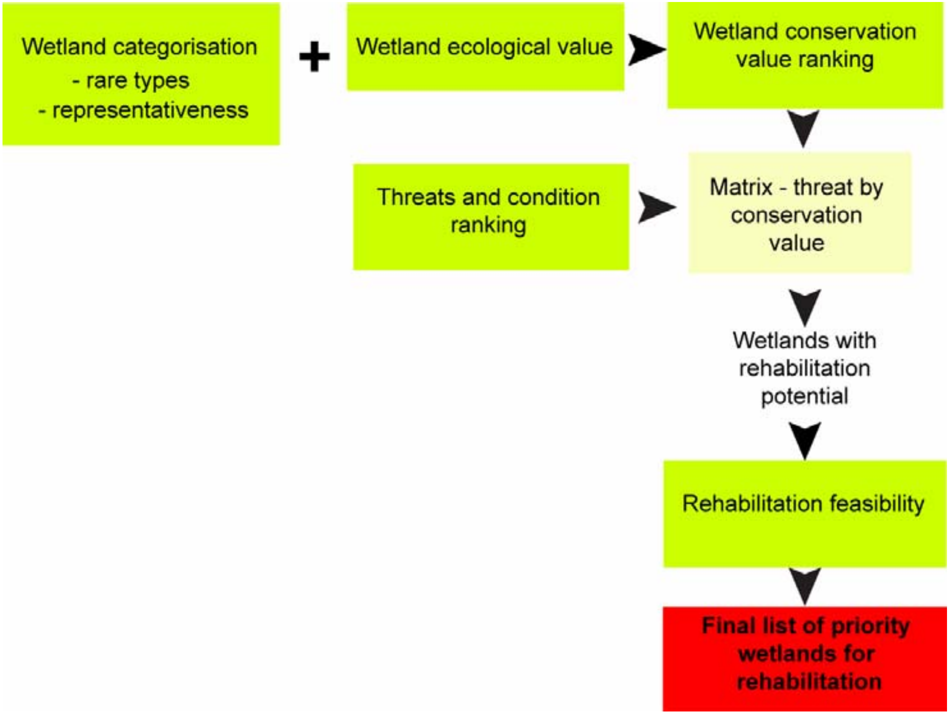

Figure 6: Approach taken in prioritisation – modified from three tiered approach of Figure 1.

Scoring system

The method trialled adopts a simple points-scoring system, which assigns scores ranging from 1 to 3 points in the following manner:

- **Ecological value** criteria are scored as 1, 2 or 3, with a score of 3 representing high ecological value, 2 representing moderate ecological value, and 1 representing low ecological value.
- **Wetland categorisation** - wetlands which are identified as rare or fit the representative criterion are upgraded to receive an automatic high ecological rating, and when combined with the ecological value scores provide the ***conservation value ranking.***
- **Threat and condition** criteria are scored as 1 to 3, with a score of 3 representing highly impacted or degraded sites.
- **Feasibility** - there are two management options possible under the feasibility section: sites can be identified as suitable for protection and are given a ***protection rank***, or sites are identified as potentially suitable for rehabilitation, and given a ***feasibility rank***. Feasibility criteria are scored as 1, 2 or 3 with a score of 3 indicating high feasibility or representing a high rehabilitation potential due to relative ease of implementing management options.

Scores are totalled for each wetland across the criteria in each part of the method (conservation value, threat and condition, and feasibility). The scores are then converted into a ranking of high, medium and low value/priority.

The final ranking is based on a combination of ***conservation value ranking*** and ***feasibility ranking*** and gives the ***rehabilitation ranking***. There is an implied cost associated with the different rehabilitation options and this is reflected in the ranks, which represents the final output of the prioritisation for rehabilitation.

The rehabilitation ranking is as follows:

Very low = low feasibility
Low = moderate feasibility and low conservation value;
Medium = medium feasibility and medium conservation value; or high feasibility and low conservation value
High = medium or high feasibility and high conservation value; or high feasibility and moderate conservation value

Weighting of the relative importance of the various determinants of ecological value and threat/condition is addressed in the pilot sensitivity analysis (see section 8). However, it is recommended that the relative confidence of each rating should be estimated based on a scale of four categories as indicated below. These categories are based on the type and scale of data used in the prioritisation:

- High confidence: data sourced from baseline sites.
- Moderate to high confidence: data sourced from published material specific to the wetland, from state databases and federally listed sites.
- Moderate to low confidence: data considered dated (more than 15 years old) and potentially unreliable, this could included information used to list sites under DIWA and Ramsar.
- Low confidence: data available at the complex level only and possibly requiring ground-truthing.

The confidence ratings listed above are assigned to the wetland polygons during the extraction of data. While not included as a formal part of the final prioritisation steps, the ratings will provide valuable information when considering the final list of priority sites and further direction when considering additional investments in data acquisition that will assist in ongoing implementation of the method.

The method should be used as a guideline and balanced against the professional judgement of individuals familiar with the study area and its wetlands. If for any reason the scoring of an individual criterion is altered then the assessors must substantiate and document their judgement as far as possible for future reference and revision.

Scoring or application of the method can be stopped at each stage, providing a ranking of just ecological value, conservation value, threat or feasibility. In all cases ground truthing of the ranks is required before application of the output is used to make management decisions.

SECTION 3: WETLAND CATEGORISATION

Defining wetlands and wetland classification

There is no single definition of a wetland. However, in general there is agreement that wetlands are typically identified by the presence of water at or near the land surface long enough to support mainly aquatic life by the presence of hydric soils and plants adapted to living in such conditions (Wolfson et al. 2002). Most States in Australia recognise the Ramsar convention definition of wetlands listed under Article 1.1: *Wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres.* The classification system used in each state can vary but most align with the Commonwealth Policy on wetlands and exclude the in channel elements in the definition of wetlands in that they distinguish between wetlands and flowing rivers.

Wetland classification is a tool that reduces the variability seen in wetlands into groups or types of wetlands based on either similarities or dissimilarities. The type of classification adopted can vary and is dependent on having either a scientific, management or regulatory application. Generally wetland classification is undertaken to divide natural ecosystems into discrete units that provide a basis for management decisions and collection of environmental data. Types of wetland classification fall into two broad categories: geographically based and environmentally based. Geographically based types include classification systems which use fixed boundaries, for example ecoregions. Environmentally based systems are typically based on hydrogeomorphic features and habitats. Many systems are hierarchical (e.g. Cowardin et al. 1979; Johnson and Gerbeaux 2004) and are often based on wetland hydrology, soils and vegetation – the three main characteristic features of wetlands.

The Cowardin system, for example, was developed by the US Fish and Wildlife Service in 1979 (Cowardin et al. 1979) and is used as the national standard in the USA for mapping and inventory work. It has three levels, the first level is based on landscape position or hydrosystem (tidal, riverine, estuarine, lacustrine and palustrine), then habitat type (vegetation cover: open water, submerged aquatic bed, emergent, shrub or forested) and the third level is based on hydrological regime ranging from saturated to permanently flooded. This type of classification system is the basis for most of the more widely used classification systems including Ramsar and the Directory of Important Wetlands.

Hydrosystems are the uppermost level of wetland classification and are generally based on general landform and broad hydrological settings, and distinctive features of water salinity, water chemistry, and temperature (Johnson and Gerbeaux 2004). Wetlands associated with the main hydrosystems are described below (from Johnson and Gerbeaux 2004) (Note that estuarine wetlands are not considered as part of this study):

> ***Palustrine*** wetlands include all freshwater wetlands fed by rain, groundwater, or surface water, but not directly associated with estuaries, lakes, or rivers. The term palustrine derives from the Latin, palus = marsh. Most wetlands are palustrine, and it is this hydrosystem that includes the greatest range of wetland classes and vegetation types.

Riverine wetlands are those associated with rivers, streams, and other channels, where the dominant function is continually or intermittently flowing freshwater in open channels. The riverine hydrosystem includes open flowing waters and both the beds and margins (riparian zones) of channels. It embraces natural waterways and artificial ones such as canals, irrigation channels, and drains. Although many wetlands occupy landforms such as valley floors, floodplains, and deltas which owe their genesis to river processes, the riverine hydrosystem extends only so far as flowing channels retain a current influence, which can be defined as the extent covered by the mean annual flood. Towards its downstream end the riverine hydrosystem meets tidal influence and merges with the estuarine hydrosystem.

Lacustrine wetlands are associated with the waters, beds, and immediate margins of lakes and other bodies of open, predominantly freshwater which are large enough to be influenced by characteristic lake features and processes such as fluctuating water level, wave action, and usually permanent and often deep water that has nil or only slow flow. Lakes can be arbitrarily defined as having a major dimension of 0.5 km or more.

Estuarine wetlands include estuaries, tidal reaches and mouths of coastal rivers, coastal lagoons, and wet habitats of open coasts where soil water is affected by sea salts. The dominant functions are the mixing of freshwater and seawater, and tidal fluctuation, both of which vary depending on degrees of direct access to the sea. The estuarine hydrosystem includes all areas of sub-tidal and intertidal zones in estuaries, and also wet ground in supra-tidal zones where surface water and groundwater receive saline contributions from wave splash, or airborne salt in sea spray; habitats which might otherwise be broadly termed coastal wetlands.

Wetland classification in South Australia

Directory of Important Wetlands in Australia

South Australia lacks a state-wide wetland classification system, with a number of classifications having been applied on a regional basis (e.g. Pressey 1986; Thompson 1986; Seaman 2002a-d, 2003; Environment Australia 2001). The Wetland Strategy of South Australia (DEH & DLWBC 2003) adopts the classification system used in the Directory of Important Wetlands of Australia (Environment Australia 2001). This classification system is based on that used under the Ramsar Convention with some modifications for the Australian situation. Under this system there are 40 types of wetlands grouped into three categories, marine and coastal, inland, and artificial wetlands. Appendix 1 lists the DIWA inland wetlands and artificial wetlands types.

Pressey (1986)

Pressey (1986) undertook a survey of the River Murray wetlands from Hume dam to the Coorong focusing on mapping wetlands that had the potential for hydrological management for the benefit of flora and fauna. Pressey's definition of wetlands did not include River Red Gum, except where areas of floodplain forests supported water bird colonies. He used a system of geomorphic and hydrological categories to identify wetlands 1 ha or larger.

Three distinct geomorphic classifications were used, one for the wetlands of the floodplain of the River Murray, one for Lakes Alexandrina and Albert and their fringing wetlands, and the third for the Coorong (not considered further). Mapping was broken into 10 sections from below Lake Hume to the Murray Mouth. Part of section 6, and all of sections 7-9, are relevant to this study.

The floodplain system had 17 geomorphic categories (12 natural and 5 artificial) (see Table 1) and 4 hydrological categories. Three of the geomorphic categories are not found in the South Australia. For wetlands of the Lower Lakes, Pressey (1986) applied a different geomorphic classification (see Table 1), with three broad categories of wetlands being recognised.

Pressey also identified four hydrological categories which are considered broad indicators of drying and wetting patterns:

1. Wetlands connected to the river at minimum regulated flow or at pool level, or potentially connected at these levels but separated by a regulator or in a few cases by a block on the inlet channel. Predominantly permanent.
2. Wetlands actually or potentially connected to the river above minimum regulated flow but at or below maximum regulated flow. Permanent to seasonal.
3. Wetlands above maximum regulated flow, filled only by surplus flow. Seasonal/intermittent.
4. Wetlands above maximum regulated flow and which receive (often saline) water from adjacent irrigated areas via drainage, runoff or seepage or in a few cases effluent water (Pressey 1986). Permanent/seasonal/intermittent.

Category 2 does not occur in the South Australian sections of the River Murray valley. Category 1 is considered permanent and is the dominant type found in South Australia (Pressey 1986). The limitations in mapping (see below) may have lead to under representation of seasonal and intermittent wetlands.

Key limitations of the mapping were the underestimation of the total number and area of wetlands due to mapping problems with depressions smaller than 1 ha, marsh area in low lying land beneath Red Gum and broad gently sloping areas of floodplain which retain water after flooding (meadow, grassy wetlands) but are poorly defined under a canopy of Red Gum. The Pressey system did not capture salinity gradients, nor did it capture habitat or dominant vegetation types. The Pressey system formed the basis for a number of subsequent studies on the River Murray wetlands.

Table 1: Pressey (1986) geomorphic categories with major hydrosystem indicated. Categories highlighted not found in study area.

Natural categories – floodplain categories (numbers relate to those used by Pressey)	Hydrosystem
1. Lentic (non flowing) tributaries: lower reaches of minor tributaries e.g. Reedy Creek near Mannum	Riverine
2. High level anabranches	
3. Lentic channel forms: sections of former river channels or anabranches, and distributary channels which no longer function as major flow routes	Riverine
4. Active channels: narrow channels in recent floodplain joined to the river at both ends – could be considered a continuum of Lentic channels	Riverine
5. Scroll swales: depressions between ridges or meander scrolls on point bar deposits.	Riverine
6. Channel margin swales: elongate bodies of water enclosed on one side by well developed levee banks, and on the other side low narrow and often discontinuous strips of sediment on margins of river channel. Usually associated with inside curves of meanders	Riverine
7. Slackwater areas: inlets on downstream side of meanders, open to the main river channel	Riverine
8. Depositional basins – discrete: broad depressions, formed by deposition in old deflation basins or by infilling. Also includes shallow basins with unclear origins	Palustrine
9. Depositional basins – interconnected	
10. Murray gorge basins: narrow and generally deep gorge within which the meandering habit of the river is constrained. The basins are typically elongate with rounded and or angular margins, many lie directly against the valley wall. Many are enclosed by levees and point bar deposits, closer to the Lower Lakes, many may be open to the main river channel	Riverine
11. Deflation basins: large rounded, sometimes circular wetlands often with lunettes.	Palustrine
12. Miscellaneous floodplain depressions: mostly small shallow and usually compact in shape. Many are likely remnants of channel forms, but some will have other origins such as from scouring.	Riverine
Artificial categories - floodplain	
13. Quarries and borrow pits	Riverine
14. Artificial channels	Riverine
15. Riverine impoundments	
16. Impounded wetlands	Riverine
17. Inundated shallow depressions: parts of the floodplain which received water from adjacent irrigation areas	Palustrine
Natural categories – Lower Lakes (excludes Lake Alexandrina and Albert, and Coorong)	
3. Littoral wetlands: areas of emergent vegetation, in many cases containing discrete basins of standing water, which fringe the lakes or which occur as "islands" on shallow banks within the lakes	Lacustrine
4. Back basins: essentially the same habitats as littoral wetland except that they are largely surrounded by areas of high ground and linked to the lakes by relatively narrow openings	Lacustrine
5. Lentic tributaries	Riverine

Thompson (1986)

Thompson (1986) classified the wetlands of the River Murray based on the connectivity to the river and eight subclasses based on hydrological regime, vegetation and slope of banks. It is predominantly a management driven scheme which focuses on the ability to manipulate water levels in the wetlands and was developed in consultation with R. Pressey; although the inclusion of subclasses based on vegetation differs to that provided by Pressey (1986).

Thompson (1986) classification system:

Class 1: directly connected to the Murray at normal pool level - permanent
Class 2: connection with the Murray is above normal pool level
Class 3: wetlands that already have active management of water level

Subclasses:

- Hydrological regime
  - Water flow – through flow at pool level/stationary at pool level
  - Permanence – permanent/semipermanent/temporary
- Geomorphology
  - Slope of bank – shallow/steep
- Vegetation
  - Submerged macrophytes – presence/absence and species
  - Dense reeds/sedges vs open water and species
  - Regenerating red gums – presence/absence
  - Fringing reeds – presence/absence by species

Thomson grouped wetlands into one of five conservation categories based on ten attributes of the ecology and other features observed in the field. Sites within each category were not ranked. Thomson (1986) listed 84 in the high conservation value category (excluded already protected sites), 8 sites worthy of rehabilitation and 20 requiring additional ecological investigation.

Jensen et al. (1996) Wetland Atlas

The other major inventory of wetlands of the River Murray valley is the Wetlands Atlas (Jensen et al. 1996) which consolidated the information presented in Pressey (1986), Thompson (1986), Lloyd and Balla (1986) and the outputs from the Wetlands Working Party (1989) and SA River Murray Wetlands Management Committee (SARMWMC 1996). Jensen et al. (1996) used the classification systems of Pressey (1986) and conservation value of Thompson (1986).

Seaman (2003)

The fringing wetlands of the Lower Lakes have been classified and mapped using the Ramsar system. The wetlands surrounding the Lower Lakes and the tributaries of Lake Alexandrina include only 3 geomorphic categories under the Pressey system, but have representatives from 10 wetland types using the Ramsar system. Recent habitat mapping of the fringing wetlands of the Lower Lakes identified 518 habitats covering an area of 24,200 ha which were assigned to 50 wetland habitat categories (Seaman 2003). The data collected for this project has been entered onto GIS database allowing condition and threats to be documented and information on extent and species use (Seaman 2003). Further the database has a prediction tool which allows maps of potential species distribution to be created based on habitat requirements of species of interest.

Classification system for prioritisation

The proposed classification system is shown in Table 2 and is based largely on the Ramsar and DIWA systems (some categories have been excluded as they don't occur in the study area) with the coding system of DIWA being the preferred option for use in mapping and storage of data. Justification for using these classification systems is as follows:

- Ramsar and DIWA capture salinity –a feature not captured by Pressey or Thompson and considered a key driver of wetland ecology
- Acknowledges hydrology as the driver of wetland ecology. Geomorphology dictates where in the landscape wetlands occur, whereas hydrology dictates ecological responses
- Allows for cross referencing between the information collected for Ramsar and DIWA listed wetlands.
- The Pressey system is considered too coarse, with broad geomorphic categories unlikely to capture biotic responses known to occur within the categories – eg the Ramsar system identifies10 types compared to 3 by Pressey for the fringing wetlands of the Lower Lakes.
- Promotes a single system across the state and falls in line with the state Wetlands Policy, and the guidance given in the project brief that the outputs of this project must be able to contribute to programs at the regional, state and national levels

South Australia DEH has rationalised existing spatial datasets by resolving disparity between polygons in spatial wetlands layers which resulted in a spatial layer of 2000 polygons representing wetlands on the floodplain (Miles and Bevan 2006). These polygons include a mixture of single basin wetlands and wetland complexes. The rules for describing or allocating a wetland to a complex varied between different studies and this introduces some difficulties for the current project. Ecological data, where available, has been linked to individual polygons rather than complexes. However in some cases data are only available at the complex level.

In order to apply the prioritisation process DIWA categories will need to be assigned to each wetland polygon. The DIWA classification is partly vegetation dependent, therefore information on dominant vegetation type for each wetland polygon will be required. Whilst the data contained in Thompson (1986) and Seaman (2003) will provide this information for many of the wetlands, there is a subset for which there is no existing data on wetland vegetation. Where information is lacking visual examination of aerial photography or other spatial imagery such as SPOT5 or Landsat will be used to assign wetland categories. Similarly salinity will need to be established for each wetland polygon.

Common wetland types

The following descriptions of common wetland types are adapted from Butcher (2005) and Mitsch and Gosselink (2000a):

> **Meadow wetlands/grassy meadows/herb dominated** are largely rainfall dependent systems which typically occur in grasslands and or forests/woodlands and are usually only wet in winter and spring (alternate names could include vernal pools, wet meadows, wet prairies). The

vegetation can be quite similar to marshes, but they generally have water for less time, tending to be predominantly dry in summer (Butcher 2005). It has been suggested that due to their rainfall dependence, meadows typically contribute little to water quality at the catchment level, however if they receive surface water inflows then they have the potential to remove nutrients and sediments (Mitsch and Gosselink 2000a). In Australia these intermittent wetlands support a highly distinctive biota and are extremely productive systems (Butcher 2003). In many areas they are numerically dominant but tend to be smaller in size, and are often more susceptible to impacts (Butcher 2005). This wetland type is often under-represented in wetland mapping and inventory programs.

Marsh wetlands are surface water dominated systems and highly variable and as such are thought to harbour significant biodiversity. They can have a range of depths and have water frequently (shallow marshes) or continually (deep marshes), with most of their water coming from surface inputs (runoff, flooding, overbank flows) (Butcher 2005). They can also receive groundwater inputs. They can form in depressions in the landscape, along the edges of permanent lakes and in floodplain systems. Marshes tend to be dominated by floating leafed plants or emergent soft stemmed plants (sedges, reeds, grasses). These wetlands are also highly productive systems with runoff from surround land usually containing nutrient inputs. Differences in water chemistry are usually related to the magnitude of nutrient and other chemical inputs in addition to the interactions between surface and groundwater inflows (Mitsch and Gosselink 2000a). Soil chemistry is determined by a combination of typically mineral soils and varying amounts of organic input from the vegetation. The high productivity and variability of inundation pattern of this group of wetlands means they support significant aquatic life.

Swamp wetlands differ from marshes in that they tend to be dominated by trees rather than grasses and herbs.

Lakes and ponds are poorly defined. For the purposes of the present study they are separated from marshes and swamps in that they are dominated by open water. Lakes tend to be larger and deeper than ponds with macrophyte growth restricted to the littoral zone. Ponds are smaller, don’t tend to stratify, and can have submergent macrophyte growth.

Table 2: Wetland classification showing links between Ramsar, DIWA and the Pressey (1986) geomorphic categories.

				Ramsar	DIWA[1]	Pressey geomorphic categories	
						Floodplain	Lower Lakes[2]
Freshwater	Flowing water	Permanent	Rivers, streams & creeks	M	B1	1, 4, 6, 7, 9, 10, 14	5
			Deltas	L	B3		3,4
			Springs	Y	B17		3,4
		Seasonal/Intermittent	Rivers, streams & creeks	N	B2		
	Lakes & ponds	Permanent	> 8 ha	O	B5	3, 4, 6-11, 16	
			< 8 ha	Tp	B9	3, 4, 6-11, 13, 16	3, 4
		Seasonal/Intermittent	> 8 ha	P	B6	3, 8, 11, 16	
			< 8 ha	Ts	B10	5, 8, 11, 12, 16, 17	3, 4
	Marshes & swamps	Permanent	Herb dominated	Tp	B9	5, 8, 11, 12, 16	3, 4
		Seasonal/Intermittent	Herb dominated	Ts	B10	5, 8, 12, 16, 17	3, 4
			Shrub dominated	W	B13	5, 8, 12, 16, 17	3, 4
			Tree dominated	Xf	B14	5, 8, 12, 16	3, 4
Saline brackish & alkaline	Lakes & ponds	Permanent		Q	B7	8, 11, 12	3, 4
		Seasonal/Intermittent		R	B8	8, 11, 12	3, 4
	Marshes & swamps	Permanent		Sp	B11	12, 17	
		Seasonal/Intermittent		Ss	B12	12, 17	3, 4

[1] Category B4 excluded as this is taken to represent floodplains, not discrete wetlands – this could include a number of different wetland types from other categories.
[2] Lakes Alexandrina and Albert – excluded from study

SECTION 4: REPRESENTATIVENESS AND UNIQUENESS – WETLAND TYPE

Key assets of biodiversity which are often equated to high conservation value include rare species, rare ecological communities, and areas considered to be good representatives of an ecosystem type. These have driven the principals of reserve design, which are useful for consideration in the development of a wetland prioritisation method and relate especially to the goal of identifying sites worthy of conservation/protection. The three main principals on which reserve design are based are biodiversity hotspots or areas of high species richness, complementarity and representativeness (Bryan 2002; Kati et al. 2004):

1. Biodiversity hotspots are areas which support large numbers of species, and or have a high proportion of rare, threatened or endemic species and is the most traditional approach to reserve design
2. Complementarity maximises the addition of new attributes to an existing reserve system, with attributes being species, endemic species or landscape units
3. Representativeness aims to ensure that environmental variation is well represented in reserve networks and can be applied using standard typologies of habitat or vegetation types that can be used to represent diversity of the environment. Representativeness can be applied to capturing the diversity of a biogeographical region as well (Bryan 2002).

Species richness data are often lacking or incomplete and therefore have limitations in application. In situations when data on species richness or significant species are lacking, but the habitat preferences of the species of interest are known, it is possible to use habitat representativeness for conservation planning (Kati et al. 2004). This is distinct from vegetation representativeness, which is often the main surrogate used to determine reserve designs as it lends itself well to remote sensing techniques and tends to require less time and budget resources to collect than species data. At best this is a surrogate measure, and the pros and cons of this and other surrogates of biodiversity or conservation value will be discussed further in section 5.

Rarity and representativeness of wetland type at the landscape scale will be determined on the basis of the DIWA classification. This process will allow the diversity of wetland types present along the River Murray valley in South Australia and the number of wetlands belonging to each type to be determined. The remainder of this section discusses representativeness and uniqueness of wetland types.

Data requirements for prioritisation based on representativeness

Usually there are two main data requirements for undertaking an assessment of representativeness of wetlands: a classification system and or a biogeographical framework and data on past and current extents of wetlands. Determining past extent is often difficult but is considered necessary in order to estimate how representative current patterns are in relation to past patterns (Norton et al. 2004). Representativeness is then assessed with regard to historical extent usually resulting in the most significant systems being those that have suffered the greatest losses or change over time (Norton et al. 2004).

One of the limitations of the current project is that there is no historical data on extent available. The dataset used to represent current wetland extent is the data from

Pressey (1986). Work on the Lower Lakes and the Coorong as well as other systems in South Australia indicates that the greatest changes to wetland ecosystems occurred long before 1986 (Phillips and Muller 2006; Tibby et al. 2006). This means that consideration of representativeness is constrained to only current extent. With this in mind rareness of wetland type will also be considered.

Based on published material and past experience in wetland inventory and assessment some showing non uniform loss and change in wetland types, general predictions regarding representativeness can be made:

- Lowland wetlands found along the River Murray upstream of Wellington (Pressey's Section 8) will retain a relatively small proportion of their original extent due to land use changes (particularly agriculture) and the government funded reclamation of swamp land during the 1900s. Also within this reduced number of wetlands the number of wetlands that retain a proportion of the original character will also be small and thus these wetlands will be of greater significance.
- Coastal systems are also shown to be prone to significant changes and losses. The recent work on the Coorong and Lower Lakes Ramsar site has provided a clear indication of the reduction of and alteration of fringing wetlands surrounding the Lower Lakes.
- Wetlands that exist on high ground that would have been naturally flooded at infrequent intervals, most likely under river regulation would rarely receive flood water.

Geomorphic regions

From the border to Overland Corner the River Murray meanders through a wide floodplain with a complex pattern of anabranches and billabongs. The channel in this section has cut down approximately 30m into the easily eroded Loxton and Parilla Sands of Pliocene age (Cole 1978; Eastburn 1990). The valley has up to four broad terraces indicating past channel boundaries (Eastburn 1990).

The river changes at Overland Corner where it begins to course through limestone with the valley narrowing to only 1-2 km width, 30-40m depth and sharply defined. During the mid-Pleistocene period the river was much deeper, in the order of 60m, however infilling of Recent sediments (deposits known as the Monoman and Coonambidgal Formations) have raised the valley floor to approximately 30m below the surrounding country (Cole 1978; Eastburn 1990). This part of the valley is characterised by long straight reaches alternating between cliffs and large wetlands separated from the channel by low levees (Eastburn 1990).

The valley floor of the Lower Murray (Mannum to Wellington) was previously occupied by wetlands on either or both sides of the river (Cole 1978; Eastburn 1990). At Wellington the Murray discharges into Lake Alexandrina.

For the purposes of this study the following geomorphic regions are suggested as prioritisation reaches:

1. Border to Overland Corner – wider river valley of 5-10 km width
2. Overland Corner to Mannum – narrow river valley of 1-2 km width
3. Mannum to Wellington - narrow river valley of 1-2 km width, wetland region
4. Lower Lakes: Wellington to the barrages, incorporating the fringing wetlands of Lake Alexandrina and Lake Albert as well as the tributaries (Finniss River,

Currency Creek) and the islands in Lake Alexandrina near the barrages. The study area for this project excluded wetlands on the ocean side of the barrages influenced by tides, and Lake Alexandrina and Albert.

Criteria for prioritisation based on representativeness and rarity

Wetland rarity is defined here as referring to wetlands which are representative of systems that are no longer widespread and are therefore considered unique (DEH 2003). Deciding on what constitutes a representative amount or at what level a wetland type is under represented is usually governed by local or regional targets. The intention of the method is that all wetland categories will be represented in the final priority list. However, this does not mean that wetland categories are represented proportionally to their frequency of occurrence. As the dataset being used is based on information collected in 1986, it will be necessary to validate that the wetlands identified in this first tier still exist, and that they retain the characteristics typical of the wetland type. The criteria were arrived at in discussions with the Steering Committee.

Wetland categorisation criteria 1 – Rare type

- Wetland types that retain less than 10 examples, or are naturally rare within a geomorphic region are rated high priority within the study area.

Wetland categorisation criteria 2 - Representativeness

- If a wetland category is unrepresented or poorly represented in the list of wetlands which have high ecological value, then additional sites are to be chosen from those with a medium ecological value score to make up to 10% of the number of wetlands from that wetland category.

Considerable discussion was given to how to deal with wetlands that were already listed under the DIWA and Ramsar. Initially listed sites were to be automatically assigned a high conservation value, however as the listing of a site may not necessarily reflect high ecological value it was felt that listed sites should not be promoted as automatically being of higher conservation value. This aspect was further explored in the pilot testing phase (see section 8).

SECTION 5: ECOLOGICAL VALUES

Ecological values of wetlands

The values assigned to wetland systems can be considered from many perspectives, including that of:

- Social amenity (e.g. recreational opportunities),
- Economic benefit (e.g. source of water for agriculture or stock and domestic supply),
- Ecosystem services (e.g. water quality improvement, flood mitigation),
- Biodiversity conservation (e.g. habitat for flora and fauna, including threatened species and communities) and
- Ecosystem functioning (e.g. productive capacity, cycling of nutrients and energy).

The allocation of limited resources to the rehabilitation of wetlands will depend on how the various values assigned to wetlands are weighted and ranked. Ultimately decisions will be based on a mixture of social, economic and environmental considerations and factors. This report focuses on environmental values assigned wetlands in the study area, and seeks to identify a subset of wetlands that are a high priority for rehabilitation based on their value from an ecosystem perspective. Balancing environmental values against social and economic factors in order to finalise the allocation of resources to wetland rehabilitation is beyond the scope of this project and will be addressed via a separate process involving stakeholders with an interest in wetland management in the study area. The SAMDB NRM will manage this process.

Ecological values may be assigned to wetlands at a range of scales, such as at the level of populations, ecosystems and the biosphere (e.g. Mitsch and Gosselink 2000b). These values can be expressed in terms of goods and services that we derive (e.g. a source of materials, water quality improvement, flood mitigation), or in terms of wetland function in the landscape (e.g. primary and secondary production, cycling of material and energy). Often, we assign a higher value to wetlands that we consider to be in good 'condition', assuming that such wetlands can deliver the goods and services that we value on an ongoing basis. However, it is important to recognize that even wetlands in modified condition can still be valuable, for example as refuge for aquatic biota in the landscape or to complement other wetlands with a high value (e.g. provide forage for birds that normally reside at wetlands with a high conservation status). This is of particular relevance when considering rehabilitation goals and objectives, as maintaining or improving the condition of modified systems may prove to be as important at a regional scale as protecting sites in good condition.

Value can be very difficult to define and assign in terms of ecosystem goods and services, or in terms of ecological functioning because we do not have appropriate indicators and or lack the data to make such estimates across a whole inventory of wetlands. Mostly we rely on measures such as species richness, or the presence of threatened species or communities. However, the use of such measures as surrogates for environmental value can be problematical. For example, there are often gaps in our taxonomic knowledge (e.g. Georges and Cottingham 2002) or differences in the spatial extent of available data or in sampling intensity at sites where data already exist. In addition, biodiversity 'hotspots' defined after a certain biological group very seldom coincide with hotspots defined after another biological group (Prendergast et al. 1993; Lombard 1995; Gaston and Williams 1996; Howard et al. 1998; Ricketts et al. 1999). This means that prioritisations that rely on species richness measures (e.g. Hahn et al. 2005; Mountford et al. 2006) may be misleading; a high conservation status based on the presence of species or communities of conservation significance may simply reflect sampling effort. Other wetlands may also contain important species or communities but do not have assigned or recognised conservation significance, as they have not been surveyed.

Data limitations are often encountered when trying to assign value and condition ratings to freshwater systems, including wetlands. For example, as part of the Tasmanian Conservation of Freshwater Ecosystem Values project, Dunn and Heffer (2004) considered 32 attributes representative of 'special value' with a view to identifying sites of high conservation value (Table 3). However, only 13 attributes were finally adopted as there was often insufficient data available from which to assess each attribute consistently across the State. Establishing restoration priorities across wide geographic areas ultimately depends on the extent of the inventory data available, which is often patchy and makes applying principles and criteria consistently across wide geographic areas a challenge (e.g. Finlayson et al. 2004). Fortunately this project has access to a high quality inventory data for a subset of wetlands for the study area, and the potential exists to build on the existing database with further inventory work (see section 1 – links with other initiatives).

Table 3: Criteria and attributes* proposed by Dunn and Heffer (2004) for Special Values of freshwater ecosystems, indicating the initial proposed list and those finally recommended (shaded) for the Tasmanian Conservation of Freshwater Ecosystems Values project.

Criterion	Attributes
It is the habitat of rare of threatened species or communities, or location of rare or threatened geomorphic or geological features	Threatened flora and fauna species Threatened flora (forest communities) Priority flora (non-forest) and fauna communities Conservation dependant (priority flora and fauna species) Rare or threatened geomorphic or geological features or processes
It demonstrates unusual diversity of features, habitats, communities or species	Flora species richness Fauna species richness Richness of plant and animal communities High diversity of limnological geomorphic features
It provides evidence of the course or pattern of the evolution of Australia's landscape or biota	Disjunct flora and fauna Areas of high changes (breaks) Fauna species of phylogenetic distinctiveness Flora species of phylogenetic distinctiveness Biogeographical outliers Palaeolimnological areas Palaeobotanical areas Flora centres of endemism Fauna centres of endemism Toehold species
It provides important resources for particular life history stages of biota	Fish nursery areas Fish migration routes/breeding areas Stop-over/seasonal sites for migratory birds Bird breeding areas
It acts as a refuge from past or present processes	Remnant vegetation Refugium from past processes Wildlife corridor Dispersal route-colonisation area

Processes and resources extend beyond the place to sustain and enhance associated aquatic ecosystems	Sustains downstream or adjacent aquatic systems and floodplains Interconnected aquatic systems (wetland complex, karst)
It is of importance in scientific understanding of the ecosystem or its biota, in the past, present or future	Type localities Long-term monitoring sites
Exhibits important landscape scale characteristics	Undisturbed river system from headwater to sea

* Note: numerous other attributes were considered by Dunn and Heffer (2004) but were not included as they were covered by other attributes or because there was insufficient information/data with which to apply the measure consistently.

Examples of common ecosystem value measures applied to wetland systems include (e.g. DNRE 2002; DEH & DWLBC 2003; Dunn and Heffer 2004):

- Naturalness;
- Rarity;
- Representativeness;
- Diversity (including geomorphic diversity, diversity in wetland complexes, centres of endemism);
- Importance to other systems (e.g. hydrological connection, wildlife corridors, foraging near bird breeding areas);
- Ecological functioning (water quality improvement, nutrient cycling, flood mitigation, sediment deposition and erosion control);
- Threatened species, communities, processes;
- Biotic characteristics include aquatic community composition, primary and secondary production, growth, reproduction, recruitment and survival;
- Physical characteristics include hydrological regime, connectivity and geomorphological processes (e.g. erosion and deposition);
- Refugia for flora and fauna.

Kingsford et al. (2005) propose six criteria as the basis of assessment of conservation value of rivers and component ecosystems (includes wetlands) (from Kingsford et al. 2005):

The river or dependent ecosystem:

• *is largely unaffected by the direct influence of land and water-resource development*

A river with a natural or near-natural flow regime and relatively little catchment disturbance is a large-scale ecosystem, retaining most natural features, processes and biota. Unaltered ecosystems that lie within highly altered river basins can also retain natural features, processes and biota. Such undisturbed systems provide important reference points for assessing the health of modified systems. Undisturbed rivers from source to outfall are particularly valued, as they are rare, even at a global scale. Relatively few of the world's ecosystems are truly 'natural' because of pervasive threats (e.g. exotic species, climate change). This criterion applies to rivers and component ecosystems (river segments, floodplains, wetlands, estuaries) that are predominantly natural, rather than necessarily pristine.

• *is a good representative example of its type or class.*

Protecting the diversity of ecosystems and species is the cornerstone of most biodiversity conservation strategies. Conservation of representative ecosystems is a strategy to capture the range of biodiversity. Representative systems in good condition provide useful benchmarks for monitoring river management and restoration, and have very high conservation value where other examples of a system type in good condition are rare or non-existent. Note the application of this criterion is dependent upon river classification.

• *is the habitat of rare or threatened species or communities, or the location of rare or threatened geomorphic or geological feature(s).*

Protection of rare and threatened species and communities is essential to biodiversity conservation. Whole communities may be at risk by threats to riverine ecosystems in disturbed or undisturbed rivers. Disturbed systems may be more prone to localised species extinctions, and protection may mitigate threatening processes, though protection of communities in undisturbed rivers usually presents a more viable and cost-effective option. Some rare geomorphic or geological features are threatened by human impacts, with little likelihood of regeneration within human time scales.

• *demonstrates unusual diversity and/or abundance of features, habitats, communities or species.*

'Hot spots' or sites with highly diverse communities or abundance, can provide the most cost-effective way to conserve a large number of species or a significant percentage of a population of a species, feature or habitat.

• *provides evidence of the course or pattern of the evolution of Australia's landscape or biota.*

River form and behaviour and biota are markers of evolution. Taxa that are endemic or have Gondwanan affinities are considered to have particular value. Australia is noted for its unique terrestrial species and has many distinctive aquatic taxa.

• *performs important functions within the landscape.*

Rivers and component ecosystems sustain habitats, communities and species at a landscape scale. Rivers and their dependent ecosystems can provide refugia within the landscape, especially during dry periods and, seasonally, in monsoonal Australia. They allow many terrestrial fauna to live in inhospitable environments because of the presence of water and abundant riparian and floodplain vegetation. Rivers and component ecosystems provide resources (e.g. food, habitat) for a range of fauna during different seasons or critical stages in their life history (e.g. breeding, recruitment, migration) and corridors for distribution and re-colonisation.

These criteria can be applied at different spatial scales and Kingsford et al. (2005) suggest a nested hierarchical approach similar to the fine and coarse scale filters applied by The Nature Conservancy, among others (Phillips and Butcher 2006 and references therein). Kingsford et al. (2005) also suggest that assessment of 'attributes' is best done at the river segment or homogenous river reach scale, but that protection is best achieved when managed at the catchment scale.

Criteria selection and justification – wetland ecological value

The broad criteria presented above were all considered in developing the specific criteria for determining ecological value of the prioritisation method. The principles adopted for selecting measures of ecological value in this project are that:

- Rehabilitation priorities should not be at the expense of protecting high value wetlands already being managed;
- The prioritisation scheme must be simple to understand and deploy;
- The prioritisation scheme must utilise existing data, or data that will be relatively easy or cost-effective to collect;
- The prioritisation scheme should be sufficiently robust as to include wetlands in the SA MDBC inventory for which there is little or no survey information (e.g. site specific information on species richness, vegetation type and cover, geomorphic variability etc.);
- The scale of application of the prioritisation tool will be at the whole River Murray valley in South Australia.

Identification of wetlands with high conservation value is proposed on the basis of:

- Representativeness of the wetland categories described for the study area (see section 3),

Rarity of wetland type, and

- Ecological values based on aspects of diversity, rarity, and biological structure and function.

Threatened flora and fauna

Flora and fauna records are a common starting point in terms of assigning wetland value; sites with high species richness or that support threatened species are often assigned a high ecological value. However, it is important to recognise the limitations of such an approach. At a regional scale, uneven survey effort can mean that undue emphasis is given to sites that are rich in taxa or for which there are records of threatened species. Sites that have not been surveyed may be considered less valuable simply because there is little or no information on the taxa present. It will also be necessary to confirm that sites already recognised as significant retain the values for which they were originally listed (i.e. that the listings are supported by contemporary data and information). For example, Finlayson and Rea (1999) point out that the sites included in the Directory of Important Wetlands in Australia are based on limited and incomplete data and subjective interpretation of criteria.

This issue is not unique to the River Murray wetlands, and without a complete inventory this continues to be a data limitation which will influence the wetlands identified as having high ecological value.

In South Australia, the term 'threatened species' refers to species classified as either rare, endangered or vulnerable on *Schedules 7, 8 and 9* respectively of the *National Parks and Wildlife (NPW) Act 1972* (DEH website):

> **Endangered** species are under the most threat and likely to become extinct in the near future unless the circumstances and factors threatening their survival cease to occur.
> **Vulnerable** species are those likely to move into the endangered category in the near future unless the circumstances and factors threatening their survival cease to occur.
> **Rare** species are those that are the least threatened, but at some risk due to their low numbers, restricted distribution or observed declines.

Species are also listed as threatened at the national level under the *Environment Protection and Biodiversity Conservation (EPBC) Act 1999*. These plants and animals tend to receive priority for conservation activities because they are threatened at both the national and State level (DEH website).

Threatened flora and fauna are considered in two criteria. The first sub-criterion assigns a higher ranking based on the taxonomic diversity (number of different taxonomic groups with listed species). The second criterion considers the level of threat, with species listed at the national level under the EPBC Act receiving a higher ranking. Threatened species data considered presence/absence data only. Threatened invertebrate fauna are not considered in the current study as information and sampling effort are considered insufficient across the study area.

Habitat – structure, extent and connectivity

Species richness and or diversity measures are often used to identify sites of high conservation value, with sites with higher numbers of species being valued more highly. In the absence of complete species inventories sites can be listed on the basis of being important for single taxonomic group. However, hotspots defined after a one biological group (e.g. birds) very seldom coincide with hotspots defined for others (Butcher 2003; Kati et al. 2004).

For the present study there is insufficient information across all wetlands in the region to apply a criterion based on species richness and so surrogate measures will be used. Habitat complexity and extent are commonly used surrogates for diversity with the assumption being that greater complexity will support greater numbers of species. Habitat will be considered as structural layers (availability), and in terms of habitat extent (% cover of each type). Initially, habitat availability will be based on vegetation structural diversity (trees, shrubs, sedges, large woody debris, islands); however it may be feasible to include consideration of geomorphic features (e.g. irregularity of shoreline).

Wetlands often provide critical or important habitat for different biota at particular life history stages, such as for migratory species and as breeding sites. This represents an important aspect of connectivity.

Three habitat criteria are proposed which provide information on wetland habitat structure, diversity (as a surrogate for species richness) and importance of habitat as breeding and or migration sites.

Hydrological regime diversity

Hydrology is considered the fundamental driver of wetland ecology (Mitsch and Gooselink 2000a). Wetlands along the River Murray valley have had their natural hydrological regimes significantly altered by river regulation. Wetlands with low elevations have had a significant increase in water permanency, and wetlands at higher elevations are dry more often. The hydrological regime criterion is based on whether the wetland is permanent, seasonal or intermittent, and assumes that seasonal and intermittent systems are more heterogeneous in nature and therefore support greater structural and biotic diversity. Wetland complexes with variable water regimes will score higher.

Ecological values considered but not included

A number of ecological value measures were considered for inclusion in the framework but omitted for reasons such as the difficulty in applying them consistently across the study area and lack of data. The following is a brief discussion on the reasons for omitting various ecological value measures.

Diversity and abundance measures
Wetlands that are considered to be biodiverse or capable of supporting particular taxa in great abundance are often considered to have high ecological value. However, the inclusion of diversity and abundance measures in a scheme such as that proposed in this study poses some problems. Biodiversity measures and indices are usually based on inventory data for individual wetlands. However, sampling effort and data availability is usually patchy at regional scales. This can mean that sites that have not been surveyed are automatically given a lower ecological value, irrespective of whether or not they are species rich or support large numbers of biota. In addition, inventories at a wetland are often based on a single (or at least limited) sampling. As wetland communities can naturally be quite variable (e.g. there can be large seasonal fluctuations in diversity and abundance), assigning ecological value on the basis of a single inventory can result in bias, as variability related to factors such as climate, season and hydroperiod may not be accounted for. Accounting for this variability would require intensive sampling effort, which is unrealistic given the level of resources that would initially be required for such an undertaking across the study area. However, revisiting diversity measures could be useful once there is a consistent level of inventory undertaken across the study area (Brooks et al. 2004), as it will then be possible to consider the geographic range of various taxa and explore distribution in relation to environmental drivers and processes.

Wetland size
Large wetlands are often assigned a high ecological value on the assumption that larger size confers greater habitat heterogeneity and availability, and thus greater biodiversity (e.g. species richness). However, this may not always be the case. For example, species richness may decline in wetlands as salinity increases (e.g. Williams et al. 1990) and species diversity in large saline lakes can be relatively low (albeit with large species abundance and productivity) (e.g. Boulton and Brock 1999). In addition, small isolated wetlands can play a critical role in the maintenance of regional biodiversity (e.g. Butcher 2003; Meyer et al. 2003). The loss of small wetlands can lead to localised loss of biota and diversity, and even the collapse of meta-populations as wetlands become isolated and biota cannot migrate to new areas (e.g. Semlitsch 2000; Semlitsch and Bodie 1998). Assigning a higher priority to wetlands on the basis of their large size runs the risk that smaller wetlands, which can account for much of the biodiversity occurring at a regional scale, are ignored.

Ecological Integrity
It is desirable to include measures of ecological integrity in any ranking of wetland ecological value. Information on wetland functional attributes, such as production, respiration, carbon and nutrient transformations, and trophic interactions, can all provide insights on the drivers of current condition that help identify rehabilitation priority. However, there is insufficient data available for considering or applying measures of ecological integrity consistently across the study region.

Habitat connectivity
Similar to ecological integrity, inclusion of habitat connectivity measures is desirable when considering wetland protection and rehabilitation measures. However, inclusion of such measures is usually limited by a number of factors (e.g. Dunn and Heffer 2004), including a lack of consistent data and a limited understanding of habitat and resource requirements for particular life history stages of biota, such as fish and birds. In addition, the response of biota such as birds may vary depending on factors

such as the availability of habitat and food resources that can vary according to landscape scales drivers (e.g. climate conditions, hydroperiod).

Summary of ecological value criteria

Five ecological value criteria will be tested during the pilot stage as summarised in Table 4. Details of the specific criteria and how they are scored in the refined method are presented Appendix 9.

Table 4: Summary of ecological value criteria being pilot tested.

Ecological value criteria	Intent
1. Threatened flora and fauna – taxonomic diversity	Relates to rarity and "hot spots" for species of conservation
2. Threatened flora and fauna	Conservation value of significant species
3. Habitat structure layers	Greater habitat diversity has the potential to support greater number of species
4. Habitat extent	Measure of habitat extent – relates to stability and resource availability
5. Hydrological regime diversity	Assumes that variable hydrological regimes promote diversity.

SECTION 6: THREATS TO RIVER MURRAY WETLANDS

Ecosystem condition can be used both as a measure of ecological value and also as an indication of threat. Wetland condition is taken as the state or ecological condition of a wetland, which is an integrated measure of the composition, structure and biotic interactions characteristic of the site. Wetlands in poor condition are usually affected by threats that alter attributes such as hydrology, habitat availability or water quality. Most wetland condition assessments are multi-metric and based on the key ecological features of wetlands, hydrology, hydric soils and distinctive biota (Roberts and Butcher 2006).

It is important to note the difference between baseline inventory programs (e.g. River Murray Baseline survey) and condition assessments. While baseline inventory programs collect information on the physical, chemical and biological components of wetlands, wetland condition assessments take this information (and additional data) to make a judgement on the "health" of a system, often in comparison to an expected or reference state. Wetland condition assessments typically identify the status of, and threats to, wetlands as a basis for the collection of more specific information, usually through monitoring activities. Wetland condition assessment methods are typically referential, however the means by which reference condition is established can vary (Roberts and Butcher 2006). Many approaches assess current condition only: with rating of condition being based on expert opinion (e.g. Butcher 2005) or by making comparisons to unimpacted or best attainable reference sites (Young and Sanzone 2002; Faber-Langendoen et al. 2006). This typically arises due to a lack of baseline data on wetland ecological features and a poor understanding of the variation in key wetland attributes (Roberts and Butcher 2006). Other methods use an agreed point in time, often pre European settlement, as the target reference condition (e.g. the Index of Wetland Condition; DSE 2005).

Currently there is no statewide wetland condition assessment program in operation in South Australia. The River Murray Baseline survey provides benchmark data from which current condition can potentially be established however, attempts at converting the data into condition ratings have proven unsuccessful to date (Shirley and Holt 2005).

For the purposes of this study we are restricted to using existing data, which is limited for both measures of wetland condition and threats to wetlands. Therefore the criteria have been built around the "traditional" threat categories and in most cases are either indirect measures of threats or measures of visual responses to those threats.

Threats categories

Threats can be defined as (Hart et al. 2005):

"An action or activity that has the capacity to adversely affect an ecological asset and its values."

Under this definition, threats are synonymous with "stressors" (as defined by the USEPA 1998) and "pressures" (as defined by the OECD 2003) and incorporate biological, physical and chemical components and processes that can impact the condition and ecological values of a natural resource.

Threats to wetlands across South Australia have been identified in the State's Wetland Strategy (DEH & DWLBC 2003). Under this strategy: "failure to value the services and benefits of wetlands"; and "a lack of baseline information and integrated approaches", have been identified as the root causes of threats to wetlands. The following are the major threats and management issues for wetlands across the State that arise from these root causes:

1. Destruction of wetlands – conversion to alternative uses;
2. Changes to water regimes;
3. Introduced plant and animal species;
4. Pollution impacts;
5. Inappropriate land use practices;
6. Salinity;
7. Over exploitation of wetland resources.

The strategy identified river regulation and water resource use as the most significant threat to wetlands of the Murray-Darling Basin. In addition, the strategy identified the following management issues as relevant to the River Murray wetlands:

- Altered flow regimes;
- Water diversion – artesian;
- Water diversions – surface sources;
- Accelerated run-off through channelisation;
- Conversion of wetlands to drainage basins;
- Stormwater, sewage and irrigation water disposal;
- Water quality (urban run-off, industrial pollution, septic tanks);
- Impact of forestry and / or agricultural chemicals;
- Local and regional rising groundwater;
- Creation and management of artificial wetlands, watering points;
- Overgrazing of riparian zones and floodplain by stock;
- Floodplain cropping and horticulture;
- Introduced plant and animal species;
- Recreational impacts;
- Cultural significance of wetlands;
- Limited management data; and
- Lack of community extension services.

Acid sulfate soils are also identified as a risk to wetlands of the River Murray valley.

Threats have the potential to impact on the value and condition of wetlands either directly or indirectly accelerating or exacerbating the effects of natural processes such as drought, fire or climate change (Figure 7). In addition, the interaction between threats and impacts to wetlands is complex with the impacts of multiple threats having cumulative or synergistic effects to wetland condition.

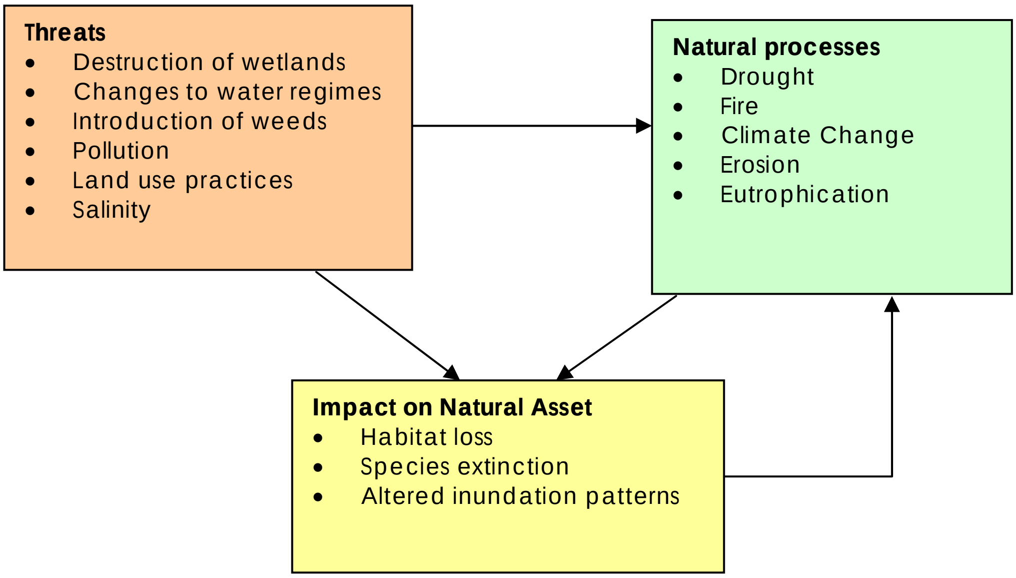

Figure 7: Relationship between threats, natural processes and impacts to wetlands.

Data requirements for identifying threats to River Murray wetlands

Data required to identify and assess threats to wetland condition and values include:

- Information at the regional or catchment scale to capture threats to individual wetlands that originate outside the immediate surroundings of the wetland (eg river regulation);
- Information at the local scale to capture threats and impacts that are the result of local actions (eg adjacent land use, vegetation clearing);
- Time series information to enable trend as well as extent in threats and impacts to be determined;
- Direct data on threatening activity or process (as opposed to inferred information on threat from observed response or impact); and
- Data on impact to wetland condition or values to enable relative importance of threat to be determined;

This data can be sourced from previous on ground surveys and collected baseline information as well as from remote sensing and modelling of trends in large scale threats such as water regulation and salinity.

This having been said, it is recognised that wetland management and prioritisation must be able to be implemented in situations of poor data availability. As a consequence, surrogates and indicators will need to be identified for each of the threat criteria selected. Data on current condition based on data collected under the River Murray Baseline Survey is included here as well. Potential indicators and data sources for each threat criterion are provided in the section below.

Criteria selection and justification

The following is a brief description of some of the key threats to wetlands in the study area. The relative influence of these threats will form the basis of threat criteria; the greater the scale or influence of the threat, the less chance there is for successful long-term rehabilitation.

Salinity

Salinity has long been recognised as a key threat to the condition of riverine and wetland ecosystems (e.g. MDBC 1999; Hart et al. 2003) and the management of salinity levels in wetlands along the River Murray in South Australia is a significant natural resource management issue (DEH and DLWBC 2003). Fluctuations in salinity due to wetland filling and drying patterns are normal (a pulse disturbance (e.g. Lake 2003), and wetland flora and fauna can tolerate salinity to various degrees. However, prolonged increases in salinity beyond 1500 EC units (μS/cm) (a press disturbance) can decrease the abundance, species richness and diversity of plants and animals in wetlands (e.g. Nielson et al. 2003a and b). Persistently high salinity due to the accumulation of salt in the sediments or surface water of wetlands can constrain the recovery of wetlands expected with rehabilitation.

Salinity problems across the study area result from rising groundwater due to changed landuse and management (e.g. irrigation, land clearing, floodplain disposal of drainage water), river regulation and rising in-stream salinity levels (i.e. salt exported from upstream catchments) (Croucher et al. 2004). The geological setting of the River Murray in the study area is such that groundwater moves towards the river. As the salinity of groundwater moving into the river valley is generally high, the salinity of the River Murray doubles between the border and Morgan (DWLBC website). Without intervention, salt loads entering surface waters are expected to increase over the next 30-50 years, with the greatest contribution expected to be from expanding groundwater mounds under irrigation areas (MDBC 1999).

Altered hydrology

Wetlands are characterised by seasonal patterns of water level (hydroperiod) that define the rise and fall of surface and subsurface water. Changes to these patterns can affect biota and ecological processes and are considered one of the major disturbances to aquatic ecosystems (e.g. MDBC 2002 and 2001). Disruption of the hydrological integrity of a system such as the River Murray can affect attributes such as (e.g. Bunn and Arthington 2002):

- Physical and geomorphic processes,
- The timing, duration and extent of floodplain inundation,
- Habitat availability at both local and landscape scales,
- Biological and ecological processes for riverine and floodplain flora and fauna (e.g. breeding, migration, recruitment, metabolism, competition),
- Water quality and the cycling of nutrients and energy,
- Resilience to invasive flora and fauna species.

Hydrological integrity can be assessed by comparing current water regime with natural, historic or simulated natural. Regulation and diversion of water across the entire Murray Darling Basin has seen a reduction of median annual flow in the lower River Murray to approximately 38% of natural (RMCWMB & Government of South Australia 2002). It has also altered the characteristic seasonality of flows, particularly for floodplain/wetland areas, and increased their isolation from the river channel (i.e. reduced river-floodplain connectivity) (e.g. Thoms et al. 2000; Jensen et al. 2000). The influence of both reduced annual flows, and regulating infrastructure such as weirs and locks, has affected the hydrological integrity of wetlands across the entire study area to varying degrees. Some wetlands have become permanently inundated, the seasonal pattern of filling and drying may have been altered to varying degrees, while many wetlands receive water from the river far less frequently than natural.

Regulating structures have been installed at some of the high value wetlands across the study area to manipulate their hydrological regime. This allows managers to protect or reinstate the natural pattern of filling and drying and its associated ecosystem benefits.

Under current legislation, any action that controls the movement of water in or out of a wetland that is connected to the River Murray at normal pool level requires a water licence and water allocation (Croucher et al. 2004) Licence applications must be accompanied by Wetland Management Plan (WMP) that considers the potential threats, solutions, actions and management responsibilities required to protect the biological and physical integrity of the wetland (RMCWMB & DWLBC 2003, cited in Croucher et al. 2004).

Landuse context and intensity
Land use changes and intensity measured at the catchment or landscape scale can be assessed in a number of different ways, including consideration of the condition of riparian corridors, remnant native vegetation cover, the proportion land uses that may adversely affect water quality in the catchment, and the number of dams or barriers on streams (Tiner 2004). Tiner (2004) states with as little as 10% of impervious land in the catchment that stream health begins to decline and serious degradation occurs if imperviousness exceeds 30%. Even smaller levels of imperviousness can damage stream and wetland health if impervious areas are connected directly to the receiving water by efficient stormwater drainage (Walsh, et al. 2004; Cottingham, et al. 2004) Wetland assessment must include consideration of landscape or catchment setting if rehabilitation is to succeed.

Wetland buffer
Vegetation surrounding wetlands is considered to be very important in the management of water and wildlife resources. Referred to here as wetland buffers, surrounding terrestrial vegetation plays a key role in physical and chemical filtration processes that protect water resources (e.g. drinking water, fisheries) from siltation, chemical pollution, and increases in water temperature caused by human activities such as agriculture, and urban development (e.g. Lowrance et al. 1984; Forsythe and Roelle 1990 cited in Semlitsch and Bodie 2003; Tiner 2004). Semlitsch and Bodie (2003) state that it is widely accepted that buffers or riparian strips of 30–60 m wide will effectively protect water resources. The required width of the buffer zone for sustaining biota and or ecological processes will vary as these operate at different scales.

Wetland connectivity
Connectivity of ecosystems is a fundamental concept widely used in spatial ecology, with most measures only considering distance to nearest neighbour patch/wetland. Scale dependent measures such as wetland connectivity and wetland buffer are affected by the scale of assessment (e.g. radius of wetland buffer assessed). In some situations the simplest measures have been shown not to be the most effective measure of connectivity (e.g. Moilanen and Nieminen 2002). Connectivity can be measured as:

- Spatial connectivity - distance between wetlands assuming no functional connectivity – straight position of wetland in landscape. Examination of spatial connectivity allows the option of assigning higher value to clusters of wetlands: this assumes higher biodiversity values are captured with larger number of wetlands.

- Functional connectivity - deals with issues of fragmentation, loss of biological connectivity – corridors. Considering the loss of hydrological connectivity between floodplain wetlands and parent river (river regulation impacts) allows the examination of issues such as the maintenance of habitat for wildlife.

The relative importance of connectivity is influenced by position in landscape and type of wetland. It is likely that functional connectivity in floodplain wetlands is probably more important than spatial position relative to other wetlands – although these are linked. Aspects of wetland connectivity are captured by several criteria: ecological criterion 5 and threat criterion 4.

Threats considered but not included

Barriers to fish

Barriers such as weirs and other regulating structures were considered but not included as a threat criterion, as it was felt that the relationship between wetland type and dependency of fish species was not well enough known across the study area. Also, as Leigh and Zampatti (2005) point out, barriers occur throughout the study area and relating the impact of individual barriers to particular wetlands would be difficult.

Water quality

Water quality is a primary driver of the growth and vigour of wetland plants. It has the potential to influence wetland vegetation composition, and can cause shifts in primary productivity at fast (weekly to annual) time scales. Nutrient removal and storage capacity in wetlands is controlled by the interaction of a number of physical, chemical and biological processes in the soil and biota, with wetlands able to act as sinks for nutrients, as well as being sources of nutrients entering into downstream systems (Butcher 2005).

Increases in phosphorus and nitrogen (i.e. eutrophication) can be detrimental to the structure and the function of wetland plant communities. Phosphorus is generally the more limiting nutrient in the freshwater systems, while nitrogen tends to govern plant productivity rates. Typically, anthropogenic addition, or loading, of these nutrients can cause ecological imbalance, shifting the structure and function of the ecosystem. Trigger values for the main water quality variables (such as nutrient concentration, turbidity, salinity etc) for inland small seasonal wetlands are not available as yet, and so surrogates of water quality are typically used to assess changes to water quality (Butcher 2005).

A threat criterion for water quality was considered, but as water quality data for individual wetlands are likely to be limited, landuse intensity will be used as a surrogate for nutrient and sedimentation threats. The wetland buffer measure also provides a potential surrogate for water quality.

Invasive species

The impacts of invasive species are an obvious threat to wetland ecosystems. However, a threat criterion was not included as it was felt that impacts could not be separated from other threatening processes. The threat from invasive species is considered to be pervasive and that all wetlands had the potential to impacted. This was based on the assumption that all wetlands connected to the main river channel would have invasive fish species, and all wetlands would be exposed to feral animals. Consideration of invasive species is included in the biophysical feasibility section of the method and will most likely require collection of site specific data.

Geomorphic and soil integrity

There are no standard methods for assessing the geomorphological integrity of inland shallow wetlands. Shoreline erosion has two main causes: the wetland water level has been artificially raised above the normal range, and the protective shoreline vegetation has been degraded (Butcher 2005).

Surrounding land surface integrity can also play a role in the increased mobilisation or delivery of sediments to wetlands. Loss of soil integrity can result from clearing of native vegetation, pugging and compaction by stock, cultivation and use of heavy machinery (Butcher 2005).

Grazing by introduced livestock occurs over approximately 60% of Australia. Livestock tend to concentrate around water sources, including wetlands, particularly in drier periods, thus increasing the affects of grazing and trampling (Jansen and Robertson 2001; Jansen and Robertson 2005). The effects of grazing on wetland geomorphology, vegetation and water quality are well documented (Jansen and Robertson 2001). Uncontrolled access by livestock to land around wetlands can lead to:

- Increased run off,
- Bank erosion,
- Loss of productive land,
- Decline in important wildlife habitat, and
- Reduced water quality.

Livestock can tend to favour areas around wetlands and rivers, often being seen in and along waterways. This can lead to overgrazing and erosion of bank soils, which can in turn allow increased weed invasion. Stock trails are often formed, which can also increase inputs of nutrients and sediments, with animal dung and urine affecting water quality (River Landscapes 2006).

Discussions with the Steering Committee and feedback from the stakeholder workshop (see Appendix 4) suggested that alterations to bed and bank areas of wetlands were not considered a significant threat at present. An exception to this is the issue of erosion and sedimentation in the Lower Lakes resulting from stable water levels and wind action (Phillips and Muller 2006). At this stage, a criterion has not been included in the prioritisation method, although it could be added at a later date if needed (see Appendix 2).

Acid sulfate soils

Acid sulfate soils (ASS) predominantly occur in lowland coastal and estuarine areas, particularly whose soils have been influenced by the last major sea level rise some 10,000 years ago. Bacteria in organically rich, waterlogged sediments convert sulfate from tidal waters and iron from the sediments to iron disulfide (iron pyrite). When exposed to air, iron sulfides oxidise and produce sulfuric acid (Sammut 2000). The soil itself can neutralise some of the sulfuric acid but any remaining acid can move through the soil, and ultimately acidify nearby soil, groundwater and surface waters. ASSs occur predominantly in:

- Estuarine areas and coastal lowland areas such as mangroves, tidal flats, salt marshes and swamps;
- Inland wetland areas;
- Saline inland areas; and
- Near mining operations.

Waterlogged areas where iron sulfide layers occur are often drained for agriculture or exposed during land development. This can accelerate the natural rate of oxidation, so that large amounts of acid groundwater are released rapidly into nearby waterbodies. Acid leaching can also follow drought periods. Local water tables can be lowered during drought, exposing ASS. Subsequent flooding after a drought can then mobilise acid. The impacts of this acid water can be acute or chronic, and may include (Appleyard et al. 2003; Sammut 2000):

- Adverse changes to the water quality of the soil, groundwater, surface water, wetlands, watercourses and estuaries;
- Soil acidification;
- Degradation of water-dependant ecosystems and ecosystem services;
- Loss of habitat and biodiversity;
- Invasion and dominance of wetlands and waterways by acid tolerant water plants and plankton species.
- Loss of plant yield;
- Poor quality water sources for stock, irrigation and human use;
- Bared soil surfaces in discharge areas;
- Increased human health risks associated with arsenic, aluminium and other heavy metal contamination in surface and groundwater, and acid dust;
- Loss of visual amenity from rust coloured stains, scums and slimes from iron precipitates;
- Corrosion of metallic and concrete structures (concrete cancer) such as roads, bridges, pumps, drainage pipes and foundations;
- Blockage of perforated plastic pipe drainage systems by iron precipitates; and
- Financial burden of treating and rehabilitating affected areas, and maintenance of infrastructure.

The nature and scale of management of ASS makes rehabilitation of affected sites difficult and expensive. For example, the addition of agricultural lime can neutralise sulfuric acid, but this is usually too costly for large areas of badly affected land (Sammut 2000; White et al. 1997). In some instances re-flooding land with freshwater can halt further acidification and may even reverse the acidification process if the site can be kept wet and there is sufficient organic matter for sulphate reduction by bacteria. However, great care is required in applying such an approach, as re-flooding can increase acid discharges if acid water sits close to ground surface and can flow to nearby waterways following rainfall. Further, the re-flooding of drained, partially oxidized floodplains with freshwater may not be feasible because of the large volumes of acid stored in the soil, a lack of labile organic matter in the sediments needed to reduce sulfate and irreversible changes to the soil due to oxidation (White et al. 1997). The use of freshwater re-flooding requires caution and technical advice before it is applied.

Recent studies have demonstrated that some saline wetlands develop sulfidic material deposits in the River Murray floodplain environment, with sulfidic materials accumulating after brackish or saline wetlands remain permanent for several years. The hydrology of saline wetlands plays an important role in the development of potential acid sulfate soil conditions. Studies are underway to determine the hydrological regime that would decrease the risk of developing potential acid sulfate soil conditions during the rehabilitation of Lower Murray wetlands (Lamontagne et al. 2004; Hale and Butcher 2005). More detailed information about the formation and identification of sulfidic materials and their environmental risks can be found in Lamontagne et al. (2004).

Managing acidic outflows requires an understanding of the interaction between chemical and hydrological processes across landscapes. Wetlands affected by ASS are likely to be considered difficult to rehabilitate and will most likely receive a low priority for rehabilitation in this study until it can be demonstrated that amelioration techniques such as re-flooding can be applied without undue detriment to nearby wetlands and waterways.

ASS initially was to be considered as part of assessing the feasibility of rehabilitation, however existing data are not considered adequate to provide an assessment of the threat across the whole study area.

Summary of threat criteria

Five threat criteria will be tested during the pilot stage as summarised in Table 5. Details of the specific criteria and how they are scored in the refined method are presented Appendix 9.

Table 5: Summary of threat criteria being pilot tested.

Threat criteria	Intent
1. Salinity	Identifies sites with changing salinity regime
2. Altered hydrology - hydroperiod	Change in frequency of inundation
3. Altered hydrology – water source	Identifies sites which have been isolated from their natural water source, and also sites which have been altered to a more permanent regime
4. Landuse intensity	Landscape scale surrogate for Nitrogen inputs into wetland – relates to water quality
5. Wetland buffer	Local scale surrogate measure for altered functions which impact on the wetland water quality (sedimentation, increased nutrient run off, loss of organic material inputs)

SECTION 7: FEASIBILITY OF MANAGEMENT

Wetland rehabilitation and feasibility

There has been considerable discussion in the restoration ecology literature of terms such as restoration, rehabilitation, remediation and reclamation, and what each seeks to describe (Bradshaw 1996; Kaufman et al. 1997; Palmer et al. 1997; Rutherfurd et al. 2000 and others). The term ‘rehabilitation’ has been used throughout this report, as this refers to the reinstatement of desired features of riverine and wetland ecosystems (structural or functional) that may have been impaired or lost, rather than a complete return to ‘natural’ or ‘pre-disturbance’ conditions implied by the term ‘restoration’ (e.g. see Rutherfurd et al. 2000). The project study area has undergone fundamental change since European settlement, so a return to some ‘natural’, ‘pre-disturbance’ or ‘pristine’ condition (even if it were possible to define this for the study area) is considered unfeasible.

Reviews of rehabilitation project success (e.g. Smokorowski et al. 1998; Lockwood and Pimm 1999; Lake 2001; Bond and Lake 2003; Pretty et al. 2003) suggest that many rehabilitation projects ultimately fail or are only partially successful in achieving their stated objectives. Success rates in terms of ecological response can be low, even when habitat targets have been met. Some of the reasons for this are:

- A lack of clear and agreed rehabilitation objectives,
- A mismatch between the scale of the rehabilitation and the underlying sources of degradation,
- The isolation of newly installed habitat from source or re-colonising populations,
- Mismatch between the roles of different stakeholders (e.g. project implementation may be the responsibility of state or local stakeholders, but project funding may depend on other sources over a shorter timeframe),
- A lack of monitoring, evaluation and review.

While this study focuses mainly on rehabilitation from a wetland ecosystem perspective, it is important to note that the management measures adopted will depend to a large degree on socio-economic considerations. Sources of funding, the role and responsibilities of various stakeholders, and a willingness by stakeholders to be involved (or not) are some of the factors that can affect the rehabilitation measures adopted, and where and when they are applied. Well crafted rehabilitation plans and associated priorities for action may mean little if there is no support, or if there is antagonism, from stakeholders. Time spent with stakeholders that might be involved or affected by a project is a wise investment, as is a communication strategy that keeps stakeholders informed and committed. The method developed for this project will allow socio-economic priorities to be added at a later stage by the SA MDB NRM Board.

The following points on rehabilitation success were noted by Cottingham et al. (2005) based on the experience of the former Cooperative Research Centre for Freshwater Ecology:

- Australian and international experience suggests that most rehabilitation projects will fail if the scale of stressor(s) and/or the scale of the response required are not considered carefully. It is important to take the time to examine and understand the history of land-use change and management in your catchment.

- It is important to establish working relationships with the stakeholders who will be involved in decisions on the rehabilitation techniques that can be applied and the ongoing conduct of a project. This will take time and energy, but is a wise investment.
- Planning for rehabilitation projects should include an assessment of the scale of past and present factors that have affected current conditions and resulted in the need for rehabilitation. Examine the history of your catchment. Have the stressors that have caused degradation been identified? Are they still active? At what scale do the stressors apply? Is the river system still responding to these or other stressors?
- The highest priority should go to the protection of high value riverine and floodplain assets (systems); for example, those in best condition, that are representative, that are hotspots of biodiversity or productivity, or serve as refugia and can supply colonising organisms that may disperse to newly rehabilitated or available areas. These assets play a critical role in maintaining the resilience of river systems and their ability to recover from disturbance.
- River systems are often subject to multiple impacts and legacy effects from past land and water management practices. While some riverine attributes may respond quickly to rehabilitation, full recovery is likely to take decades and will require ongoing commitment and patience.

The activities and processes that threaten wetland condition can act at varying scales. An important consideration in developing rehabilitation priorities is to consider the scale at which past disturbances or current threats apply, as this will in turn influence the scale of actions needed for successful rehabilitation. Key factors to consider are if the underlying processes that led to degradation are still active, and whether localised rehabilitation efforts are likely to succeed in the face of disturbances that operate at large spatial and temporal scales (Figure 8).

Approach to evaluating feasibility

This study seeks to assist the following management objective:

To prioritise wetlands for rehabilitation based on consideration of conservation value, threats and current condition.

The broad nature of this objective means that determining rehabilitation potential or feasibility requires more than the criteria for conservation value and threats. The assessment of conservation value and threat will place the wetlands into three broad categories: ecologically intact, moderately disturbed or severely disturbed (Brooks et al. 2006). The next step is to consider rehabilitation potential in light of technological and physical (e.g. infrastructure) constraints. However, as Brooks et al. (2006) point out, no ranking methods currently exist for catchment assessments that are capable of reliably combining ecological assessments with technological and other constraints. This remains the task of resource managers and falls in the realms of best professional judgement (Brooks et al. 2006).

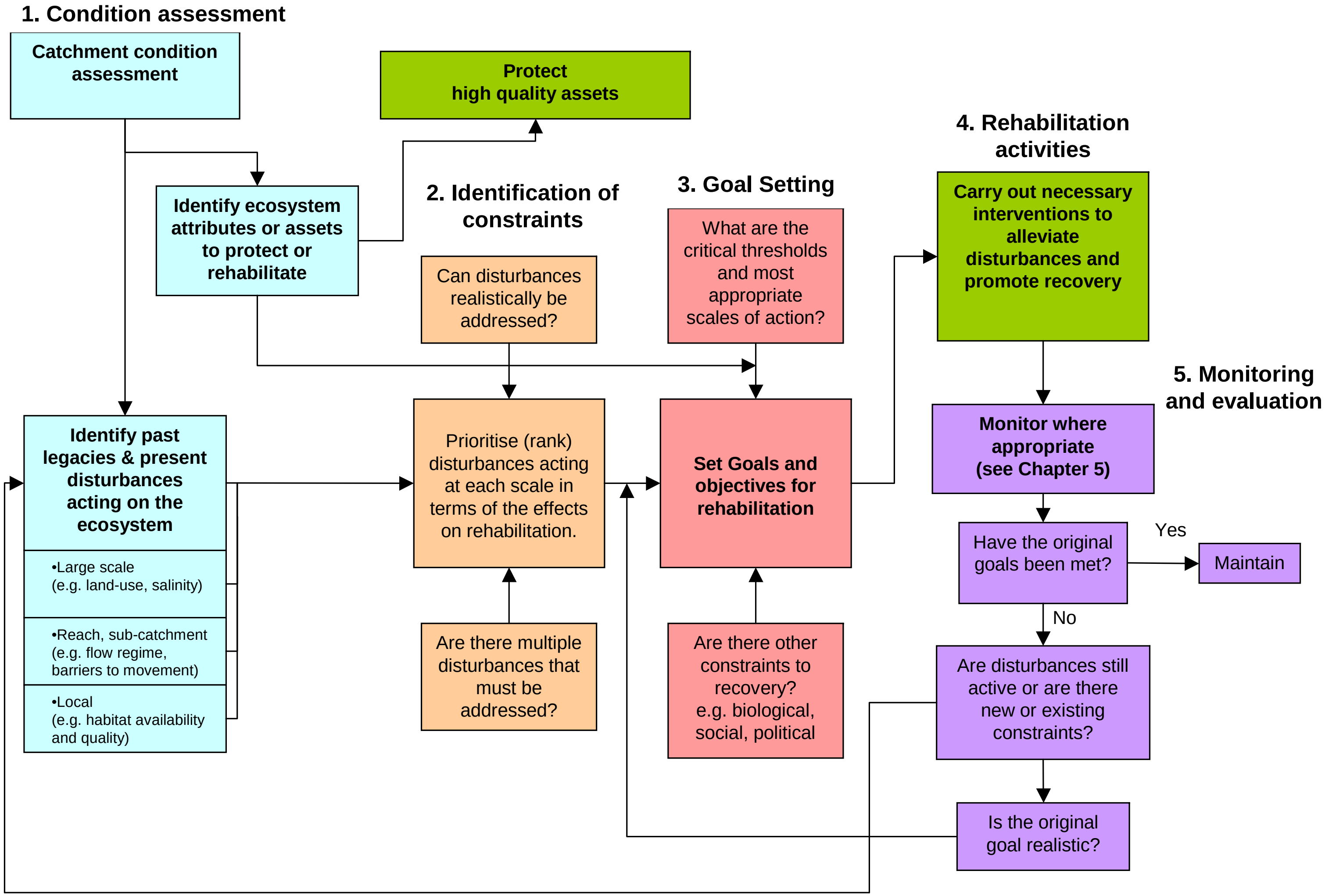

Figure 8: General approach to identifying rehabilitation constraints and priorities (from Cottingham et al. 2005: adapted from Suding et al. 2004).

The feasibility assessment for this project includes a series of criteria relating the management potential and key large scale threats affecting each wetland. A matrix is created using the conservation value and threat rating for each wetland (see Figure 9). Wetlands identified as having a low threat rating should represent wetlands least threatened and therefore requiring little intervention, with the management option being protection. This subset of wetlands is graded into three ranks based on their conservation value. For example wetlands with high conservation value and low threat are considered a high priority for protection (dark blue cell in Figure 9).

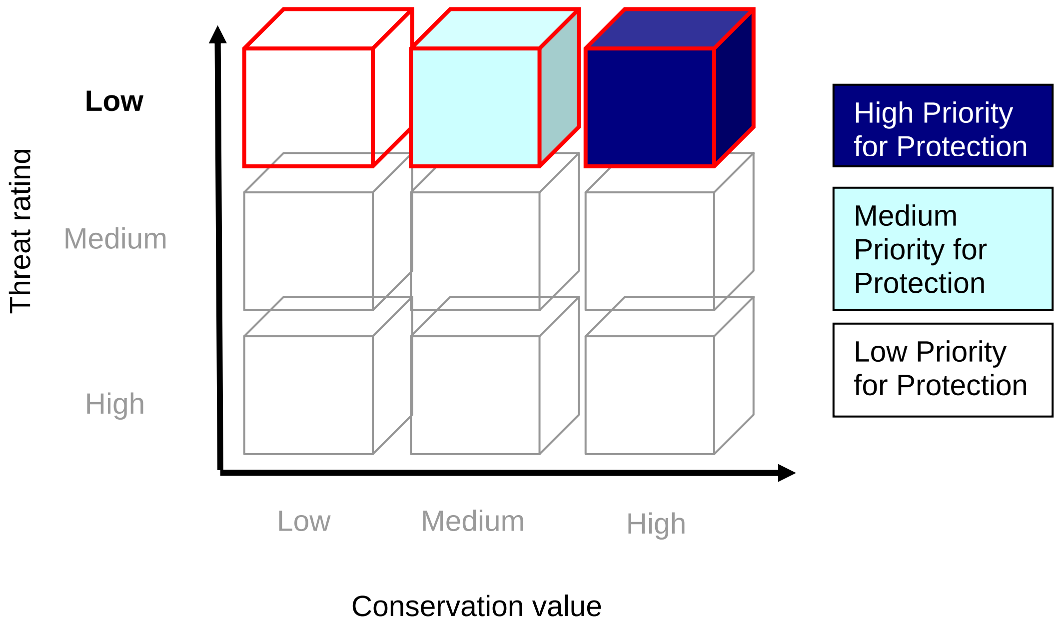

Figure 9: Conservation value versus threat rating matrix showing how the wetlands with a Low threat rating are ranked for protection.

Each wetland was considered in relation to the threat/conservation value combination that placed them in the sub set of wetlands considered to have rehabilitation potential. The subset of wetlands that had their rehabilitation potential evaluated are those which were representative or rare wetland types and those of medium conservation value and medium threat (see Figure 10).

Wetlands that fall into the high threat low conservation value most likely represent wetlands that are severely degraded, requiring considerable commitment of resources with no guarantee of gaining a successful rehabilitation outcome (Figure 10). Rehabilitation of this latter group of wetlands would in most instances, be considered to have a low priority.

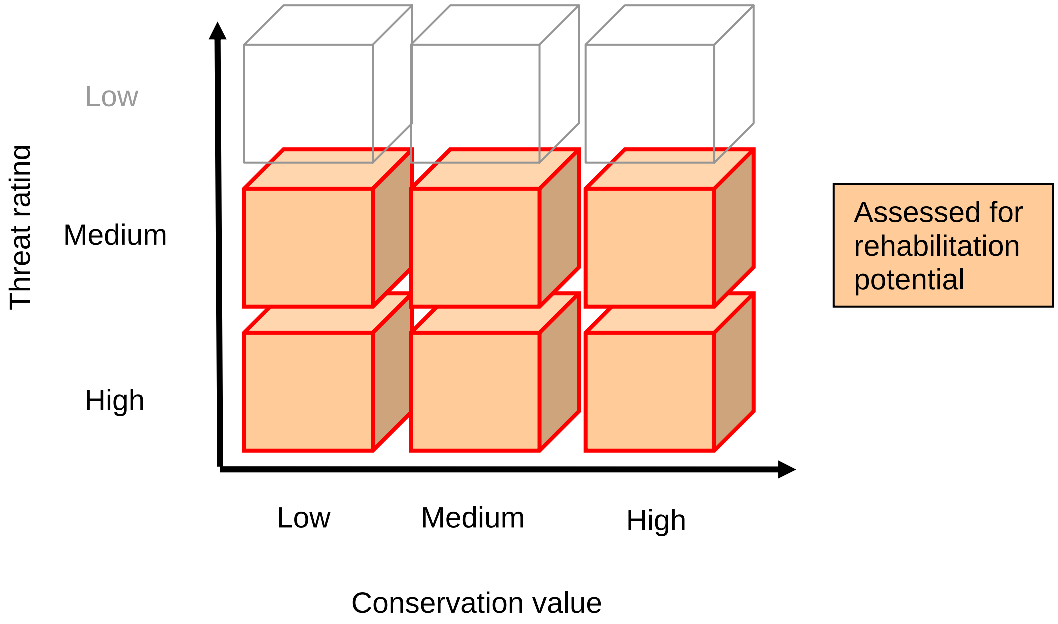

Figure 10: Conservation value versus threat rating matrix showing the wetlands which are assessed for rehabilitation potential.

The feasibility criteria are based on a series of questions that consider elements of the key drivers of wetland condition: salinity, hydrology and biophysical attributes. Prior to the pilot testing, the feasibility section of the method was initially set out as a four part Decision Support Tree (DST). The first part was called the “show stopper” filter which was intended to be used to identify wetlands with threats which could not be managed. For example, salinity impacts are considered difficult to reverse, as they are often associated with groundwater intrusions and broader catchment scale impacts (e.g. land clearing). Certain areas of the floodplain will be subject to ongoing salinisation from groundwater intrusion. Some wetlands within these high salinity risk zones may be very hard to rehabilitate as their water source, which drives the hydrology of the wetland, is causing the salinisation.

The next part of the DST related to altered salinity and hydrology, which are considered large-scale drivers of ecosystem condition, often with hysteresis effects (Figure 19 in Appendix 6). The final part of the DST related to the biophysical aspects of rehabilitation and explored site-specific constraints on rehabilitation, and in many cases was considered to have a greater range of management options and a lower degree of difficulty (Figure 20 in Appendix 6).

The order of issues presented in the DST represents a progression from the most to least difficult in terms of rehabilitation, with salinity impacts considered more difficult and costly to rehabilitate than hydrological changes. The biophysical rehabilitation of wetlands is, in general, considered the easiest (in the absence of salinity and hydrology impacts) as in many cases the technology and cost required is substantially less than the other drivers (e.g. fencing is less technical and cheaper than installing control structures to manipulate hydrology). Whilst cost is not an overt consideration in the DST, it is implied with the different activities associated with the rehabilitation of wetland functions or control of threats.

The original feasibility DST, including the show stoppers can be seen in the draft method in Appendix 6.

However, once the pilot data began to be tested it became evident that there was a significant amount of redundancy in the original DST, and that data limitations meant that some questions could not be answered, requiring additional data or, more often, a site visit. The biophysical questions in particular were felt to be inadequate as it could be argued that all wetlands could potentially benefit from some biophysical management such as restriction of grazing, re-vegetation works etc.

Thus to complete the pilot testing, the feasibility DST was simplified to a set of criteria based on the DST components, and then further refined after consultation with the Steering Committee. The modifications made make the method more consistent through each of the stages and maintains the simple scoring system approach used for assessing ecological value and threat. Once the conservation threat matrix has been formed, wetlands are spilt into those requiring protection (three ranks) and those which requiring rehabilitation, based on the following criteria:

Feasibility criterion 1 - Manipulation of hydrology is possible through existing entitlement flows and or manipulation of weirs for wetlands above Wellington, or hydrology is affected by lake levels.

Wetlands above Wellington

- Commence to flow < 10,000 ML/day = 3
- Commence to flow 10,000 - 50,000 ML/day = 2
- Commence to flow > 50,000 ML/day = 1

Wetlands below Wellington

- Connected at lake level = 3
- Within 30m of lake shore = 2
- >30 m from shore = 1

Feasibility criterion 2 - Salinity impacts

- Wetlands with no evidence of secondary salinisation – scores 3
- Wetlands with some evidence of salinisation – scores 2
- Wetlands with evidence of acute secondary salinisation – scores 1

Feasibility criterion 3 - Manipulation of hydrology with infrastructure. Relevant to wetlands above Wellington only.

- Wetland has no inlet or inlet > 10m = 1
- No infrastructure present but inlet 10m or less and therefore possible to insert control structure = 2
- Existing infrastructure present* = 3

*Note that ‘existing infrastructure present’ was based on advice from DEH that barriers present at a wetland were (unless otherwise stated) to be equated to infrastructure.

The feasibility rank is scored as follows:

Wetlands above Wellington
8 - 9 = High

6 - 7 = Medium
3 - 5 = Low

Wetlands below Wellington
5 - 6 = High
3 - 4 = Medium
2 = Low

The final ***rehabilitation ranking*** is based on a combination of ***conservation value rank*** and ***feasibility rank***. There is an implied cost associated with the different rehabilitation options and this is reflected in the ranks. This represents the final output of the prioritisation for rehabilitation.

The final ranking is as follows:

Very low = low feasibility
Low = moderate feasibility and low conservation value;
Medium = medium feasibility and medium conservation value; or high feasibility and low conservation value
High = medium or high feasibility and high conservation value; or high feasibility and moderate conservation value

The method development was a highly iterative process, with the end product the result of several testing and reviewing phases. This is not meant to be a “black box” tool, but a highly transparent method which should undergo further refinement as improved data becomes available. Therefore the following recommendations are made:

- Wetlands identified as high priority for rehabilitation will require a second level of assessment once the actual management goal for each wetland is established. At this point questions such as ‘can an ecological gain be achieved?’, ‘is the cost prohibitive to attain the ecological gain?’, and ‘is the gain sustainable without significant ongoing allocation of works and/or funds?’ can be applied. This level is more targeted, and will require more specific objectives to be established than the simple statements used in the criteria.

- It is recommended that consideration of the potential of biophysical rehabilitation options, such as restricting grazing, native vegetation planting and control of weeds, be assessed during a site visit, as this may help further refine priorities for management. There will also be a strong link to some of the other initiatives and projects currently underway – e.g. project on prioritising weir pool manipulation, conservation of significant floodplain units, and prioritisation of floodplain areas for environmental flow allocations.

- All wetlands that are identified as being a high priority for rehabilitation should also be assessed in the field or provided priority for future baseline monitoring. This will ensure that a minium data set is collected for all high priority wetlands and also potentially identify sites which may need their ranking reassessed.

- Wetlands which receive a high conservation value but receive a low feasibility rank should be checked by a “local” expert and or a site visit should be undertaken to ground truth the ranking, to ensure they are not falsely excluded.

SECTION 8: PILOT TRIAL RESULTS

Data were collected and the prioritisation method trialled for 100 sites selected at random from the list of wetlands that occur in the study area. The location and details of the sites are presented in Appendix 5 (ranks presented represent the output which includes the post pilot testing refinements - see below). Comments regarding data collation, actual data and the results from testing of the method are contained in Appendix 7 and 8.

Modifications to draft method

A number of modifications were made to the draft method (see Appendix 6) so that it could be applied consistently and so that various sensitivity analyses could be run. Modifications were necessary due to data type and limitations, as well as redundancy or logic flaws in the draft method, particularly in the feasibility section. Modifications to the draft method included the following:

Wetland categorisation criterion 1 - Rare wetland type
The cut-off number of wetlands used in the draft criterion was reduced in proportion to the number of wetlands used in the pilot. This meant that instead of up to10 wetlands equating to a rare type from approximately 1100 wetlands, if there were only 1-2 wetlands of a wetland type per the 100 pilot test they were considered rare and assigned high priority.

Threat Criterion 1
Threat criterion 1 was modified as DEH provided salinity data as a ranking of salinity impacts with a range of 0-5, with 0 being no visible signs of salinisation and 5 representing 'acute salinity problems'. This meant the draft criterion would not fit well with the data, hence it was modified.

Feasibility of rehabilitation
There were two major modifications to this section of the method. The pilot testing and sensitivity analysis presented in the following sections are based on the following criteria and scoring system.

Once the conservation threat matrix has been formed, wetlands are spilt into those requiring protection (three ranks) and those which requiring rehabilitation, based on the following criteria:

Feasibility criterion 1 - Salinity impacts

- If the wetland scores a 3 under Threat Criterion 1 = N (Not feasible)

Feasibility criterion 2 - Manipulation of hydrology with infrastructure

- Wetland has no inlet or inlet > 10m = N (Not feasible)
- No infrastructure present but inlet 10m or less and therefore possible to insert control structure = 2
- Existing infrastructure operable = 3

Feasibility criterion 3 - Manipulation of hydrology is possible through existing entitlement flows and or manipulation of weirs

- Commence to flow < 50,000 ML/day = 3
- Commence to flow 50,000 - 80,000 ML/day = 2
- Commence to flow > 80,000 ML/day = N (Not feasible)

If any of the conditions set out in the criteria are not feasible then that wetland is not considered further - it doesn't get a score for the other criteria. Feasibility is scored as follows:

N = Not feasible
Low feasibility = 4
Medium feasibility = 5
High feasibility = 6

The final ranking is based on a combination of ***conservation value ranking*** and ***feasibility***. There is an implied cost associated with the different rehabilitation options and this is reflected in the ranks. This represents the final output of the prioritisation for rehabilitation.

The scoring for the final ranking is as follows:

N= NOT feasible for rehabilitation:
Low = low feasibility and medium or low conservation value;
Medium = medium or high feasibility and medium conservation value;
High = medium or high feasibility and high conservation value

In this version, wetlands which had a high threat low conservation value combination were considered as not feasible for rehabilitation. However, due to some data issues and concern that no wetland should be considered "beyond help" the final feasibility criteria and scoring (as presented in section 7 and Appendix 9) were developed and tested as a final post pilot testing refinement of the method. The results are presented in the summary section below and represents the final version, and corresponds to the final rehabilitation ranking (Appendix 7) based on the refinements adopted after pilot testing.

Sensitivity analysis

Rarity of wetland types
For the pilot study, wetlands were considered rare if they were the only one or two of a type (up to 2% of 100 pilot test sites) as per the DIWA classification. DEH listed a number of wetland polygons as a mixture of types and these were considered as distinct wetland types for the purpose of the rarity assessment. Only one artificial wetland (DIWA class C2, wetland polygon) was in the pilot data and as such was a rare wetland type. After reviewing the ecological values assigned to this wetland it was allocated a low conservation ranking instead of an automatic high conservation ranking. Had the site been treated as per the rarity criteria it would have been put into the high protection ranking, which was considered inappropriate for this wetland. It therefore recommended that in future artificial wetlands identified as being a rare type be reviewed to establish if they merit a high conservation value rating.

A total of 8 wetlands were identified as rare using the 2% cut off as a measure of rarity. Increasing the cut off up to 4% of a particular type resulted in 12 wetlands being identified as rare (see Appendix 8, rarity worksheet). This higher cut off captured an additional wetland type, not considered rare under the initial criterion.

Two of the additional sites identified as rare ended up receiving a high protection ranking and two were considered not suitable for rehabilitation (Table 6). A final decision on the cut off for rarity will be dependent on having a better understanding of the breakdown of wetland numbers by wetland type for the whole study region. As this was not available in the pilot a final recommendation on which is more suitable is not possible.

Table 6: Rarity sensitivity analysis

Category	Rare up to 2%	Rare up to 4%
Protection - High	7	9
Protection - Medium	26	24
Protection - Low	13	13
Rehabilitation - High	1	1
Rehabilitation - Medium	3	3
Rehabilitation - Low	8	8
Rehabilitation – Not feasible	42	42
Total	**100**	**100**

Threat Weighting

An initial application of the prioritisation method was undertaken with all threat criteria being weighted equally (see Appendix 8, worksheet Threat weighting 2). This resulted in an underestimation of the number of sites requiring rehabilitation works and identified 78 % of sites as requiring little or no rehabilitation, but protection measures only. Of these, 5 wetlands had severely altered hydrology and a further 6 had both altered hydrology and salinity.

Altered hydrology and salinity have been identified as key threats to the wetlands in the study area and as detailed in Section 2 are key drivers of wetland condition and ecology. As a consequence, these threat criteria (TC1 and TC2) were weighted to reflect their importance to wetlands in the system. A weighting factor of two was applied to these threat criteria such that:

Threat criterion 1: Salinity – actual (local scale).

- Wetlands with no evidence of secondary salinisation – scores 2
- Wetlands with some evidence of salinisation – scores 4
- Wetlands with evidence of acute secondary salinisation – scores 6

Threat criterion 2: Altered hydrology – hydroperiod (frequency of inundation).

- Wetlands with little or no evidence of altered hydroperiod – scores 2
- Wetlands with evidence of altered hydroperiod - change in frequency of inundation considered moderate – scores 4
- Wetlands with evidence of significant change in hydroperiod with a significant shift in frequency of inundation that has resulted in a shift in permanency – scores 6

Total threat scores were also modified to reflect this change:

- Score of 15-20 – High threat
- Score of 10-14 – Medium threat

- Score < 10 – Low threat

Application of this weighted threat criteria resulted in greater separation of wetlands into “protection” and “rehabilitation” categories (see Appendix 8). As a consequence, 46 % of wetlands were identified as requiring minimal rehabilitation works (Table 7) and assigned priorities for protection, and the remaining 54 wetlands were assessed for feasibility of rehabilitation works.

Table 7: Comparisons of prioritisation with and without weighting factors applied to salinity and hydrology threat criteria.

Category	No Weighting	Weighting (now base case)
Protection - High	11	7
Protection - Medium	49	26
Protection - Low	18	13
Rehabilitation - High	0	1
Rehabilitation - Medium	3	3
Rehabilitation - Low	0	8
Rehabilitation – Not feasible	19	42
Total	**100**	**100**

Weighting of threat criteria is recommended and has been adopted into the final prioritisation method. As a consequence, all other sensitivity analyses and comparisons have been made against this set of test data.

DIWA Listing

A sensitivity analysis was conducted on the use of DIWA listing as a criterion for assigning high conservation value to a wetland (see Appendix 8). This resulted in 10 additional wetlands being identified as a high priority for protection (making a total of 17 wetlands in this category) and an additional 3 wetlands identified as high priorities for rehabilitation (Table 8).

Table 8: Sensitivity analysis on DIWA listing.

Category	Base Case	DIWA = H value
Protection - High	7	17
Protection - Medium	26	17
Protection - Low	13	12
Rehabilitation - High	1	4
Rehabilitation - Medium	3	3
Rehabilitation - Low	8	5
Rehabilitation – Not feasible	42	42
Total	**100**	**100**

Whilst DIWA sites should, in theory, automatically receive adequate protection due to being listed as sites of national importance, the sensitivity analysis showed that some of these sites also require rehabilitation work. The simple fact that a site is DIWA listed does not preclude it from requiring ongoing maintenance and or rehabilitation. Based on this finding it is recommended that DIWA listing should not be used as a criterion for ecological value.

Feasibility Assessment – Size of Inlet Structure

Part of the hydrological feasibility analysis (FC2) is reliant on an assessment of the size and number of inlet channels that could be regulated to control wetland hydrology:

Feasibility criterion 2 - Manipulation of hydrology with infrastructure

- Wetland has no inlet or inlet > 10m = N (Not feasible)
- No infrastructure present but inlet 10m or less and therefore possible to insert control structure = 2
- Existing infrastructure operable = 3

In order to apply this scoring system, a decision on the maximum width of inlet channel that could feasibly be regulated had to be made. An initial estimate of 10 m was applied (total width of all channels combined). As a comparison, this was increased to 20 m and the method applied again (see Appendix 8). The increase resulted in a minor change in the number of wetlands considered feasible for rehabilitation works (Table 9).

Table 9: Sensitivity analysis on inlet width considered feasible to regulate.

Category	**10 m width**	**20 m width**
Protection - High	7	17
Protection - Medium	26	17
Protection - Low	13	12
Rehabilitation - High	1	2
Rehabilitation - Medium	3	5
Rehabilitation - Low	8	10
Rehabilitation – Not feasible	42	37
Total	**100**	**100**

Forty-two wetlands had no inlets from which to use control structures to regulate hydrology, and so were considered not feasible for rehabilitation. Relying on the presence of inlets with either existing structures or having to potential to have infrastructure installed may be a weakness in the criterion, as there may be other means of manipulating wetland hydrology. For example, it may be possible to construct new inlet channels or removing flow barriers. The Steering Committee should consider if other options for manipulating or installing infrastructure exists, and what data are required to capture this using remotely sensed data.

Feasibility Assessment – commence to fill

The hydrological feasibility analysis (FC3) was modified slightly for the wetlands in the lower lakes reach. There is no commence to fill data available for the lower lake sites and the ease of being able to manipulate their hydrology requires review. In the absence of any commence to fill data the wetlands were assigned a medium score of 2 for FC3. Wetland 99 was assigned a score of 3 as it is permanently connected to the lake and as such requires less than 50,000 ML/day to be inundated. This criterion may need refinement if and when commence to fill data are available for wetlands in the lower lakes reach. Currently it does not take into consideration barrage operations and raising and lowering of lake levels.

(NOTE: this was addressed in the final refinement of the method post pilot testing - see summary section below).

Baseline Sites

A sensitivity analysis was conducted to compare results for sites where data had been collected as part of the Baseline Wetland Surveys with non baseline sites. Of the 100 wetlands selected for the pilot test, 27 were wetlands included in the River Murray Baseline Wetland Survey Program. Although there was some additional data available for these sites, the baseline surveys were not condition assessments and the applicability of the data collected to the prioritisation method was limited. In addition, the prioritisation methodology was designed to be applicable to wetlands predominantly via remote sensing analysis and the application of existing datasets across the study area. This is reflected in the results of this sensitivity analysis (Figure 11) where there was little difference in the prioritisation of sites that were a part of the Baseline Wetland Survey program and those that were not. However, the River Murray Baseline Wetlands Surveys are not the only sources of data for wetlands in the study area. There is little or no information on sampling effort at sites outside the River Murray Baseline Wetlands Surveys and as such it is not possible to determine if the ranking of sites is a result of sampling effort. The key point regarding the baseline sites is that there is a much greater level of confidence in the data, particularly for listed species records.

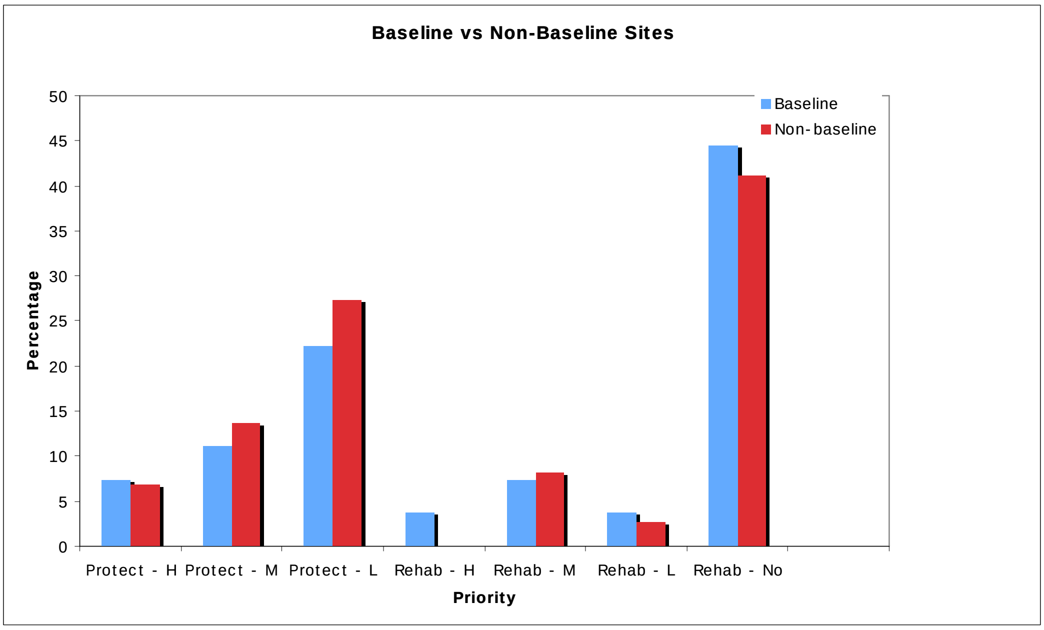

Figure 11: Comparison of prioritisation of wetlands as a result of River Murray Baseline Survey

Comparison to Thompson (1986) conservation ranking

Only 38 of the 100 pilot test sites were surveyed by Thomson (1986) and assigned a conservation value. Thomson assigned a high conservation value to 26 wetlands, 9 of which fall out as being not suited to rehabilitation, the rest receiving a protection ranking. Direct comparison to Thomson's ranking is not possible as the criteria which he used do not match directly to those used in the prioritisation method, although there are similarities (e.g. higher value assigned to wetland complexes, higher value of intermittent wetlands over permanent wetlands). Thompson did not address feasibility for rehabilitation as part of his approach and as such it is likely the degree of “sensitivity” is greater in the prioritisation method. Deterioration of wetland condition in the 20 years since Thomson’s survey may also influence the results. Even so, the proportion of sites which were identified as requiring protection did reflect a large subset of Thomson’s high conservation value sites and does provide a measure of confidence in the prioritisation method.

Table 10: Thomson (1986) conservation ranking against output of prioritisation method

Category	Thomson High	Thomson High - Mod	Thomson Moderate	Thomson Moderate - Low	Thomson Low
Protection - High	3				
Protection - Medium	10	1	1		1
Protection - Low	4	1			
Rehabilitation - High			1		
Rehabilitation - Medium					
Rehabilitation - Low		2		1	
Rehabilitation – Not feasible	9		2		2
Total	**26**	**4**	**4**	**1**	**3**

Summary: Post pilot testing refinement

As mentioned above the method underwent further refinement after the pilot testing was completed. This involved reworking the feasibility criteria, required data and scoring. The refined feasibility criteria are presented in section 7 and in Appendix 9. Breakdown of results by reach is present in Table 11. There were no changes to the protection ranks assigned, and only the rehabilitation ranks changed as a result of the reworking (see data for this in Appendix 8 worksheet 8 “test scores final feasibility”).

Seven sites were identified as being of high conservation value with low threats, thus requiring little or no additional management/rehabilitation and were assigned the category of Protection - High. Most of these sites were located within reach 4 (Lower Lakes - Wellington to the barrages). Eight sites, the majority within the lower lakes area, were identified as the highest priority for rehabilitation. Overall, the method resulted in sites being assigned to all categories, with no obvious patterns. This indicates that the method provides a reasonable first cut of sites for rehabilitation and protection.

Table 11: Number of wetlands per ranking by reach for pilot test.

Category	Reach 1	Reach 2	Reach 3	Reach 4	Total
Protection - High		1		6	7
Protection - Medium	4	7	8	7	26
Protection - Low	1	3	7	2	13
Rehabilitation - High	3			5	8
Rehabilitation - Medium	2	1	6	2	11
Rehabilitation - Low	1		1	3	5
Rehabilitation – Very Low	14	13	3		30
Total	**25**	**25**	**25**	**25**	**100**

Expert panel review

Members of the Steering Committee undertook a review of the pilot test results after the feasibility criteria were refined (see Appendix 10). The purpose of this sensitivity analysis was to test the results against expert local knowledge of the wetland systems. The assessments were made without reference to the raw data and therefore some of the comments made are likely to reflect data issues. The following is a synopsis of their findings with comments from the project team where appropriate.

Upper Murray

> *The pilot results were not compared against the raw data to determine the factors(s) contributing to a particular conservation, threat, or feasibility score, in particular polygons rated as Rehabilitation - VL were difficult to assess. However, in general, most of the final ratings seemed valid when compared to local knowledge of the site.* Extract from expert review - see Appendix 10.

Fourteen sites were assessed against local knowledge in the Upper Murray, with 9 sites considered as having valid ratings. The following issues were raised for the sites considered to have an invalid rating:

1. **Regional salinity:** Polygon 36 is located on "*highly salt affected floodplain. The surrounding area is dominated by irrigated horticulture*". The wetland did not show any signs of salinisation according to the data provided by DEH and therefore received a good rating against the salinity criterion, as it only considers site, not regional conditions. The comment that the surrounding landscape is "dominated" by irrigated horticulture does not match the data provided for this polygon - 70% of the surrounding landuse (500m radius) was rated as conservation/public land.
2. **No judgement made as to validity of rating:** Two sites (10 and 23) had comments made but no statement regarding the validity of the ratings. We are assuming the rating is being questioned. The comments for these polygons relate to data that was not captured in the dataset. Improved hydrological connectivity at polygon 10 through lowering of sils, and dependence on storm water rather than river water at polygon 23.
3. **Depth and listed species:** Polygon 35 was suggested as worthy of a higher rating due to its depth. Depth was not a measure in the classification of wetlands. The site apparently supports silver perch, but this data has not have been included in the dataset.
4. **Condition:** Polygon 25 had the following comment - "*Narrow channel connected at pool. Site appears to be in good condition. Feasibility should be higher*". The presence of the inlet was captured in the feasibility criteria. Condition is not captured in the criteria. Converting the SA River Murray Baseline survey data into a condition rating for sites is an area of further development for the Board. When developed, condition ratings can be included in prioritisation method at a later time.

Lower Murray

> *For the most part the ratings were either as or close to the expected. Data quality is assumed to be the largest impact on the quality of results. However, some significant discrepancies were identified.*

Only 13 of the 26 wetlands seemed to have a valid rating. Most probably this discrepancy will relate to the data set available (this includes sites between Wellington and Blanchetown), but without the data set it is not possible to assess this accurately. Those that were expected to rate differently were for the most part close to the expected rating. Of the unknown polygons the majority of ratings seemed acceptable with only a few questionable, where some were well removed from any river connection and some were reed islands. Again this is probably an issue with the data set.

As there were definitely some wetlands that were rare in the region, the main overall concern is the lack of high protection rating. Another concern is the not feasible rating for some of the wetlands, in particular Wellington East. In comparison, other wetlands that are defiantly not feasible were given a better rating. Extract from expert review - see Appendix 10.

After reviewing the comments made for each wetland polygon the sites that were considered to fall outside of the expected rating can be grouped as follows:

1. **Classification issues:** Four sites (73, 70, 55, and 56) were identified as having potentially incorrect ratings due to classification issues. Wetland 73 was identified as a rare type in the region and it was suggested a higher rating would have been expected. This wetland was identified as DIWA category B5, and under the criteria for uniqueness was not considered a rare type. Polygon 56 was not considered a “wetland” and that revegetation would be a valid option at this site. Polygon 55’s rating was also questioned on the basis of being a “dairy swamp channel”. On advice from the Steering Committee all wetlands (including channels and creeks) which were on the GIS data layer were to be included. We agree with the comment regarding polygon 70: it is a marina and should have been rated as very low rehabilitation potential.
2. **Mapping issue:** Polygon 76 was identified as a mapping error; no comment was made as to the validity of the rating. This reflects the need to ground-truth the GIS layers to ensure wetlands are still as they are listed.
3. **Presence of listed species:** Three sites (81, 59, 99) were considered as having a lower than expected ratings on the basis of these sites having listed species. There are two ecological criteria that consider the presence of listed species so this information was included in the rating. If these are the only reasons for which the ratings were considered too low by the expert reviewers, then this suggests that the ratings for these sites are valid within the framework of the method.
4. **No justification provided**: Two sites (45 and 78) were suggested as being lower than expected, but no reasons were provided.
5. **Grazing:** One site (85) was considered too highly rated on the basis that the site was heavily grazed. Grazing is not a landuse activity easily discerned from remote sensed data; however this is captured in the criterion on surrounding landuse.
6. **Feasibility ratings:** Two sites (57 and 75) were considered worthy of a higher rating based on rehabilitation potential. Polygon 57 was suggested as a candidate for revegetation. This type of biophysical rehabilitation option was not included in the feasibility section after discussion with the Steering Committee. The suitability of a site for revegetation has to be established through an on site visit, potentially after the application of the prioritisation. Polygon 75 was identified as having a control structure that would allow manipulation of the hydrology. This was not identified from the data set

provided. If the presence of a control structure was included in the data then the rating would be medium feasibility, medium rehabilitation potential.

The validity of the results for the Lower Murray pilot sites, we believe, are higher than the suggested 50% (13/26 wetlands). The ratings for potentially 8 of the 13 sites identified as incorrect, may be appropriate ratings when considering that the issues raised were actually captured by the criteria (listed species, surrounding landuse) or that no reason was provided for questioning the rating. It is acknowledged that some sites did receive inappropriate ratings (particularly polygon 70). Wetland types were not weighted according to their degree of modification or the fact that they may be open channels, this aspect of wetland classification was not addressed in the method and may be an area that requires further consideration.

Overall there were no obvious trends where all sites were consistently under or over rated; ratings varied on a site by site basis and reflect the level of knowledge of the individual wetlands held by the expert reviewers.

Knowledge gaps and data issues

DEH provided all data used in the pilot testing phase of this project. The following includes comments from DEH on difficulties in sourcing data and also on how the data was interpreted for the application of criteria. Data limitations and future needs are also presented.

Wetland classification

DEH identified the main attributes necessary for the classification of wetlands using the DIWA system as being:

Wetland size – Standard polygon attribute common to all mapped wetlands

Physical form – Imagery and existing feature codes in other datasets were available at a scale that enabled geo-physical attributes to be confidently assessed.

Water regime – Reasonable degree of confidence except for the ‘lower lakes’ wetlands where the water regime remains undocumented for many of the wetlands.

Conductivity - Quantitative data was available for some of the wetlands, however ‘fresh’ was the default during the classification process. The ‘lower lakes’ reach contains some naturally saline wetlands, but these have not been isolated with a high degree of confidence. The salinity (value) of most of the wetlands was unavailable, so vegetation mapping was used as a surrogate to identify whether a wetland was fresh or saline. In DIWA, the same physical wetland form can be common to fresh and saline systems and is classed differently. For example, ‘B10’ (seasonal freshwater marsh), and ‘B12’ (seasonal saline marsh).

Vegetation/substrate – datasets were available to describe communities to species level. Soil landscape units mapping was available to verify %organic /inorganic matter.

The pilot dataset identified a couple of wetlands that are effectively marinas. There is no specific category within the ‘Human-made’ wetlands in DIWA to describe these features. The closest class is ‘C2’, ‘Ponds, including farm ponds, stock ponds and small tanks’.

'B10', referring to a 'seasonal intermittent freshwater pond and marsh on inorganic soils, includes seasonally flooded meadows, sedge marshes' was generally used in preference to 'B13', 'Shrub swamp; shrub dominated freshwater marsh' because of the tendency for many of these to be 'sedge-dominated' rather than 'shrub - dominated'. There may be some cases where the latter is more appropriate, since the selection of a DIWA class was largely dependent on the accuracy of the vegetation mapping.

Wetlands that have been classified as 'B10' may also be 'B4' (riverine floodplains, flooded river basins, seasonally flooded grassland) as there appears to be common elements in both classes. 'B10' was used in preference to 'B4' (most commonly for the seasonally flooded meadows), but upon reflection there are numerous cases where the two classes should be used together.

Under represented wetlands

An issue of concern is how to handle shallow grassy meadows, as they are under-represented in the wetlands database (based on comments in Pressey 1986) and are likely to fall out as structurally simple. This is an area that requires further attention, potentially through additional inventory work that could expand the existing wetland layer to capture more of these wetland habitats across the study region. Under the DIWA classification these wetlands would most likely be classified as:

> *B10 - Seasonal/intermittent freshwater ponds and marshes on inorganic soils; includes sloughs, potholes; seasonally flooded meadows, sedge marshes*

This category was numerically dominant in the pilot data set (see comment above).

Data sourcing and interpretation issues

Comments from DEH regarding difficulties in sourcing and interpretation of data used to populate the database used for the prioritisation method is presented in Appendix 7. The following relate to specific issues of applying the data for the pilot testing.

Landuse assessment

The scale at which this was measured was less than the agreed 1000 m. The data provided for the pilot used a 500 m radius and included bare ground as a landuse. Bare ground is not a landuse but rather a consequence of land use activities, or it may be naturally occurring. It can occur across several of the landuse categories and as such these measures should have been recalculated. The inclusion of bare ground was most likely done due to time constraints and should be easily rectified for future application of the method. However, both of these factors will potentially change the scores for Threat Criterion 4. As the purpose of the pilot was to test the method and not produce a final list of priority sites, this issue is not a major concern.

Current/natural hydrology data interpretation

Threat criterion 2, altered hydrology, was based on data provided on current/natural hydrology calculated from the Flood Inundation Model (FIM) for the wetlands above Wellington. Interpretation of the data for the purpose of scoring was as follows:

- Wetlands which had an increase in ARI of 1 year = little or no evidence of altered hydroperiod

- Wetlands with an increase in ARI of 2-4 years = moderate alteration in hydroperiod
- Wetlands with an increase in ARI of >4 years = significant alteration in hydroperiod

Hydrology data for wetlands around the lower lakes

There is a lack of information on the hydrological regime of many of the wetlands surrounding the lower lakes. Expert opinion was used to describe the hydrology of many of the sites. In some cases the hydrology of wetlands was relatively unknown and the reliability of the information supplied was considered low. Also the development of the criteria for assessing feasibility of manipulating the hydrology of the lower lakes was based on expert opinion of the Steering Committee members. The assumption that wetlands that fall within 30 m of the lake shorelines can be influenced by variable lake levels needs verification.

Poor hydrological data remains a limitation and is an issue that will require further attention for the full application of the method to all wetlands in the study region.

Consistent level of survey data

Continued survey and inventory of wetlands will improve the confidence with which the method can be applied. To allow future comparison of abundance and diversity consideration should be given to converting biological data collected under the Baseline Survey program into metrics which could be used in assigning ecological value to the wetlands. For example macroinvertebrate data have not been used, nor have measures of diversity or abundance measures for fish, plants, birds and amphibians been captured.

REFERENCES

Amat, J.A., Rendón, M.A., Rendón-Martos, M., Garrido, A., and Ramírez, J.M. (2005). Ranging behavious of greater flamingos during the breeding and post-breeding periods: Linking connectivity to biological processes. *Biological Conservation* 125: 183-192

Appleyard S., Wong S. and Dawson M. (2003). General guidance on managing acid sulfate soils. Western Australia Department of Environment.

Bond N. and Lake P.S. (2003). Local habitat restoration in streams: Constraints on the effectiveness of restoration for stream biota. *Ecological Management and Restoration* 4: 193–198.

Bradshaw A. (1996). Underlying principles of restoration. Can. J. Fish. Aquat. Sci. 53(1), pp. 3-9.

Brooks, R. P., Wardrop, D.H., and Cole, C.A. (2006). Inventorying and Monitoring Wetland Condition and Restoration Potential on a Watershed Basis with Examples from Spring Creek Watershed, Pennsylvania, USA *Environmental Management.* 38:673-87.

Bryan, B.A. (2002). Reserve selection for nature conservation in South Australia: Past, present and future. Australian Geographic Studies 40: 196-209.

Bunn S. and Arthington A. (2002). Basic Principles and Ecological Consequences of Altered Flow Regimes for Aquatic Biodiversity. *Environmental Management* 30: 492–507.

Butcher, R.J (ed) (2005). Wimmera wetland condition assessment project Technical Report. Wimmera Catchment Management Authority.

Butcher, R. and Hale, J. (2005). Wetland recovery prioritisation. A report to the Dept of Water, Land and Biodiversity Conservation, South Australia, and the CRC for Freshwater Ecology.

Cole, P.J. (1878). Soils and land use of the River Murray valley in South Australia. *Proceedings of the Royal Society of Victoria* 90: 167-174.

Cottingham, P., Bond, N., Lake, P.S., Arthington A. and Outhet, D. (2005) Recent lessons on river rehabilitation in eastern Australia. Technical Report. CRC for Freshwater Ecology, Canberra, ACT.

Cottingham P, Walsh C., Rooney G. and Fletcher T. (2004). Urbanization impacts on stream ecology - from syndrome to cure? Outcomes of workshops held at the Symposium on Urbanization and Stream Ecology Melbourne University, Melbourne, Australia 8th - 10th December 2003, CRC Freshwater Ecology, CRC Catchment Hydrology and Melbourne Water.

Cowardin, L. M., Carter, V. Golet, F. C., and LaRoe, E. T. (1979). Classification of wetlands and deepwater habitats of the United States. U. S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. Jamestown, ND: Northern

Prairie Wildlife Research Center Home Page. http://www.npwrc.usgs.gov/resource/1998/classwet/classwet.htm (Version 04DEC98).

Croucher, D. Stribley, L. Franssen, I, and Miles M. (2005) Tools for Managing, Modelling and Accounting for Salinity in the South Australian Murray- Darling Basin (SAMDB).

Department for Environment (2003). Salinity Investment Framework Interim Report – Phase I 2003, Department of Environment, Salinity and Land Use Impacts Series No. SLUI 32. Western Australia.

Department for Environment and Heritage & Department of Water, Land and Biodiversity Conservation (2003). Wetlands Strategy for South Australia. Department for Environment and Heritage, South Australia.

DNRE (2002). Healthy rivers, healthy communities & Regional growth: Victorian river health strategy. Department of Natural Resources and Environment, Melbourne.

DSE (2005). Index of Wetland Condition: Conceptual framework and selection of measures. Victorian Government, Department of Environment and Sustainability, Melbourne

Dunn H. and Heffer D (2004). The Tasmanian Conservation of Freshwater Ecosystem Values Project: defining and selecting special values. Proceedings of the 4th Australian Stream Management Conference: linking rivers to landscapes, Launceston, Tasmania, 199-204.

DWR (2000). State Water Plan 2000 - South Australia. Department for Water Resources, Adelaide.

Eastburn D. (1990). The River. In The Murray. Mackay, N., and Eastburn, D.(eds). Pp3-16. Murray Darling Basin Commission, Canberra, Australia.

Environment Australia. (2001). A Directory of Important Wetlands of Australia. Third Edition. Environment Australia, Canberra.

Faber-Langendoen, D., J. Rocchio, M. Schafale, C. Nordman, M. Pyne, J. Teague, T. Foti, and P. Comer. (2006). Ecological Integrity Assessment and Performance Measures for Wetland Mitigation. NatureServe, Arlington, Virginia.

Finlayson, C.M. and Rea, N. (1999). Reasons for the loss and degradation of Australian wetlands. *Wetlands Ecology and Management* 7: 1-11.

Finlayson C.M., van Dam R. Benzaken D. and Inglis R. (2004). Towards the development of a decision support system to select wetlands for strategic intervention. Report of a technical workshop held in Townsville, 8-9 December 2003. Australian Government Department of the Environment & Heritage.

Gaston K. J. and P. H. Williams (1996). Spatial patterns in taxonomic diversity. In K. J. Gaston [ed.], Biodiversity, a biology of numbers and difference, 202–229. Blackwell Science, London, UK

Georges, A. and Cottingham, P. (2002) Biodiversity in inland waters - priorities for its protection and management. Recommendations from the 2001 Fenner Conference on the Environment. Technical Report 1/2002, Cooperative Research Centre for Freshwater Ecology, Canberra.

Gopal, B., and Junk, W.J. (2000). Biodiversity in wetlands: an introduction. In *Biodiversity in wetlands: assessment, function and conservation*. Volume 1. Gopal, B., Junk, W.J., and Davis, J.A. (eds). Pp1-10. Backhuys Publishers, Leiden, The Netherlands.

Hahn L., Murphy C., Schmidt A. and Fileds T. (2005). Idaho wetland conservation prioritization plan. Idaho Conservation Data Center, Idaho Department of Fish and Game, USA.

Hale, J and Butcher, R. (2005) Lower Murray Swamps Wetland Rehabilitation Guide. A report to the Dept of Water, Land and Biodiversity Conservation, South Australia, and the CRC for Freshwater Ecology.

Hart, B.T., Lake, P.S., Webb, J.A., and Grace M.R. (2003). Ecological risk to aquatic systems from salinity increases. *Australian Journal of Botany*, 51**:** 689-702

Hart B, Burgman M, Webb A, Allison G, Chapman M, Duivenvoorden L, Feehan P, Grace M, Lund M, Pollino C, Carey J & McCrae A (2005). Ecological risk management framework for the irrigation industry. Report to National Program for Sustainable Irrigation (NPSI), Water Studies Centre, Monash University, Clayton, Australia.

Heron, S., Butcher, R., Doeg, T. and Sovitslis, A. (2004) Wetland Prioritisation Scoping Study for the Victorian Mallee. Report prepared for the Mallee Catchment Management Authority by Heron Environmental Consulting, Heidelberg

Howard, P.C., Viskanic, P., Davenport, T.R.B., Kigenyi, F.W., Baltzer, M., Dickinson, C.J., Lwanga, J.S., Matthews, R.A., and Balmford, A. (1998) Complementarity and the use of indicator groups for reserve selection in Uganda. *Nature* 394: 472–475

Hughes, M. Hornby, D.D., Bennion, H., Kernan, M., Hilton, J., Phillips, G., and Thomas,R. (2004). The development of a GIS-based inventory of standing waters in Great Britain together with a risk based prioritisation protocol. *Water, Air, and Soil Pollution: Focus*. 4: 73-84.

IUCN. (2002). Developing a method for prioritizing sites for freshwater biodiversity conservation. In: *IUCN Freshwater Biodiversity Assessment Programme Workshop*. Gland, Switzerland.

Jansen, A. and Robertson, A.I., (2001). Relationships between livestock management and the ecological condition of riparian habitats along an Australian floodplain river. *Journal of Applied Ecology* 38: 63-75.

Jansen, A. and Robertson, A. I., (2005). Grazing, ecological condition and biodiversity in riparian river red gum forests in south-eastern Australia. *Proceedings of the Royal Society of Victoria* 117: 85-95.

Jensen A., Good M., Harvey P., Tucker P. and Long M. (2000). River Murray barrages environmental flows. An evaluation of environmental flow needs in the Lower Lakes and Coorong. South Australian Department of Water Resources, Adelaide.

Jensen, A., Paton, P., Mowbray, T., Simpson, D., Kinnear, S., and Nichols, S. (1996). Wetlands Atlas of the South Australian Murray Valley. A summary of knowledge of Murray Valley wetlands as a basis for integrated catchment management. South Australian River Murray Wetlands Management Committee Department of Environment and Natural Resources.

Johnson, P, and Gerbeaux, P. (2004). Wetland types in New Zealand. Department of Conservation, Te Papa Atawhai.

Kati, V., Devillers, P., Dufrene, M., Legakis, A., Vokou, D., and Leburn, P. (2004) Hotspots, complementarity or representativeness? Designing optimal small-scale reserves for biodiversity conservation. *Biological Conservation*: 120: 471-480.

Kaufmann J.B., Beschta R., Otting N. and Lytjen D. (1997). An ecological perspective of riparian and stream restoration in the western United States. *Fisheries* 22:12-23.

Kingsford, R.T., Dunn H., Love D., Nevill J, Stein J., and. Tait J. (2005). Protecting Australia's rivers, wetlands and estuaries of high conservation value: a blueprint, Land & Water Australia. Product Number PR050823.

Kondolf, G. M., A. J. Boulton, S. O'Daniel, G. C. Poole, F. J. Rahel, E. H. Stanley, E. Wohl, A. Bång, J. Carlstrom, C. Cristoni, H. Huber, S. Koljonen, P. Louhi, and K. Nakamura (2006). Process-based ecological river restoration: visualizing three-dimensional connectivity and dynamic vectors to recover lost linkages. *Ecology and Society* 11(2): 5. [online] URL: http://www.ecologyandsociety.org/vol11/iss2/art5/

Lake P.S. (2001). On the maturing of restoration: Linking ecological research and restoration. *Ecological Management and Restoration*, 2:110–115.

Lake, P.S. (2003). Ecological effects of perturbation by drought in flowing waters. *Freshwater Biology*, 48: 1161-1172.

Lamontagne, S., Hicks, W.S., Fitzpatrick, R.W. and Rogers, S. (2004) Survey and description of sulfidic materials in wetlands of the Lower River Murray floodplains: Implications for floodplain salinity management. CSIRO Land and Water Technical Report 28/04.

Leibowitz, S. G. (2002). An approach to geographic prioritization of wetland management given limited effort and information. In: Tiner, R. W. (Ed.) Watershed-based Wetland Planning and Evaluation. A collection of papers from the Wetland Millennium Event (August 6-12 August, 2000, Quebec City, Quebec, Canada). Association of State Wetland Managers, Berne, NY. 17-40.

Leigh, S and Zampatti, B (2005). A preliminary prioritisation of barriers to fish passage within anabranch and off-channel habitats along the River Murray SA. Report prepared for the Department of Water, Land and Biodiversity Conservation. South Australian Research and Development Institute (Aquatic Sciences), Adelaide.

Lloyd, L.N. and Balla, S.A. (1986). *Wetlands and water resources of South Australia*. Conservation Projects Branch, South Australian Department of Environment and Planning, Adelaide.

Lockwood J. and Pimm S. (1999). When does restoration succeed? In: Ecological assembly rules: perspectives, advances, retreats. Weiher E. and Keddy P. (eds). Cambridge University Press, Cambridge, UK.

Lombard, A.T. (1995). Introduction to an evaluation of the protection status of South Africa's vertebrates. *South African Journal of Zoology* 30:63-70.

Lowrance, R.R., Todd, R.L., Fail, J., Hendrickson, O., Leonard, R., and Asmussen, L.E. (1984). "Riparian Forests as Nutrient Filters in Agricultural Watersheds." *Bioscience,* 34:374-377

MDBC (1999). The Salinity Audit, Murray-Darling Basin Commission, Canberra, ACT.

MDBC (2001). Rivers as ecological systems – the Murray Darling Basin. Young W. J. (Ed.). Murray Darling Basin Commission, Canberra.

MDBC (2002). The Living Murray. A discussion paper on restoring the health of the River Murray. Murray Darling Basin Commission, Canberra.

Miles, M, and Bevan, N. (2006). River Murray Floodplain Prioritisation Project: Summary of Pilot. Unpublished report, Department of Environment and Heritage, South Australia.

Mitsch, W.J., and Gosselink J.G. (2000a). Wetlands Third Edition, John Wiley & Sons, Inc New York

Mitsch W. and Gosselink J. (2000b). The value of wetlands: importance of scale and landscape setting. *Ecological Economics*, 35: 25-33.

Moilanen, A., and Nieminen, M. (2002). Simple connectivity measures in spatial ecology. *Ecology* 83:1131-1145

Mountford J.O., Roy D, Cooper J., Manchester S., Swetnam R., Warman E. and Trew J. (2006). Methods for targeting the restoration of grazing marsh and wet grassland communities at a national, regional and local scale. *Journal for Nature Conservation* 14, 46-66.

Muller, K, and Phillips, B (2006) Ecological character of the Coorong and Lakes Alexandrina and Albert Wetland of International Importance. South Australian Department of Environment and Heritage.

Nielson D., Brock M., Crossle K., Harris K., Healey M. and Jarosinki I. (2003a). The effects of salinity on aquatic plant germination and zooplankton hatching from two wetland sediments. *Freshwater Biology*, 48: 2214–2223.

Nielson D., Brock M., Rees G. and Baldwin D. (2003b). Effects of increasing salinity on freshwater ecosystems in Australia. *Australian Journal of Botany*, 51:655-665.

Norton, N.; Weatherhead, M.; Snelder, T.; Hurren, H.; Chadderton, L.; Brown, D. (2004). New Zealand Waters of National Importance: Developing a biodiversity framework for rivers and lakes. Unpublished NIWA Client report.

NWPASS (2000). National strategy for the management of coastal acid sulfate soils. National Working Party on Acid Sulfate Soils, ARMCANZ, ANZECC and Ministerial Council Forestry, Fisheries and Aquaculture.

OECD (2003). Organisation for Economic Cooperation and Development Environmental Indicators – Development, Measurement and Use. Reference Paper, Paris.

Palmer M.A., Ambrose R.F. and Poff N.L. (1997). Ecological theory and community restoration ecology. *Restoration Ecology*, 5, pp. 291–300.

Palmer, M., Berhardt, J., Allan, J., Lake, S., Alexander, G., Brooks, S., Carr, J., Clayton, S., Dahm, C., Follstad, J., Galat, D., Loss, S., Goodwin, P., Hart, D., Hassett, B., Jenkinson, R., Kondolf, G., Lave, R., Meyer. J., O'Donnell, T., Pagano, L. and Sudduth, E., (2005). Standards for ecologically successful river restoration, *Journal of Applied Ecology*, 42: 208 – 217

Phillips, B. and Butcher, R. (2006). River Parks: Building a system of 'Habitat Management Areas' across the Murray-Darling. An international and national review of freshwater 'protected areas' for conserving aquatic biodiversity and river health. Report to the Murray Darling Basin Commission.

Pressey, R.L. (1986). Wetlands of the River Murray below Lake Hume. (Environmental Report 86/1). Murray Darling Basin Commission, Canberra.

Pretty J.L., Harrison S.S.C., Shepherd D.J., Smith C., Hildrew A.G. and Hey R.D. (2003). River rehabilitation and fish populations: assessing the benefit of instream structures. *Journal of Applied Ecology*, 40, pp. 251–265.

Ramsar (2005). An Integrated Framework for wetland inventory, assessment and monitoring (IF-WIAM). Resolution IX.1 Annex E

Ricketts, T. H., E. Dinerstein, D. M. Olson, C. J. Loucks, W. Eichbaum, D. DellaSala, K. Kavanaugh, P. Hedao, P. T. Hurley, K. M. Carney, R. Abell, and S. Walters. (1999). Terrestrial ecoregions of North America: a conservation assessment. Island Press, Washington, D.C., USA.

River Landscapes (2006). Land and Water Australian. http://www.rivers.gov.au/model/stockaccess.htm#nativevegetation.

RMCWMB & DLWBC (2003). Guidelines for the development of wetland management plans for the River Murray in South Australia. River Murray Catchment & water Management Board and the Department of Land, Water and Biodiversity Conservation.

RMCWB & Government of South Australia (2002). Water allocation plan for the River Murray prescribed water course. River Murray Catchment Water Board & Government of South Australia

Roberts, J., and Butcher, R. (2006). Classification and condition of wetlands, with special reference to vegetation. Prepared for the Vegetation Steering Committee of the Sustainable Rivers Audit, Murray Darling Basin Commission, Australia.

Rutherfurd I., Jerie K. and Marsh N. (2000). A Rehabilitation Manual for Australian Streams: Volume 2. Cooperative Research Centre for Catchment Hydrology Land and Water Resources Research and Development Corporation.

South Australian River Murray Wetlands Management Committee and Department of Environment and Natural Resources (SARMWMC) (1996): Wetlands Atlas of the South Australian Murray Valley, Government of South Australia

Schweiger, E.W., Leibowitz, S.G., Hyman, J.B, Foster, W.E., and Downing, M.C. (2002). Synoptic assessment of wetland function: a planning tool for protection of wetland species biodiversity. *Biodiversity and Conservation* 11: 379-406.

Sammut J. (2000). An introduction to acid sulphate soils. Natural Heritage Trust and the Australian Seafood Industry Council.

Seaman, R. L. (2002c). *Wetland Inventory of Kangaroo Island, South Australia*. Department for Environment and Heritage, South Australia.

Seaman, R.L. (2002d). *Wetland Inventory of Mt Lofty Ranges*. Department for Environment and Heritage, South Australia.

Seaman, R.L. (2002a). *Wetland Inventory of the Northern Agricultural Districts South Australia*. Department for Environment and Heritage, South Australia.

Seaman, R.L. (2002b). *Wetland Inventory of the Eyre Peninsula South Australia*. Department for Environment and Heritage, South Australia.

Seaman, R.L. (2003). Coorong and Lower Lakes habitat mapping program. Conservation Programs, Department for Environment and Heritage, South Australia.

Semlitsch, R.D., and Bodie, J.R (2003). Biological criteria for buffer zones around Wetlands and Riparian Habitats for Amphibians and Reptiles. *Conservation Biology* 17: 1219-1228.

Shirley, M and Holt, M. (2005). Review of the Application of the Wetland Condition Assessment Framework. Report to the SA MDB NRM Board. Sinclair Knight and Merz.

Smokorowski K., Withers K. and Kelso J. (1998). Does habitat creation contribute to management goals? An evaluation of literature documenting freshwater habitat rehabilitation or enhancement projects. Canadian Technical Report of Fisheries and Aquatic Sciences No. 2249.

Suding K., Gross K. and Houseman G. (2004). Alternate states and positive feedbacks in restoration ecology. *Trends in Ecology and Evolution*, 19: 46-53.

Tibby, J., Gell, P., Fluin, J., Heynes, D., and Flett, I (2006). Defining the reference condition and trajectory of Ramsar wetlands using sediment diatom histories. Catchments to Coasts Cairns Australia, 9-14 July 2006. Joint AMSAR SWS conference.

Tiner, R.W. (2004). Remotely-sensed indicators for monitoring the general condition of “natural habitat” in watersheds: an application for Delaware’s Nanticoke River watershed. *Ecological Indicators* 4: 227–243

Thoms, M.C., Southwell, M, McGuiness, H.M. (2005).Floodplain-river ecosystems: Fragmentation and water resource development. *Geomorphology* 71: 126-138

Thoms M., Suter P., Roberts J., Koehn J., Jones G., Hillman T. and Close A. (2000). Report of the River Murray scientific panel on environmental flows. River Murray – Dartmouth to Wellington and the lower Darling River. Report to the Murray Darling Basin Commission, Canberra

Thompson M. B. (1986). River Murray Wetlands: their characteristics, significance and management. For the Nature Conservation Society of South Australia and the Department of Environment and Plannin, Adelaide.

Tockner, K., Malard, F., and Ward, J.V. (2000). An extension of the flood pulse concept. *Hydrological Processes* 14: 2861– 2883.

USA EPA (1998). Lake and reservoir bioassessment and biocriteria. Technical Guidance Document. USA Environmental Protection Agency, Office of Water, Washington D.C. EPA 841-B-98-007

Walsh, C.J., Leonard, A.W., Ladson, A.R. and Fletcher, T.D. (2004) Urban Stormwater and the Ecology of Streams, CRCFE, Canberra

Wetland Care Australia (1998). Wetlands Management Study. Report for the Riverine Local Action Planning Associations.

Wetlands Working Party (1989) Enhancing Wetlands. South Australian River Murray Wetlands Working Party. Engineering and Water Supply Department, and Department of Environment and Planning, Adelaide.

White I., Melville M., Wilson B. and Sammut J. (1997). Reducing acidic discharges from coastal wetlands in eastern Australia. *Wetlands Ecology and Management*, 5: 55-72.

Whittaker, R.J., Araújo, M.B., Jepson, P., Ladle, R.J., Watson, J.E.M., and Willis, K.J. (2005). Conservation biogeography: assessment and prospect. *Diversity and Distribution* 11: 3-23.

Wolfson, L., Mokma, D., Schultink, G. and Eckhart, D. (2002). Development and use of a wetlands information system for assessing wetland functions. *Lakes and Reservoirs: Research and Management* 7: 207-216.

Young, T.F. and S. Sanzone (eds). (2002). *A framework for assessing and reporting on ecological condition*. Prepared by the Ecological Reporting Panel, Ecological Processes and Effects Committee. EPA Science Advisory Board. Washington, DC. 142 p.

APPENDICES

Appendix 1: DIWA wetland types

Inland wetland types and artificial wetland types as described in the Directory of Important Wetlands in Australia (2001). (Note: Marine and Coastal zone wetlands and human made wetlands are not shown here).

B – Inland Wetlands

1. Permanent rivers and streams; includes waterfalls
2. Seasonal and irregular rivers and streams
3. Inland deltas (permanent)
4. Riverine floodplains; includes river flats, flooded river basins, seasonally flooded grassland, savanna and palm savanna
5. Permanent freshwater lakes (> 8 ha); includes large oxbow lakes
6. Seasonal/intermittent freshwater lakes (> 8 ha), floodplain lakes
7. Permanent saline/brackish lakes
8. Seasonal/intermittent saline lakes
9. Permanent freshwater ponds (< 8 ha), marshes and swamps on inorganic soils; with emergent vegetation waterlogged for at least most of the growing season
10. Seasonal/intermittent freshwater ponds and marshes on inorganic soils; includes sloughs, potholes; seasonally flooded meadows, sedge marshes
11. Permanent saline/brackish marshes
12. Seasonal saline marshes
13. Shrub swamps; shrub-dominated freshwater marsh, shrub carr, alder thicket on inorganic soils
14. Freshwater swamp forest; seasonally flooded forest, wooded swamps; on inorganic soils
15. Peatlands; forest, shrub or open bogs
16. Alpine and tundra wetlands; includes alpine meadows, tundra pools, temporary waters from snow melt
17. Freshwater springs, oases and rock pools
18. Geothermal wetlands
19. Inland, subterranean karst wetlands

C- Human-made wetlands

1. Water storage areas; reservoirs, barrages, hydro-electric dams, impoundment's (generally over 8 ha).
2. Ponds; includes farm ponds, stock ponds, small tanks; (generally below 8 ha).
3. Aquaculture ponds; fish ponds shrimp ponds
4. Salt exploitation, salt pans, salines
5. Excavations; gravel pits; borrow pits, mining pools.
6. Wastewater treatment areas; sewage farms, settling ponds, oxidation basins.
7. Irrigated land; includes irrigation channels and rice fields, canals, ditches
8. Seasonally flooded arable land, farm land
9. Canals

Appendix 2: Additional criteria

The following criteria were considered in the development of the prioritisation method but were not included due to data limitations.

Ecological value criteria:

1. Habitat connectivity

- Wetland is internationally important and a national critical breeding and feeding link for migratory species – scores 3
- Wetland is nationally important for the breeding and or feeding link for biota – scores 2
- Wetland is regionally important in terms of connectivity for the survival of wetland species in the region – scores 1

2. Ecological Integrity – trophic status

It was suggested that the presence of high trophic status biota at a wetland could be an indicator of health in wetlands (suggests intact food webs). However understanding of trophic status of wetland species is highly limited in Australia, therefore this measure was not included in the prioritisation method.

3. Diversity and abundance measures

The current ecological value criteria relating specifically to biota recognise threatened species only, and thus give greater weighting to these species. It has been proposed that consideration be given to creating criteria which reflect biodiversity in general and specifically that criteria based on diversity and abundance measures are considered. Whilst it is acknowledged that diversity and abundance data would be useful to include in the assessment of ecological value of wetlands, the project was limited to use of existing data. The Ramsar criteria for conserving biological diversity provide an example of the type of criteria used in this manner (Group B of the criteria: reproduced from http://www.ramsar.org/key_criteria.htm). Further inventory work would be required to adequately use such criteria across all wetlands in the study area.

Group A of the Criteria. Sites containing representative, rare or unique wetland types

> *Criterion 1: A wetland should be considered internationally important if it contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.*

Group B of the Criteria. Sites of international importance for conserving biological diversity

Criteria based on species and ecological communities

> *Criterion 2: A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities.*

> *Criterion 3: A wetland should be considered internationally important if it supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.*

Criterion 4: *A wetland should be considered internationally important if it supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.*

Specific criteria based on waterbirds

Criterion 5: *A wetland should be considered internationally important if it regularly supports 20,000 or more waterbirds.*

Criterion 6: *A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of waterbird.*

Specific criteria based on fish

Criterion 7: *A wetland should be considered internationally important if it supports a significant proportion of indigenous fish subspecies, species or families, life-history stages, species interactions and/or populations that are representative of wetland benefits and/or values and thereby contributes to global biological diversity.*

Criterion 8: *A wetland should be considered internationally important if it is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend.*

Specific criteria based on other taxa

Criterion 9: *A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of wetland-dependent non-avian animal species.*

Threat criterion:

1. Geomorphic and soil integrity – alteration to bed and bank (local scale)

- Wetlands with no evidence of alteration to bed or bank – scores 1
- Wetlands with evidence of alteration to bed or bank– scores 3

Based on discussions with the Steering Committee and stakeholders it was decided that alterations to bed and bank of wetlands was not a significant threat influencing wetland ecological values, although this varied across the study area.

Appendix 3: External Peer Review and response

Response to Peer Review by Richard Kingsford: South Australian River Murray Wetland Prioritisation Project Water's Edge Consulting – Draft 4 (4/9/06)

The following is the project teams formal response the review provided by Professor Richard Kingsford on Draft 4 of the SA River Murray Wetland Prioritisation Project. The comments have been retained and our response, where required, is shaded with grey.

We welcomed the critical feedback and appreciate the time taken to provide the review. Most of the points raised are addressed in the subsequent report drafts and during the pilot testing as indicated by our comments below.

It should be noted that our responses have been discussed in general with the Steering Committee and fall in line with their stated preferences.

General comments

Overview

The project is generally well thought out and rigorously developed. The writing was clear and generally unambiguous. The approach of assessing representativeness, ecological value, threats and feasibility is inherently sound and will contribute to good management of wetlands in the area. The process of ranking wetlands is an inherently difficult process because of the inadequacies of data availability. There are no clearly accepted protocols for how such assessments should be done and so different methodologies are underway around Australia. This not necessarily a bad thing but often reflects the idiosyncrasies of different systems.

Floodplains

Inclusion or exclusion of floodplains is always one of the most contentious issues to deal with in relation to wetland management and protection. Clearly floodplains are defined as wetlands under most definitions that are used nationally and internationally. They are problematic because boundaries are not easily defined.
As a result, floodplains are often omitted from analyses. It appears that this is the approach in this prioritisation project as well. This is problematic because they may retain some of the more important biotic features required for river health. Careful thought needs to be given about omitting such important habitat features. They would be likely to be included in broader assessments anyway (see below) which might mean the data for this area would be missing. Also while they may possibly end up in the category of low feasibility because of the inability to influence river management upstream, this may be important. It will potentially add value to the processes of the Living Murray and restoration of river flows.

I believe floodplains should be included, even if these are defined in relation to river segments (see below) and then linked in the data sets. This may require some work allowing for separation as polygons on a GIS analysis.

This is a commonly encountered issue in wetland studies – how to deal with floodplains and discrete water holding areas on a floodplain. Floodplain prioritisation is being undertaken in a separate project by the SAMDBNRM Board, with this project dealing with discrete water holding depressions only. The separation has been made clearer in Section 1 of the report under Scope.

Classification
I support the broad classification approach (i.e. palustrine, riverine, lacustrine) although I think for completeness 'estuarine' should be added (on p. 11). Broad classification of wetlands is a useful approach although I am not convinced that the Cowardin et al. (1979) classification at lower levels is particularly useful in Australia (see Kingsford et al. 2004) for concerns about this. The issue is mainly lack of available data that can define the temporal changes well. The Cowardin et al. (1979) system was applied to Victoria's wetlands (Norman & Corrick 1988) but I understand, with limited success, because some of the categories were not temporally stable. Further, even if these lower classification levels apply in South Australia, they are unlikely to apply more broadly (see below).

It would be useful to continue to use the broad categorisation (i.e. palustrine, riverine, lacustrine, estuarine) as descriptors on all data sets for the wetlands, also adding another column in Tables 1 and 2 to define the various types of wetlands. It was not clear whether constructed wetlands (storages, sewage ponds, dams) were to be included. If so, these could be allocated a separate category of 'constructed' or 'human-developed' wetlands (e.g. artificial channels if recommended by Steering Committee). The categorisation of such wetlands is always problematic because they may have some of the ecological characteristics of other wetland types.

The estuarine category was left out as the scope of the study does not extend to the estuarine areas of the Coorong. Having said that, it will be added to the text for completeness. Hydrosystem has been added to Table 1.

The main classification being adopted is that of DIWA which is originally based on the Cowardin (and others) approach. The lower levels of Cowardin are not appropriate for Australian wetlands and are not intended for use in the present study.

Constructed wetlands are being included except for borrow pits. Several of Pressey's geomorphic types are "man-made" and these are to be included as directed by the Steering Committee. This is explained in the report in Section 1 under Scope.

Wetland categorisation – uniqueness and representativeness
Criterion 2 in this process is listing under DIWA and/ or Ramsar. Clearly these are important criteria but they may not represent relative ecological value. Identification of DIWA wetlands and listing of Ramsar wetlands have generally not be done through an objective process of assessment. So the relative importance of such wetlands may not be as high as is often considered by governments and communities. It would be worth having some discussion text here about these drawbacks so managers and users are aware of potential flaws in the nomination of these areas.

This issue has been discussed in great detail with the Steering Committee and also at the stakeholder workshop. The intention as of the last Steering Committee meeting (October 2006) is that this criterion be removed. However, during the pilot test, a sensitivity analysis will be undertaken to investigate how much of a difference weighting listed sites would make to the final ranking of sites, and if this higher value is reflected in the ecological value of the listed sites. There is a certain level of obligation that listing under DIWA and Ramsar entail, and it may be that regardless of the concern over the validity of the listing and how this relates (or not) to their ecological value, these sites will be treated differently in the method.

Ecological values/ criteria assessment

a. *Threatened species*. The choice of two 'threatened species' categories to drive prioritisation could be a problem as it may skew protection and conservation management to wetlands and their biota that may not be recoverable. Currently the prioritisation for ecological value has two threatened species criteria which mean that this issue has considerable weight in any final score. Threatened species identification and management results in considerable debate among conservation biologists and ecologists about whether the focus should be predominantly on these groups or not. Certainly, they are important from a management point of view but I would prefer an equal weight be given to diversity and abundance. It may be much more profitable and successful to concentrate on those habitats/ wetlands that have a good chance of success and where the ecosystems still supports a high biodiversity. Criteria such as those used by Ramsar recognise and apportion a certain focus on measuring high biodiversity. Also, status of threatened species is generally dependent on scant information. It is likely there are many more species not currently endangered that should be if there was sufficient information available.

I would recommend development of a criterion that reflects diversity and/or abundance (i.e. number of species, abundance of groups).

The points made are valid, however as this method is limited to using available data, criteria based on diversity and abundance data are not possible at this point in time. The type of criteria suggested will be noted in the report as criteria which may be possible to add once additional data is collected.

b. *Structural habitat*. Two structural habitat criteria may favour plants over animals, as their surrogate value may not be as clear as we hope. It may be that structural value is not that important for different animal species (e.g. invertebrates, fish, waterbirds) where the food value of the wetland may be much more significant. Also, I am concerned about the potential confounding effect of size. Presumably a small wetland could have a high percentage of structural habitat and therefore score highly on this criterion but a large wetland might have much more structural habitat but it is a relative small proportion of the wetland and so it would score low on this aspect. And yet in terms of overall conservation value the structural habitat of the large wetland may be ecologically much more important. One way of dealing with this issue is to have a measure of the amount of habitat. The inclusion of another criterion for diversity and abundance would also help picking up other ecological values.

After discussions with the Steering Committee the measures on structural habitat will remain. The two measures capture structural complexity and extent. Granted not all species respond to structural complexity in the same way, however the general principal of more habitat diversity/heterogeneity the greater biodiversity is the basis for these criteria. The measures are not designed to capture one group of biota over another, but rather be a broad surrogate for biodiversity.

Small wetlands with structural complexity should be valued as they provide an important component of regional diversity both in wetland type and as reservoirs of biota. These wetlands tend to be the most numerically dominant in the landscape and also historically the most threatened. As noted not all biota use these wetland resources in the same manner – size, habitats, permanency all influence the types and numbers of species that occur at them. There are numerous studies that have shown small, isolated wetlands have high biodiversity and conservation value – it all depends on how you measure value. Equally there are studies showing the importance of large permanent wetlands to migratory waterbirds.

The criteria will be reviewed after pilot testing, however as indicated above additional criteria which address diversity and abundance may be added at some point in the future.

Threat assessment

a. *Altered flow regime*. The two key threats of altered flow regime that can be relatively easily measured are whether wetlands receive too little water (usually the floodplains) or too much water a relatively small proportion of wetlands that are well connected to the river. It would be useful to separate out these two threats in the criteria as they require different management responses. The former relates to floodplains and so may be relevant to this group (see recommendations on floodplains).

Altered flow regime is captured in three ways:

- Altered permanency relates to water source
- Frequency of inundation relates to return rates
- Connectivity relates to barriers and loss of hydrological connectivity

As discussed above floodplains are included as a wetland type in this project.

b. *Invasive species*. Animal pests are problematic to measure although abundance or density of carp may be possible. Weeds are possibly more easily measured in terms of percentage area covered. Separation and development of separate criteria for weeds may be possible.

Invasive species are not included in the method – follows discussions with Steering Committee. This may be an issue in the feasibility section – pending pilot testing results.

c. *Salinity*. Obviously some wetlands may be naturally saline and this can be an important type of wetland in natural landscapes that supports a unique assemblage of aquatic organisms. It is not clear how the salinity criterion might deal with wetlands that are naturally saline. It would be better to at least define these different types of salinity up front – anthropogenic vs natural salinity. And then it may be possible to not rank the salinity threat high for those wetlands that are known to be naturally saline.

Modifications to the criterion for salinity had already been made, being simplified to determining if secondary salinisation has occurred. Captures changes to fresh and naturally saline systems, some of which are becoming hypersaline.

d. *Landuse intensity*. I found the scores allocated for this threat criterion confusing. Distance was confounded with proportion affected. Further clarity is needed in defining this so that the reader knows how a wetland that has 20% intensive land use within 150m might differ in scores from a wetland with 20% intensive land use within 1000m.

The intent of having multiple widths assessed was to determining the most meaningful width to be included in the method. The criterion has been reworded, and a single width decided on in conjunction with the Steering committee. Landuse intensity will be measured using a boundary of 1000m.

e. *Wetland buffer*. As with the salinity criterion, some wetlands may not have an obvious buffer or their natural vegetation may be seasonal consisting of grasses and so not easily detectable. This does not mean that their ecological condition is necessarily affected and so their threat score should be low. This issue requires some discussion and a decision on how such wetlands may be identified and not penalised in the scoring.

Modifications to the criteria have been made after discussions with the Steering Committee and following the Stakeholder workshop.

f. *Tree health*. More objective criteria here would be useful in terms of what constitutes poor, moderate and good. How do these measures equate to different canopy covers and Grimes scores? It is important that this information is repeatable and so objective.

Tree health is no longer included as a criterion in the method based on discussions with the Steering Committee.

Evaluation of assessments - numerical processes
There is a danger that generation of numbers and scores can lead to over confidence in the assessment. It is difficult to know exactly how scoring behaves and how well different scoring methods reflect actual ecological values, given that most of the time we operate in data poor areas. Scoring can also average out particular scores of importance.

So a wetland may have a high score for one criterion but low scores on others mean that it would have an overall low score. In fact it may be more appropriate for the wetland to have an overall high score.

There are two ways of gaining more confidence in the process. One is to make sure that not just final scores are considered and there is transparency that allows for high scores on a singly criteria to be adjusted so that the overall score can be raised. The other important process is to institute a review process involving an expert panel. Expert panels familiar with the area have been show to be extremely cost effective and useful in ensuring that scoring systems adequately reflect the ecological values when there is little information. This expert panel process can also assist with the assessment of threat scores.

It is anticipated that the pilot test phase will address some of these issues – the method has been developed so that the transparency is retained. There will be a number of sensitivity analysis undertaken – one of these will be matching the conservation rankings produced by Thompson (1986) as a means of double checking. Expert opinion (Steering Committee members) will also be used to double check that rankings produced by the method reflect the known status of wetlands (where possible).

Feasibility
It is obviously important to separate the evaluation of ecological criteria from the assessment of threats and then the feasibility of management as is done in the approach put forward. Rather than discuss potential ‘show-stoppers’, it may be worth defining out management at different scales. It may not be possible for local or regional management for wetlands that require more water. That does not necessarily mean that management should be ignored, particularly if these wetlands rank highly in terms of ecological assessment. It may be that there is a need for more pressure at a large spatial scale for management (i.e. whole river). For example,

such information may be important in influencing future management options for the Living Murray.

The feasibility section of the draft report 4 has been substantially changed and will most likely be modified again in light of the pilot testing. Hopefully the changes adopted will take on board most of the comments given above.

Broad applicability

There is a broad issue of compatibility. A few regional bodies are currently embarking on a wetland prioritisation process within their areas of responsibility. In addition the Australian government and state and territory governments are considering directions in conservation and protection of aquatic ecosystems that will demand a process of prioritisation. A challenge for a regional process such as this one will be to ensure that the necessary data are collected that will allow for use of information collected to be further used for any broader prioritisation tasks that may occur in the future at state or national scales. At the data level, it will be important to ensure that data sets are rigorously developed and have well defined spatial tags and associated data that could be relatively easily aggregated for analyses and broader scales of management.

At the broad compatibility level, it would be useful to cross check how the ecological values and spatial scales identified for measurement for this project match those already developed at the national scale (e.g. Kingsford et al. 2005) or for the Murray-Darling Basin (Phillips et al.). Many of these criteria are well established and it would not be onerous to perform a check with these processes. In particular, this would mean examining the ecological values developed by Kingsford et al. 2005 and showing how the values from this project relate to these and which ones have or have not been omitted and why. Further, Kingsford et al. suggest adoption of three spatial scales (i.e. drainage divisions, river basins, river segments). Clearly all wetlands for this part of the River Murray will be in the Murray-Darling Basin Drainage Division and the River Murray Basin but it would be useful to check the spatial scale of river segments and attach these descriptors to each wetland to allow for future broader wetland assessments.

The issues of broader applicability have been noted – in particular there are identified synergies between several regional projects as well as national programs. Data is being collated using the DIWA classification thus allowing the information to be used for other purposes.

The ecological values identified in Kingsford et al relate more specifically to identifying aquatic reserves – this is not the central point of the current project. However, further discussion of the main points of Kingsford et al (2005) and Phillips and Butcher (2006) will be included as appropriate. Phillips and Butcher (2006) also relates to the issue of aquatic reserves, in particular the concept of habitat management areas and the conservation of native fish.

Data availability and reliability

Any project of this type of scale suffers from inadequate data sets. On p. 17 (para. 1), there is discussion of the vegetation assessment and salinity. It may not be possible to access data for some areas and so possibly it would be better to leave these wetlands out of such assessments instead of ‘guessing’. This raises the issue of data reliability. It may be worth considering a category that provides an assessment of reliability of data sets or possibly use of surrogates where it is not possible to access the data.

Data limitations are a major challenge for this project – this will be further investigated during the pilot testing. Some of the data has been recorded for wetland complexes (complexes have multiple wetland polygons which are hydrologically connected) and rules for interpreting the data acknowledges this limitation - that the data may not relate to each individual wetland polygon in a complex.

Layout and organisation

The report was generally well organised although there was some avoidable repetition. As a draft, the referencing still requires considerable work to ensure that all publications cited are listed in the references. There were a few instances of notes to the authors reminding them that issues needed to be checked or followed up. Some tables had little to no information (e.g. Tables 3 & 4).

Some of the repetition has been removed – this was largely an artefact of the progressive reporting required by the Steering Committee in accordance with milestones. This repetition will hopefully be completely removed in the final report. Tables 3 and 4 have been removed as they are no longer relevant to the direction of the report/project.

There should be a check of the report and replace “Data is” with “Data are”. Fig. 2 of the study area was missing and it would be useful to put this figure in the context of the spatial scales identified above (i.e. Murray-Darling Basin, River Murray, river segments). “Criterion” for one and “criteria” for > 1 (see page 27-28).

Agreed – maps of the study area and four geomorphic regions have subsequently been included.

Specific Comments

1. Table 1. The comments’ section should presumably have a comment for each of the wetland types identified by Pressey.

This table will most likely be modified or possibly removed from the final report

2. Table 3. It is not clear what is meant by 1986-current? How is an assessment made of whether there has been wetland loss?

This table has been deleted

3. Table 4. Wetland type? The broad categories could be added in here. How do these spatial divisions match to the river segments for the Lower River Murray? If the national spatial approach is to be adopted, it would be useful to also have a breakdown in relation to river segments.

The broad categories will be added as suggested. At this point the national spatial divisions are not being applied.

4. Page 22 - % goals for ecosystem protection. This figure requires some referencing. I am aware of a 15% goal set as a result of the Regional Forest Agreement but it is more likely that this number reflects political realities rather than ecological realities. I am not aware that such low percentages can effect protection of ecosystem function and biotic components. There is general acknowledgement that losses of any components will result in some loss of biota or function. My understanding is that percentages of 10-15% represent a minimum in heavily developed landscapes. The text should reflect this.

Noted – the text will be modified accordingly and references used to support this where possible.

5. Page 27 – Does ecological value criterion 1 refer ‘threatened’ for nationally listed species or state species? If the former, how does it differ to criterion 2?

Ecological value criterion 1 does not consider scale at which the taxa is listed – it is purely based on the number of different threatened taxonomic groups. Criterion 2 accounts for threat level (endangered, rare etc).

6. Page 45 – Hydroperiod. Perhaps this is would be better described as flow regime. It would then also include those wetlands/ floodplains for which there are insufficient flows (see above).

Unsure of reference – hydroperiod captures the aspects central to the method. As mentioned above floodplains are dealt with in a separate program. This project is wetland centric, not river centric and as such hydroperiod is considered the correct term to be using.

7. Pages 54-55. These were repetitions of early figures.

The structure of the report has changed and the repetition has largely been removed.

References

Kingsford, R.T., Brandis, K., Thomas, R.F., Crighton, P., Knowles, E. and Gale, E. (2004) Distribution and conservation of wetlands in New South Wales, Australia. Marine and Freshwater Research 55, 17-31.

Kingsford, R.T., Dunn, H., Love, D., Nevill, J., Stein, J. and Tait, J. (2005) Protecting Australia's rivers, wetlands and estuaries of high conservation value. Department of the Environment and Heritage, Canberra. http://www.deh.gov.au/water/publications/protecting-rivers.html

Norman, F.I. and Corrick, A.H. (1988) Wetlands in Victoria: a brief review. In The Conservation of Australian wetlands. Eds McComb, A.J. and Lake, P.S.. Surrey Beatty & Sons, Sydney*.* 17-34.

Richard Kingsford
Professor of Environmental Science
School of Biological, Earth and Environmental Sciences,
University of New South Wales

5/10/06

Appendix 4: Stakeholder review

A workshop was held in Adelaide at which interested stakeholders were introduced to the draft prioritisation method and given the chance to provide input. The following is a brief account of the key points raised during the workshop that will be considered carefully as the draft prioritisation framework is finalised.

Wetland classification
The framework will be based on the DIWA wetland types. The DIWA and Pressy classification methods have not been combined, rather each wetland polygon has both the Pressey geomorphic category and a DIWA type allocated. It was decided that the project should not create another classification method that would ultimately compete with existing approaches. The DIWA classification is considered the most appropriate as it links with other state and national approaches.

Wetlands are represented in the wetland database as polygons based primarily on work done by Pressey (1986) and the Wetland Atlas, with some refinements based on ortho-rectified aerial photography taken in 2005. It was noted that relationships between water levels and the time of year could affect the size of the wetland that is mapped. This is a limitation of the available imagery and will be rationalised by recording wetland identifiers that will be carried forward to assessments in the future.

The base unit of the method is the wetland polygon, not hydrological complexes (e.g. as used in the Wetland Atlas). Considerable discussion was made regarding the issue of data being available at the complex, rather than polygon level. The decision was made that data assigned to a polygon would be tagged if it was derived from wetland complex data. If needed, polygons can be aggregated and the prioritisation can be applied to wetland complexes later in the project. This issue will be revisited in light of outcomes from the pilot testing, which will trial the framework on a subset of 100 wetlands.

Wetland conservation and ecological value criteria
The need to adapt criteria in light of data limitations will be considered in the pilot stage of the project. Recording the criteria for ranking sites and how criteria may change due to data limitations and other factors will be an important strength, unique to this project.

Assigning wetland values on the basis of listed (threatened) species can introduce a bias; wetlands that have not been surveyed are automatically excluded. Assigning a priority to wetlands that have not been assessed for threatened species was considered in the formulation of the prioritisation framework, but it was recognised that this too can add a bias to the outcomes. Additional inventory and survey work will be required to gain an unbiased application of some criteria (such as threatened flora and fauna). However whilst the data limitations are noted, the criteria relating to listed species and sites (DIWA sites – see below) will be kept in the method.

The current form of the prioritisation framework assigns a high ranking to DIWA listed sites. It was acknowledged that some wetlands have been listed in DIWA because of their socio-economic value and that in some instances ecological condition has declined in recent times. However, some sites may have a low ecological value when considered individually, but have a high value as part of a complex. It is hoped that this issue will be addressed by considering both the conservation and ecological values of a wetland, and will be reviewed during the pilot stage of the project.

An additional limitation associated with some of the data being used in the prioritisation is that species records are mostly terrestrial with relatively little aquatic data available. It was noted that, so far, records of fish species have not been entered into the database. Fish data and additional aquatic species data will be extracted from the baseline sites where appropriate.

It will be important that the prioritisation framework is based on wetland-dependent species as far as is possible. The current GIS uses information stored in State databases; data not in the State databases are currently unavailable to the project. It was noted that incorporation of data supplied by NRM organisations was proving more difficult than originally thought. A clear process for including community data on State databases will be recommended. It was also proposed that a future project explores the use of extrapolation methods to provide data for wetlands that have not yet been surveyed (e.g. to provide habitat-area predictions).

Two particular areas identified for further development are:

- How best to represent sites that are naturally saline in the framework , currently the criteria do not account for saline systems,
- Criteria that account for structural layers present at a site – the simple structural arrangement of some systems (e.g. wetlands around the Lower Lakes) may be a natural feature but they would receive a low ranking when compared with more complex systems.

Advice from the project Steering Committee has been to develop a priority framework that will be applied to the whole study area; as a starting point, criteria are to be applied equally to all wetlands. One way to address the above issues may be to introduce some regionalisation into the framework. For example, the Lower Lakes could be considered as a region with features distinct from upstream areas. The criteria by which conservation and ecological values are assessed might then be a subset of those applied to floodplain wetlands. It is not clear if the introduction of such a regionalisation would introduce undue bias to wetland ranking and priority. Guidance will be sought from the project Steering Committee on whether or not to introduce regionalisation to the framework.

Relative wetland size was considered as a surrogate for ecological value on the premise that larger wetlands are likely to have a greater amount and diversity of habitat. However, experience has shown that small systems can have similar levels of species richness as large systems, as can temporary wetlands when compared with permanent systems. Adding wetland size as a criterion for ecological value is not proposed at this stage.

Wetland threat and condition criteria

A number of criteria were considered but omitted due to a lack of data that could be applied consistently to wetlands. These included water quality parameters, invasive species and barriers to movement of biota such as fish.

The threat of ‘increased salinity’ will be amended to ‘changed salinity’, recognising that some sites are naturally saline.

Altered hydrology will be an important threat criterion. However, there are issues that have to be addressed before applying this criterion in the priority framework. The seasonality of wetland inundation cannot be ascertained from the current floodplain inundation model (FIM). Representation of the threat of altered hydrology will be refined with regard to commence-to-fill levels and recurrence frequency (i.e. relative change in current versus natural frequency of attaining commence-to-fill levels). It was noted that the FIM does not apply to wetland sites around the Lower Lakes. This again raises the issue of whether or not to apply different criteria to different regions.

It was agreed that the proposed Threat Criterion 5 (geomorphic and soil integrity) be dropped from the framework as erosion was not considered a significant threat across the study area and data were unlikely to be available at the scale required.

The proposed Threat Criterion 6 (acid sulphate soils - ASS) was considered relatively insensitive and likely to result in the same ranking for all wetlands. Alternative surrogates might include depth to groundwater and salinity. Exploring correlations between ASS and salinity will be recommended as an issue for further investigation.

There was discussion on the intent of Threat Criterion 8 (wetland buffer), with the project team explaining the criterion was intended as a surrogate for integrity of ecological processes associated with riparian/buffers surrounding wetlands. The processes include sedimentation, nutrient cycling, and inputs of organic material with the assumption being that an intact buffer would provide these functions thus maintaining wetland condition.

Threat Criterion 9 (tree health) will be renamed vegetation health, as some systems (e.g. saline wetlands) are unlikely to be surrounded by trees. The need for this criterion will also be reconsidered, as it may duplicate threats related to altered hydrology and salinity.

Threat Criterion 10 (wetland connectivity) will be difficult to capture with existing data. It will be combined with Ecological Criterion 6 (hydrological regime/complexity).

Feasibility DST

Salinity Feasibility Filter

Salt Inception Schemes (SIS) – the presence of SIS has been incorporated into the salinity risk measure used in Threat Criterion 2 and so may provide little additional immediate benefit if included in the prioritisation framework. Existing SIS will not change current salinity threats but new schemes may address future trends. The inclusion of the SIS component of the salinity filter will be reviewed during the pilot study. It may be possible to uncouple SIS from the salinity risk should this be considered useful for future assessments.

Hydrology Feasibility Filter

It was suggested that the measure for existing infrastructure be expanded to include consideration of the potential to manipulate hydrology through construction of new regulating structures. Consideration of the number and width of inlet and outlet channels would be useful for assessing the influence of current and proposed infrastructure.

It was suggested that the availability of water allocations would be better expressed as “will existing river flows meet the hydrological needs of the wetland” based on CTF and river hydrology. Advice will be sought from the Steering Committee on the preferred terminology.

It was also recommended that the criterion that considers risks to other ecosystems should be removed, as it would be difficult to determine with existing data. Ecological risk assessment will be recommended as a requirement when developing site-specific rehabilitation plans.

Biophysical Feasibility Filter
It was recommended that this filter be removed from the prioritisation framework, as it requires site specific information. However, the intent of the filter was still considered useful and will be included as an appendix with a recommendation for use on a list of priority wetland sites.

Cost Filter
It was recommended that this filter be removed, as it is implied in the hydrology and salinity filters.

Final subset of sites should be based on hydrology and salinity filters. Further refining can then be undertaken with site visits and additional data collection.

Other issues
Conservation Sites
It was noted that there may need to be a finer separation of wetlands that require minimal maintenance and those that will require some on going works. Sites that fall into the conserve category may need a feasibility filter to identify or rank wetlands that can easily be conserved. The need for further separation between sites will be evaluated as part of the pilot study.

Application
It was suggested that initially the prioritisation framework be applied only to the Baseline sites in the wetland database. However, a requirement of the project is that the prioritisation framework be applicable to all sites in the wetland database; focusing on the Baseline sites increases the risk that sites with good rehabilitation prospects are ignored. Advice will be sought from the Steering Committee on the preferred mix of baseline and other sites to be included in the pilot study.

It was suggested that DIWA listing should not be used as a criterion for identifying high value sites. However, there are legislative and policy requirements that mandate a high management and protection of DIWA sites. Advice will be sought from the Steering Committee on whether to maintain the high priority given to DIWA sites in the prioritisation framework.

Summary
Summary of issues to be considered during the pilot stage:
- How best to include wetland complexes in the prioritisation method,
- Recommendations to expand threatened species inventories at wetlands that have yet to be surveyed,
- The need for sensitivity analysis of results should individual ecological value criteria be omitted due to lack of data,
- Recording how criteria are modified so that the scheme remains transparent,
- Whether assigning a high ranking to DIWA-listed sites is warranted in all cases,
- The need for protocols on data-sharing arrangements between organisations to facilitate the inclusion of data in State databases,
- An future project to investigate potential data extrapolation methods to complement existing data,
- The need to separate wetlands on the basis of geomorphology or whether they are saline or freshwater systems, and whether it is acceptable to have different criteria for different groupings,
- A future project to examine the correlation between ASS and saline sites. If highly correlated with salinity, ASS could be removed as a feasibility criterion,

- Whether Threat Criterion 9 (tree/vegetation health) is necessary or whether it duplicates criteria related to altered hydrology and salinity,
- Whether the SIS component of the salinity filter is necessary in the feasibility ranking,
- The extent to which Baseline sites are included in the 100 wetlands used in the pilot trial.

Appendix 5: Pilot site locations, wetland type and priority ranking

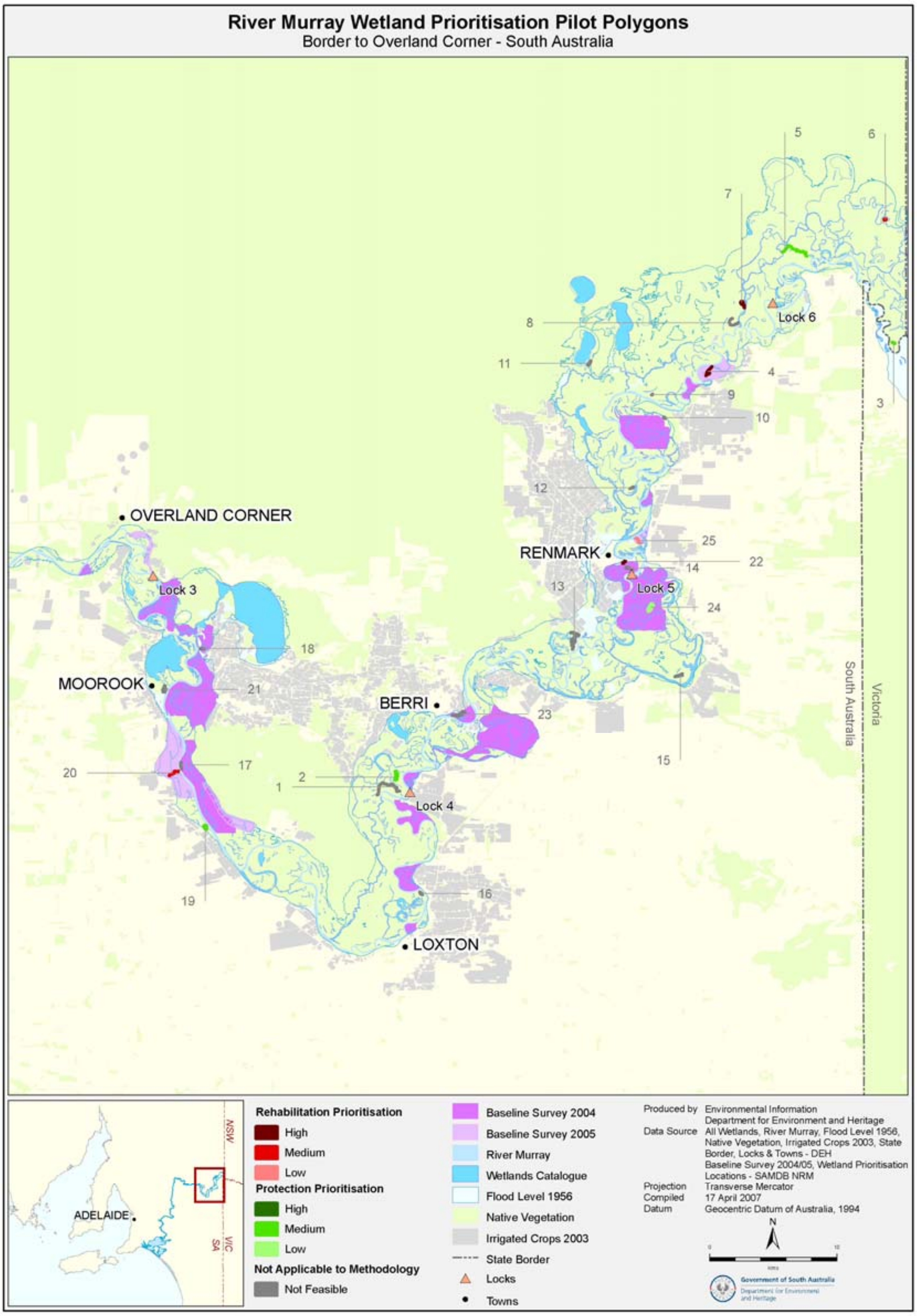

Figure 12: Prioritisation reach 1: Border to Overland Corner, showing location of pilot wetlands and output of prioritisation trial.

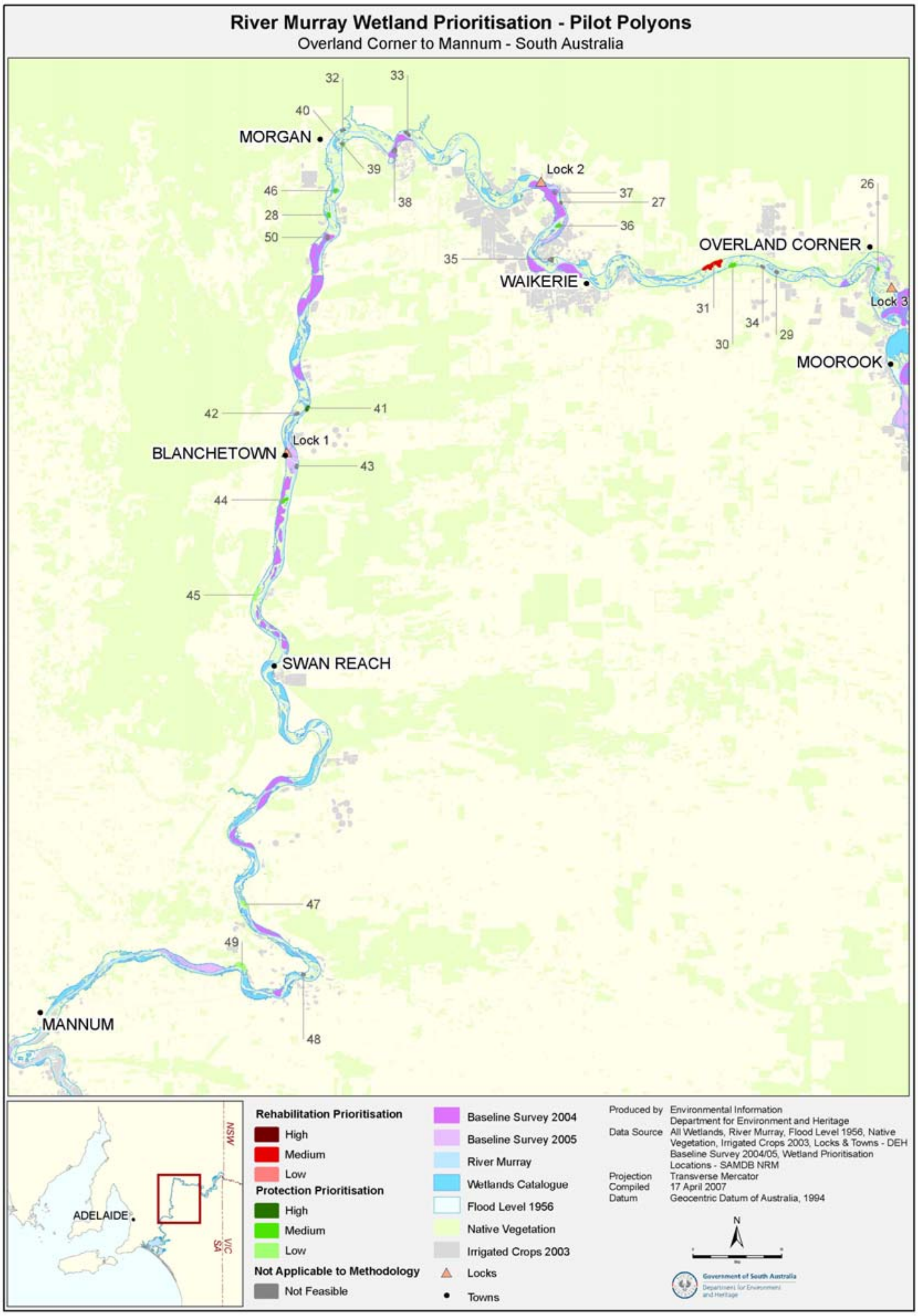

Figure 13: Prioritisation reach 2: Overland Corner to Mannum showing location of pilot wetlands and output of prioritisation trial.

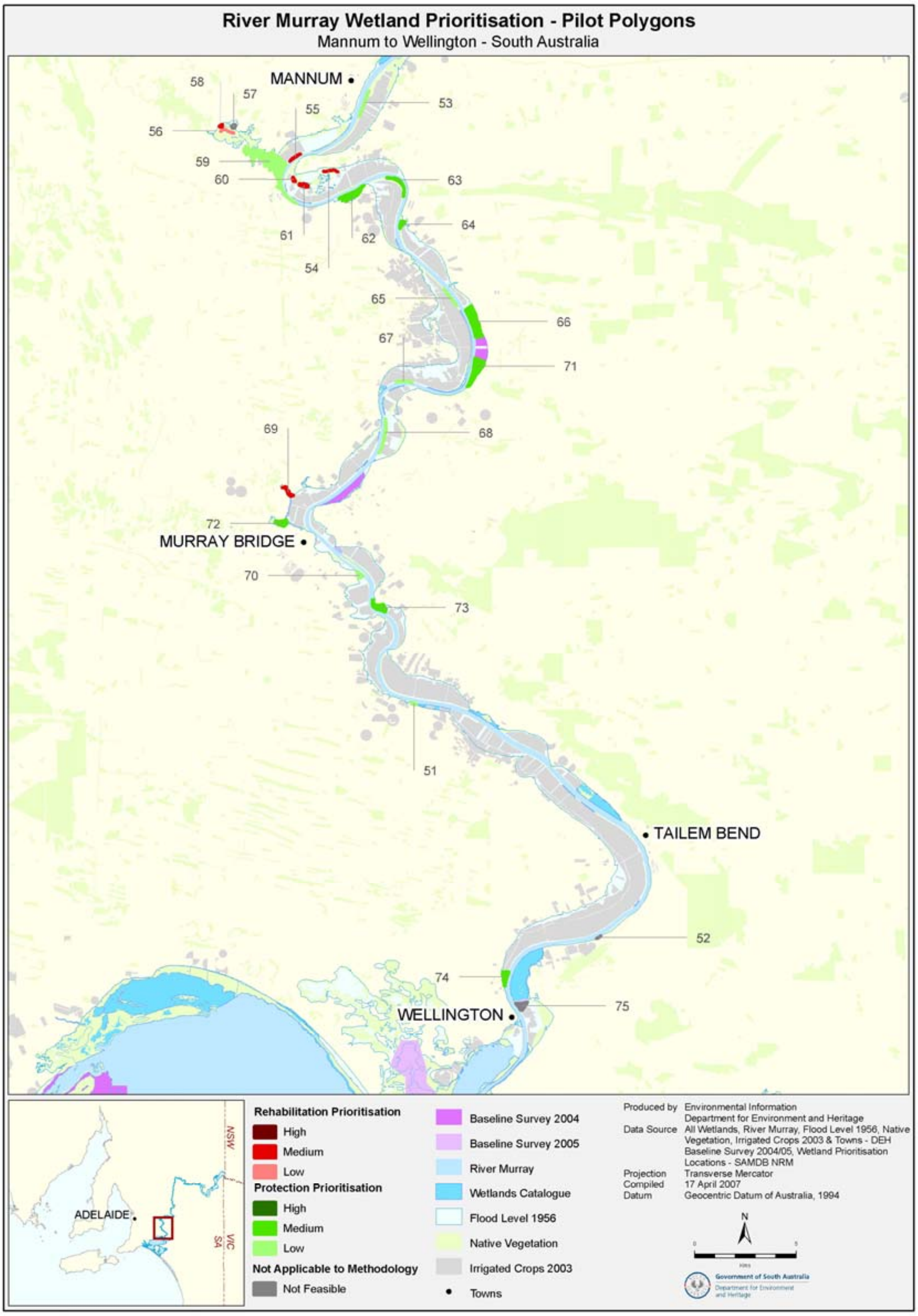

Figure 14: Prioritisation reach 3: Mannum to Wellington, showing location of pilot wetlands and output of prioritisation trial.

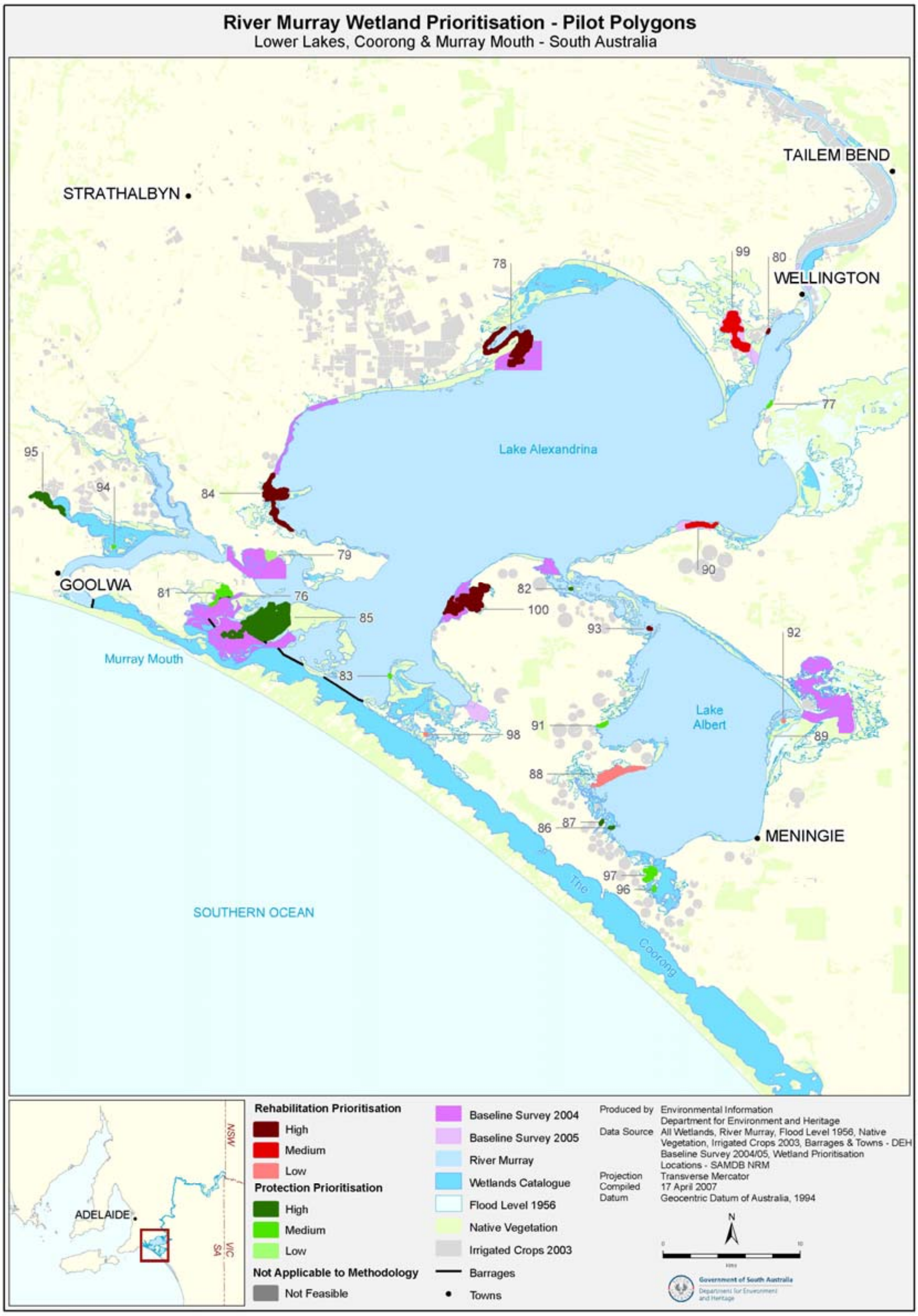

Figure 15: Prioritisation reach 4: Lower lakes, Wellington to the barrages, showing location of pilot wetlands and output of prioritisation trial.

Wetland categories of pilot sites for each prioritisation reach, showing priority rank (based on post pilot test refinements of feasibility criteria). See Appendix 1 for wetland class description

Wetland Identification Number & Ranking	DIWA Wetland Class	Hydrology (inundation)	Baseline site (Y/N?)	Wetland Identification Number & Ranking	DIWA Wetland Class*	Hydrology (inundation)	Baseline site (Y/N?)
Prioritisation Reach 1: Border to Overland Corner				Prioritisation Reach 2: Overland Corner to Mannum			
1	B2	Intermittent	N	26	B10	Intermittent	N
2	B10	Intermittent	N	27	B10	Intermittent	N
3	B10	Intermittent	N	28	B10	Intermittent	N
4	B10	Intermittent	Y	29	B10	Intermittent	N
5	B2	Permanent	N	30	B10	Intermittent	N
6	B1	Intermittent	N	31	B2	Intermittent	N
7	B10	Intermittent	N	32	B10	Intermittent	N
8	B10	Intermittent	N	33	B10	Intermittent	N
9	B10	Intermittent	N	34	B10	Intermittent	N
10	B10	Intermittent	Y	35	B2	Intermittent	N
11	B10	Intermittent	N	36	B2	Intermittent	N
12	B10	Intermittent	N	37	B2	Intermittent	Y
13	B6	Intermittent	N	38	B10	Intermittent	Y
14	B10	Intermittent	N	39	B10	Intermittent	N
15	B10	Intermittent	N	40	B10	Intermittent	N
16	B10	Intermittent	N	41	B9	Permanent	N
17	B10	Intermittent	Y	42	B10	Intermittent	N
18	B10	Intermittent	Y	43	B10	Intermittent	Y
19	B10	Intermittent	N	44	B1	Permanent	N
20	B2	Intermittent	Y	45	B1	Permanent	Y

21	B10	Intermittent	N	46	B10	Intermittent	N
22	B10	Intermittent	N	47	B10	Intermittent	N
23	B6	Intermittent	Y	48	B10	Intermittent	N
24	B6	Intermittent	Y	49	B5	Permanent	N
25	B1	Intermittent	Y	50	B10	Intermittent	Y

Wetland Identification Number & Ranking	DIWA Wetland Class	Hydrology (inundation)	Baseline site (Y/N?)	Wetland Identification Number & Ranking	DIWA Wetland Class*	Hydrology (inundation)	Baseline site (Y/N?)
Prioritisation Reach 3: Mannum to Wellington				**Prioritisation Reach 4: Lower Lakes - Wellington to barrages**			
51	B9	Permanent	N	76	B10	Intermittent	Y
52	B10	Intermittent	N	77	B9	Permanent	N
53	B1	Permanent	N	78	B13,B10	Intermittent	Y
54	B2	Intermittent	N	79	B10	Intermittent	N
55	B1	Permanent	N	80	B10	Intermittent	N
56	B2	Intermittent	N	81	B5	Permanent	Y
57	B10	Intermittent	N	82	B9	Permanent	N
58	B10	Intermittent	N	83	B9	Permanent	N
59	B5	Permanent	Y	84	B10, B13	Intermittent	N
60	B10	Intermittent	N	85	B2, B5, B10, B13	Intermittent	Y
61	B10	Intermittent	N	86	B12	Intermittent	N
62	B5	Permanent	N	87	B12	Intermittent	N
63	B2	Intermittent	N	88	B10	Intermittent	N
64	B9	Permanent	N	89	B10	Intermittent	N
65	B1	Permanent	N	90	B5	Permanent	Y

66	B5	Permanent	Y	91	B10	Intermittent	N
67	B1	Permanent	N	92	B10	Intermittent	N
68	B1	Permanent	N	93	B9	Permanent	N
69	B10	Intermittent	N	94	B9	Permanent	N
70	C2	Permanent	N	95	B9,B10	Permanent	N
71	B5	Permanent	Y	96	B10	Intermittent	N
72	B6	Intermittent	Y	97	B10	Intermittent	N
73	B5	Permanent	Y	98	B10	Intermittent	N
74	B5	Permanent	Y	99	B5	Permanent	Y
75	B10	Intermittent	Y	100	B10, B8	Intermittent	Y

Key to colour: Priority rankings

Protection - High
Protection - Medium
Protection - Low
Rehabilitation - High
Rehabilitation - Medium
Rehabilitation - Low
Rehabilitation – Very low

Appendix 6: Draft prioritisation method

The draft prioritisation method is summarised in Figure 16, with a detailed description of each step following. The method was refined through a stakeholder workshop, and external peer review.

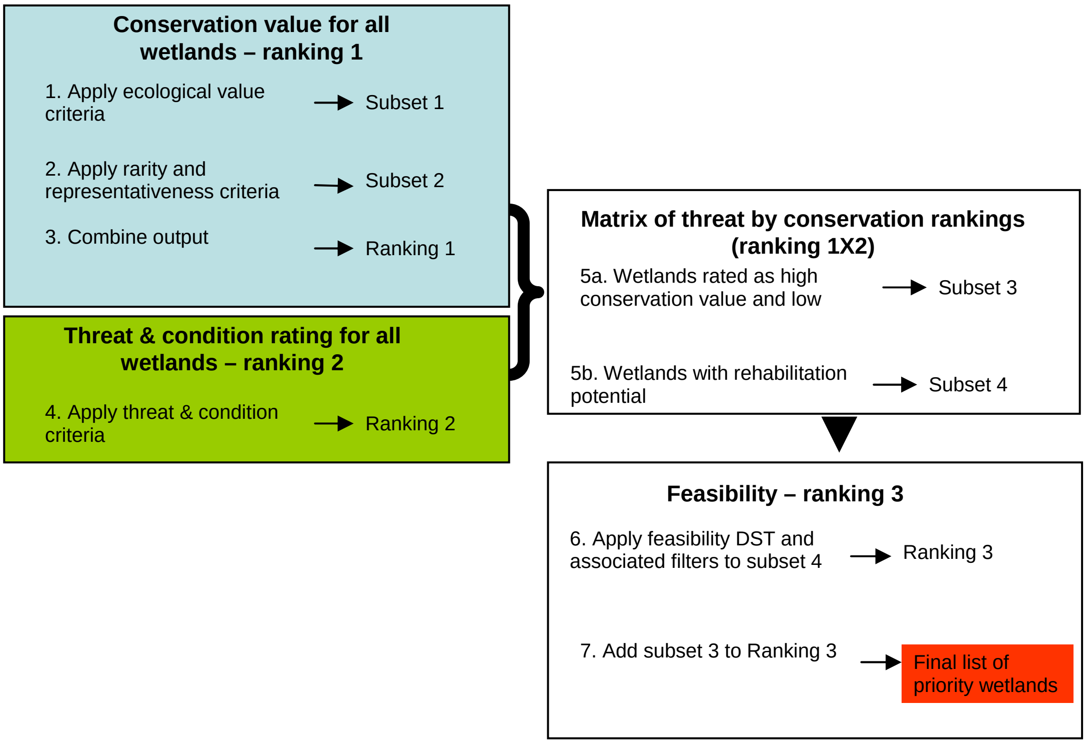

Figure 16: Summary flow chart of prioritisation method.

Step 1: Wetland ecological value

Apply criteria for assessing wetland categorisation to all wetlands.

Ecological value criterion 1 - threatened flora and fauna – taxonomic diversity.

This criterion is based on data for species records which fall within a 100m radius of the wetland polygon:

- Wetlands with listed species in 2 or more taxonomic groups – scores 3
- Wetlands with listed species in 1 taxonomic group – scores 2
- Wetlands with no listed species – scores 1

Ecological value criterion 2 – threatened flora and fauna – level of threat listing.

This criterion is based on data for species records that fall within a 100m radius of the wetland polygon:

- Wetlands with species listed as endangered – scores 3
- Wetlands with species listed as and vulnerable to rare, or are listed as migratory under the EPBC Act – scores 2

- Wetlands with species listed as insufficient data or no listed species – scores 1

Ecological value criterion 3 – structural habitat layers within the wetland (defined as wetland polygon).

- Wetlands with 2 or more structural habitat layers (e.g. trees + shrubs, sedges + trees, sedges + open water etc. Note it is not necessary to always have a tree layer – e.g. Samphire wetlands) – scores 3
- Wetlands with a single structural type – scores 2
- Wetlands with open water only or bare ground – scores 1

Ecological value criterion 4 - habitat extent within the wetland (defined as wetland polygon).

- Wetlands with 1 or more structural habitat >60% wetland area – scores 3
- Wetlands with 1 or more structural habitat 30-60% wetland area – scores 2
- Wetlands with 1 or more structural habitat <30% wetland area – scores 1

Ecological value criterion 5 - hydrological regime diversity.

- Wetland is part of a hydrological complex which has wetlands with more than 1 hydrological regime – scores 3
- Single wetland or part of a complex with a seasonal/intermittent regime – scores 2
- Single wetland or part of a complex with a permanent regime – scores 1

Criteria scores will be summed to arrive at an overall ecological value rating:

Score of 13-15 – High value
Score of 9-12 – Medium value
Score 5-8 – Low value

<u>Output: subset 1 wetlands with ecological value score</u>

Step 2: Rarity and representativeness

Apply criterion for assessing rarity <u>to all wetlands</u>.

Wetland categorisation criterion 1 – rare type.

- Wetland types that retain less than 10 examples, or are naturally rare within the study area – score High

Apply criterion for representativeness by reviewing scores assigned to each category for ecological value

Wetland categorisation criterion 2 – representativeness.

- If a wetland category is unrepresented or poorly represented in the list of wetlands which have high ecological value, then additional sites are to be chosen from those with a medium ecological value score to make up to 10% of the number of wetlands from that wetland category – scores High.

Output: subset 2 containing rare and representative sites

Step 3: Wetland conservation value

Combine wetland subset 1 and 2 to provide a list of High, Medium and Low ***conservation value*** wetlands. Note that conservation value is the final ranking achieved by combining ecological value, rarity and representativeness. It is this ranking that will be crossed against threat rating.

Output: Ranking 1 – conservation value of all wetlands

Step 4: Wetland threat and condition

Apply criteria for assessing wetland threat and condition to all wetlands.

Threat criterion 1: Salinity – actual (local scale).

Wetlands with no evidence of secondary salinisation – scores 1
- Wetlands with evidence of secondary salinisation – scores 3

Threat criterion 2: Altered hydrology – hydroperiod (frequency of inundation).

Shifts in permanency equate to shifts from seasonal to intermittent, with seasonal being defined as alternating wet and dry with the seasons, usually filling annually. Intermittent wetlands alternate between wet and dry but at lower frequency than annually. Determination of the degree of alteration in the hydroperiod is based on the FIM and considering the change in flood return rates:

- Wetlands with little or no evidence of altered hydroperiod – scores 1
- Wetlands with evidence of altered hydroperiod - change in frequency of inundation considered moderate – scores 2
- Wetlands with evidence of significant change in hydroperiod with a significant shift in frequency of inundation that has resulted in a shift in permanency – scores 3

Threat criterion 3: Altered hydrology – connectivity (local scale).

- Wetlands with unrestricted flow paths between the wetland and its hydrological water sources (river, local runoff, or groundwater) – scores 1
- Wetlands with inflow and outflow pathways blocked by artificial banks, levees, or structures. There is limited hydrologic connection to the natural water source – scores 3

Threat criterion 4: Landuse intensity (local scale).

The proportion of each landuse type will be established at 1000m from the edge of the wetland polygon:
- Wetlands surrounded by landuse types: forestry, native vegetation, nature conservation and other wetland/aquatic systems –scores 1
- Wetlands surrounded by landuse types: non irrigated agriculture, cropping, horticulture – scores 2

- Wetlands surrounded by landuse types: urban, intensive agriculture (eg feed lots), irrigated agriculture – scores 3

Ranking scores for each category of landuse intensity is multiplied by the proportion present within the 1000m radius.

Final scores are converted as follows:

- Wetlands rated as 250-300 – scores 3
- Wetlands rated as 150-250 – scores 2
- Wetlands rated as <150 –scores 1

Threat criterion 5: Wetland buffer – (local scale).

Wetland buffer is based on combining assessment of the buffer width and the proportion of the wetland perimeter with a woody vegetated buffer:

Buffer width:

- Wetlands with buffer >30m wide – scores 1
- Wetlands with buffer 10-30m wide –scores 2
- Wetlands with buffer <10m wide –scores 3

% of perimeter with buffer:

- Wetlands with >80% of perimeter with woody vegetation buffer - scores 1
- Wetlands with 30-80 % of perimeter with woody vegetation buffer – scores 2
- Wetlands with <30% of perimeter with woody vegetation buffer – scores 3

Score for buffer width X score of % of perimeter = total for wetland buffer.

The scoring here is different to that for ecological value, with higher scores representing poorer wetland condition or a higher threat rating (i.e. are more likely to be degraded). Criteria scores will be summed to arrive at an overall threat rating:

Score of 13-15 – High threat
Score of 9-12 – Medium threat
Score 5-8 – Low threat

<u>Output: Ranking 2 - threat ranking for all wetlands</u>

Step 5: Wetlands with rehabilitation potential

Create a matrix using the conservation value ranking and the threat ranking (Figure 17).

This step identifies wetlands that have rehabilitation potential.

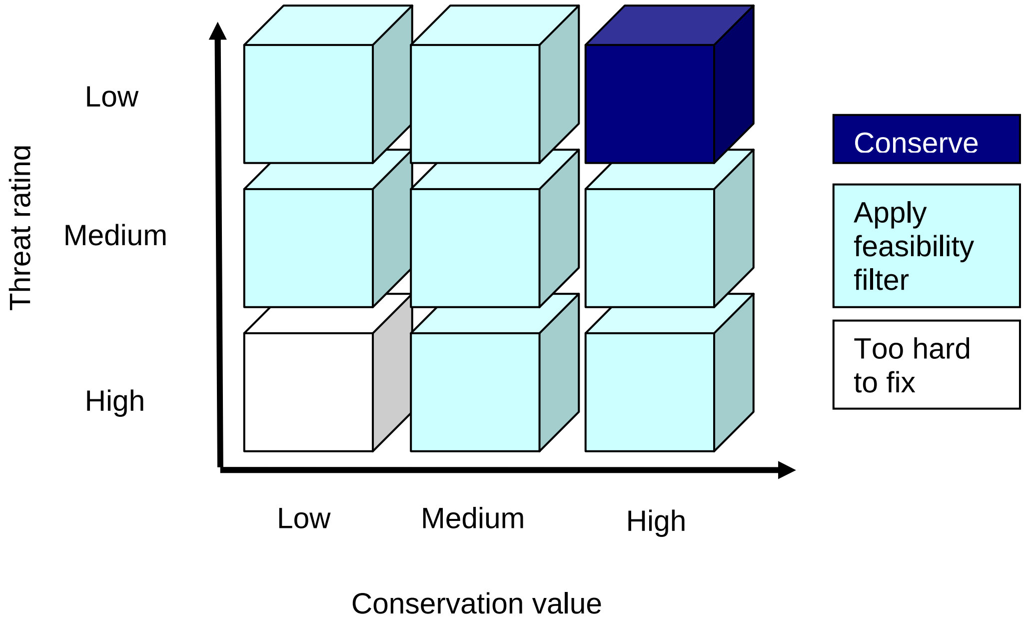

Figure 17: Diagrammatic representation of output of threat rating by conservation value matrix to produce a subset of wetlands on which to evaluate feasibility of undertaking rehabilitation activities.

Output: subset 3 list of high value sites which should be protected and subset 4 -list of wetlands with rehabilitation potential (medium threat and medium conservation value)

Step 6: Evaluate feasibility of rehabilitation options

Apply DST to each wetland identified as having rehabilitation potential.

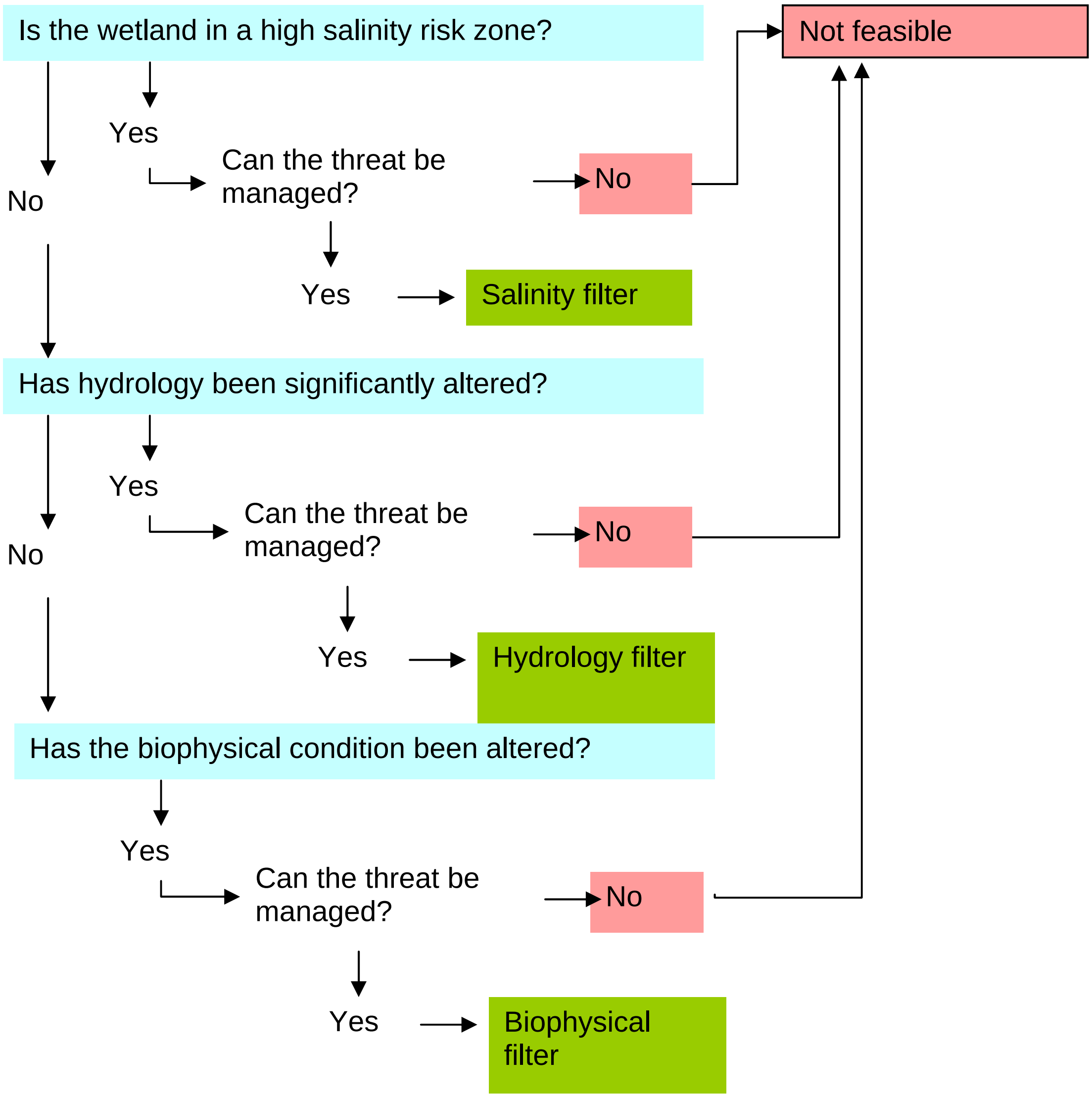

Figure 18: Feasibility DST – "Show stoppers" these questions establish if the wetland can be managed and which questions to apply.

Salinity objective: manage salt inputs

Is it feasible to manage the surface hydrological regime to influence salt levels in the wetland? → No – scores 1

- Yes → Infrastructure requires modification in order to allow manipulation – scores 2
- Yes → Water and infrastructure available to allow manipulation – scores 3

Hydrology objective: reinstate/manipulate the flow regime

Manipulation of hydrology possible by use of existing or new infrastructure? → No – scores 1

- Yes → Infrastructure needs modification or construction. Size of inlet suitable for structure to be inserted – scores 2
- Yes → Inlets and outlets are fully operable – scores 3

Is manipulation of the wetland hydrology possible with existing river flows and or weir pool manipulation? → No – scores 1

- Yes → Weir pool manipulation is feasible; wetland is affected if flows > 50,000ML/day - scores 2
- Yes → Manipulation is feasible; wetland is affected by weir manipulation at entitlement flows or is connected to the river at pool level– scores 3

Figure 19: Salinity and hydrology questions/filters – relates feasibility of management actions to a simple objective for each driver.

Biophysical objective: rehabilitate biophysical condition

Can connectivity be re-established? → No – scores 1

- Yes → Connectivity can be re-established through revegetation of areas between wetlands – scores 2
- → Connectivity can be re-established by reinstating hydrological connectivity – scores 3

Is revegetation required? → No – scores 3

- Yes → Small to moderate amount of revegetation is required – scores 2
- → Significant amount of revegetation is required – scores 1

Can the influence of invasive species be controlled? → No – scores 1

- Yes → Invasive species biology and management requirements poorly understood and considered hard to gain control – scores 2
- → Invasive species biology and or management well understood and considered relatively easy to gain control – scores 3

Will fencing lead to an improvement? → No – scores 1

- Yes → Fencing will control grazing – scores 2
- → Fencing will address overgrazing, erosion and re-establishment of vegetation – scores 3

Are acid sulfate sediments a concern? → No – scores 3

- Yes → Management actions limit the potential problems – scores 1

Figure 20: Biophysical questions/filter– relates feasibility of management actions to a simple objective of rehabilitating wetland biophysical condition.

Output: Ranking 3 - list of wetlands and their priority for rehabilitation

Step 7: Final list of priority sites

Combine Ranking 3 with Subset 3 (sites which should be protected/conserved identified in step 5a).

Output: Final priority listing for wetlands of conservation and rehabilitation potential for the South Australian River Murray

Appendix 7: Pilot data

The following is an account of the issues encountered during collation of the data set used to test the method.

Allocating DIWA classes to wetlands using remote data and imagery sets (P. Wainright, March 2007).

Difficulties allocating DIWA classes remotely

The main attributes necessary for the classification of wetlands using the DIWA system are:

Wetland size – Standard polygon attribute common to all mapped wetlands

Physical form – Imagery and existing feature codes in other datasets were available at a scale that enabled geo-physical attributes to be confidently assessed.

Water regime – Reasonable degree of confidence except for the 'lower lakes' wetlands where the water regime remains undocumented for many of the wetlands

Conductivity - Quantitative data was available for some of the wetlands, however 'fresh' was the default during the classification process. The 'lower lakes' reach contains some naturally saline wetlands, but these have not been isolated with a high degree of confidence.

Vegetation/substrate – datasets were available to describe communities to species level. Soil landscape units mapping was available to verify %organic /inorganic matter.

In addition the following points should be noted as well:

1. The salinity (value) of most of the wetlands was unavailable, so vegetation mapping was used as a surrogate to identify whether a wetland was fresh or saline. In DIWA, the same physical wetland form can be common to fresh and saline systems and is classed differently. For example, 'B10' (seasonal freshwater marsh), and 'B12' (seasonal saline marsh).

2. The pilot dataset identified a couple of wetlands that are effectively marinas. There is no specific category within the 'Human-made' wetlands in DIWA to describe these features. The closest class is 'C2', 'Ponds, including farm ponds, stock ponds and small tanks'.

3. 'B10', referring to a 'seasonal intermittent freshwater pond and marsh on inorganic soils, includes seasonally flooded meadows, sedge marshes' was generally used in preference to 'B13', 'Shrub swamp; shrub dominated freshwater marsh' because of the tendency for many of these to be 'sedge-dominated' rather than 'shrub -dominated'. There may be some cases where the latter is more appropriate, since the selection of a DIWA class was largely dependent on the accuracy of the vegetation mapping.

4. Wetlands that have been classified as 'B10' may also be 'B4' (riverine floodplains, flooded river basins, seasonally flooded grassland) as there appears to be common elements in both classes. 'B10' was used in

preference to ‘B4’ (most commonly for the seasonally flooded meadows), but upon reflection there are numerous cases where the two classes should be used together.

Broader issues with data interpretation

1. Natural versus artificial channel form
The distinction between an artificial channel-form (a canal for example) and a naturally occurring channel was difficult to discern from the imagery. In several cases a feature appeared to be natural but some artificial modifications/extensions had been made.

2. Emergent vegetation
Emergent vegetation (commonly willows) made the classification of some linear wetlands difficult because it obscured underlying features.

3. Salinity
The distinction between primary and secondary salinity was subjective because it was based on a visual assessment of the substrate (visible salt scars) within the wetland polygon compared with the condition of neighbouring substrate. At the Lower Lakes, the presence of visible salt scalds was precipitated by primary salinity, however the degree to which secondary salinity exacerbated these symptoms is largely unknown. (All salt scalds have been attributed as secondary salinity in the dataset, but this involves a considerable amount of guess-work and requires some revision).

4. Grazing
Grazing within and adjacent to wetland polygons was difficult to identify if stock, tracks or grazing infrastructure wasn’t visible in the imagery.

5. Inlets.
Some wetlands have been mapped as an open ‘embayment’ on the main river channel. In such cases these wetlands were not given a score of ‘1’ for their open interface with the river channel.

6. Complexes.
The attribution of wetland complexes was based on hydrological connectivity at some time in the past. Because of gross changes to the hydrological regime, a number of the attributed complexes are no longer functional complexes. Unless it was known with confidence that a wetland no longer functioned as a complex, the mapped attribution was applied.

7. Water regime.
Imagery and mapping did not agree in some instances. If the imagery contradicted the mapping and it was obvious the attribution was incorrect, a change was made, if not, the mapped attributes were used as the default.

8. Current/Natural Hydrology.
This was calculated using the Flood inundation Model (FIM) for the upper three reaches and was based on the opinion of the expert panel for the ‘lower lakes’ reach. Due to random selection and obscurity of some of the wetlands, the panel had some difficulty populating a field for each polygon.
The model has some difficulty with the elevation change between channel forms and the surrounding terrain and therefore tends to lose accuracy at finer scales.

9. Barrier.
A ‘barriers’ layer was used in conjunction with a visual inspection of the imagery, however there are likely to be unmapped/unsighted barriers that effect hydrological processes.

10. Threatened Species.
Although both opportunistic and survey records were used, the fauna and flora records in the State Ecological Databases are terrestrially biased. Water dependent species are not well represented in the database. Anecdotal records and local opinion suggest that these records are highly conservative. Records from the SKM baseline surveys were added where the survey point fell within a pilot polygon.

11. Acid Sulphate Soils
The soil mapping undertaken by PIRSA (Primary Industries and Resources, South Australia) identifies soils high in sulfidic materials. The mapping was prescribed for agricultural applications and susceptibility is determined primarily by the following

At least the lower part of the soil profile must be saturated for most of the year AND

Land lies within a geological formation containing pyrite bands,
OR Near surface water tables are highly saline (more than 10,000 mg/kg dissolved salts),
OR There are gypsum deposits in the landscape (eg lunettes around salt lakes or salt pans, gypseous hummocks),
OR Gypsum segregations (crystals or soft flakes) occur in the soil profile
salt concentrations in the soil.
No specific wetland sampling was undertaken. Data is coarse and considered to be a guide only.

Appendix 8: Pilot test results

See attached CD containing data and test results.

Comments are used throughout the spread sheets to list the criteria used, scoring information or advice on data issues.

The following is a list of the worksheets:

1. data 211206:
This is the data as supplied by DEH on the 21st of December 2006. It formed the basis of the pilot testing.

2. test scores no weighting
This worksheet represents the original test run of the method. Wetland categorisation criterion (WC1) has been modified to reflect the smaller number of wetlands being tested in the pilot. Threat criterion 1 (TC1) has been modified but not weighted.

3. test scores threat weighting 2
Threat criteria 1 & 2 have had a weighting of two applied. This is the base for all sensitivity analyses.

4. test scores threat weighting 3
Sensitivity analysis in which threat criteria 1 & 2 have a weighting of three applied.

5. test scores rarity 4%
Sensitivity analysis looking at difference in output if rare wetlands are increased from 1-2% as per the base case to 2-4% of total number of wetlands.

6. test scores DIWA
Sensitivity analysis in which DIWA sites are automatically assigned a high conservation ranking regardless of their ecological value, rarity or representativeness.

7. test scores inlet
Sensitivity analysis in which the inlet size is varied from 10 m to 20 m.

8. test scores feasibility final
This represents the final post pilot testing refinement of the method. The feasibility criteria are reordered, inlet size is based on 20m, and new data is used for the lower lakes (not supplied in worksheet 1) to assess ability to manipulate hydrology. A feasibility rank is provided (based on separate, refined, scoring systems for wetland above and below Wellington) which is combined with the conservation value rank to provide the final rehabilitation rank.

Appendix 9: Final method

The final prioritisation method is summarised in Figure 21, with a detailed description of each step following. The method was refined through a stakeholder workshop, and external peer review, and again after completing the pilot testing.

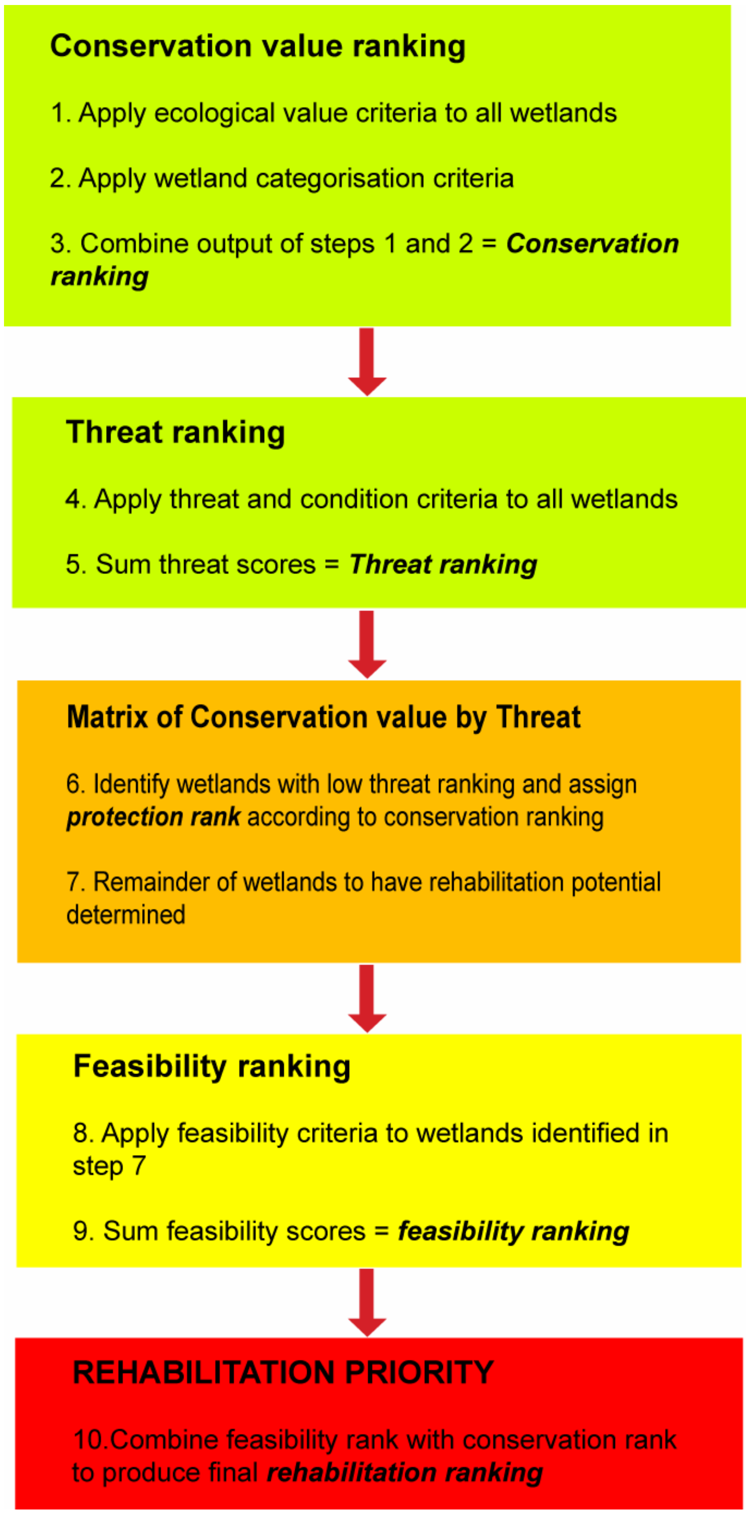

Figure 21: Summary flow chart of prioritisation method.

Step 1: Wetland ecological value

Apply criteria for assessing wetland categorisation to all wetlands.

Ecological value criterion 1 - threatened flora and fauna – taxonomic diversity.

This criterion is based on data for species records which fall within a 100m radius of the wetland polygon:

- Wetlands with listed species in 2 or more taxonomic groups – scores 3
- Wetlands with listed species in 1 taxonomic group – scores 2
- Wetlands with no listed species – scores 1

Ecological value criterion 2 – threatened flora and fauna – level of threat listing.

This criterion is based on data for species records that fall within a 100m radius of the wetland polygon:

- Wetlands with species listed as endangered – scores 3
- Wetlands with species listed as and vulnerable to rare, or are listed as migratory under the EPBC Act – scores 2
- Wetlands with species listed as insufficient data or no listed species – scores 1

Ecological value criterion 3 – structural habitat layers within the wetland (defined as wetland polygon).

- Wetlands with 2 or more structural habitat layers (e.g. trees + shrubs, sedges + trees, sedges + open water etc. Note it is not necessary to always have a tree layer – e.g. Samphire wetlands) – scores 3
- Wetlands with a single structural type – scores 2
- Wetlands with open water only or bare ground – scores 1

Ecological value criterion 4 - habitat extent within the wetland (defined as wetland polygon).

- Wetlands with 1 or more structural habitat >60% wetland area – scores 3
- Wetlands with 1 or more structural habitat 30-60% wetland area – scores 2
- Wetlands with 1 or more structural habitat <30% wetland area – scores 1

Ecological value criterion 5 - hydrological regime diversity.

- Wetland is part of a hydrological complex which has wetlands with more than 1 hydrological regime – scores 3
- Single wetland or part of a complex with a seasonal/intermittent regime – scores 2
- Single wetland or part of a complex with a permanent regime – scores 1

Criteria scores will be summed to arrive at an overall ecological value rating:

Score of 13-15 – High value
Score of 9-12 – Medium value

Score 5-8 – Low value

<u>Output: subset 1 wetlands assigned a ecological value score</u>

Step 2: Wetland categorisation - rarity and representativeness

Apply criterion for assessing rarity <u>to all wetlands</u>.

Wetland categorisation criterion 1 – rare type.
Where multiple wetland types are assigned to a polygon, and a rare type is part of that polygon, then the polygon is assigned a high value on the basis of the rare component.

- Wetland types that retain less than 10 examples, or are naturally rare within the study area – score High

Apply criterion for representativeness by reviewing scores assigned to each category for ecological value

Wetland categorisation criterion 2 – representativeness.

- If a wetland category is unrepresented or poorly represented in the list of wetlands which have high ecological value, then additional sites are to be chosen from those with a medium ecological value score to make up to 10% of the number of wetlands from that wetland category – scores High.

<u>Output: subset 2 wetlands identified as rare or representative sites</u>

Step 3: Wetland conservation value ranking

Combine wetland subset 1 and 2 to provide a list of High, Medium and Low ***conservation value*** wetlands. Note that conservation value is the final ranking achieved by combining ecological value, rarity and representativeness. It is this ranking that will be crossed against the threat rating.

<u>Output: Conservation ranking</u>

Step 4: Wetland threat and condition

Apply criteria for assessing wetland threat and condition <u>to all wetlands.</u>

Threat criterion 1: Salinity – actual (local scale).

The distinction between primary and secondary salinity was subjective because it was based on a visual assessment of the substrate (visible salt scars) within the wetland polygon compared with the condition of neighbouring substrate. At the Lower Lakes, the presence of visible salt scalds was precipitated by primary salinity, however the degree to which secondary salinity exacerbated these symptoms is largely unknown. All salt scalds have been attributed as secondary salinity in the dataset, but this involves a considerable amount of guess-work and requires some revision (P. Wainright, pers. comm.). DEH provided the data for salinity as a 5 point scale which was converted to a 3 point score in line with the other criteria. Note that this criterion has double weighting.

- Wetlands with no evidence of secondary salinisation – scores 2
- Wetlands with some evidence of salinisation – scores 4
- Wetlands with evidence of acute secondary salinisation – scores 6

Threat criterion 2: Altered hydrology – hydroperiod (frequency of inundation). Note that this criterion has double weighting.

- Wetlands with little or no evidence of altered hydroperiod – scores 2
- Wetlands with evidence of altered hydroperiod - change in frequency of inundation considered moderate – scores 4
- Wetlands with evidence of significant change in hydroperiod with a significant shift in frequency of inundation that has resulted in a shift in permanency – scores 6

Threat criterion 3: Altered hydrology – connectivity (local scale).

- Wetlands with unrestricted flow paths between the wetland and its hydrological water sources (river, local runoff, or groundwater) – scores 1
- Wetlands with inflow and outflow pathways blocked by artificial banks, levees, or structures. There is limited hydrologic connection to the natural water source – scores 3

Threat criterion 4: Landuse intensity (local scale).

The proportion of each landuse type will be established at 1000m from the edge of the wetland polygon:

- Wetlands surrounded by landuse types: forestry, native vegetation, nature conservation and other wetland/aquatic systems –scores 1
- Wetlands surrounded by landuse types: non irrigated agriculture, cropping, horticulture – scores 2
- Wetlands surrounded by landuse types: urban, intensive agriculture (eg feed lots), irrigated agriculture – scores 3

Ranking scores for each category of landuse intensity is multiplied by the proportion present within the 1000m radius.

Final scores are converted as follows:

- Wetlands rated as 250-300 – scores 3
- Wetlands rated as 150-250 – scores 2
- Wetlands rated as <150 –scores 1

Threat criterion 5: Wetland buffer – (local scale).

Wetland buffer is based on combining assessment of the buffer width and the proportion of the wetland perimeter with a woody vegetated buffer:

Buffer width:

- Wetlands with buffer >30m wide – scores 1
- Wetlands with buffer 10-30m wide –scores 2
- Wetlands with buffer <10m wide –scores 3

% of perimeter with buffer:

- Wetlands with >80% of perimeter with woody vegetation buffer - scores 1
- Wetlands with 30-80 % of perimeter with woody vegetation buffer – scores 2
- Wetlands with <30% of perimeter with woody vegetation buffer – scores 3

Score for buffer width X score of % of perimeter = total for wetland buffer.

Step 5: Threat ranking

The scoring here is different to that for ecological value, with higher scores representing poorer wetland condition or a higher threat rating (i.e. are more likely to be degraded). Threat criteria scores are summed to arrive at an overall threat ranking:

- Score of 15-20 – High threat
- Score of 10-14 – Medium threat
- Score < 10 – Low threat

Output: Threat ranking

Step 6: Identify wetlands for protection

Create a matrix using the conservation value ranking and the threat ranking (Figure 22).

This step identifies wetlands that have a low threat ranking, therefore requiring little or no rehabilitation. The rehabilitation rank reflects the conservation rank. Those with the combination of low threat and high conservation value equal high protection.

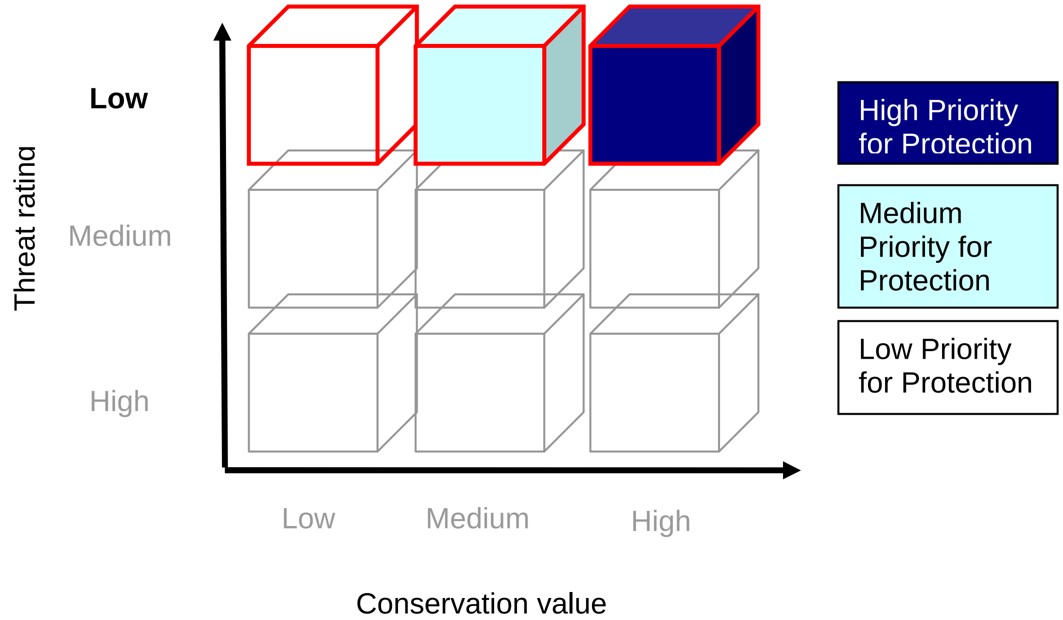

Figure 22: Conservation value versus threat rating matrix showing how the wetlands with a Low threat rating are ranked for protection.

<u>Output: Protection ranking</u>

Step 7: Identify wetlands for assessment of rehabilitation potential

From the Threat Conservation matrix wetlands which have a low conservation rank and high threat rank are considered likely to have a very low rehabilitation potential (bottom left cell in Figure 23)

The remaining wetlands which (Figure 23) are put through the feasibility assessment.

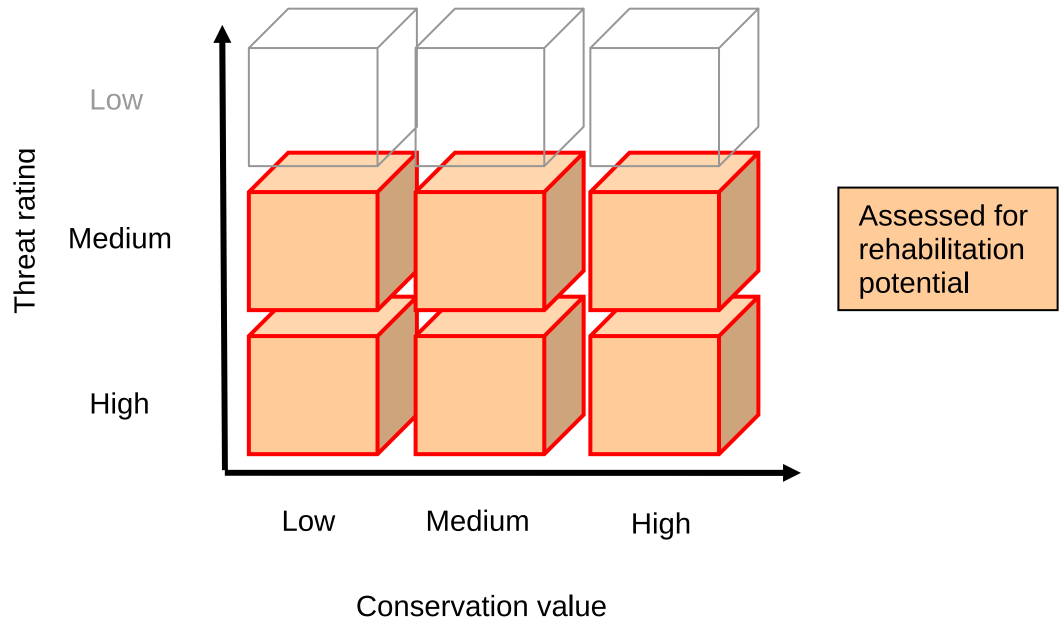

Figure 23: Conservation value versus threat rating matrix showing the wetlands which are assessed for rehabilitation potential.

<u>Output: subset of wetlands at which rehabilitation is feasible</u>

Step 8: Feasibility

Apply feasibility criteria to subset of wetlands identified in step 7.

Feasibility criterion 1 - Manipulation of hydrology is possible through existing entitlement flows and or manipulation of weirs for wetlands above Wellington, or hydrology is affected by lake levels.

Data for this criterion is based on commence to fill data for wetlands above Wellington. Wetlands below Wellington are scored according to their degree of hydrological connectivity to Lake Alexandrina and Albert. Barrage manipulation will raise and lower lake levels and those wetlands within a 30m boundary of the lake, and which are not connected to the lake via an inlet or channel, may be affected by lake level changes.

Wetlands above Wellington

- Commence to flow < 10,000 ML/day = 3
- Commence to flow 10,000 - 50,000 ML/day = 2
- Commence to flow > 50,000 ML/day = 1

Wetlands below Wellington

- Connected at lake level = 3
- Within 30m of lake shore = 2
- >30 m from shore = 1

Feasibility criterion 2 - Salinity impacts

- Wetlands with no evidence of secondary salinisation – scores 3
- Wetlands with some evidence of salinisation – scores 2
- Wetlands with evidence of acute secondary salinisation – scores 1

Feasibility criterion 3 - Manipulation of hydrology with infrastructure. Relevant to wetlands above Wellington only.

- Wetland has no inlet or inlet > 10m = 1
- No infrastructure present but inlet 10m or less and therefore possible to insert control structure = 2
- Existing infrastructure present* = 3

*Note that ‘existing infrastructure present’ was based on advice from DEH that barriers present at a wetland were (unless otherwise stated) to be equated to infrastructure.

Step 9: Feasibility ranking

Due to data limitations there are different criteria applied to the wetlands above and below Wellington. The feasibility rank is scored as follows:

Wetlands above Wellington
8 - 9 = High
6 - 7 = Medium
3 - 5 = Low

Wetlands below Wellington
5 - 6 = High
3 - 4 = Medium
2 = Low

Step 10: Rehabilitation ranking

The final ranking is based on a combination of ***conservation value ranking*** and ***feasibility***. There is an implied cost associated with the different rehabilitation options and this is reflected in the ranks. This represents the final output of the prioritisation for rehabilitation.

The final ranking is as follows:

Very low = low feasibility
Low = moderate feasibility and low conservation value;
Medium = medium feasibility and medium conservation value; or high feasibility and low conservation value
High = medium or high feasibility and high conservation value; or high feasibility and moderate conservation value

Once the final priorities have been assigned ground-truthing will be necessary to further refinement management approaches for each wetland.

Appendix 10 Expert review of pilot test results

The following comments were supplied by members of the Steering Committee and local experts.

Comparison of Wetland Prioritisation Pilot Results Against Local Knowledge (Upper Murray)

Of the 100 pilot polygons, there were 14 located between the border and Blanchetown sites with sufficient local knowledge to be considered (note no field visits were undertaken). Only two sites were rated for protection (Little Toolunka Flat and Brenda Park Lagoon). The majority were rated for Rehabilitation, with most of them (8) falling into the Rehabilitation – VL category.

The tables below provide the pilot polygon number and the wetland complex name together with a comment on the rating.

Table 12 Sites rated as Protect – Medium

Pilot ID	Wetland Complex	Comment
36	Little Toolunka	The polygon represents a temporary basin located on a highly salt affected floodplain. The surrounding area is dominated by irrigated horticulture. Would have thought the threat rating would be medium or high.
46	Brenda Park Lagoon	Already a 'managed' wetland with a flow regulator installed to manipulate water levels. The site appears to be in good condition. Rating seems valid.

Table 13 Sites rated as Rehabilitation – VL (i.e. low value x high threat)

Pilot ID	Wetland Complex	Comment
10	Woolenook Bend	Part of Squiggly Creek. Lowering of sills has been undertaken to increase inundation of this site.
14	Paringa Paddock	Temporary basin on floodplain. Rating seems valid
13	Disher Creek	Irrigation disposal basin – highly salt affected. Rating seems valid
23	Martins Bend	Stormwater basin adjacent to Berri Township means the site receives water without having to rely on rises in river level increasing flexibility for rehabilitation
17	Beldora Lagoon	Temporary basin on floodplain. Rating seems valid
18	Cobdogla Basin	Irrigation disposal basin – highly salt affected. Rating seems valid
35	Big Toolunka	Part of inlet channel. This is a unique wetland for the area due to its depth and as a result provides habitat for large-bodied fish including silver perch. Value of site should be higher, however the silver perch were sampled during the 2006 Baseline Survey and this data was not included in the pilot prioritisation
37	Nigra Lagoon	Temporary basin on floodplain. Rating seems

		valid

Table 14 Sites rated as Rehabilitation – Low

Pilot ID	Wetland Complex	Comment
25	Paringa Island	Narrow channel connected at pool. Site appears to be in good condition. Feasibility should be higher.

Table 15 Sites rated as Rehabilitation – Medium

Pilot ID	Wetland Complex	Comment
20	Yatco Lagoon	Narrow channel connected at pool, however surrounding area is fairly salt affected. Rating seems valid

Table 16 Sites rated as Rehabilitation – High

Pilot ID	Wetland Complex	Comment
4	Murtho Park	Narrow channel connected at pool. Site appears to be in good condition. Rating seems valid
22	Paringa Paddock	Relatively narrow waterbody connected at pool. Site appears to be in good condition. Rating seems valid

The pilot results were not compared against the raw data to determine the factors(s) contributing to a particular conservation, threat, or feasibility score, in particular polygons rated as Rehabilitation - VL were difficult to assess. However, in general, most of the final ratings seemed valid when compared to local knowledge of the site.

(Lower Murray)

Of the 100 pilot polygons, there were 26 located between the barrages and Blanchetown sites with sufficient local knowledge to be considered (as with the upper Murray no field visits were undertaken). Fourteen sites were rated for protection nine for rehabilitation, and three VL category (not feasible). The last table presents the assessment by Adrienne Frears and Tumi Bjornsson based on our general knowledge of the area.

The tables below provide the pilot polygon number and the wetland complex name together with a comment on the rating.

Table 17 Sites rated as Protect

Polygon	Protection	Name	Notes
73	M	Swanport	This wetland has both an open water section as well as a herb land section. This is a rare wetland in the region. Rating should probably have been high protection.
70	L		It is a Marina. Rating should be not feasible
72	M	Rocky Gully wetland.	Rating seems valid
71	M	Sunnyside wetland.	Rating seems valid
66	M	Paiwalla Wetland.	Rating seems valid
49	L		Rating seems valid
45	L		Would have expected a rating of medium as with 44
44	M	Moorundi complex.	A creek connecting a larger wetland in the Moorundi complex. The adjacent land is used for sheep grazing. Rating seems valid

95	H	Currency Creek.	Rating seems valid
81	M	Shadows lagoon	Significant remnant stands of Melaleucas, threatened fish, EPBC listed birds & fish, rare vegetation for region. Rating should probably have been high protection or rehabilitation
76	H	Shadows lagoon	Same as above. Part of Shadows lagoon. No idea why these polygons are separate.
85	H	Mundoo island.	Should potentially have a lower in rating. Heavily grazed area. Although Cape Barren Geese use area extensively.
79	L	Clayton	Samphire. Rating seems valid
74	M	Wellington North.	Rating seems realistic

Table 18 Sites rated as Rehabilitate

Polygon	Rehabilitation	Name	Notes
69	M	Preamimma creek.	Rating seems valid
55	M		This is a dairy swamp channel. It should probably have a low rating
59	L	Reedy Creek wetland.	It is one of few that has an independent catchment contributing to the Murray in South Australia. It has a large number of birds recorded. I would have expected at least a medium rehabilitation or protection.
56	L	Reedy Creek wetland.	This is a creek not a manageable wetland. Rehabilitation is relevant regarding revegetation and could therefore be elevated to medium.
58	M	Reedy Creek wetland.	These two (57 & 58) should have come out as the same priority. They are samphire basins next to each other with no real management potential besides revegetation. Medium rehabilitation seems valid
84	H	Reedy Point Complex.	Rating seems valid
78	H	Tolderol.	Should be probably be high protection rather than high rehabilitation
99	M	Pelican Lagoon.	Should be high protection as the Bell frog has been heard here, so has the Pygmy perch & threatened birds
90	M	Poltaloch	Rating seems valid

Table 19 Sites rated as Not Feasible

Polygon	Not Feasible	Name	Notes
57	VL	Reedy Creek wetland.	These two (57 & 58) should have come out as the same priority. They are samphire basins next to each other with no real management potential besides revegetation.
43	VL	Sweeney's	This wetland is a shallow depression above pool level in the Moorundi complex. There is a significant wetland adjacent to it with a management plan (Sweeney's). There is no need to invest resources in this depression. Rating seems valid
75	VL	Wellington East.	This one is not only easy to manage through the instillation of a structure but also shows great promise of success.

			Rating seems incorrect

Table 20 Sites rated that were unknown

52	VL	Unknown	OK
51	L	Unknown	OK
68	L	Unknown	OK
67	L	Unknown	OK
65	L	Unknown	OK
64	M	Unknown	OK
63	M	Unknown	OK
62	M	Unknown	OK
61	M	Unknown	Not Feasible. Removed from any river connection. Irrigation in surrounding area.
60	M	Unknown	Not Feasible. Removed from any river connection. Irrigation in surrounding area.
54	M	Unknown	Not Feasible. Removed from any river connection. Irrigation in surrounding area.
53	L	Unknown	Dairy swamp channel
48	VL	Unknown	OK
47	L	Unknown	OK
94	M	Unknown	A reed island in the middle of a larger complex. Should probably be rated low protection
80	H	Unknown	OK
77	M	Unknown	OK
92	L	Unknown	OK
89	L	Unknown	OK
96	M	Unknown	OK
97	M	Unknown	OK
86	H	Unknown	OK
87	H	Unknown	OK
88	L	Unknown	OK
91	M	Unknown	OK
93	H	Unknown	Reed Island in middle of Narrung Narrows. Rating seems unrealistic
82	H	Unknown	Reed Island in middle of Narrung Narrows. Rating seems unrealistic
83	M	Unknown	Not Feasible

For the most part the ratings were either as or close to the expected. Data quality is assumed to be the largest impact on the quality of results. However, some significant discrepancies were identified.

Only 13 of the 26 wetlands seemed to have a valid rating. Most probably this discrepancy will relate to the data set available (this includes sites between Wellington and Blanchetown), but without the data set it is not possible to assess this accurately. Those that were expected to rate differently were for the most part close to the expected rating. Of the unknown polygons the majority of ratings seemed acceptable with only a few questionable, where some were well removed from any river connection and some were reed islands. Again this is probably an issue with the data set.

As there were definitely some wetlands that were rare in the region, the main overall concern is the lack of high protection rating. Another concern is the not feasible rating for some of the wetlands, in particular Wellington East. In comparison, other wetlands that are defiantly not feasible were given a better rating.