A standardised protocol for assessing the suitability of permanent wetlands for disconnection.

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Project Background

As agreed by First Ministers, a number of measures including the disconnection of wetlands have been progressively implemented over recent months. Additional wetlands in South Australia and NSW have been identified as having the potential to return relatively high yields in evaporative savings (Murray-Darling Basin, Dry Inflow Contingency Planning Overview Report to First Ministers April 2007).

The restoration of the natural wetting and drying regimes is typically expected to improve habitat availability for indigenous flora and fauna. However, within the current management context there are a number of site specific conditions that may expose wetlands to long-term or irreversible damage. These conditions include acidification potential, shallow groundwater, and the role of the wetland as critical drought refugia for threatened or rare species persistence. Both these factors will be considered in the proposed assessment.

It is recommended that these wetlands undergo ecological assessment to ensure that long-term or permanent ecological damage will not be sustained, before commencement of construction of works to disconnect them. Sites that are identified as supporting threatened species are likely to require assessments under the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act).

The States have agreed in MDBC Out-of-Session Resolution 138 that the Environmental Watering Group (EWG) will consider and provide advice to the MDBC on a standardised rapid flora and fauna assessment protocol and an ongoing wetland monitoring programme identifying environmental trigger points to guide the management of the closure and reopening of wetlands. The monitoring program will enable a clear evaluation of both short term and long term impacts of drying on the ecology of the wetland.

Project Objective

The specific objectives of this project are:

1. The development of a standardised wetland assessment protocol for use in assessing suitability of selected permanent wetlands for temporary disconnection.
    - The protocol must include as part of the initial assessment a determination of a wetlands' possible status as a critical drought refuge;
    - The protocol is to include an assessment of the significant risks of long-term or irreversible damage to the wetland

2. The development of an ongoing wetland monitoring programme that is able to detect significant wetland degradation as a result of the disconnection and associated drawdown.
    - The ongoing wetland monitoring programme must have inbuilt triggers that initiate action to intervene in the drawdown if monitoring reveals significant degradation.

Project Approach and Methodology

The key issues considered essential for determining wetland suitability for disconnection are:

1. *In-situ* Water quality
2. Acidification potential
3. Vegetation condition
4. Fish community
5. Critical Drought Refuge
6. Environmental Trigger Points

Anticipated outputs and deliverables of this Project

The output and deliverable of this project is a stand alone, documented wetland assessment protocol that includes all required detail, background and methodologies. The document is intended to be the basis of a consultancy brief to contract suitable organisations or individuals to conduct the rapid appraisal of candidate wetlands and the ongoing monitoring programme.

The document will provide the MDBC with a tool to:

1. assess the suitability of selected permanent wetlands for temporary disconnection as part of the drought contingency measures.
2. assess if a wetland is a critical drought refuge.
3. determine if a wetland is being significantly degraded as a result of the disconnection and associated drawdown. The ongoing wetland monitoring programme will have inbuilt triggers that initiate action to intervene in the drawdown if it monitoring reveals significantly degradation.

The knowledge generated by this project will provide the MDBC with a documented, scientific and defensible means of prioritising wetlands for temporary disconnection

Important Considerations

This document does not take into account permits, legislative and statutory requirements that may apply to implementation of this monitoring program.

Operators need to develop their own safety procedures in accordance with the OHS policies of their employers or companies.

Part A: Pre-disconnection Surveys

Objective:

Assess the suitability of selected permanent wetlands for temporary disconnection as part of the drought contingency measures.

General observations and parameters to record:

An initial inspection of each wetland should be used to identify major habitat types (e.g. emergent, submerged, and overhanging vegetation, and rocks, woody debris, open water, inlet/outlet channels and bare bank). This information should be recorded on a map or line drawing of the wetland. Sampling sites within wetlands should be selected based on these characteristics to ensure representative habitats are sampled.

The map datum WGS 84, and the position format UTM/UPS should be used for recording GPS locations of all sites.

In addition to standardised photo-points, additional photos of anything unique or interesting about the wetlands should be taken.

The prevailing weather conditions e.g. Temperature (cold, mild, warm, hot), Wind speed (calm, light breeze, breezy, windy); cloud cover (0-25, 25-50, 50-75, 75-100%); Rain (none, drizzle, shower, rain), at the time of sampling should be recorded.

Record the names and respective agencies of field personnel undertaking the survey.

Methods:

In-situ Water quality

The following sections are adapted from Baldwin et al., (2005).

◊ *Important Considerations:*

The data collected in the assessment of water quality is essential for the assessment of acidification potential.

Standard water quality parameters: electrical conductivity (μs cm^{-1}), pH, and turbidity (Secchi depth, cm); water temperature (°C), and dissolved oxygen (DO, mgL^{-1}) shall be recorded at each wetland. These parameters can be measured using individual, parameter specific equipment, however for convenience and logistical purposes, it is recommended that operators use a pre-calibrated multi probe unit such as a Horiba, Quanta-Hydrolab or TPS water quality meter.

Water quality measurements should be made at a minimum of 3 sites within each wetland. Sampling sites within wetlands should be selected based on characteristics such as depth, inlet and outlet channels open water zones to ensure measurements are representative of the range of habitats present.

Thermal and salinity stratification can exist in some wetlands. Considerable differences in parameters such as DO can exist between surface and bottom waters as a consequence of temperature or salt induced stratification. Consequently, at each site within the wetland where water quality is recorded, at least two measurements of each parameter should be taken; one from near the surface (about 0.2m below the surface) and one near the bottom of the water body (about 0.2m above the sediment).

Key water quality parameters such as temperature, dissolved oxygen and pH can vary diurnally. Therefore, the time of measurement should be recorded. Any subsequent measurements should be taken at the same time of day wherever possible. Measurements taken in the early morning can be anticipated to reflect minimum dissolved oxygen concentrations as oxygen is consumed by heterotrophic metabolism overnight. Measurements taken in the afternoon are more likely to capture peaks in temperature, but can also be expected to capture variations in factors such as dissolved oxygen and pH that are influenced by photosynthetic activity of phytoplankton and submerged aquatic vegetation.

Electrical Conductivity (salinity)

(Adapted from Baldwin et al., (2005).

◊ *Background*

High salinities in wetlands can be caused by seepage of saline ground waters into wetlands or by concentration of surface waters through evaporation (Tucker 2003). Salt concentrations in excess of 1000 mgL^{-1} can begin to affect species composition in Australian wetlands and increasing salinisation is considered a long-term threat to the health of many inland wetlands (Nielson *et al.*, 2003).

◊ *Key Issues*

- What is the baseline salinity in the wetland?
- Is the salinity at a level likely to affect the wetland flora and fauna?

◊ *Methodology*

The standard method for determining electrical conductivity is based on APHA 2510 B, which can be adapted for field measurements.

This method requires a field based conductivity meter with a range of at least 0 – 50,000 $\mu S\ cm^{-1}$ at 25°C, a resolution of 1 $\mu S\ cm^{-1}$ at 25°C for conductivities less than 5,000 $\mu S\ cm^{-1}$ and an accuracy of at least 1% or 1$\mu S\ cm^{-1}$, whichever is greater. The meter must be calibrated to the range expected for the water body and used according to the operating instructions. Operators should also refer to the standard operating procedures of their relevant agencies.

Electrical conductivity measurements are temperature dependent. Therefore, if the conductivity meter is not equipped with a temperature sensor, a calibrated thermometer will also be required. Record (i) temperature and (ii) whether conductivity values have been standardised to 25°C. If the conductivity meter does not automatically correct for temperature, this will need to be done manually. The electrode should be rinsed with deionised water between measurements.

Water Column pH

(Adapted from Baldwin et al., (2005).

◊ *Background*

pH in natural waters usually falls within the range of about 6-9. Measured pH outside this range may indicate unusual processes. Low pH may be caused by high organic loads ('blackwater' – Barmah Millewa Forum, 2001) bacterial process (e.g. nitrification or sulphate reduction or oxidation of sulfidic sediments) (McCarthy *et al.*, 2006; McCarthy *et al.*, 2003). High pH may be caused by some bacterial processes (e.g. denitrification) or accelerated algal growth (e.g. algal blooms - (McKelvie 2002)); with the latter showing potentially large diurnal changes.

◊ *Key Issues*

- What is the baseline pH in the wetland?
- Is the pH at a level indicating susceptibility to acidification or at a level likely to affect the wetland flora and fauna?

◊ *Methodology*

pH measurements can be made accurately and reproducibly in the field using a glass electrode. Standard methods for measuring pH include APHA standard method APHA 4500 – H+ B and Australian Standard AS 2300.1.6 – 1989. Operators should also refer to the standard operating procedures of their relevant agencies.

This method requires a field portable pH meter with in-built temperature compensation and an accuracy of at least 0.1 pH units, attached either to both a glass and reference electrode or a combination electrode. The meter must be calibrated (including slope response and junction potential) to the range expected for the water body and used according to the operating instructions. The electrode should be rinsed with deionised water between measurements.

Water Clarity

(Adapted from Baldwin et al., (2005).

◊ *Background*

Light penetration (clarity) is one of the principal controls for determining primary productivity in wetlands. The clarity of the water is dependent on the amount of material (including clays, other inorganic matter, organic matter and algal and bacterial cells) that is either dissolved or suspended in the water column.

◊ *Key Issues*

- What is the baseline turbidity in the wetland?

◊ *Methodology*

The primary options (which are related but not necessarily interchangeable) for determining the optical properties of water are turbidity (measuring the degree of light scatter turbidity), and visual index of light penetration (secchi disk). There are Australian Standards for the construction and use of a secchi disk (AS 3550.7). American Public Health Association (1998) describes standard techniques for determining turbidity (APHA 2130 B).

Turbidity should be measured using a field portable turbidity meter with a range of 0-1000 NTU. The meter must be calibrated to the range expected for the water body and used according to the operating instructions. The electrode should be rinsed with deionised water between measurements. If the turbidity of samples exceeds 1000 NTU, the samples should be diluted by a known ratio with deionised water in order to obtain a turbidity reading within the range of the instrument. The recorded value must then be corrected for the dilution factor. Although it is preferable to measure turbidity *in-situ*, samples can be stored for up to 24 hours before analysis in the laboratory (AS 5667.1). Alternatively, turbidity can be measured either using a nephelometer (turbidity meter) or turbidity tube. An additional alternative is the measurement of light penetration using a secchi disk.

Dissolved Oxygen

(Adapted from Baldwin et al., (2005).

◊ *Background*

The saturation concentration of oxygen in water is typically in the range of 7-10 mgL^{-1} depending on the water temperature. However, the dissolved oxygen concentration can be substantially higher (due to phytoplankton/macroalgae photosynthesis) or lower (due to phytoplankton/macroalgae respiration and or heterotrophic metabolism of organic material. Low oxygen levels can be detrimental to many higher organisms and changes in oxygen concentration can affect the way nutrients cycle in a water body.

◊ *Key Issues*

• What is the baseline level of dissolved oxygen in a floodplain water body?
• Is there sufficient dissolved oxygen to support aquatic organisms such as fish and invertebrates?

◊ *Methodology*

Dissolved oxygen concentrations can be determined chemically using a Winkler titration (APHA 4500-O B). However, electrochemical measurements using a membrane electrode and meter (APHA 4500-O G) are simpler and more convenient for field monitoring. Operators should also refer to the standard operating procedures of their relevant agencies.

It is preferable to measure the oxygen concentration *in situ* rather than taking a discrete sample and then measuring it. Consequently, dissolved oxygen should be measured with a field portable oxygen meter with a range of 0 - 20 mg L^{-1}. The meter must be calibrated and used according to the operating instructions.

Electrode response is dependent on salinity so it is important that electrical conductivity is measured and recorded at the same time as dissolved oxygen. Record (i) EC and temperature and (ii) whether dissolved oxygen measurements have been automatically corrected for salinity and temperature. If not, this will need to be done manually (It is preferable to have an instrument that compensates for both temperature and salinity automatically). The electrode should be rinsed with deionised water between measurements.

Blue-Green Algae

(Adapted from Baldwin et al., (2005).

◊ *Background*

Phytoplankton are an important element in the ecology of wetlands and floodplain lakes. Cyanobacteria (Blue-Green algae) are a naturally occurring phytoplankton, usually represented in low cell concentrations. However, the generation of blooms of cyanobacteria can be problematic for the environment and human health, particularly when toxin producing strains are involved.

◊ *Key Issues*

- What BGA species are present, and in what abundances prior to disconnection of the wetland?

◊ *Methodology*

Analysis of phytoplankton species should be performed by trained and experienced staff. Submission of collected samples to NATA accredited laboratory for analysis is recommended.

For shallow wetlands, a grab sample (~250mL) should be taken from 0.5m below the water surface. Depth integrated samples should be collected from deep wetlands. Samples should be kept cold (not frozen) and preserved with Lugol's solution for identification and enumeration.

Acidification Potential

◊ *Background*

The following two paragraphs are extracts from Baldwin *et al*. (2007) (see references in that paper),

"*Sulfidic sediments form when sulfur compounds are reduced to sulfide by anoxic bacteria in the presence of organic carbon, and the sulfide reacts with metals in the sediment (predominantly iron) to form sulfidic minerals such as iron pyrite (Roden and Edmonds, 1997). Sulfidic sediments can adversely affect aquatic ecosystems because dissolved sulfides are toxic to aquatic organisms (e.g. Postgate, 1984), and high levels of sulfate reduction can produce noxious odours (Lamontagne et al., 2004). Furthermore, oxidation of reduced sulfidic sediments (e.g. through exposure to the air) can produce anoxia and increased levels of acid, which can be flushed into the water body and cause harm to aquatic organisms (Sammut et al., 1993). In a recent survey of 81 wetlands in the Murray-Darling Basin, more than 20% had evidence for the presence of sulfidic sediments at levels that could lead to ecological damage (Hall* et al. *2006).*

Implementing a drying phase in wetland management is increasingly common (Casanova and Brock 2000), but if sulfidic sediments are present, drying can oxidise sulfidic minerals and generate acid (actual acid sulfate soils). For example, the partial drawdown of a wetland in western NSW resulted in an extensive fish kill because of exposure and oxidation of sulfidic sediments leading to acidification (McCarthy et al. 2006). Many of the wetlands identified with sulfidic sediments had been inundated for extended periods of time, either because of river regulation, elevated groundwater levels and/or because they are used as disposal basins for water of poor quality. Conversely, reduced sulfur species tend not to build up to harmful levels in wetlands that have frequent (annual) wetting and drying cycles."

The following information is adapted from Baldwin *et al*. (2005) and Baldwin *et al*. 2007:

◊ *Key Issues*

- Is the wetland at risk due to factors such as the presence of sulfidic sediments, pH, salinity etc?
- Will changes in hydrology affect the oxidation of sulfidic materials

◊ *Methodology*

Water Quality
Record the colour and appearance of the wetland water and presence of floating debris or biological films on the water's surface (in particular, those of rust- or orange colouration). Water quality data from the measurements of water column conductivity (µS cm-1), and pH, are required for assessment of acidification potential.

Water Sampling
At the three locations where the standard water quality parameters (see section above) are measured, collect a 500mL water quality sample (total for each wetland = 3) in pre-washed PET containers. Label the containers with the appropriate information (wetland, site, sampling date, and name of staff collecting samples). Immediately upon sample collection, preserve the water sample via the addition of 2mL of 1M zinc acetate solution. The sample should be placed on ice in an esky and frozen as soon as practicable. Upon return to the laboratory, the samples should be kept frozen until analysis.

Sediment Sampling
At the three locations near where the standard water quality parameters are measured, at a point approximately 0.5m back from the water's edge, use a shovel to dig a hole approximately 0.3m down into the soil profile. Record any evidence of sulfidic sediments (e.g. red oxidised surface layer overlying black sulfidic sediment). Using the shovel, obtain a clean 0.3m deep sample of the soil profile and transfer it into a zip lock bag. Label the container with the appropriate information (wetland, site, and sampling date). The sample should be placed on ice in an esky. Upon return to the laboratory, the samples should be kept refrigerated until analysis.

Water sample analysis
It is recommended that samples be analysed for water column sulphate concentration using the turbidimetric method at the Wodonga MDFRC (NATA accredited) laboratory (following, Rayment and Higginson 1992).

Sediment Analysis
It is recommended that the analysis for sediment conductivity and pH be undertaken by the Wodonga MDFRC (NATA accredited) laboratory. However, a brief description of the method is outlined below (based on Rayment, GE & Higginson, FR 1992, Australian Laboratory Handbook of Soil and Water Chemical Methods. Inkata Press, Melbourne, Australian Soil and Land Survey Handbook, vol 3).

Sediment conductivity and pH is measured as the electrical resistance and pH of a 1:5 soil:deinoinsed water suspension. The pH can be determined on the same soil suspension prepared for the measurement of electrical conductivity. However, because there is leakage of KCl from the pH reference electrode, the electrical conductivity must be measured first. The conductivity and pH meters and electrodes must be calibrated and used according to the operating instructions.

Air dry sediment samples and homogenise (e.g. grind in a mortar and pestle to pass through a 1 mm sieve). Prepare a 1:5 soil:water suspension by weighing 10 g air-dry soil (<2 mm) into a bottle. Add 50 mL deionised water. Mechanically shake at 15 rpm for 1 hour (to dissolve soluble salts). Stir these solutions with a mechanical stirrer during measurement. Rinse the conductivity (EC) probe with deionised water. Place EC probe electrode in sediment/soil suspension and record the conductivity. Immerse the pH electrode into the soil suspension. Record the pH value obtained when the equilibrium is reached. Rinse the probes with deionised water between samples.

Acidification Potential Assessment:
Use the Decision-Support Scheme (Fig. 1) from Baldwin *et al*. (2007) to determine the acidification potential for individual wetlands. Sites that exceed the water quality guidelines or other trigger points have a high likelihood of containing sulfidic sediments. Wetlands that are at risk of acidification and salinisation should not be considered for disconnection. If the site is deemed to be a priority site for disconnection, a full assessment for the presence of sulfidic sediments must be implemented before initiating a drying cycle (per Baldwin et al., 2007).

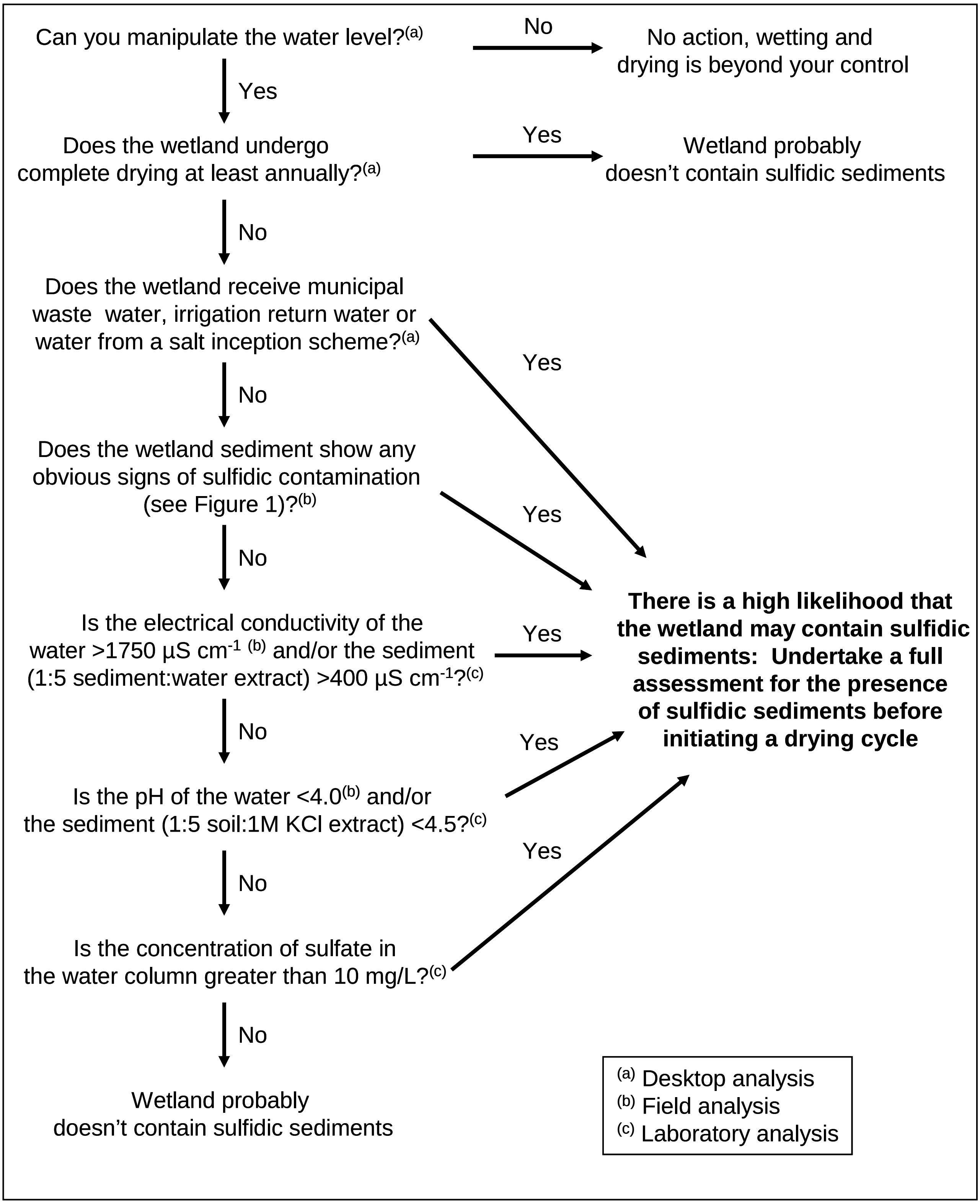

Figure 2. Decision-support scheme developed by Baldwin et al. (2007) for initial assessment of the likelihood that an inland wetland contains sulfidic sediments at levels that could cause ecological damage (reproduced with permission).

Groundwater

◊ *Background*

Groundwater level and salinity is a major factor influencing vegetation condition and acidification potential. Reducing hydraulic head on the groundwater system by disconnecting wetlands that have shallow-depth to groundwater may result in intrusion of saline groundwater into the wetland, potentially inducing salinisation and acidification (McCarthy *et al*., 2003). Not all wetlands under consideration will have pre-existing groundwater bore networks, but at those that do, monitoring of level (and salinity) should be undertaken.

◊ *Key Issues*

- What is the depth to groundwater pre-disconnection?
- Does the depth to ground predispose the site to groundwater intrusion?

◊ *Methodology*

Groundwater levels need to be correlated to surface water levels for variations in level to be interpreted. Consequently readings of surface water level gauges installed and surveyed to AHD should be included. Operators should refer to the standard operating procedures of their relevant agencies. However, groundwater monitoring and evaluation should conform to Murray-Darling Basin Groundwater Quality Sampling Guidelines (Groundwater Working Group, undated-available directly from the Murray-Darling Basin Commission).

Wetland and terrestrial plant assemblages

◊ *Background*

Vegetation is a primary feature of wetland ecosystems providing habitat and influencing factors such as primary and secondary production, soil stability, nutrient cycling and water quality (Baldwin *et al*., 2005). As the distribution and abundance of wetland vegetation is strongly influenced by hydrology, alterations to wetting and drying cycles are likely to impact on these assemblages and consequently ecosystem function (*e.g.* nutrient cycling, soil condition, provision of food resources and structural habitat).

It should be noted that assessment of species composition in autumn or winter will complicate analysis of data as senescence of annual plants can (i) complicate identification and (ii) cause underestimation in species counts (Baldwin et al., 2005).

Understorey (non-woody vegetation)

◊ *Key Issues*

- Are rare or threatened plant communities present?
- What is the abundance and distribution of plant species (including weed and invasive species) prior to disconnection?

◊ *Methodology*

Quantitative vegetation surveys will follow the procedure developed by Nicol and Weedon (2006) for the South Australian component of the Chowilla Floodplain Icon Site. This procedure has subsequently been implemented at the Victorian (Lindsay-Mulcra-Wallpolla) component of the Chowilla Floodplain Icon site and at the Hattah Lakes Icon Site (Scholz *et al.*, 2007).

Optimum quadrat size will be determined by assessing species area curves obtained from adjacent 1 x 1 m quadrats at each elevation. Assessments undertaken on the Chowilla Floodplain suggests that 15 x 1 m quadrats are likely to suffice (Nicol and Weedon 2006). However, to ensure representative sampling occurs, 20 x 1m should be used.

At each wetland, depending on size, establish up to four sites (spaced as widely as possible e.g >500m apart around the perimeter of the wetland). The initial inspection of the wetland should be used to identify substantial differences in vegetation functional groups and community distributions. If distinct communities exist, this should be taken into account when locating sites. At each site, four transects (comprised of 20m x 1m quadrats) spatially separated by 50m will be surveyed. Transects are to be arranged in a straight line, with each of the replicate transects running perpendicular to the wetland (Figure 2). Quadrats within each transect are to be established at 0 cm (the standing water level at the time of sampling), +30cm and +60 cm to survey the riparian vegetation. One quadrat per transect will also be established at 30 cm and 60cm below the water (or the deepest point if the depth is less than 30 cm). Transect elevation should be determined using a laser level or similar surveying device.

The location of all quadrats will be recorded by GPS and should be permanently marked with a hardwood survey peg (e.g. 2 x 2 x 30cm) labelled with the transect #. It should however be noted that survey pegs are susceptible to vandalism and or theft.

Systematically proceed down the transect recording the presence/absence of each plant species that has live roots within each 1 x 1m cell to complete each 20m x 1 m quadrat and a score out of 20 for respective species. In addition to vegetation, bare earth and coarse woody debris are to be included as taxa (and given a score of one for each respective cell). Species abundances will be determined by frequencies, with each quadrat divided into 1 x 1 m cells and the presence or absence of species in each noted.

Plants should be identified to species level using appropriate taxonomic keys (e.g. Cunningham *et al.* (1981), Sainty and Jacobs (1981), and Romanowski (1998). It is important to collect representative voucher specimens (or high high-resolution digital photographs) of plant species that the operator is not familiar with which should then used to develop a reference collection or be lodged at a herbarium. A trained plant taxonomist should verify all identifications.

◊ *Data Analysis*

A complete species list identifying rare, threatened, exotic and invasive plant species should be presented.

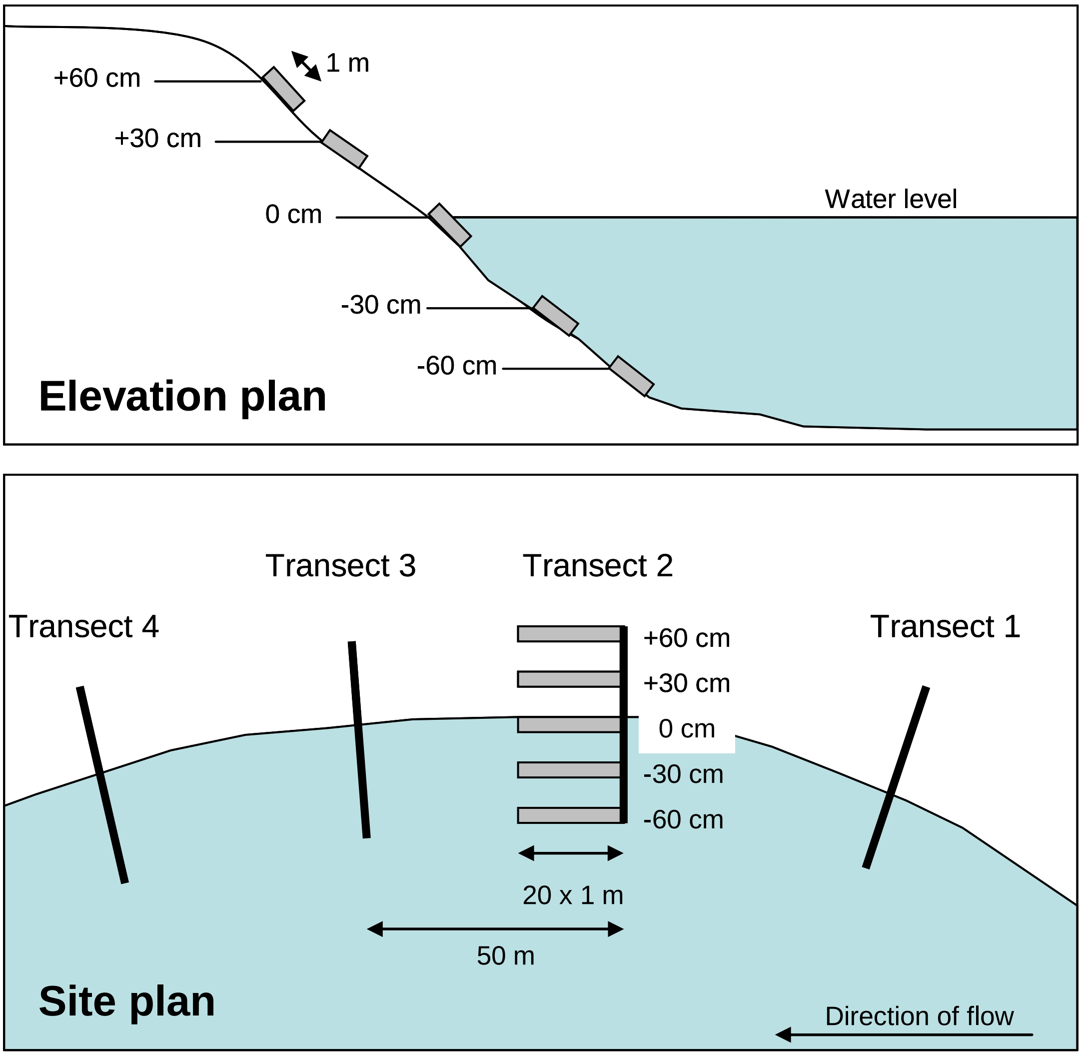

Figure 2. Elevation and plan view of transect layout for vegetation monitoring in permanent wetlands (Figure courtesy Oliver Scholz).

River Red Gum & Black Box condition

◊ *Background*

The following three paragraphs are extracted from Scholz et al., (2007) (see references in that paper).

River red gums (*Eucalyptus camaldulensis* Dehnh. Myrtaceae) (RRG) play an important functional role within floodplain and wetland systems through their provision of carbon (e.g. leaf litter) and habitat for a range of aquatic and floodplain fauna (*e.g.* Briggs and Maher 1983, Briggs *et al.* 1997, Baldwin 1999, MDBC 2003a). During extended periods of drought, RRGs may become increasingly reliant on access to groundwater using deep tap roots (Zohar 1985, White *et al*. 2001). Where such resources are not available or are saline, RRGs may reduce their water requirement by shedding leaves, thereby reducing transpiration rates (*e.g.* Thorburn *et al.* 1994, Thorburn and Walker 1994, Roberts and Marston 2000, MDBC 2001). Whilst such responses by individuals to short-term water deficits are often non-lethal and reversible, little is currently known of the cumulative impact of longer dry spells on the resilience of RRGs.

Black box (*Eucalyptus largiflorens* F. Muell.) (BB) typically form open woodlands on floodplains and fringing ephemeral and intermittent wetlands and water courses. BB differs from RRGs in being less tolerant of flooding but more tolerant of prolonged dry conditions. Hence BB woodlands tend to occur higher on the floodplain than RRGs and would naturally (*i.e.* prior to regulation) have been subject to only extremely infrequent incidental shallow flooding from major events if at all (Roberts and Marston 2000, White *et al.* 2003).

Definitions of tree 'health' or 'condition' vary considerably depending on user context (*e.g.* timber harvest, water catchment services, carbon sinks, wildlife habitat *etc.*). Field surveys have been used to assess RRG (and black box) condition within the Lower Murray River floodplain (*e.g.* Lane and Associates 2003, 2005, 2006, MDBC 2003a,b). These assessments of tree crown condition rely on the visual assessment of individual trees using one or more subjective categorical rating scales (refer to review in Scholz *et al.* 2006). Many of the indices typically used, have not been specifically developed for assessing tree condition on lowland river floodplains, and this has resulted in limited success of this approach. However, staff from the South Australian Department for Water, Land and Biodiversity Conservation (DWLBC) and The Murray-Darling Freshwater Research Centre (MDFRC) have recently (2005-07) been investing considerable resources into developing a robust, standardised field methodology specifically for assessing tree condition on lowland river floodplains.

Where present immediately adjacent to wetlands the condition of RRG and BB should be evaluated.

◊ *Key Issues*

- What is the baseline condition of riparian trees prior to disconnection?

◊ *Methodology*

The methodology (unpublished) of assessing red gum condition is based on a series of visual assessments of certain characteristics for individual trees. Each assessment is made against a hypothetical reference condition of the given tree if it was in full 'health'. The parameters defined in the methodology are; bark condition, canopy cover, new growth, canopy density, reproductive status, leaf condition, mistletoe load, and diameter at breast height. This technique was developed with the intention of having a simple, repeatable methodology for condition monitoring, that has an additional suite of parameters that can be included (*e.g.* during periods of intervention monitoring or for areas of specific interest) to complement the data collected during condition monitoring. The three primary parameters suitable for monitoring of tree condition at wetlands under consideration for disconnection are; (1) bark condition, (2) canopy cover, and (3) new growth. Diameter at breast height should also be recorded. The methodology to be used is detailed below.

Decide on location and numbers of transects to be established based on size of wetland and the number of trees present. Where possible, a minimum of 2 transects, each comprised of 30 trees should be used. Where possible, each transect should be more than 500m away from the next nearest transect.

Select the starting point for the transect in a location where 30 mature trees (DBH > 10 cm) are readily accessible. Trees shall be numbered 1 to 30. GPS locations of individual trees shall be recorded. Where practicable (and permissible) trees should be temporally marked to aid repeatability of transects. Two options for marking the trees are (i) flagging tape and (ii) plastic tags (e.g cattle/sheep tags). Flagging tape is less invasive, but previous experience has shown this to approach to more susceptible to vandalism and less durable. Fitted tags should denote (marked with permanent marker such as paint pen) the transect location code tree #, and be located at head height on a consistent side of the tree that is easily approachable for the transect. Failure to accurately identify individual trees compromises the ability to assess (i) the impact of disconnection on individual trees; and (ii) the influence of pre-existing tree condition on response to wetland disconnection.

Using the methodology outlined below, assess the individual condition of the 30 trees within each transect. Observers should record wetland site, transect #, date, and GPS location of each individual tree. Observers should also record the GPS location, approximate number and condition (% healthy, stressed, dead) of stands of saplings (saplings >3 m high but < 10 cm DBH, saplings 0.25 – 3 m high and seedlings (< 0.25 m high) within the transect.

1. Bark Condition

Long term dead trees (Fig 3.A) have no bark and have lost all of their medium and fine branches. Very stressed trees have cracked bark, deep vertical cracks in the bark, that expose the heartwood (Fig. 3.B and 3.C). Trees with cracked bark have generally lost all of their leaves or only have dead leaves (see Table 1.1 for ranking).

2. Canopy Cover

Canopy cover is a measure of the spatial extent of the tree canopy (see Fig. 4). Canopy cover is assessed as the extent to which the existing canopy fills the hypothetical full extent of the canopy structure (see Table 1.2 for ranking). It is important to note that old trees may have substantial gaps in the canopy as the canopy structure (branches) spread apart.

3. New Growth

Records the presence of new growth, either new leaves, or epicormic growth (see Fig. 5), and is measured as the spatial extent of new or epicormic growth on the branches and trunk (see Table 1.3 for ranking).

4. Diameter at Breast Height

Record the diameter of the tree at 1.2m above the ground.

Table 1.1: Assessment of bark condition.

Category	Description and Range
0	Long Term Dead (no bark or fine branches)
1	Cracked Bark
2	Intact Bark

Table 1.2: Assessment of canopy condition.

Category	Description and Range	% Cover
0	No canopy or sparse dead leaves (near dead)	0%
1	Full or substantial canopy of dead leaves (near dead)	0%
2	Sparse canopy of live leaves (highly stressed)	<10%
3	Minimal Cover (stressed)	10-25%
4	Moderate Cover (moderately stressed)	26-75%
5	Full Cover (healthy)	75-100%

Table 1.3: Assessment of New Growth

Category	Description and Range	% Cover
0	None	0%
1	Sparse	<10%
2	Minimal Cover	10-25%
3	Moderate Cover	26-75%
4	Dense Cover	75-100%

Figure 3. Assessment of bark condition [A] Long-term dead tree (Category = 0); [B] & [C] Cracked Bark (Category = 1).

Figure 4. Assessment of canopy condition [A] No canopy or sparse dead leaves (near dead, Category = 0); [B] Moderate Cover (stressed, Category = 3); [C] Full Cover (healthy, Category = 5).

Figure 5. Assessment of new growth [A] Dense cover (Category = 4).

Fish Community

Note: Ethics approval and appropriate licences for fish sampling will need to be obtained prior to sampling.

◊ *Background*

Fish represent an integral component of wetland systems. Wetlands often contain substantial numbers of rare and threatened species (Smith and Fleer 2007).

◊ *Key Issues*

- What is the species diversity and abundance of the total fish community?
- What is the diversity and abundance of rare and threatened species?

◊ *Methodology*

Site selection within wetlands

Identify major habitat types (e.g. emergent, submerged and overhanging vegetation, rocks, woody debris, shallow/deep, open water, and bare bank) and obvious variations in hydrology (inlet-outlet channels). Based on these observations of habitat diversity, sampling should occur in geographically, morphologically and or hydrographically discrete sections within individual wetlands in order to maximise the diversity of fish species and life stages (intervals) sampled. A description of the habitat where the fishing effort (active and passive) is targeted, and the relevant GPS co-ordinates shall be recorded.

Between wetlands, sites should be selected with a view to standardise fishing effort across specific habitat types. This will improve the capacity to make local and regional comparisons between fish communities and fish-habitat preferences.

◊ *Sampling gear:*

The following methodology is adapted from Richardson et al., (2005) and Baldwin et al., (2005).

Effective sampling of wetlands requires a combination of active (e.g. electrofishing) and passive (e.g. fyke nets) techniques.

- ***Active Fishing - Electrofishing:***

Either boat or backpack electrofishing can be used depending on the size, depth and ease of access of the wetlands to be sampled. Efficiency of electrofishing will also be constrained by factors such as the turbidity and salinity of the water column.

Boat electrofishing should be used in large, deep wetlands where access permits. Backpack electrofishing should be used in small shallow wetlands where it is not practical to use a boat. A minimum of 8 (preferably 12) electrofishing shots should be performed at each site, with a minimum of 2 minutes between each shot. Boat electrofishing shots should be of 90 second “power on” time. Each boat electrofishing shot should attempt to cover approximately 300-400 m of bank habitat. Backpack electrofishing shots should be of 150 second “power on” time.

Electrofishing shall be carried out in accordance with the *Australian Code of Electrofishing Practice* (Anon. 1999). All electrofishing operations must be carried out under the supervision and control of a Senior Operator who has been awarded a Certificate of Competency in Electrofishing Procedures and Safety for the particular type of equipment being used.

- ***Passive Fishing - Small fyke nets:***

A minimum of four small fyke nets (SFN) shall be used to sample the small bodied fish at each wetland. SFN have dual wings (each 2.5 m x 1.2 m) with a first supporting hoop (∅ = 0.4 m) fitted with a square entry (0.15 m x 0.15 m) covered by a plastic exclusion grid with rigid square openings (0.05 m x 0.05 m). SFNs have a stretched mesh size of 2 mm.

- ***Large fyke nets:***

Where active (electrofishing) techniques are not viable (due to factors such as depth, turbidity, salinity, access etc), a minimum of four large fyke nets (LFN) shall be used to complement the small fyke nets described above. LFN have a central wing (8 m x 0.65 m) attached to the first supporting hoop (∅ = 0.55 m) with a mesh entry (0.32 m, stretched) and stretched mesh size of 28 mm.

◊ *Sampling protocols:*

A description of the habitat where the fishing effort (active and passive) is targeted, and the relevant GPS co-ordinates shall be recorded.

For electrofishing effort, operators should record; number and duration (including power time on) of shots, electrofishing unit settings, mean depth, distance traversed in each shot, proportion of each habitat sampled.

For fyke netting effort, operators should record set and pull times (fyke nets will be set in the afternoon and collected the following morning) and depth of water.

The end of fyke nets not fitted with exclusion grids (e.g. LFN) shall be suspended above the water surface in order to allow bi-catch such as turtles and water rats to breathe if they become captured within the net.

Within wetlands, SFNs will be set parallel to the shore line; LFNs will be set perpendicular to the shoreline with the cod ends towards the middle of the wetland. Within inlet/outlet channels, nets shall be set in pairs (each pair will only represent one set of nets) obliquely to stream banks, facing upstream and downstream to assess fish movement into and out of the wetland.

For large bodied species, standard lengths (SL ±0.5 mm) should be recorded in the field. All small bodied species caught will be counted in the field. Captured fish will be identified to species level according to McDowall (1996), with the exception of the *Hypseleotris* genus, which is currently under review (Bertozzi *et al.*, 2000). All native fish will be returned live to their site of capture. Exotic fish should be humanely destroyed and disposed of in accordance with the operator’s ethics and licensing permits.

Catches will be standardised to fish per survey (survey CPUE) and fish per site (site CPUE).

◊ *Data analysis:*

Primary data outputs include the assessment of fish community species richness, variability, and diversity, total catch for a fixed level of sampling effort, recognition of any rare/threatened/endangered species, and the identification of any recent spawning events based on size frequency distributions.

Photo-points

The purpose of photo-points is to provide a visual assessment of changes in vegetation condition over time. Consistency in photographs is essential to provide a valuable observational record of trends in condition over time. A minimum of two photo-points shall be established for each wetland. The photo-points should be representative of the wetland landscape, and the locations must be clearly identifiable.

Mark the photo points by inserting a survey peg (e.g. HDPE (poly) 3 x 3 x 130 cm with a painted tip) in the ground. Label the survey peg with the site number. Insert a “sighter” peg 10m away from main peg (see Fig. X). Record GPS location. A small white board (e.g. 0.3 x 0.3m) with the wetland name, site #, and date (dd/mm/yyyy) should be placed at the base of the “sighter” peg.

Photos should be taken using a high-resolution (≥5MP) digital camera. The photo is taken from the base of the photopoint peg with a camera focus set on infinity (Fig. 6). Where possible (due to elevation and aspect) the viewfinder should centred on the sighter peg. In all circumstances the camera should be held in landscape mode 🗗. Record photo #, with reference to wetland, photopoint number and GPS location.

Blue-tooth enabled GPS and blue tooth enabled cameras, which imbed GPS coordinates into the photos and synchronise with GIS software are recommended.

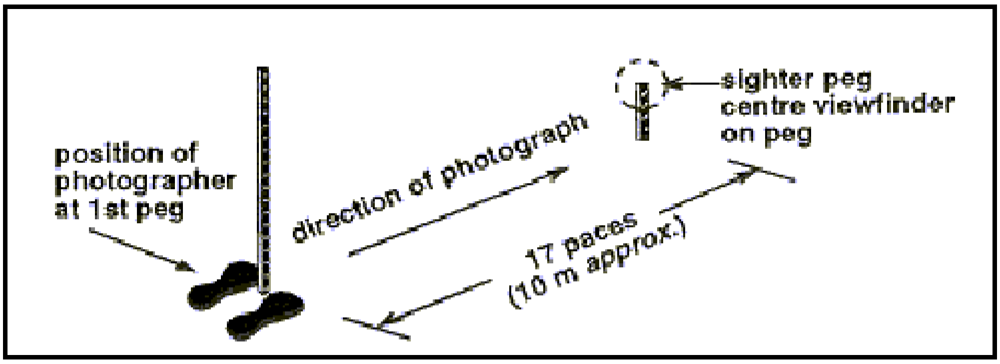

Figure 6. Position of photograph at photopoint.

Budget

Pre-disconnection survey

The estimated budget for the pre-disconnection survey is $10,219 per wetland. This budget is based on the following:

1. Fish and Water Quality Sampling requires 2 staff for 2 days including an overnight set of nets.
2. Vegetation (tree and understorey vegetation) and surface/groundwater monitoring requires 2 staff for 1 day
3. Travel is based on wetlands being located within 100km of the operational staff's base of operations (200km round trip, with 2 teams).
4. Each field team (fish and water quality; and vegetation and surface/groundwater) will be comprised of a researcher and technician.
5. 5 days for a research scientist to produce a written, site specific report.
6. It is considered likely that backpack electrofishing will be the most viable active fishing technique at most sites. Sites suitable for boat electrofishing will need to account for the additional cost of the transport and operation of the electrofishing boat, and the associated additional staff resources required to operate the electrofishing boat (total additional cost approximately $900 per day).

Table 2. Estimated budget for preliminary surveys.

Item	$
Staff Costs	
Senior Researcher	$721
Researcher	$4,768
Technician	$1,245
Field Costs	$1210
Consumables & Analysis	$625
Capital	$1650
TOTAL	**$10,219**

Part B: Ongoing Monitoring Programme

Objective:

The development of an ongoing wetland monitoring programme that is able to detect if a wetland is being significantly degraded as a result of the disconnection and associated drawdown. The programme will have inbuilt triggers that initiate action to intervene if monitoring reveals significant degradation.

General Considerations

It is anticipated that a number of potentially negative impacts (dis-benefits) may arise from the introduction of a drying phase in permanently inundated wetlands. The following sections provide a simple conceptualisation of potential responses to wetland disconnection and subsequent re-flooding as water resource availability improves. Potential risks are identified in order to (i) ensure that monitoring activities focus on key issues that could result in long-term or irreversible damage; and (ii) critically assess changes in ecological condition arising from management actions.

Sites that are identified as "critical drought refuge" and subsequently protected from drought contingency measures (e.g. disconnection) should be monitored to ensure that the wetland maintains habitat of suitable quality (e.g. depth, water quality). If habitat quality deteriorates, consideration should be given to the development of strategies for maintaining depth and/or water quality to ensure the wetland continues to function as a critical drought refuge.

Sites that are considered for disconnection but are not deliberately disconnected for reasons of logistics or environmental threats (e.g. acidification) should be monitored to ensure that long-term or irreversible damage does not occur through unintentional drying during weir pool drawdown.

A sub-set of wetlands that are not disconnected (because of role as critical drought refuges, environmental threats or logistics) can be used as control sites in order to improve capacity to determine causal effects of changes in wetland condition associated with wetland disconnection. Analytically, a range of approaches would then be available, depending on the structure of the data (Stewart-Oaten and Bence 2001). Thus, undisconnected wetlands may serve as covariates in a Before–After–Control–Impact (BACI) (model-based) approach to reduce extraneous variance and serial correlation; whereas in the absence or inadequacy of Before data, a model-based Impact Versus Reference Sites (IVRS) approach may be preferable. However, due to the actual availability of multiple prospective 'impact' sites (i.e. disconnected wetlands), a design-based (e.g. longitudinal) experimental study may be implementable, either according to traditional protocols (Downes *et al.*, 2002) or to novel ANOVA designs that take explicitly into account hierarchical and (auto)correlation structures in time (Vilizzi 2008). Finally, ecological and environmental monitoring (including identification of trigger values: cf. Part C, below) could also be achieved by the use of multivariate control charts (Anderson and Thompson 2004).

Electrical Conductivity

It is anticipated that disconnection will result in drawdown in surface water levels in the wetlands via evaporation. Evaporative processes are likely to increase salinity concentrations during the drying phase. Consequently it is anticipated that the water column electrical conductivity (salinity) will increase during the drawdown phase. This is a natural process that is not likely to induce long-term or irreversible damage in shallow wetlands that do not provide critical drought refuge. However, (i) reductions in hydraulic head on the groundwater system associated with decreasing surface water levels in the wetland may result in the influx of saline groundwater into the wetland; and (ii) salinity in deep, retaining wetlands that are considered to provide critical drought refuge may increase beyond threshold levels for many biota.

- *Risks*
  1. Due to groundwater intrusion, water column salinity may increase beyond levels normally associated with evaporative processes.
  2. Water column salinity in deep, retaining wetlands may increase beyond threshold levels for biota

pH

Disconnection of the wetland may induce substantial changes to biogeochemical processes. If sulfidic sediments are present in the wetland, exposure of large areas of wetland sediments during a drawdown may result in the oxidation of reduced sulphur compounds and subsequent release of hydrogen ions into the water column when the wetland is re-flooded. This process can result in acidification of the wetland, potentially resulting in long-term or permanent ecological damage.

◊ *Risks*

1. Water column pH may change (increase/decrease) during drawdown.
2. Water column pH may change (increase/decrease) during re-flooding.

Dissolved Oxygen

The oxidisation of organic matter in aquatic systems by bacteria and fungi can generate a substantial oxygen debt and anoxic conditions in waterways. De-oxygenation of the water column via microbial degradation of natural organic material (e.g. leaf litter abscised from riparian trees, vegetation that develops (or senesces) on the wetland basin during the dry phase, sediment bound organic material etc) may occur during the re-flooding phase. Oxidisation of sulphidic sediments can also contribute to the generation of anoxic conditions. Ecological impacts of water column de-oxygenation include highly visible impacts such as fish kills, reduced growth rates, and less visible impacts such as disruption of endocrine systems (Wu *et al.*, 2003), embryonic development in fish (Shang and Wu 2004), and degradation of aquatic macroinvertebrate communities (Walsh *et al.*, 2001). Under anoxic conditions, dissolved organic nitrogen may be metabolised to ammonia and nitrate (Harris 2001), and sediment-bound pollutants such as phosphorus may be remobilised into the water column (Laws 1993; Martinova 1993), potentially increasing the concentration of nitrogen and phosphorus available to support nuisance and harmful algal blooms. Long-term or irreversible impacts of water column de-oxygenation are likely to be confined to deep retaining wetlands that provide some level of ecological refuge.

◊ *Risks*

1. Dissolved oxygen concentration in the wetland may decrease during the draw down or re-flooding stage.

Blue-Green Algae

Phytoplankton are an important element in the ecology of wetlands and floodplain lakes. Cyanobacteria (Blue-Green algae) are a naturally occurring phytoplankton, usually represented in low cell concentrations. However, factors such as the establishment of stratified conditions and nutrient pulses (from sediments or inflowing water) can generate conditions conducive to phytoplankton (algal) blooms. It is considered highly unlikely that the development of a phytoplankton bloom will induce long-term or irreversible damage within shallow wetlands that are disconnected. However, phytoplankton blooms may be problematic in deep, retaining wetlands considered to provide critical drought refuge (e.g. water column de-oxygenation following bloom die off or dark respiration, toxin producing strains).

◊ *Risks*

1. Cell counts of blue green algae may increase in response to disconnection.
2. Re-flooding of the wetland may stimulate a short lived, but substantial (bloom) increase in cell counts of phytoplankton.

Groundwater

Reductions in the hydraulic head on the groundwater system associated with decreasing surface water levels in the wetland may result in changes in groundwater levels and salinity. Decreases in depth to groundwater may result in the influx of saline groundwater into the wetland. Removal of surface water may reduce any through bank or vertical recharge (and freshening) of the groundwater system. Consequently groundwater salinity may increase post disconnection.

◊ *Risks*

1. Depth to groundwater may decrease post disconnection
2. Groundwater salinity may increase post disconnection.

Hydrology

The intent of disconnecting wetlands is that reducing lateral connectivity between wetlands will reduce transmission losses of water from the system, by preventing water leaving the river channel to replace water lost from wetlands by evaporative processes. If through bank leakage occurs, disconnection of wetlands by the installation of physical barriers at wetland inlet and outlet points will be ineffective. Furthermore, groundwater levels need to be correlated to surface water levels for variations in groundwater level to be interpreted. Consequently readings of surface water level gauges installed and surveyed to AHD should be included.

◊ *Risks*

1. Due to surface water recharge through “leaky banks”, surface water levels within wetlands may not decrease post disconnection and anticipated water savings may not be realised.

Soil Condition

Key Issues:

If the wetland is at risk of acidification due to factors such as the presence of sulfidic sediments, pH or salinity of surface water or wetland sediments, or groundwater intrusion, soil pH and salinity may change markedly during either the draw down or re-flooding stage.

◊ *Risks*

1. Due to groundwater intrusion, soil salinity may increase post disconnection.
2. Due to oxidation of sulfidic sediments, soil pH may decrease post disconnection.

Wetland and terrestrial plant assemblages

The distribution and abundance of wetland vegetation is strongly influenced by hydrology. Consequently disconnection of the wetland and the associated introduction of a dry phase is likely to impact on the distribution and abundance of individual species and assemblages within the wetland. Impacts may include reduced vigour of submerged and emergent vegetation, germination of species including weeds on the receding water line. Riparian tree condition may decrease as soil water availability decreases. This impact may become more pronounced if saline groundwater rises into the root zone due to decreased hydraulic head on the groundwater system associated with decreasing surface water levels. Pre-existing tree condition may influence the response of individual trees to wetland disconnection and subsequent re-flooding.

◊ *Risks*

1. Distribution and abundance of native understorey species may decrease in response to wetland disconnection.
2. Distribution and abundance of exotic/invasive understorey species may increase in response to wetland disconnection.
3. Tree condition may decrease post disconnection.

Fish Community

Shallow wetlands are likely to dry rapidly upon disconnection and will not provide refugia for fish stranded within the wetland. Deep wetlands that maintain water of appropriate quality for extended periods (>12 months) may provide refugia to confined fish. Wetland disconnection may result in a reduction in the relative abundance and biomass of fish as water quality (e.g. dissolved oxygen, salinity, pH, temperature) and habitat availability (submerged and emergent vegetation, woody debris) decreases and predation by birds increases. Partial drawdown of deep, retaining wetlands may temporally benefit large bodied fish. i.e. if prey becomes concentrated during the isolation phase, predators don't have to expend as much energy to feed, therefore individual condition (and consequently reproductive potential) may increase. It is anticipated that this scenario would be dynamic. Shifts in water quality and trophic level composition may generate conditions that can no longer support large bodied fish, and conditions favourable to small bodied native fish may become established.

◊ *Risks*

1. Variability in the structure of fish assemblages may increase or decrease as a consequence of environmental stress or impact.

2. Relative abundance and biomass of rare/threatened small bodied fish in deep retaining wetlands may decrease due to predation by large bodied native fish or birds.
3. Water quality in deep, retaining wetlands will decline to a condition not conducive to sustaining native fish.

Methodology

Important Considerations:

Key water quality parameters that influence habitat quality for flora and fauna (dissolved oxygen, pH and salinity) should be measured during both the draw down (drying) and re-flooding (re-wetting) periods. Primary considerations for monitoring water quality should reflect the relevant statutory standards.

All sampling and assessments should be undertaken in accordance with the methods described in Part A (pre-disconnection surveys).

Where pre- and post-disconnection understorey data are available, shifts in assemblage composition should be assessed using multivariate (e.g. NMS Ordination (McCune *et al.* 2002), distance-based Permutational Multivariate Analysis of Variance (PERMANOVA) (Anderson 2001), multivariate analysis of dispersions (Anderson 2006)) and Indicator Species Analysis (Dufrene and Legendre 1997). Whereas overall species–environment relationships should be more appropriately analysed by a diversified approach, including e.g. direct gradient analyses (Legendre and Legendre 1998), uni-/multi-variate regression trees (De'ath 2002; De'ath and Fabricius 2000), hierarchical partitioning (Mac Nally 2000; Mac Nally 2002). Further, all-scale spatially-explicit structures in fish assemblage composition could also be modelled by the recent PCNM (Principal Coordinates of Neighbour Matrices) approach (Borcard *et al.*, 2004; Brind'Amour *et al.*, 2005).

Timing

Water quality should be sampled monthly during the disconnection. Fish communities should be sampled 3-monthly during the disconnection phase. Sampling should continue for 12-months after the subsequent reconnection phase.

Understorey (non-woody vegetation) should be sampled 6-monthly during the disconnection phase. River Red Gum and Black Box condition should be sampled 3-monthly during the disconnection phase. Sampling for both classes of vegetation should continue for 12-months after the subsequent reconnection phase.

Budget

Ongoing Monitoring survey

The budget for ongoing monitoring was constrained by MDBC Out-of Session Resolution 138, and it is anticipated that wetlands may be disconnected for up to 2-years. The budget is based on the following assumptions:

1. The wetland is disconnected for 18-months. This approach allows for monitoring to continue for 6-months post re-flooding allowing assessment of wetland recovery. If the wetlands are disconnected for the full 2-years or longer, the budget will need to be revised accordingly.

2. Water Quality (including sediments), groundwater and riparian tree condition sampling should be performed every six (6) weeks. This allows for recognition of decline in ecological condition and subsequent management intervention within meaningful time lines.

3. Water Quality (including sediments), groundwater and riparian tree condition sampling requires 2 technicians for 1 day, plus 1 day of researcher time to manage, analyse and interpret data.

4. The full suite of sampling described in Section A should be performed every 6 months. Given that the first sampling is covered in the baseline survey, and that sampling is expected to continue for 2 years post disconnection, 3 follow up surveys are recommended.

5. Assessment of the full suite of parameters three (3) times reduces the number of 6-weekly water quality, groundwater and tree condition sampling trips required from 17 to 14.

6. Travel is based on wetlands being located within 100km of the operational staff's base of operations.

The estimated budget is $36,253 (14 x $2,589) for 6-weekly water quality and tree condition surveys, and $22,720 (3 x $7,573) for 6-monthly repeat surveys of the full suite of parameters. Total cost for the ongoing monitoring program is therefore $58,973. This estimate is itemised in Table 3 and Table 4 respectively.

Parameters that may be anticipated to reduce the per wetland budget include; inability to utilise electrofishing equipment at individual wetlands due to site specific conditions, and reduced requirement for water quality and fish community surveys at wetlands that dry completely following disconnection.

Table 3. Estimated budget for 6-weekly water quality and tree condition surveys.

Item	$
Staff Costs	
Researcher	$894
Technician	$830
Field Costs	$525
Consumables & Analysis	$340
TOTAL	**$2,589**

Table 4. Estimated budget for 6-monthly wetland condition surveys.

Item	$
Staff Costs	
Senior Researcher	$721
Researcher	$4,172
Technician	$1,245
Field Costs	$525
Consumables & Analysis	$910
TOTAL	**$7,573**

Part C: Trigger Values and Management Responses:

Objective:

Define trigger points that initiate action to intervene if monitoring reveals significant degradation.

Protect wetlands from acidification and salinisation

Key Issues:

Sites that exceed the water quality guidelines or other trigger points outlined in the decision support network (Fig. xx) have a high likelihood of containing sulfidic sediments. Acidification may result in irreversible or long term damage to the ecological function of wetlands.

Trigger Points:

- Sites deemed to be at risk of acidification or groundwater intrusion from shallow, saline groundwater should not be disconnected.

- Water quality (pH and conductivity) should be monitored at all sites to ensure that ANZECC guidelines for water quality are not exceeded.
    - Does the salinity exceed that due to evaporation and is the increase likely to adversely affect wetland biota (e.g. >1000 mgL^{-1}) upon reinundation?
    - Is the pH at a level likely to affect the wetland flora and fauna (i.e <6)?

Recommendations:

- Maintain surface water levels in sites deemed to be at risk to acidification or salinisation.

- Re-instate inundation phase at sites beginning to show signs of acidification or ground-water driven salinisation.

Protect rare and or threatened fish communities

Key Issues:

MDBC Out-of-Session Resolution 138 states that critical drought refuges should be maintained. Consequently, managers should protect wetlands that support communities of rare/threatened fish species: These wetlands should not be considered for disconnection, particularly if they are shallow.

Trigger Points for refuge wetlands:

- If the wetland depth declines to less than 1m, consideration should be given to the development of strategies for maintaining depth to ensure the wetland continues to provide refuge.

- Wetlands will only provide refuge if water quality standards are maintained (e.g. dissolved oxygen, pH, salinity)
    - Is there sufficient dissolved oxygen (nightly minima >2ppm) to support aquatic organisms such as fish and invertebrates?
    - Are cell counts of BGA above trigger guidelines (>15,000 cells/ml)?

- Generation of BGA blooms comprised of toxin producing species.

Trigger Points for disconnected wetlands:

- The presence of large native fish after disconnection should initiate a planned relocation to a suitable refuge.

Recommendations:

- Where possible weir manipulation should be used to initiate a draw down in wetlands prior to installation of a physical barrier to fish movement. This process will provide natural cues for native fish to leave the wetland, and consequently minimise impacts on native fish communities.

- Pumping water into retaining sites should improve environmental value of refugia (e.g. improve water quality via improved dissolved oxygen levels and decreased salinity).

Protect significant vegetation.

Key Issues:

Long lived vegetation is a significant environmental asset due to the impact its loss has on wetland condition and its low resilience. Long lived vegetation is also important for habitat provision and the refuge healthy floodplain and riparian trees provide during times of drought. As a consequence one of the largest risks associated with draining wetlands will be the loss of long lived plants such as river red gum and black box.

Monitoring on the Chowilla Floodplain Icon Site associated with watering projects demonstrates condition thresholds for the recovery of River Red Gums. The results indicate that 96% of trees with intact bark and >10% canopy cover respond to the application of environmental water. However, only 78% of trees with intact bark and <10% remaining canopy, and only 16% of trees with cracked bark and <10% remaining canopy will respond to the application of environmental water (Wallace 2005).

Trigger Points:

- Wetlands supporting rare or threatened plant communities should not be disconnected.

- Site with substantial proportions of stressed trees (category 3 or less) should not be disconnected.

- Decline of tree condition from moderately stressed (category 4 - moderate canopy cover; 26-75%) to stressed (category 3 Stressed - minimal cover; 10-25%) should be viewed as trigger for management intervention.

Recommendations:

- Maintain surface water levels in sites containing high proportions of stressed trees or rare/threatened plant communities.

- Re-instate inundation phase into sites beginning to show signs of declining condition.

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