Regeneration around Lake Mokoan in March 2008

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COVER PHOTOGRAPH

Pale Knotweed *Persicaria lapathifolia* at Green Swamp, 28 March 2008

Photograph by Jane Roberts

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REGENERATION AROUND LAKE MOKOAN IN MARCH 2008

A report to the

Goulburn Broken Catchment Management Authority

prepared by

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JUNE 2008

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Executive Summary

Introduction

A passive management approach relies on ecological processes to occur, virtually unassisted or else with the minimum of intervention by managers. This approach has been suggested for the rehabilitation of Lake Mokoan and its transformation into the Winton Wetlands through regeneration of wetland plants following drawdown. Water levels at Lake Mokoan have been progressively drawn down over several years, in a series of draw-down and partly refill sequences.

Concerns about the value of this approach to the rehabilitation of Lake Mokoan were raised whilst setting up long-term monitoring in March 2008, when it was noted that none of the sites included the two target species, Southern Cane Grass *Eragrostis infecunda* and River Red Gum *Eucalyptus camaldulensis*. This report describes regeneration around Lake Mokoan and considers the likely effectiveness of passive management as an approach to its rehabilitation.

Methods

The shoreline of Lake Mokoan was divided into 12 sectors, based on aspect and slope, to organise field work and to facilitate reporting.

The shoreline around Lake Mokoan was searched for seedlings and juveniles of the two target species, Southern Cane Grass and River Red Gum as well as for evidence of regeneration in selected other species, viz: four species in family Cyperaceae, likely to occur in wetland edge communities, Poong'ort, Tall Flat Sedge, Spiny Sedge, and Drain Flat-sedge; and three species of widely-occurring and common wetland plants, Cumbungi, Common Spike-rush, Red water-milfoil. On the northern shoreline of Winton and Sargents Swamps and around most of Green Swamp, searches were done using vertical transects, stretching from well above the water line to the water line and into the water (substrate permitting). On the southern shores, a walking search was done, as slopes were very gentle.

The location of these transects, and the occurrence of the selected species plus other points of interest, were recorded using a GPS. Maps showing the distribution of transects, target species, the four Cyperaceous species and wetland plants were produced. Where relevant, elevations of waypoints were estimated using a DEM.

Searches were done in late March 2008. Searching was quite intensive and covered more than three quarters of the shoreline quite thoroughly.

Principal Findings

Southern Cane Grass: Seedlings of Southern Cane Grass were distributed quite widely around Lake Mokoan, occurring most commonly within 1 m of the waterline, but never abundant. Young plants with stolons, presumably older than the seedlings but of unknown age, were less common. Established stands of Cane Grass at occurred at much higher elevations, above 163 m. Regeneration sites for Cane Grass were typically shallow areas where water had ponded, with cracking organic clays that appeared to be 'original' wetland soils. Rhizome parts on slight mounds of grey clay, designated relict mounds, occurred around much of Lake Mokoan and were interpreted as showing former distribution of Cane Grass prior to commissioning of Lake Mokoan.

River Red Gum: Despite the extensive area searched, there was only a little evidence of regeneration (seedlings, juveniles and saplings) and this was quite localised, occurring rarely around Sargents Swamp, along parts of the northern shore of Winton Swamp, and localised to a rocky knoll around Green Swamp.

Cyperaceae: Only three of the four species were noted: no seedlings or plants of Poong'ort were seen at all. The most commonly encountered was Drain Flat-sedge, an introduced summer-growing species, and Spiny Sedge, which occurred on sandy soils around Sargents Swamp.

Wetland Plants: Cumbungi, Red Water-milfoil and Common Spike-rush tended to co-occur, but were restricted to areas with organic cracking clays where ponding had occurred.

Sediments and Soils: Soils around Lake Mokoan were quite variable. Some areas appeared to be 'original' soils, with cracking organic clays; these were typically around northern parts of Winton Swamp, and around much of Sargents Swamp. Some areas had sandy soils, especially spits and promontories in Sargents and Winton Swamps. Some shorelines showed considerable deposition, up to 30 cm in some places, suggested that considerable re-working and re-shaping of the Lake Mokoan benthos has occurred: deposition was most noticeable in Green Swamp.

Conclusions

Regeneration is occurring at Lake Mokoan but is not proceeding uniformly around the lakeshore. The two key species, Southern Cane Grass and River Red Gum, are unlikely to self-establish widely under current circumstances, but for differing reasons. Regeneration of Spiny Sedge and of common wetland plants is also occurring around Lake Mokoan but appears to be concentrated in areas with 'original' or sandy wetland soils: seedlings etc are generally in low abundance. None of these species achieve the cover or number of recession herbs such as Aster Weed, Clammy Goosefoot, or Pale Knotweed.

Regeneration of River Red Gum is also low, despite the presence of mature reproductive trees at higher elevations. Poor regeneration is tentatively attributed to the distance between these mature trees and the waterline.

Where sediments have been deposited, principally Green Swamp and southern Winton Swamp, the substrate is now flat and uniform with little surface heterogeneity and no features to trap seeds or create micro-environments.

Recommendations

Five recommendations are made, intended to improve the extent of regeneration around Lake Mokoan,

[1] Aim to maintain stable water levels at the upper limit of the Bare Ground zone, provisionally identified as about 160.4-161.0 m AHD, over autumn-winter in the coming year (2008).

[2] Commission a small field-oriented scoping study on sediments and benthos at Lake Mokoan, especially deposited sediments, in order to establish their intrinsic variability, their suitability for re-vegetation, and to obtain advice on potential management issues and problems.

[3] Develop a solid and detailed knowledge of site characteristics, spatial variability and constraints on goals, and use these to develop a series of realistic objectives.

[4] Rather than relying on passive regeneration, adopt a new strategy of building capacity for passive regeneration. Strategic planting of a species to encourage seed fall close to regeneration sites or facilitate localised seed dispersal by water is one such option. This could prove useful for both target species, Southern Cane Grass and River Red Gum.

[5] Establish role of the diversion channel, in-flowing creeks, borrow pits and farm dams as likely propagule sources, whether positive (i.e. targeted native species) or negative (undesirable, invasive and introduced species), and dispersal pathways to regeneration sites.

Acknowledgements

We would like to thank Peter Carter and Goulburn Murray Water for permission to access Lake Mokoan; David Tongway (Ecosystem Function Analysis Training), landscape ecologist, Canberra for discussions on restoration and sediments; Jenny Hale, for cheerful organisation; and Simon Casanelia, of GBCMA, for constructive project management.

[1] Introduction

Background

Lake Mokoan is to be de-commissioned, and this is expected to save 44,000 ML water annually (Beca Planning 2006). Following de-commissioning, the wetlands that have been submerged by the storage since 1970 are to be restored. De-commissioning is a gradual process, lasting some 2-3 years. According to the Future Land Use Strategy (or FLUS), the de-commissioning phase involves allowing water levels to gradually recede and ceasing diversions into Lake Mokoan, and scheduling major works such as removing part of the dam wall, fixing the outlet gates so that they remain open and removal of control structures (Beca Planning 2006).

The FLUS set a series of visionary goals for 2021 (p.32, Beca Planning 2006) and a series of 5-year targets (p.33). The visionary goal that defines the whole restoration project is:

> The restoration of the Winton Wetlands will be a project of national and international cultural and environmental significance focussed on ecological restoration of a large wetland system.

As a landscape-scale planning document, the FLUS recognised three major phases up to 2021: de-commissioning phase, up to May 2009; establishment phase, up to 2014, for achieving a reasonable level of ecological restoration; enhancement phase, to 2021 with the development of facilities. Technical and logistic details of restoring the wetlands were scoped broadly, and the strategy for wetland restoration was to be natural regeneration in the decommissioning phase (p59, Beca Planning).

> The Winton Wetlands will be allowed to restore naturally through managed drawdown of the existing lake and the regeneration of the existing native seed bank.

The vision and the proposed strategy have been accepted and management is now moving towards achieving some of the interim targets identified in the FLUS, such as the design and implementation of a monitoring program for the littoral vegetation.

This monitoring program was designed (Roberts and Hale 2007) in three distinct parts, each with specific goals, targets, hypotheses and ecological area where relevant. Thus MP_1 was for the wetland floor, and MP_2 was for the terrestrial environment up to 100% FSL. MP_3 (not strictly a monitoring program) is a mapping exercise to document extent of vegetation types and set a benchmark. In order to structure the monitoring program, Roberts and Hale (2007) generated provisional targets and objectives, as this had not been done.

The first part of the monitoring program (MP_1 Wetland Floor) was scheduled for implementation in March 2008, but could not be fully implemented as water levels were too high and the wetland floor was submerged by relatively deep water. Accordingly a program for monitoring the littoral vegetation in the Wetland Edge was set up in its place (Roberts and Hale 2008). During the course of this, it was noted that there was no instances of River Red Gum regenerating in any of the 15 transects, or in their immediate vicinity.

This observation was significant for three reasons. First, River Red Gum, along with Southern Cane Grass, was identified as a target species in the monitoring programs for wetland restoration on account of its wide occurrence and functional significance in wetland and riparian vegetation types. Second, elsewhere in inland south-eastern Australia, it is common to find instances and examples of River Red Gum regenerating prolifically, to the extent of becoming a management issue. Third, the basic assumption of the FLUS was that the wetlands would largely regenerate naturally, hence the lack of recruits is an indication that restoration as envisaged by the FLUS may need to be re-thought.

Accordingly, it was agreed with the Goulburn Broken CMA that the second monitoring program (MP_2 Disturbance effects across elevations) could be delayed for a year with no long-term harm and that a field inspection to consider regeneration around Lake Mokoan would be a more effective use of resources.

Aims

The project has two aims:

[1] To provide a snapshot overview of wetland regeneration as of early autumn (March) 2008 for three main wetlands (Winton Swamp, Sargents Swamp and Green Swamp)[1].

[2] To comment on factors influencing wetland regeneration, based on field observations.

Data collected from the field will be analysed and the digital elevation model (DEM) modified for the Monitoring program design will be used to determine observed elevations of target species.

Observations from the field, calculated elevations and ecological knowledge about the target (and other) species observed will be used to comment on environmental factors influencing regeneration of target species.

In addition, this report addresses Task [b] carried over from Roberts and Hale (2008) as being more appropriate to address this here (with agreement from GBCMA), after completing the monitoring and after completing this project. Task [b] is:

Provide water regime management recommendations based on the monitoring results.

Approach

An hypothesis-based approach to a field evaluation of an ecological process such as regeneration is a standard way of structuring an investigation, even one that is exploratory and qualitative such as this. An hypothesis-based and tightly structured approach was difficult to implement here as the knowledge needed to construct a conceptual model at a whole-of-system scale is not available.

Although there has been a considerable investment into seed bank research in Australia, there has been very little parallel investment into understanding regeneration processes around natural systems. Consequently there is very little

[1] **Note:** Ideally other wetlands should be included in this program. However, time and budget have constrained this to the three main wetlands.

theoretical basis on which to consider how factors other than water regime, such as slope, substrate and exposure, might influence regeneration likelihood or success. In addition, there is no information on bio-physical characteristics of the study area of factors relevant to regeneration, slopes and shorelines. The most recent fine resolution aerial photography for Lake Mokoan was flown in 2004. DSE advises that, based on position of water levels, the photography was probably flown in November when water levels were 163.4-163.6 m AHD. The focus for this project includes those areas submerged in 2004 and that have been exposed relatively recently, that is since January 2007, or 162.1 m AHD and below. The last time water levels fell below 162.1 m AHD was in April 1984.

The approach used here aims to sample both horizontal and vertical environmental gradients around Lake Mokoan. On wetland and lake systems, exposure and wave action (the primary drivers of horizontal gradient) have a strong influence on particle size composition and hence on the abundance and composition of edge plant communities. At any one point around a wetland or lake system, water level history (the primary driver of vertical gradient) also has a strong influence on the abundance and composition of edge plant communities. The interaction of these two gradients controls plant distribution, and can be further modified by site-specific factors such as grazing.

Vertical transects distributed around Lake Mokoan therefore seemed the most promising means of sampling this environmental heterogeneity. Although this was the planned approach, it was not possible to anticipate how many transects could be set up in the allocated time of 4 days, due to uncertainties about time required for each transect and access around Lake Mokoan.

Terminology: Lake Mokoan is not due to be de-commissioned until May 2009, and until then, it retains its function as a storage, albeit of limited volume. In recognition of this, during the de-commissioning phase, the drawndown lake and emerging wetlands are referred to throughout this report as Lake Mokoan, and the term Winton Wetlands is used to refer to the wetlands after May 2009.

On the advice of Department of Sustainability and Environment, the names Winton Swamp and Sargents Swamp are used throughout this report in preference to Winton Central and Winton West, names that were used previously (Roberts and Hale 2007).

[2] Methods

In the Field

Field Approach

SECTORS

In order to structure sampling, the shoreline of Lake Mokoan was divided into 12 sectors (Figure 1). For the most part, the shoreline was close to the uppermost limit of dead trees or the upper limit of former woodland. Thus, on the wetland side of the shoreline there was nearly always a woodland of dead trees, of variable width extending out into the water whereas on the landward side, this dead woodland was absent except for patches in Sectors 11 (Sargents Swamp), and 5 (Green Swamp).

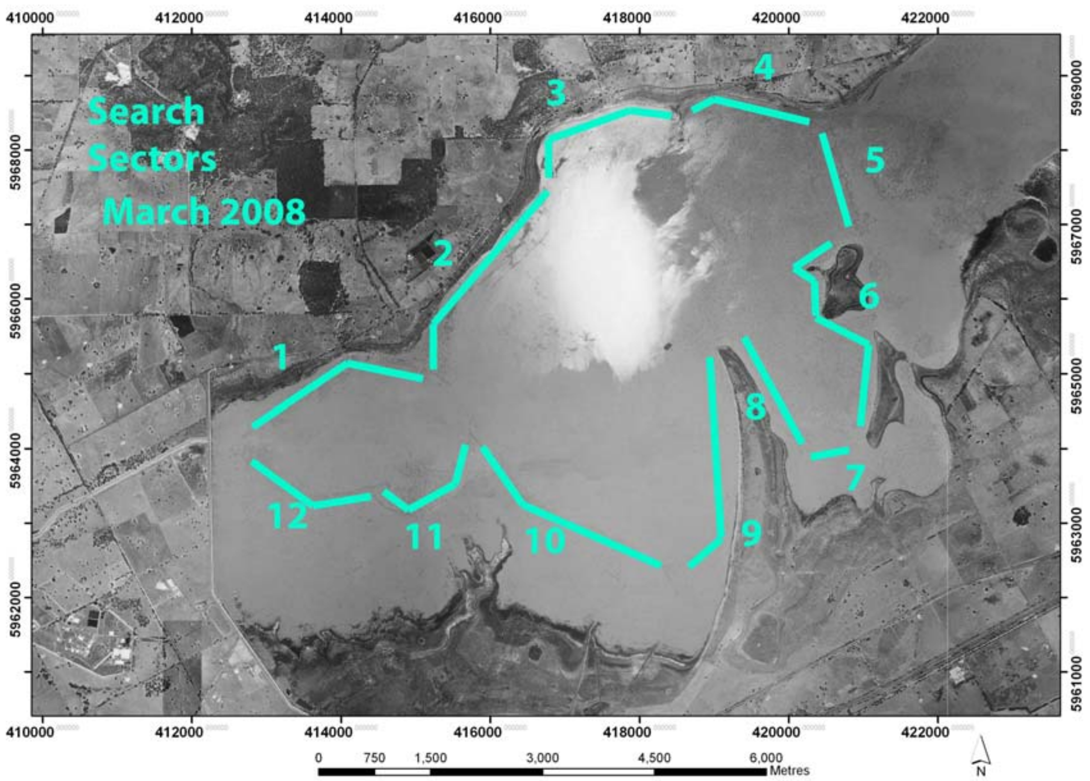

Figure 1: Sectors used to structure sampling

It was anticipated that these Sectors could prove useful in the longer term as an environmental stratification of the entire shoreline. The environmental strata are defined by aspect and slope, with slope being a subjective interpretation of maps showing modelled contours (Figure 8, in Roberts and Hale 2007). These characteristics are summarised below (Table 1). Note that:

as water levels continue to fall, the shoreline shape will change and contract, and some Sectors (notably Sector 7) are likely to be merged into adjacent ones.

Table 1: Sector Characteristics

Sector	Wetland	Aspect	Slope	
1	Sargents	south-west	moderate	
2	Winton Swamp	south-west	steep	
3	Winton Swamp	southerly	gentle	
4	Green Swamp	southerly	gentle	
5	Green Swamp	westerly	very gentle	
6	Green Swamp	west (variable)	variable	
7	Green Swamp	north-west	very gentle	
8	Green Swamp	north-east	gentle	
9	Winton Swamp	westerly	moderate-steep	
10	Winton Swamp	north-east	very gentle	
11	Sargents	north	very gentle	
12	Sargents	north	very gentle	

SEARCHES

Search techniques evolved as the study progressed, resulting in three 'methods'. The first (Vertical Search) was an immediate response to a field opportunity to record the presence of Southern Cane Grass *Eragrostis infecunda*, henceforward referred to as Cane Grass. The second (Vertical Transect) was a refinement of the first and used a more structured approach to locating search sites and to recording the search area.

For Vertical Searches and Vertical Transects, the search area was a rectangle at right angles to the shoreline, approximately 20-50 m wide, but not formally marked out. This kind of searching was suitable for short slopes with well-defined zonation patterns, such as northern shores, Green Swamp and off The Spit. Neither of these was sensible for the southern shorelines where slopes were very long, and gentle. thus third technique was used (Walking). Accordingly, the southern shoreline in Sectors, 12, 11 and part of 10 was walked, starting from the former dam wall. This search pattern therefore emphasised 'horizontal' distributions, and is referred to as Walking.

Vertical Searches: Vertical searches were done at frequent intervals, approximately every 200-400 m or when a stand of Southern Cane Grass was sighted. Two observers then searched on-foot to establish highest and lowest occurrence of Cane Grass at that site. The co-ordinates of the highest and lowest occurrences of Cane Grass were recorded, and also of patches in-between as well as other ecological observations, however as Start (highest point searched) and End (lowest point searched) were not routinely recorded, the search area was not rigorously defined.

Date implemented: 12^{th} March 2008.

Vertical Transects: Vertical transects were located to sample Sectors and within-Sector variation, with the intention of having3-4 sites per Sector. Sectors were targeted that had not been covered by Vertical Searches. The intention was to implement this more structured approach to all Sectors (i.e. replacing Vertical Searches) but this was not feasible, due to time constraints. Transects were chosen to be within relatively short walking distance of road access.

Two observers searched from a high point, well above Southern Cane Grass if present or where it was expected to be, down to the waterline. Co-ordinates were recorded of the Start (highest point) and End (lowest point, usually the waterline) of each Vertical Transect, as well as the upper boundary of each vegetation zone, the position of target species and other points of interest. For this, a zone was subjectively defined as an abrupt change in vegetation, signalling a change in species composition and structure.

Dates implemented: 25-27th March 2008.

Walking: The southern shorelines were searched on foot, leaving the vehicle parked on the dam wall. The two observers walked along the top of the shoreline, which was here relatively narrow and locally steep, stopping at points of interest, and searching more widely when required. There was one detour southwards away from the shoreline to investigate conditions away from the shoreline. The search area was thus a linear ramble, ranging in width but generally about 10-25 m wide. Recording was done as for Vertical Transects.

Dates implemented: 27th March 2008.

Incidental Log: In addition to these three deliberate searches, incidental observations were made while moving between sites or as part of setting up Wetland Edge transects (Roberts and Hale 2008), and are referred to as Incidental Log.

Notes

Field notes focused on Selected species and points of interest.

Selected Species: Searching focused on a limited number of species, selected for differing reasons.

There were two target species, as identified in the monitoring program: Cane Grass and River Red Gum. In addition, there were several species indicative of Edge and Wetland habitats: four species from the family Cyperaceae, the first three (Poong'ort *Carex tereticaulis,* Tall Flat-Sedge *Cyperus exaltatus*, and Spiny Sedge *Cyperus gymnocaulos*) chosen because these native species are likely to be part of restored Wetland Edge communities, and the fourth, which is introduced, Drain Flat-Sedge *Cyperus eragrostis,* chosen because it is so prevalent that can be interpreted as reliable indicator of favourable conditions for regeneration over summer. Finally, the list of species was extended to include three species of wetland plants noted as being important Wetland Floor species in March 2008 (Red Water-milfoil *Myriophyllum verrucosum*, Common Spike-Rush *Eleocharis acuta*, Cumbungi *Typha* spp.). The three Wetland Floor species were added while in the field because they occurred close to Cane Grass seedlings.

Points of interest: these were unplanned observations of features of possible ecological interest and included trashline, farm dams, seedlings of introduced species.

Conditions

Weather during field work was bright and cold, with occasional storms including hail storms. There had been heavy rain in the few days preceding field work.

The gauge on the Outfall channel read 160.73 m AHD on 27th March 2008.

DATA PROCESSING

Waypoints: A data matrix was prepared with co-ordinates of each waypoint, sector, type of search, and all ecological observations.

Contour line data supplied by Goulburn Broken CMA (Roberts and Hale 2007) were interpolated using a kriging algorithm into a digital elevation model (DEM). This DEM was then used to derive an elevation (m AHD) for each waypoint. This was the same DEM and method used for deriving elevations in the vegetation surveys described in Appendix 4 of Roberts and Hale (2007).

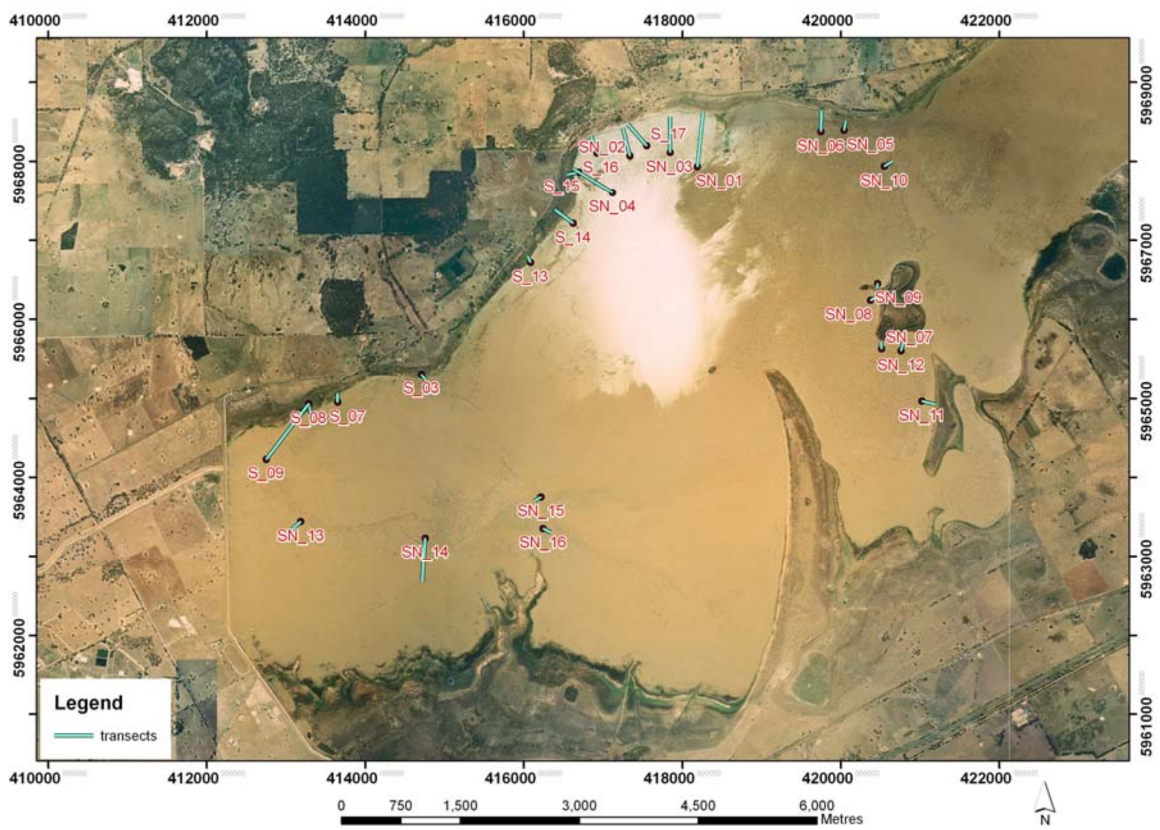

Figure 2: Vertical Searches & Vertical Transects

Map shows seven of the 30 Vertical Searches (coded S) for which Start and End of search were both recorded, and all sixteen Vertical Transects (coded SN). Blue bars indicate actual length of Vertical Searches and Vertical Transects, width is arbitrary. Walking search is not shown.

Plant Names: Common Names are used in the report. A list of all species mentioned in the text is given in Appendix 1, showing Common Names and Botanical names, ordered alphabetically by Common Name. Species names are taken from Walsh and Entwistle (1996), and Walsh and Stajsic (2007): common names are taken from the DSE/DPI Flora database.

[3] Results

Field Effort

The total field effort comprised 30 Vertical Searches, of varying intensity, 16 Vertical Transects, one walking Search, and several Incidental Logs (Figure 2).

Because the search approach developed and was refined with time, different methods were used on different Sectors. Thus Vertical Searches were concentrated in Sectors 1, 2 and part of 3; Vertical Transects were read in Sectors 3, 4, 5, 6, 10, 11 and 12; and Walking Search was used for Sectors 11 and 12, and part of 10. Sectors 7, 8 and 9 were not included due to lack of time and uncertainty in driving in the vehicle after rain to parts of The Spit. Incidental observations made during the course of other work (Roberts and Hale 2008) provided some records for Sector 9 (plotted), as well as some observations for Sector 8 and the tip of The Spit (not plotted) but no information for Sector 7. In summary, Sectors 1-3, 6, 11-12 were well-searched, Sectors 4-5 and 9-10 were partly searched, Sector 8 was not searched at all, and Sector 7 was not visited as part of any field work in March 2008.

The distribution of 216 waypoints resulting from these different searches is shown below (Figure 3), with waypoints colour-coded to show effort per wetland (Sargents, Winton Swamp, and Green Swamp) and also waypoints away from the main search areas.

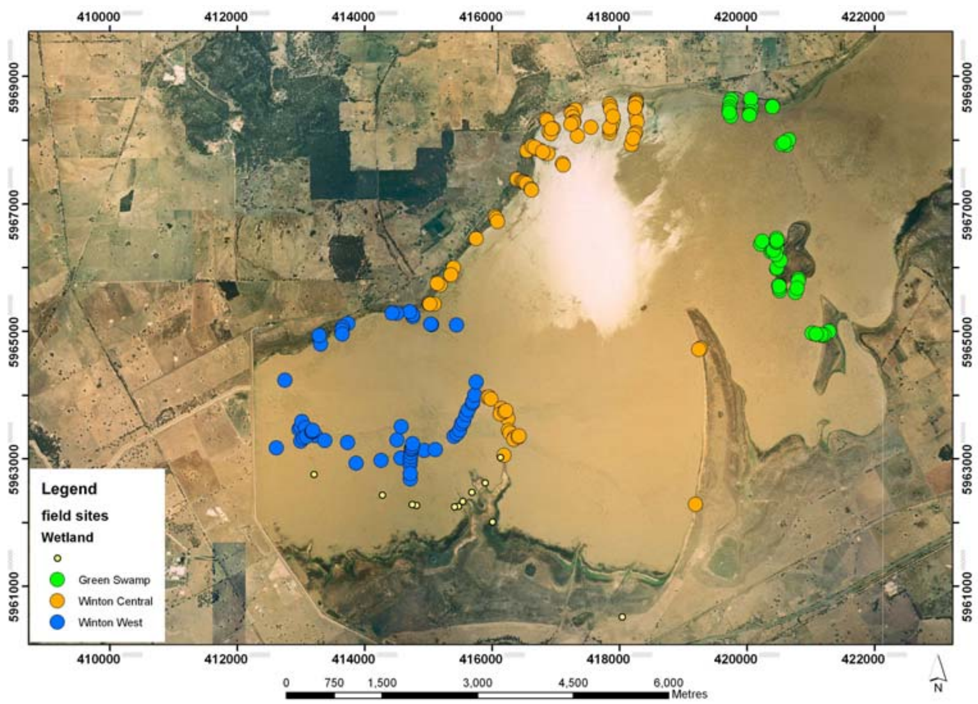

Figure 3: Field Effort, March 2008

Location of 216 waypoints, coded to show effort per wetland and indicates waypoints not associated with any particular wetland.

Zonation

Vegetation zonation was very evident on most shorelines around Lake Mokoan. On the northern shorelines (in Sectors 2 and 3 in particular, and parts of 6), five vertical zones could be easily distinguished using two well-defined bands of Plains Rush *Juncus semisolidus*, referred to here as J_1 and J_2 for upper and lower bands respectively. As is commonly reported in the scientific literature, the lower limit of each band was more clearly defined (i.e. it showed an abrupt transition to lower vegetation type) than its upper limit (which was usually diffuse), and hence the lower limit of each band of *Juncus* was logged to establish its estimated elevation.

Zonation patterns based on these *Juncus* bands are briefly described below. The "Above J_1" and "Above J_2" zones are, of necessity, a simplification, as neither of these was a uniform structure but commonly had more zones. The description includes transects from around Green Swamp where the *Juncus* bands were either absent or not obvious. In the field, a dense band of tall herbs, usually either Aster-weed or Pale Knotweed, was recognised as the ecological equivalent of J_2 for sites with no *Juncus* band (notably Sectors 4, 5 and 6).

The general pattern was as follows:

[1] Above J_1: Grasses dominant, typical species being Weeping Lovegrass, Brown-backed Wallaby Grass, Couch and Common Blown Grass, with occasional weedy terrestrial species such as Spear Thistle. River Red Gum saplings, where present, occurred towards the upper end of this zone (elevations not recorded), also occasional shrubs such as Common and Drooping Cassinia. Also present and fairly common in this zone, were well-established stands of Southern Cane Grass (see below for more details), and a trash line (see below). Tall herbs, notably Stinkwort, were more common lower down in this zone, closer to the band of *Juncus semisolidus*.

[2] J_1: Band of *Juncus semisolidus*, 50-75 cm tall, somewhat senescent but with capsules, often open rather than dense rushland, with grasses interspersed. Band width not recorded. Lower limit is at 163.0 to 164.2 m AHD (mean = 163.5 m AHD, n=10).

[3] Above J_2: Grasses sometimes dominant, and although species composition was very similar to Above J_1, Common Blown Grass was more abundant, and Brown-backed Wallaby Grass generally absent. Tall herbs were more frequent and more abundant than in Above J_1, typical species being Stinkwort, Pale Knotweed and Aster-weed, with the last two tending to be more common at the lower limits of this zone.

[4] J_2: Band of *Juncus semisolidus*, usually more than 75 cm tall, usually dense but with either Common Blown Grass or tall herbs interspersed. Lower limit is at 161.2 to 162.7 m AHD (mean = 161.7 m AHD, n =12).

[5] Below J_2: this zone comprised two sub-zones.

Herbland: Short (5-20 cm tall) herbland, cover decreasing down the zone, nearly always comprising 3-5 of the following recession plants: Clammy Goosefoot, Hairy Carpet-weed, Marsh Yellow-cress, Pigweed, Common Sneezeweed, Lesser Joyweed. On just one transect, these recession plants were completely absent and instead the herbland comprised only Star Cudweed. Common Blown Grass was occasionally present amongst the recession plants but was never as common or as abundant as in Above J_2, except where it formed a third mono-specific sub-zone, i.e. a dense grassland (as in Sector 4). Elevation range for this zone is 161.2 to 163.1 m AHD.

Bare ground: The area between the short herbland and the water line was bare, in all transects. There was no evidence anywhere of regeneration in the water, or as far as was inspected which was up to 50 m further out from the water line. The estimated upper elevation for Bare Ground ranges from 160.9 to 163.0 m AHD: if transects from Sector 6 are excluded, the upper limit for Bare Ground ranges from 160.9 to 161.4 m AHD.

Note that each ecological zone occupies a vertical range or position that changes between sites. For any given zone, its elevations were consistently lower on the very flat gradients of Section 3, and consistently higher around Green Swamp. Vertical distributions of plants are known to alter around a lakeshore in response to horizontal gradients such as exposure (Keddy 2000), and this variability makes it challenging to interpret observed regeneration patterns in terms of water level history. A further complication is that the gauge for Lake Mokoan, and therefore the reference point for ecological studies at Lake Mokoan, is at the Outfall channel which is about 5 km to the west of these transects: although giving a fair record of the storage, it is unlikely to be an accurate record of the water regime experienced by seedlings and small plants along the northern shores in particular, due to the potential seiche-generating effects of winds.

The five zones recognised above are not all directly relevant to wetland restoration. The three highest zones (Above J_1, J_1 and Above J-2) refer to former hillsides around the wetlands not to Wetland Edge or Wetland Floor. Only two zones, J_2 and Below J_2 (i.e. Short Herbland and Bare Ground), are relevant to Wetland Edge and Wetland Floor.

This zonation pattern was identified on the northern shores and proved useful to the field observers as a conceptual model. The model did not translate perfectly to all Sectors, however: Sectors 4, 5 and 6 did not have two *Juncus* bands, neither did the area around the Spit (Sectors 8 and 9), and on the southern shores the closest *Juncus* band was set back from the shoreline by more than several hundred metres, due to gentle gradients there, making it difficult to determine if it was a J_1 or a J_2.

Points of Interest

Trashline: A distinctive feature along the northern shore was a line of coarse organic material, which was recorded in Sectors 2 and 3, and possibly also occurs in Sector 1. This occurred at a higher elevation than J_1, over 163.5 to 164.8 m AHD (mean = 164.1, n=7). This presumably is a trashline, such as left by a flood peak. The last time water levels were at these elevations was November 2005-March 2006 (Appendix 2).

Formed road: A formed road with a good surface, despite being submerged for years, occurs around the southern part of Lake Mokoan, south of Sectors 11 and 12. This could be useful as a means of access in the future. Grid co-ordinates for the two places where the Walking Search intersected this formed road are: 412928 / 5963270 and 413201 / 5962750.

Farm dams: Several farm dams occur around Lake Mokoan, some quite close to water level at the time of this field work. Some had wetland plants, typically Red

Water-milfoil, Drain Flat-Sedge, Cumbungi and Common Spike-rush, and some were unvegetated.

Southern Cane Grass

Ecological Observations

Seedlings: Seedlings of Southern Cane Grass are quite inconspicuous, partly due to their fine and prostrate habit (Figure 4) but also due to the lack of mass germination and establishment. Around Lake Mokoan, seedlings tended to be solitary or in groups of 2-5.

By comparing seedlings of different sizes, it was possible to work out how their habit changed through time. Initially the seedlings are prostrate, with no erect stems and only a few stolons (sometimes referred to as runners) that are relatively short (Figure 4). With time, or under circumstances currently unknown, the number of stolons increases as does their length; eventually, the prostrate seedling starts to develop a few erect shoots. Most of the seedlings sighted around Lake Mokoan in March 2008 were prostrate; seedlings with erect shoots were uncommon.

Figure 4: *Seedlings of Southern Cane Grass*

Left: Seedlings with only 3-5 short runners, radiating out from core, and no vertical shoots. Right: Seedlings with nearly all erect shoots and only a very few spreading stolons. Note the very shallow roots, less than 5 cm long.

Colonising Phase: Once the seedling has established, it can colonise an area by vegetative growth, through the development of long stolons and the establishment of daughter plants. The stolons grow and radiate out and away from the young plant, and can root at the nodes, but only if in contact with the ground. Some of these rooting nodes develop shoots. Eventually, the connection back to the young plant is broken or senesces, isolating these plants rooting at nodes, and these then become independent: these independent plants are known as daughter plants. The growing stolons can form an extensive mat on the ground (Figure 5), several metres long.

Stolon length and distance to daughter plants were measured on one Cane Grass seedling that was establishing on the northern shore of Winton Swamp on heavy grey clay with 2-10 cm of sand blown over it. Measurements taken were:

Stolon 1: 1.4 m, no daughter

Stolon 2: 2.2 m, no daughter

Stolon 3: 2.1 m, daughter at 0.35 m, rooting at 0.7m, 0.75 m

Stolon 4: 2.0 m (damaged, incomplete), daughter at 0.8 m

Stolon 5: 1.7 m, rooting at 0.65 m

Stolon 6: 1.3 m, daughter at 0.35 m

Stolon 7: 2.1 m, daughter at 0.55 m, daughter at 1.1 m.

Based on observations made elsewhere around Lake Mokoan, stolon lengths for this particular seedling (which ranged from 1.3 to 2.2 m), were relatively short (Figure 5). Distances from mother to daughter plants ranged from 0.35 to 0.80 m.

Clearly, this type of vegetative growth is an effective way of colonising open areas.

Figure 5: *Colonising Phase*

Well-established plants and stands: A third form of Cane Grass occurred around Lake Mokoan. This had stems that were almost all erect (Figure 6), and occurred as small patches or stands, up to about 10 m^2 in area, well away (vertical or horizontal distance) from the current shoreline. Because of their form and position, they were considered much older than the seedlings and colonising phases, so are referred to as Well-established plants and stands.


Figure 6: Well-established small stands

Long-Dead Rhizomes and Relict Mounds: Small mounds of non-cracking grey clay with bits of long-dead rhizome and stem bases were common along some shorelines. Comparison with the stem bases of live Southern Cane Grass from a well-established stand (Figure 7) confirmed that these plant bits were probably Southern Cane Grass, and hence that these mounds were indicating a former distribution of Southern Cane Grass.


Figure 7: Rhizomes and Stem Bases

Left: Stems and rhizomes of well-established Southern Cane Grass. The photograph shows the dense packing of stem bases due to the very short rhizome between stems, and the dense but short root system. Right: Long dead rhizome with rootlets attached on small clay mound, Winton Swamp, Sector 3 on vertical search SN03.

Distribution

Live Cane Grass: Live Cane Grass is a presence-only record of where live cane grass was recorded so includes seedlings, cane grass with runners (detailed below) and established stands without discriminating between these. It does not include the occurrences of dead rhizomes and relict mounds (given separately below).

Live stands of Southern Cane Grass occurred quite widely around Lake Mokoan (Figure 8), much more widely than was anticipated. The plot of 81 waypoints shows live cane grass in all sectors visited except Sector 8 (eastern side of the Spit: note Sector 7 was not visited). Live cane grass also occurred at the very tip of the Spit but as no co-ordinates were noted this occurrence is not shown. The elevation range over which live stands of Southern Cane Grass were recorded was 160.8-167.6 m AHD.

On the southern side, stands of live cane grass occurred on flat ground and in subtle depressions up to 1 km away from the current shoreline. On the northern side, patches of cane grass occurred on slopes and on varying soils at quite high elevations, the highest noted being amongst a line of regenerated River Red Gums. These elevated and perched stands would not have been flooded for several years and show that cane grass once established can persist for some time on rainfall. Southern Cane Grass at Moodie's Swamp has persisted since 1993 in the absence of significant flooding (Simon Casanelia, pers. comm., May 2008). Some of these elevated stands looked senescent (grey, without any reproductive heads); one that was quite green and vigorous was anomalous and appeared to be in a run-on area as some Cumbungi was also present.

At least five stands had recently flowered, and retained parts of the panicle. This is too small an observation set to determine any patterns regarding where or under what circumstances Southern Cane Grass is flowering around Lake Mokoan, other than to emphasise the low incidence (only 5 stands noted) and the diversity of the circumstances where flowering has occurred.

Low incidence is not surprising: the species name is *infecunda* and in South Australia *Eragrostis infecunda* is commonly referred to as Barren Cane Grass. The diversity of circumstances where flowering occurred is evident in soils and elevation data. The five stands which had flowered were around Sargents Swamp and Green Swamp as well as well set back from the southern shoreline of Sargents Swamp. Mostly these stands were at relatively high elevations (163.7, 164.0, 164.7 and 167.6 m AHD) but one was much lower at 160.9 m AHD. The soils where the stands occurred included red sand, areas with no top soil, and cracking clays. Based on this, there are no obvious limitations to this species, and it is likely that combinations of factors are important in determining its occurrence and abundance.

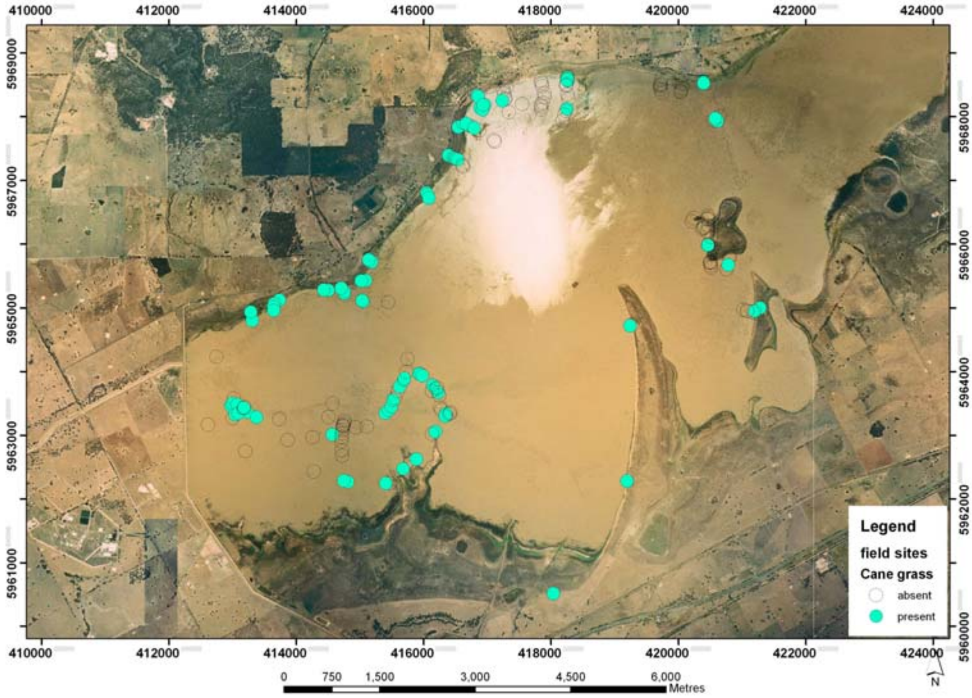

Figure 8: Waypoints where Live Cane Grass was recorded

Seedlings: Seedlings were recorded in Sectors 2, 3, 5 and 12 and were more frequent in Sectors 12 and 3 (Figure 9). The elevations over which seedlings were recorded (n = 14) was 160.8 to 161.8 m AHD, with one record at 163.7 m AHD. Most of these were between 160.8 and 161.1 m AHD (n=9).

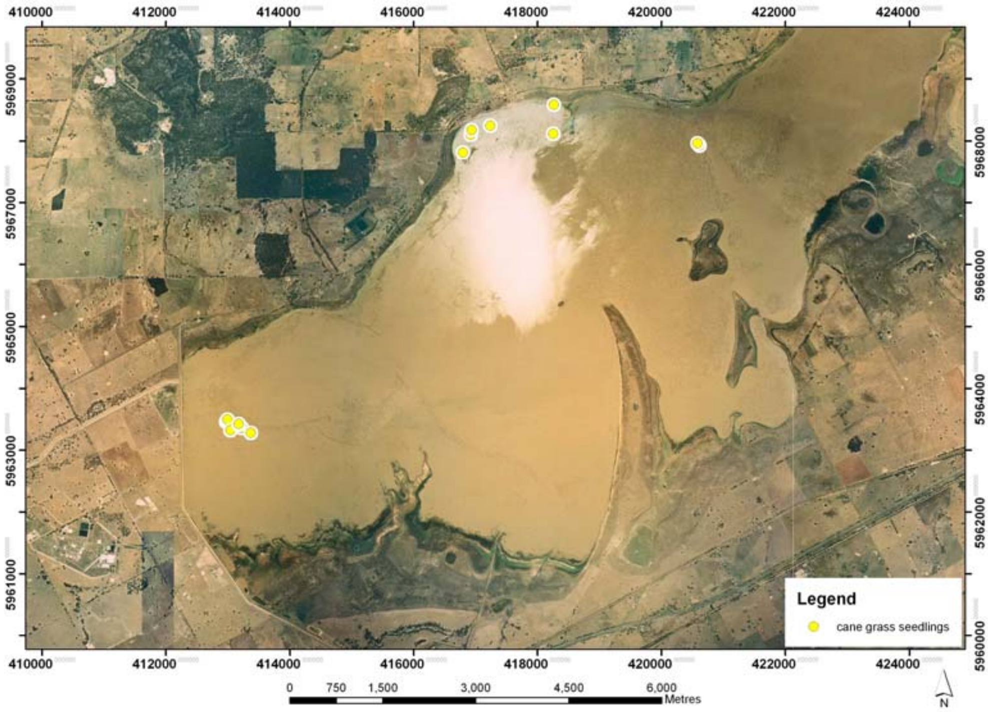

Figure 9: Seedlings of Cane Grass

Regeneration sites: Seedlings typically occurred in small depressions or areas where water had ponded (as indicated by the presence of wetland plants), and where the soil was cracking organic clays, which appeared to be original wetland soils that had survived being submerged (i.e. soils were not a recent deposit). Three types of regeneration sites were identified:

low-lying areas, immediately downslope of a band of dense *Juncus semisolidus* (Figure 10), typically along northern shoreline of Winton Swamp, in Section 3

small wetland depressions amongst dense *Juncus semisolidus* (not shown), typically along the northern shoreline of Winton Swamp, in Section 3

small depressions on the landward side of a beach with a sandy ridge (Figure 10), typically along southern shoreline of Sargents Swamp, in Sections 11 and 12.

Figure 10: Regeneration sites in March 2008

Colonising Phase: Cane grass with stolons (runners) occurred more widely and more frequently around Lake Mokoan than the seedlings and was noted in Sectors 1, 3, 5, 6, 9, 10, 11 and 12 (Figure 11). However, the elevations over which cane grass with runners occurred was similar to seedlings, ranging from 160.9 to 163.7 m AHD (n=17), with most of these occurring between 160.9 and 161.3 m AHD (n=13). Nearly all the patches with runners were relatively young plants, establishing by sending out runners but there were two patches of well-established cane grass with runners.

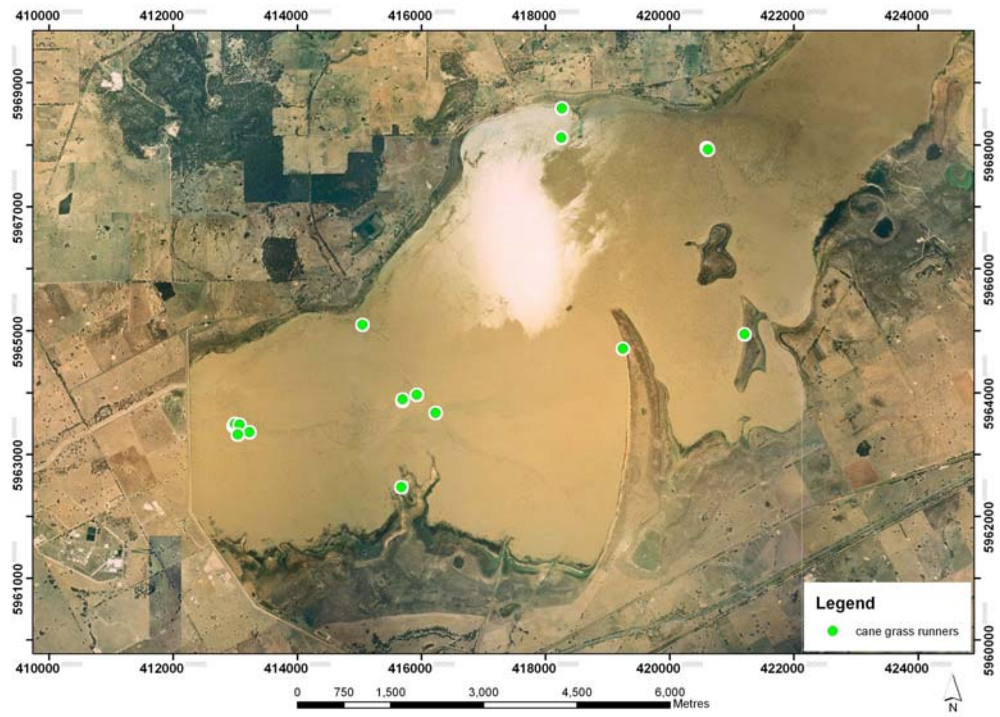

Figure 11: *Cane Grass with Stolons (Runners)*

Relict Mounds: These indicators of an earlier distribution of cane grass were noted quite widely around parts of Lake Mokoan, specifically in Sectors 2, 3, 5, 6, 11 and 12 (Figure 12). This distribution map must be considered a conservative estimate because the relevant field observations were not started at the beginning of the field program. Field impressions are that these relict mounds will probably occur in Sector 1 and 11, at least.

The estimated elevations over which these relict mounds occurred were 160.5 to 163.0 m AHD. All records of relict mounds at elevations higher than 162.0 m AHD were from around Green Swamp, in vertical searches SN_07, SN_08 and SN_09, coincidentally all on steeper profiles. As there are some uncertainties associated with the DEM, it is not clear if these relict mounds really were at higher elevations or not. Field notes for these show the mounds occurred mainly in the unvegetated zone above the water line.

Although not obvious from the distribution map, these relict mounds occurred in different types of habitats, and at contrasting positions relative to dead trees.

The habitats where relict mounds were noted were:

unvegetated areas low down vertical searches and above the water line, in areas where dead trees were either absent or very sparse;

amongst dead trees that had been well-established and mature individuals; set back from and slightly removed from the shoreline.

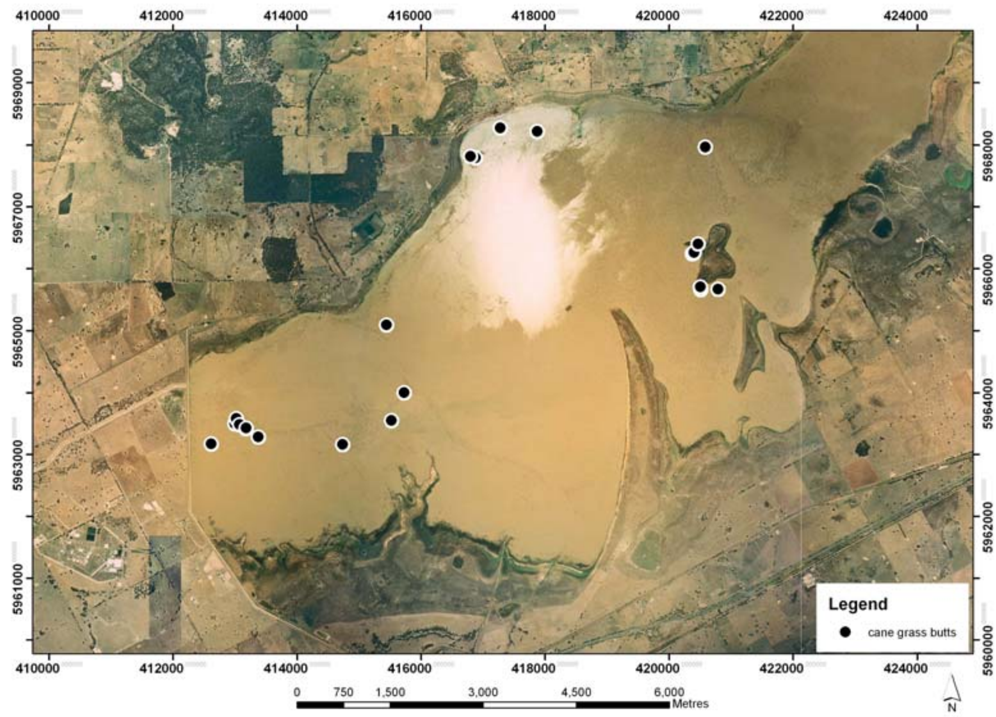

Figure 12: Relict Mounds

The contrasting positions relative to dead trees were:

amongst or downslope of the dead River Red Gums fringing the basins

upslope of the dead River Red Gums, and therefore at a higher elevation.

The first position is consistent with the historical information that Winton Swamp and Sargents Swamp had been cane grass swamps fringed by a woodland of River Red Gum; it is also consistent with contemporary zonation patterns in cane grass swamps such as Moodie's Swamp and Lake Boort. The second position is a little surprising: if taken at face value it contradicts the first position. One interpretation of this is that cane grass has a wider ecological amplitude than River Red Gums, with greater tolerance for both inundation and for drying: however, so little is known about cane grass ecology that it is not possible to support of refute this interpretation. An alternative interpretation is that these higher relict mounds do not reflect an undisturbed or pre-European distribution but instead are indicating a distribution in response to changes resulting from European settlement. Vegetation changes and dynamics are discussed further in Section 4.

Distinctive characteristics of these mounds (Figure 13) were that:

although they were mounds, the actual rise was quite small, and the topographic change was quite small

mounds tended to be inorganic grey clay

not all mounds had remains of Cane Grass

mounds tended to occur scattered through an area, with the mix of mound and inter-mound giving some topographic and substrate diversity.

Figure 13: Cane Grass rhizomes and relict mounds

Left: mound of grey clay surrounded by organic cracking dark-brown clay, Green Swamp, Sector 6 on vertical search SN12. Right: alternating mounds and depressions set back from the shoreline, Sargents Swamp, Sector 12.

Native Trees

The occurrence of immature River Red Gums and immature eucalypts (other than River Red Gums) as recorded around Lake Mokoan is shown below (Figure 14).

Out of the 15 waypoints recorded for River Red Gums, five were for more than one individual and four did not have complete co-ordinates so are not plotted. The immature River Red Gums span all four immature stages and, not surprisingly, there is a tendency for the smallest and youngest ones to be at lower elevations.

seedlings: one, only 7 cm tall, in Section 2 (161 m AHD) and two 15-20 cm tall in Section 11 (161.1 m AHD), both on sandy soils.

Juveniles: two (approximately 1 m and 1.25 m tall) in Sector 2 (162.7 m AHD), and several about 1-1.5 m tall in rubble on steep slopes in Sector 6 (163.8-163.9 m AHD).

Juvenile and sapling: one juvenile and one sapling in Sector 1 (164.4 m AHD)

poles: one 7 m tall in Section 3 (162.9 m AHD)

There were only seven records of immature eucalypts, not all with complete co-ordinates (Figure 14). Immature eucalypts are not a target species for rehabilitation so were not recorded as systematically as River Red Gums, and seven is certainly an underestimate. For example, the log does not include seedlings and juveniles occurring in depressions beside access roads, notably in Sections 5 and 6. However it is noticeable that these immature eucalypts tended to occur away from the shoreline, in what is currently a terrestrial environment (Figure 14) south of Sectors 11 and 12.

Like the immature River Red Gums, these ranged in stage and size from seedlings to saplings.

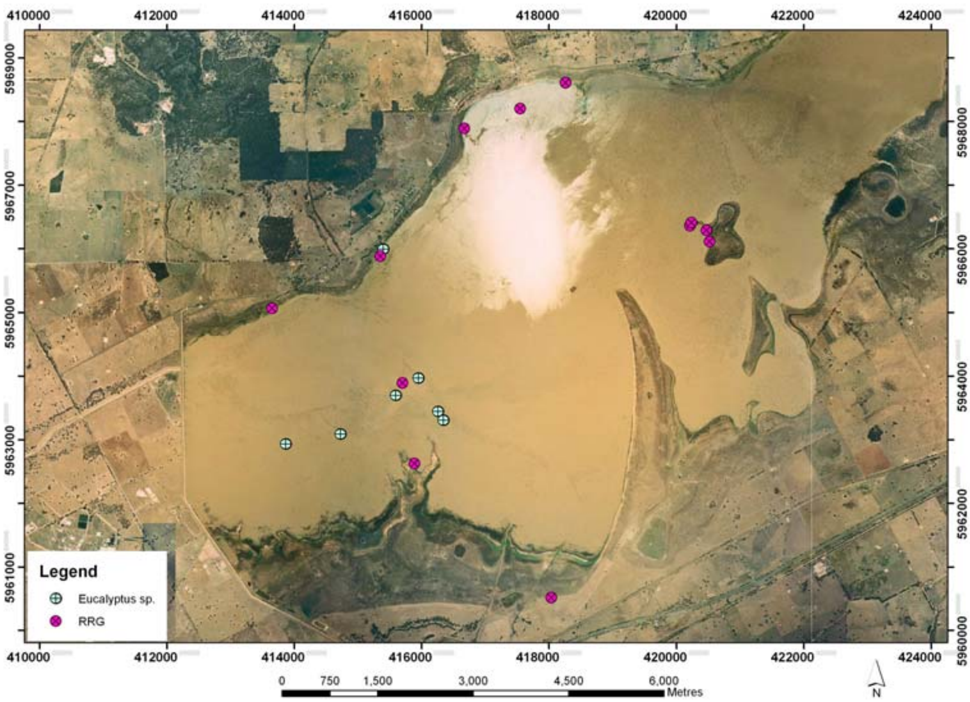

Figure 14: Waypoints where immature eucalypts were recorded

One seedling of Prickly Leaved Tea-tree *Melaleuca styphelioides* was found on the sandy ridge at the top of the beach in Sector 10. This species occurs in moist habitats along streambanks particularly along the coast of New South Wales and into Queensland. It is not native to this part of Victoria (it was removed) but is widely planted as an ornamental and for its tolerance of water-logged conditions.

Wetland Plants

Four sedges and three wetland plant species typical of Wetland Edge habitats and Wetland Floor habitats respectively, were included as targets for searches. The three sedges were selected *a priori* but the three wetland plants were chosen while in the field, and in response to finding them associated with seedlings of Southern Cane Grass in Section 3. The record for these four sedges and three wetland plants is considered to be reasonably reliable as a report on their broad spatial patterns around Lake Mokoan and on differences between Sectors. As described above, the three wetland species were selected because of their capacity for persisting for some time after soils have dried out. Unlike other submerged and amphibious species, Red Water milfoil can survive in a stranded form on damp and drying soils for some time once the heat of summer has passed making it a fairly useful indicator of the presence of submerged vegetation. In contrast, a Mud-mat, probably Small Mud-Mat, which was also found stranded at some sites, was highly desiccated, brittle and inconspicuous, making it a much less reliable indicator.

The findings for the four Wetland Edge sedges (Figure 15) are as follows:

Poong'ort was not sighted anywhere (n=0) and hence there are no records for this species

Tall Flat-Sedge was noted only twice (n=2), both times on the southern shores of Lake Mokoan

Drain Flat Sedge was the most frequently recorded (n=14), being recorded from along the northern shoreline in Sectors 3 and 4, and along the southern shoreline in Sectors 10, 11 and 12

Spiny Sedge was recorded occasionally (n=7), often on sandy soils and small spits, and nearly always from Sector 11.

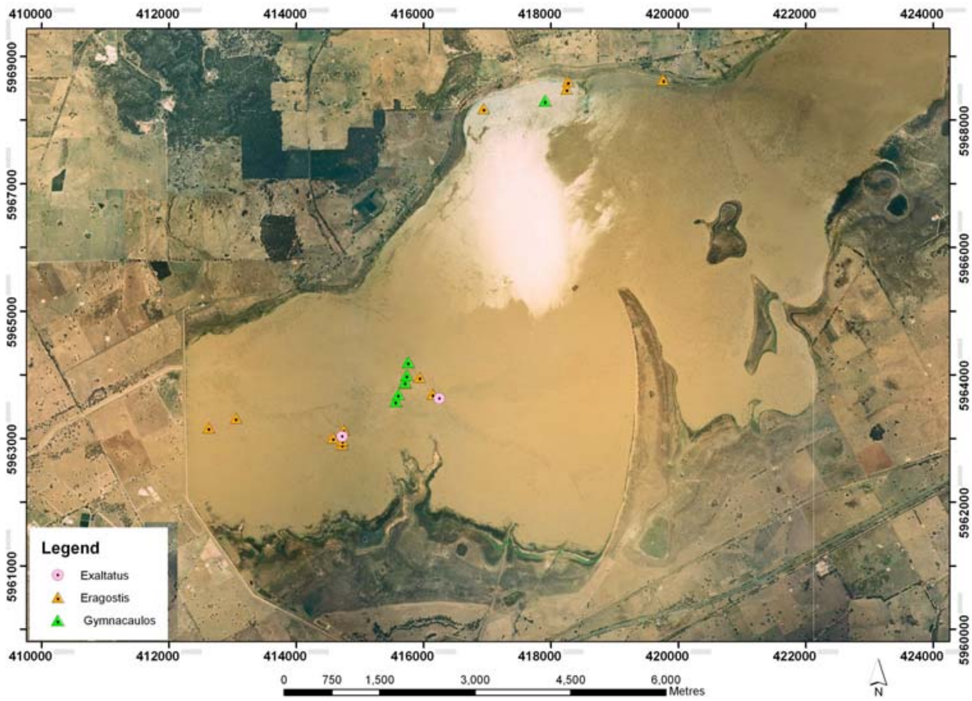

Figure 15: Waypoints with *Cyperus* sp.

The findings for the three Wetland Floor species (Figure 16) are as follows:

The three Wetland Floor plants tended to co-occur. They had quite a restricted distribution, being recorded only from Sectors 3, 11 and 12: they were not seen in Sectors 1 or 2 (the northern and steeper shores of Sargents and Winton Swamp) or in Sectors 8 and 9 (around the Spit) or Sectors 4, 5 and 6 (Green Swamp).

These three wetland plants were consistently found in the same or similar wetland depressions as seedlings of Southern Cane Grass (see above).

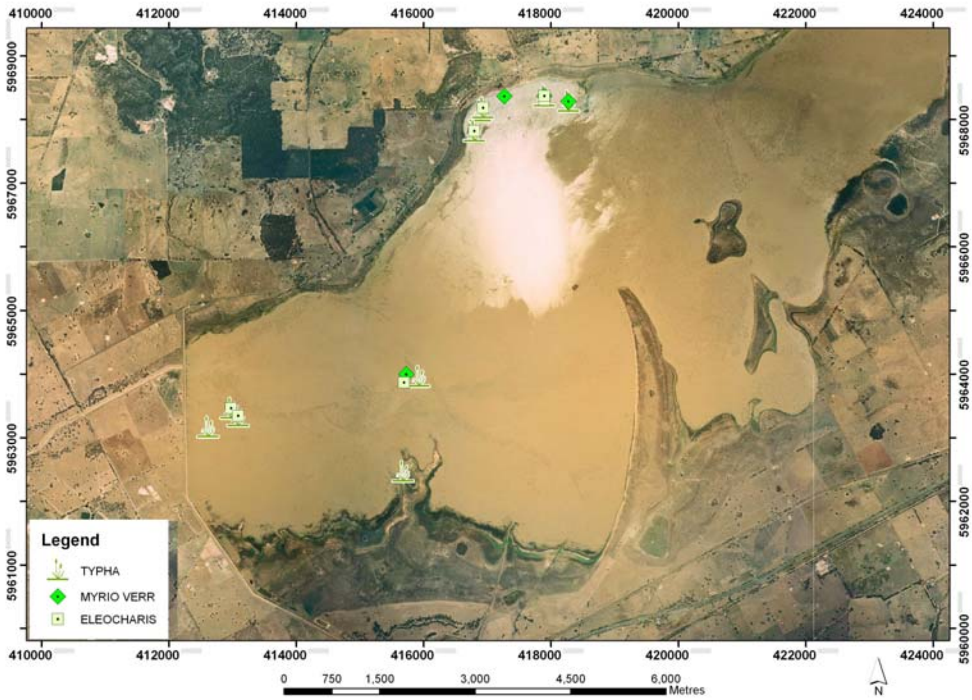

Figure 16: Waypoints with wetland plant species

Non-native Trees

The two trees considered here, willows *Salix* spp. and poplars *Populus* spp., are widespread environmental weeds in south-eastern Australia. Willows, in particular, are seen as ecological threats and are the subject of vigorous removal programs in some catchments. Poplars are not viewed as threatening as willows, yet willows and poplars are in the same family (Salicaceae) and share many ecological characteristics (Karrenberg et al. 2002). Non-native trees were not identified as targets or species of interest for the field searches but their observed presence around Lake Mokoan was noticed, and accordingly was logged.

The distribution map (Figure 17) shows juvenile willows and poplars in Sector 3 and Sector 10, that is around Winton Swamp. However this is definitely an under-estimate. For example, willows and poplars (with Cumbungi) occur along the western side of the Spit (Sector 9) where they form a distinctive green and vigorous band; these were noted while establishing transects for monitoring the Wetland Edge (Roberts and Hale 2008) but their co-ordinates were not logged.

Four different habitats were identified where seedling, juvenile and sapling willows and poplars occurred. The first two are relatively recent germination and establishments, whereas the last two are juveniles and saplings that established much earlier (higher water levels, different water regime) yet have persisted despite drawdown. The four habitats are:

sandy soils at the base of the slope along the western side of the Spit (Sector 9, not in Sector 8)

sandy ridge at the top of short and relatively steep beach (Sector 10) along the northern shore of Lake Mokoan but at elevated position and well away from current shoreline (Sector 3)

set back from southern shoreline of Lake Mokoan and Sargents Swamp in a terrestrial environment (south of Sectors 10 and 11).

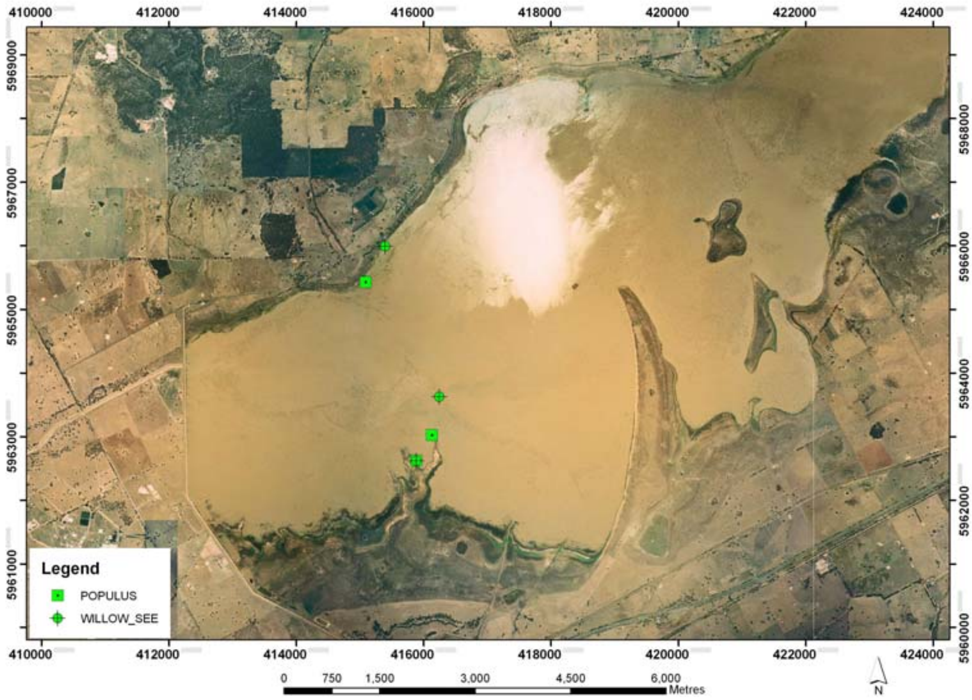

Figure 17: Waypoints where juvenile Salicaceae were recorded

Sediments & Soils

The shoreline around Lake Mokoan was more variable than anticipated with cracking grey-brown clays, sand patches, eroded areas and settled sediments, in a chequered pattern depending on location and elevation. Field observations are summarised here as Soil Characteristics and Disturbance History.

Soil Characteristics

Wetland Soils: Soils which were cracking brown-grey clays, either with an undulating gilgai-like topography or non-uniform surface, and which were at or close to the water line, were considered to be wetland soils (Figure 18), that originated prior to the commissioning of Lake Mokoan. These soils were somewhat restricted and were noted as follows:

parts of the northern shoreline (particularly Sector 3; minor patches in Sector 1)

base of wetland depressions (Sector 3)

adjacent to the southern shoreline but separated from it by a beach ridge, typically flat areas (Sectors 11 and 12, in particular; area between the embankment and Sector 12).

Sand: Sandy patches occurred occasionally around Lake Mokoan, under different circumstances and at different elevations, some close to the water line (Figure 18) and others higher up. All examples of sandy shores were above the water and became silty or clay just at or below the waterline: no instances of sand below the waterline were noted. Sandy patches occurred as follows:

a sandy spit projecting into the water, relatively low elevation, becoming colonised by Spiny Sedge; localised occurrences (northern shore at junction of Sector 1 and 2, northern shore in Sector 3, southern shore in Sector 11, junction Sectors 10 and 11)

sandy shore above the water line along western side of the Spit (Sector 9)

sandy ridge at top of shore, the shoreline being relatively short, the sand ridge higher than ground further away from shore (stretches along Sectors 10 and 11)

sandy ridge set back from current shoreline, deposited when water levels were higher (Sector 9, along western side of the Spit)

coarser sand on mid-slopes and upper slopes (around 'island' in Sector 6, western side of The Spit, Sector 9).

Other soil types also occurred around Lake Mokoan but were not easily categorised.

Figure 18: Variability in soils around Lake Mokoan close to the waterline

Left: blocky grey-brown clays with fine grey clay in-between, northern shore in Sector 3. Right: spit of fine sand separating Sectors 10 and 11

Disturbance

Severe erosion: For this report, erosion is counted as severe if it results in the removal of top soil leaving behind subsoils or rocky material (Figure 19). It is severe because it has removed the 'rooting medium' where plants normally grow and results in a substrate that is inhospitable for growing plants. Severe erosion was noted at several points around Lake Mokoan, typically in the middle and upper slopes between current water level and Full Supply Level or 166.9 m AHD (Souter and Lewin 1999).

upper slopes and mid-slopes of northern shores of Lake Mokoan (Sector 2 in particular)

upper slopes of exposed rocky outcrops at the tip of the Spit (between Sector 8 and 9) and on what was an 'island' (Sector 6)

mid-slopes of the western side of the Spit (Sector 9) extensive areas south of the southern shoreline.

The quantities removed and broken up are possibly quite considerable: for example, the rocky promontory at the tip of the Spit. Two willows well to the south of Lake Mokoan are perched above the contemporary surface which appears to indicate a loss of about 30 cm from the immediate surroundings. This is a tentative interpretation of the willow pedestals but if verified, this is a substantial loss.

As most of this material is presumably still within the Lake Mokoan system, this implies there has been a considerable re-distribution. Because they lack topsoil, the eroded areas are very unlikely to become colonised by plants, except perhaps in a few depressions and hollows where wind-blown materials accumulate.

Erosion: The partial removal of top soil is categorised as a non-severe form of erosion, because although this may have removed some soil and probably also the seed bank, there is still some top soil remaining. This is not as conspicuous as severe erosion, and the only example used here is the removal of soil from around the base of trees, which was quite localised (Figure 19), being noted from Sector 3.

Figure 19: Examples of erosion around Lake Mokoan

Left: severe erosion mid-slope of the western side of the Spit, in Sector 9. Right: minor erosion from around a tree, northern shore of Lake Mokoan in Sector 3.

Sedimentation: Particles settling out of the water column can change the characteristics of the wetland floor through smothering and so altering biogeochemical processes at the sediment-water interface, and by burying the seedbank.

Sedimentation was notable for being quite deep, up to 30 cm, very fine and well-sorted, occasionally characterised by a gelatinous feel or else with an algal film on the surface (Figure 20). The resulting surface is uniform in character, lacking 'features' such as branches or twigs, and essentially flat with no surface topography (Figure 20). Sometimes, it was possible to feel a firm wetland floor underneath, and occasionally also buried logs, twigs, and organic material. Sedimentation thus meant that not only were sediment-water column processes altered but the loss of any surface heterogeneity.

Sediments were categorised as ‘deep’ meaning that there was no trace of the original wetland floor, or ‘minor’ meaning particles settling into the wetland floor but not completely obscuring its characteristics.

Deep sediments occurred quite widely, but were particularly evident in Green Swamp (Sectors 4, 5, 6 and 8) and southern shores of Winton Swamp (Sector 9).

Minor sedimentation was uncommon and was noted only in Sector 6.

Figure 20: Sedimentation around Lake Mokoan

Top: Deep (up to 30 cm) sedimentation on western shore of The Spit, in middle part of Sector 9. Left: Sedimentation around trees, northern part of Green Swamp in Sector 4. Right: Minor sedimentation that has in-filled cracking clays, Sector 6.

[4] Discussion

Regeneration in March 2008

Linking Zones to Time

The zonation patterns described above show that all the regeneration to date has occurred either on recently exposed sediments or higher up the slopes. There was no evidence of any regeneration in or under water in Vertical Transects that sampled the Wetland Edge and onto the Floor: some in and under water regeneration may have occurred in small localised sites such as shallow depressions.

Seedlings are most likely to survive the germination stage if environmental stresses are minimised and in wetlands this means relatively stable water levels. For most species, the most likely cause of seedling stress and death are complete submergence (due to rising water levels) or exposure and desiccation (due to falling water levels).

Assuming this conceptual model is sound, it should therefore be possible to date and age the vegetation in a particular zone by correlating its elevation with water level history (Appendix 2). Over the last five years, water levels have been relatively stable for a 2-6 month period in autumn-winter in most years (Table 2) but at different elevations. The elevation of the lower band of *Juncus semisolidus* (zone J_2, at 161.2-162.7 m AHD) correlates fairly well with the most recent stable period, in autumn-winter 2007. This implies that these tussocks are less than a year old, that the Recession Herbland downslope of J_2 is even younger, and that the Bare Ground downslope of that has been exposed for only a relatively short time, only months.

Table 2: Stable periods likely to have favoured seedling establishment

Timing and Duration of Stable period	Elevation (m AHD)
2002: March to September	163.8-164.0
2003: April to June	162.3-162.4
2004: April to July	162.5
2005: no stable period	
2006: April-September	163.0-163.1
2007: August-September	161.6-161.7

On the face of it, this recent regeneration is an encouraging sign. It demonstrates that conditions are favourable along the northern shorelines of Lake Mokoan, in particular in Sector 3, for the regeneration and persistence of Plains Rush *Juncus semisolidus* and for short recession herbs. However these species are probably not regenerating from any seedbank but as a result of dispersing in. Most of these are prolific seeders (Figure 21). They are also quite widespread, generalists, mostly short-lived and opportunistic. As an assemblage, they are typically only a transient element of the wetland vegetation, and are probably only of limited significance in terms of wetland restoration as early colonisers.

The main point of interest is what follows these early colonisers. The information to date (Roberts and Hale 2008) suggests that this is mostly species of a similar ecological character. Possibly this is because the sustained high water levels of April-September 2006, which were higher than the stable periods in the three preceding years (Table 2), may have affected species colonising at those times. This interpretation is provisional and would best be confirmed by correlating species composition with elevation, which is the subject of MP_2 (Roberts and Hale 2007).

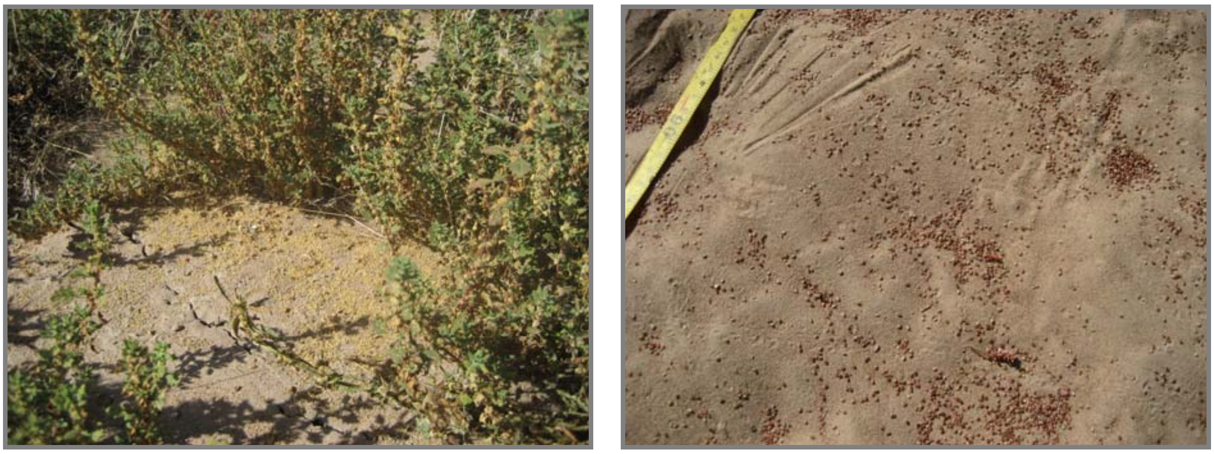

Figure 21: Seed rain

Two common plant species from the wetland edge that produce abundant seed, noted at Lake Mokoan in March 2008: Clammy Goosefoot (left) and Pale Knotweed (right).

Southern Cane Grass

Southern Cane Grass is one of two target species identified for monitoring (Roberts and Hale 2007), therefore its regeneration status and potential is of considerable interest to restoration of the Winton Wetlands.

The current distribution of Southern Cane Grass, as established by searches through March 2008 (Figure 8), shows that it has established and persisted in areas well away from its presumed historical distribution across the wetland floor of Sargents and Winton Swamps. Moreover, it seems Southern Cane Grass does have capacity to colonise new areas in response to disturbance, as evidenced by dead cane grass rhizomes on spoil excavated from a dam and on spoil excavated from beside a drainage line. The areas where live stands were found are quite diverse, suggesting that once established, Southern Cane Grass has the capacity to persist in diverse soils and under differing water regimes, including some quite dry conditions. The implications for rehabilitating the Winton Wetlands are that for Southern Cane Grass, the emphasis needs to be on achieving successful establishment.

The searches identified four distinct stages in Southern Cane Grass: seedlings, young plants with stolons (runners), established plants and relict mounds. Each of these is associated with a particular range in elevation and hence to a different stage in the history of Lake Mokoan, as shown below (Table 3). Note that:

relict mounds indicate the distribution of Southern Cane Grass prior to Lake Mokoan being commissioned (i.e. before 1970); these are clustered at 161 m AHD.

all Live indicate the distribution achieved by Southern Cane Grass whilst Lake Mokoan was operated as a storage (between 1970 and 2007); these occur over a wide elevation range but are clustered at 161 and 163 m AHD.

Seedlings and Runners indicate very recent germination and establishment of Southern Cane Grass: these are clustered at 161 m AHD.

Table 3: Distribution of Cane Grass observations by 1-metre elevation bands

	Elevation (m AHD)								n
	160+	161+	162+	163+	164+	165+	166+	167+	
All Live	5	29	9	20	10	4	3	1	81
Seedlings	2	12	-	1	-	-	-	-	15
Runners	2	11	1	3	-	-	-	-	17
Relict Mounds	6	11	3	1	-	-	-	-	21

The occurrence of seedlings and young plants with runners is indeed a positive sign, as it indicates that conditions favourable for regeneration do occur around Lake Mokoan. However there are strong indications that passive regeneration on a large-scale, as anticipated by the FLUS (Beca Planning 2006) will be problematic, and these are:

the availability of suitable regeneration sites across the floor of Sargents and Winton Swamps is unknown;

the precise requirements (water depth in particular) for germination and establishing are unknown;

there is strong evidence of low fecundity, notably the small number of seedlings and young plants despite a surprising abundance of established stands, and as also indicated by the species name *infecunda*

reproduction ecology of this species (what triggers it to reproduce) and whether it forms a viable seed bank are unknown.

River Red Gum

River Red Gum is the second of two target species identified for monitoring (Roberts and Hale 2007) and, like Southern Cane Grass, its current regeneration status at Lake Mokoan is of considerable interest in terms of understanding the feasibility of restoring the wetlands.

Regeneration status was surprisingly poor. Although poor regeneration had been anticipated and was the stimulus for this study, it was nonetheless surprising to find so few seedlings and juveniles. However the situation for River Red Gum is very different from Southern Cane Grass in that its regeneration requirements (at least in terms of water regime) are well-known (e.g. Roberts and Marston 2000), and it is a prolific producer of seeds.

In hindsight, the reasons for poor regeneration of River Red Gum are assumed to be principally due to seed not arriving or being dispersed to suitable regeneration sites; a secondary reasons could be due to herbivory from hares and kangaroos, although as these were not very abundant, herbivory is unlikely to be important except locally. Sites where immature River Red Gums were noted were almost all relatively close (within 50 m) to a stand of mature trees, often a re-growth line close to 100% FSL. The two seedlings growing on sandy ridge at the top of the beach in Sector 11 are the exception to this: their occurrence is attributed to material being washed in down the Inlet Channel or the creeks that flow into the southern part of Winton Swamp.

If this interpretation is sound, then there is little likelihood of widespread passive regeneration around Lake Mokoan and also little likelihood of the situation improving rapidly without some kind of intervention. The distance between seed source and regeneration site is unlikely to diminish and may increase if water levels are drawn down further.

Soils, Sediments, Succession and Seed banks

Soils

The quantities of soils and surface material that has been removed and presumably re-distributed around Lake Mokoan appear to be quite large. Quantities removed are not known but the depths are considerable, up to 30 cm deposition and possibly 30 cm degradation (Figures 19, 20). Re-distribution of sediments has been recognised by others (e.g. p29, Wrigley Dillon 2006) but the implications have been overlooked. Re-shaping and changing the wetland surface is possibly of little consequences per se but these do have implications for the accuracy of the DEM, and for the relationship between storage volume and water level.

Sediments

The regeneration status described above refers primarily to areas with sandy or original wetland soils. As described above, the sediments that have settled out onto the wetland Floor and Edge in Green Swamp and in the south-eastern part of Winton Central results in a habitat that is flat and uniform and lacking any micro-topographic variability known to increase establishment and diversity of wetland plants (Larkin et al. 2006). The characteristics of this sediment, as best determined by field inspection, were that it lacked coarse organic material, was well-sorted and deep, sometimes with cracks developing, and had a film of biological activity on the surface (Figure 20).

In terms of Walker and del Moral (2003), sediments such as these are the result of disturbance and the turnover of plant species on these is succession. If the sediments have no biological legacy, that is if there are no surviving plants, animals or microbes, then this is primary succession. Although the sediments at Lake Mokoan have undoubtedly lost all their plants, seeds and microfauna, they appear to have retained some biological activity and therefore they can be considered as secondary succession. This is a positive attribute for re-vegetating the sediments as it means the development time should be shorter. Advice is needed on whether regeneration on these sediments will proceed differently from regeneration on original sediments, and if so whether this is a question of time or whether management intervention would be beneficial.

Because this was an observational study, no soil analyses were done so the physical and chemical properties of these sediments is not known. However, their likely characteristics can be inferred from an assessment of soil capability undertaken in July 2006 (Wrigley Dillon 2006). This was done for DSE as part of background information for the FLUS. Sampling was quite limited, only 14 pits in two areas, and was done when water levels were approximately 163 m AHD and Lake Mokoan was at 34% FSL. The assessment distinguished sediments, meaning fine settled particles found on the surface of soils near the waterline, from soils and subsurface soils.

The study found that the typical depth for sediments in the south-western part of Lake Mokoan (now high ground above Sector 10) was 2 cm, and ranged from 1-5 cm. The chemical analyses showed that the sediments had 1.0-3.5% organic carbon (p29), were strongly acidic with pH in the range 5.0-5.6 (p24), and had moderate to high levels of sulphur with 15-33 mg per kg, as measured by the KCl technique which measures free sulphate, some adsorbed sulphate and some labile sulphur (p27, Wrigley Dillon 2006). Characteristics such as pH less than 6, high sulphur levels and a history of near permanent inundation are amongst those used to determine the potential for acid sulfate soils in inland wetlands (Baldwin et al. 2007).

Clearly there is a need for an expert evaluation of these sediments, as a growing medium for plants, and as soils requiring specific management or rehabilitation measures.

Seedbanks

Although there has been considerable interest in seedbanks in Australia, the emphasis has been on composition and on how imposing particular environmental conditions affects composition and abundance of seedlings. Thus a critical issue in the rehabilitation of Lake Mokoan is that very little is known about seed longevity of wetland species under natural conditions. An Australian study on resilience in temporary wetlands reported that species richness in dry-stored wetland sediments decreased by approximately 50%, from more than 50 to approximately 25 species over just 9 years (Figure 4, in Brock et al. 2003). No Australian studies on wet-stored wetland sediments were located.

It is the opinion of the authors that the sediments collected from the floor of Lake Mokoan are unlikely to be a rich or useful source of seeds or propagules, and that regeneration around Lake Mokoan is probably largely driven by seeds that have recently ‘arrived’.

This is a hypothesis that would be worth testing. Knowing the answer will help to inform whether or not rehabilitation should rely on passive management approaches.

Managing the Water Regime

Wetland Edge and Wetland Floor are two distinct habitats at Lake Mokoan, both requiring regeneration. Passive regeneration can be encouraged by managing water levels appropriately, and the best option for this is to provide a sustained period of relatively stable water levels, taking as a template one of the stable periods described above (Table 2). Unfortunately, within the coming year, it will be difficult to maintain Lake Mokoan as a storage and to provide two sustained periods of stable water levels. Therefore it will be necessary to choose between wetland Floor and wetland Edge.

Targetting wetland Edge is considered a better option because:

it capitalises on recent regeneration

it is less of a step change from preceding conditions so would be unlikely to stress (through exposure and desiccation) any desirable seedlings that may have established recently

it is less a less risky option, that is regeneration is known to be occurring in the Wetland Edge

the fifteen transects set up for monitoring the wetland Edge (MP_WE, in Roberts and Hale 2008) are centred on the wetland Edge.

In addition, focussing on the wetland Edge will allow time for developing a better understanding of what is best needed for the Wetland Floor, and its characteristics.

Wetland Restoration at Lake Mokoan

This section presents two points relevant to wetland restoration that have arisen out of this project.

Reference Points

Historical information is useful when restoring wetlands but the information available tends to be very scant. This makes it difficult to appreciate what was the intrinsic variability of a wetland or to appreciate ecological changes that may have occurred.

During the course of this project, the idea was developed that water levels in Winton and Sargents Swamps were higher might be expected under average natural conditions in the period immediately prior to the commissioning of Lake Mokoan. This idea was influenced by the distribution of relict cane grass mounds and by field observations made while doing searches, as follows:

Helen Aston's photographs from late summer 1959 (dated 15 February 1959) show cane grass in water about 50-75 cm deep and shallow water around an open River Red Gum woodland (Top Left and Middle Left in Figure 6; depths explained in Appendix 1; Roberts and Hale 2007). Normally this would be a season of low water levels.

An excavated (and in-filled) drainage line was found, running in to the southern shore of Sargents Swamp, suggesting early earthworks intended to increase flow into the wetland.

Inverted zonation, that is relict mounds of Southern Cane Grass higher than the fringe of dead trees, which suggests it has responded to some environmental change. This was most frequently recorded around Green Swamp.

The implications are that the relict cane grass mounds are not all of the same vintage, and some may be reflecting an altered situation.

Restoration Planning and Process

To-date, the restoration process has proceeded on the assumption that the vision and strategy outlined in the FLUS (Beca Planning 2006) provides sufficient technical basis for achieving restoration. This report, based on very basic observations over 4 days in the field, shows this assumption is not tenable.

It is now clear that there needs to be some investment in articulating constraints and determining what is feasible, in defining where these apply, in quantifying constraints, in spatially-explicit characterisation of the sites, in building capacity fro regeneration, in re-thinking objectives, and in scoping alternative means of achieving the original goals. According to restoration ecologists (e.g. Shafroth et al. 2008, David Tongway, pers. comm., March 2008), establishing realistic restoration objectives, prioritising actions and sites, and developing a site-specific restoration plan should come well before embarking on monitoring and adaptive management.

A generic approach to restoration recognises four significant stages (Figure 21).

[1] Setting realistic objectives: ‘realistic’ in this context means determining – as explicitly and as quantitatively as feasible - financial and human resources needed, the likely response time-frames, the nature and extent of ecological constraints (if any) and whether these modify the overall objectives, the risks involved, and the natural and political time frames. This stage is interactive and iterative, and may need to invest in acquiring knowledge. The outputs, in the form of a coherent suite of spatially-explicit objectives, will be necessary inputs to the Restoration Plan.

This stage is fundamental to the whole restoration. The opinion of Shafroth et al. (2008) is that “We suggest that taking the time to consider these three elements early in the planning process can significantly improve the success and cost-effectiveness of meeting the restoration goal.” (with the three elements being evaluation of non-ecological factors, of ecological factors and re-casting the vision as objectives).

[2] Completing a site-specific Restoration Plan: this is a ‘how to …’ document or manual that spells out the procedures, methods, and exact sites to be used in implementation, any ‘sub-plans’ that may be needed, what pre- and post-implementation monitoring is to be done, and the feedback processes and questions for adaptive management such as success criteria. All these need to be thought through and agreed on prior to writing the Restoration Plan.

[3] Implementation: this is the action stage, where the Restoration Plan is implemented and monitoring commences (unless flagged to commence earlier). Being more hands-on, the type of skills and technical inputs needed here are distinct from the other stages. By this stage it will be already agreed what methods to be using where, and for what species; for example where passive regeneration is expected to be successful, and where intervention such as planting will be required.

[4] Evaluation: this is the feedback stage, where monitoring results c are used to evaluate progress towards objectives and against success criteria. This is also the time when adaptive management can begin, and when methods and objectives may need to be re-cast.

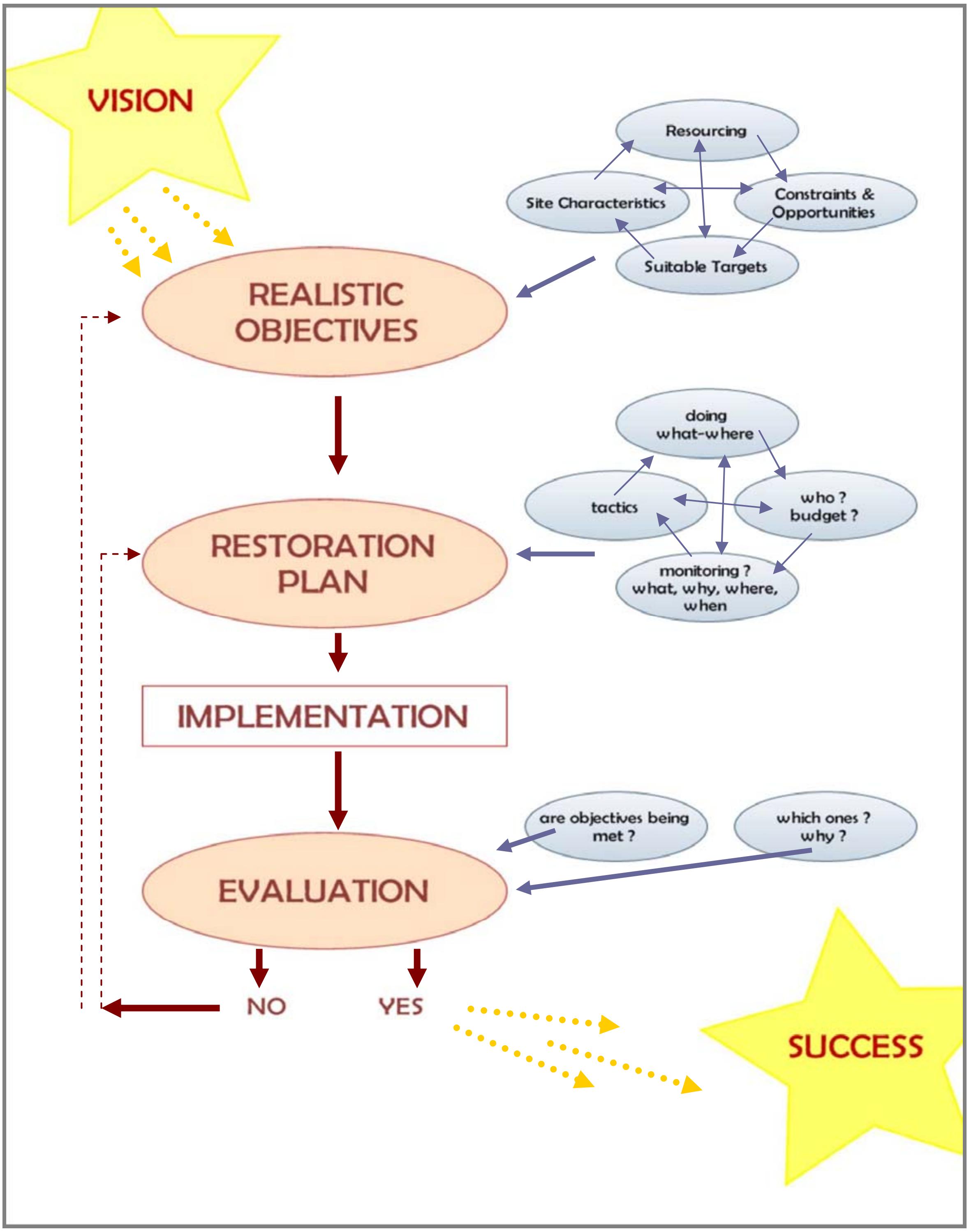

Figure 21: Steps in Restoration

Based on discussions with David Tongway and Shafroth et al. (2008).

It is strongly recommended that:

Realistic objectives be formally developed for the three larger wetlands, Sargents, Winton and Green Swamps.

Realistic objectives be set for the nine smaller wetlands in the eastern section; and for the grasslands.

Conclusions

Regeneration is occurring at Lake Mokoan but is not proceeding uniformly around the lakeshore. The two key species, Southern Cane Grass and River Red Gum, are unlikely to self-establish widely under current circumstances, but for differing reasons.

Clear evidence was found that Southern Cane Grass is regenerating but the very low numbers of seedlings and young plants are a strong indication that the rate of expansion and colonisation will be very slow, especially in relation to the quite large area of wetland floor in Winton and Sargents Swamp. Relying on passive regeneration for this species is therefore not a sensible option for the long-term. If Southern Cane Grass is to be retained as a target species, it will be necessary to invest in a planting program to boost the number of seeds in the system.

There was also clear evidence that River Red Gums were regenerating however the number of seedlings and juveniles was very low, even lower than Southern Cane Grass. Regeneration conditions appeared favourable, therefore it was assumed, but not demonstrated, that the very poor regeneration status for this species was due to the seed source being too far from the shoreline: i.e. that the seeds were not dispersing to the regeneration sites. As this situation is unlikely to change and as River Red Gum is a key species around wetlands, it will be necessary to abandon the idea of passive regeneration. An alternative strategy was proposed, of strategic plantings at carefully chosen sites, in order to develop better-placed seed sources and so boost passive regeneration into the future.

Regeneration was variable amongst the indicator species used in this study. Two Edge indicators, Poong'ort and Tall Flat Sedge, were virtually unrepresented in the regenerating vegetation although potentially important in Edge communities. Another one, Drain Flat Sedge was more common though nowhere reaching the abundance or height it typically reaches beside irrigation channels or regulated channels. The fourth Edge indicator, Spiny Sedge, appeared well-established on sandy soils where these did occur. The three wetland plants used as indicators, Red Water-milfoil, Common spike-rush and Cumbungi, although not widespread overall, were regenerating well in specific areas such as small depressions so were clearly limited by habitat availability.

Farm dams could have a role in boosting seed availability, and increasing the seed rain into Lake Mokoan and across the wetland floor. A passive management approach would be to protect these from human and stock impact and interference where needed, and provide a water regime that would encourage the development and flowering and fruiting of wetland plants and so maintain a seed supply. This assumes that seeds would disperse locally around the dams and become established. A more active management approach would be to plant these dams to target species or to species with short dispersal distance (such as the large-seeded Cyperaceae), actively provide suitable growing conditions by topping up water levels from a tanker, and determine whether the assumption of the role of farm dams was true, by monitoring to see if planted species were establishing locally. This could be another means of building capacity.

The distribution of farm dams could be mapped from aerial photography. Borrow pits, although much deeper and further from the shoreline, could possibly also serve a similar purpose.

Weedy species, notably willows and poplars, were occasionally recorded, possibly brought in to Sector 10 by the in-flowing creeks or channel.

Spatial characterisation of the study area, specifically its environmental characteristics and their variability, is a significant knowledge gap. Although this scoping study identified through observation a number of micro-habitats where regeneration was successful, it was not feasible to scale up these positive observations to a whole of site assessment.

Recommendations

Five recommendations come out of this study:

[1] Water level management: Aim to maintain stable water levels at the upper limit of the Bare Ground zone, provisionally identified as about 160.4-161.0 m AHD, over autumn-winter in the coming year (2008).

[2] Sediments: Commission a small field-oriented scoping study on sediments and benthos at Lake Mokoan, especially deposited sediments, in order to establish their intrinsic variability, their suitability for re-vegetation, and to obtain advice on potential management issues and problems.

[3] Restoration Planning: Develop a solid and detailed knowledge of site characteristics, spatial variability and constraints on goals, and use these to develop a series of realistic objectives.

[4] Passive Regeneration: Rather than relying on passive regeneration, adopt a new strategy of building capacity for passive regeneration. Strategic planting of a species to encourage seed fall close to regeneration sites or facilitate localised seed dispersal by water is one such option. This could prove useful for both target species, Southern Cane Grass and River Red Gum.

[5] Propagule Sources: Establish role of the diversion channel, in-flowing creeks, borrow pits and farm dams as likely propagule sources, whether positive (i.e. targeted native species) or negative (undesirable, invasive and introduced species), and dispersal pathways to regeneration sites.

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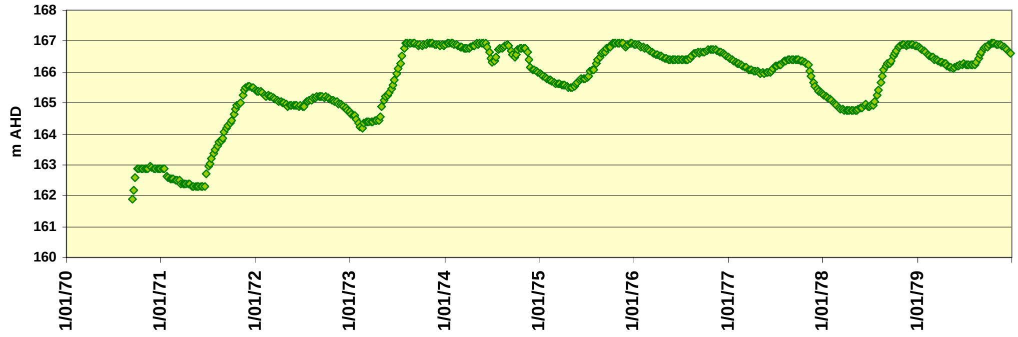
Appendix 1: Plant names

List of Common and Botanical Names used in this report (alphabetical order by common name). Introduced species are indicated by (*).

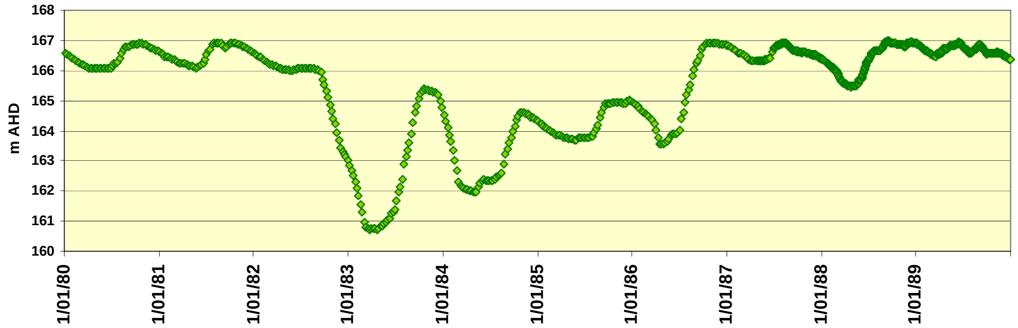
Aster-weed *Aster subulatus* (*)
Bracken *Pteridium esculentum*
Brown-backed Wallaby Grass *Austrodanthonia duttoniana*
Clammy Goosefoot *Chenopodium pumilio*
Common Blown Grass *Lachnagrostis filiformis*
Common Cassinia *Cassinia aculeata*
Common Sneezeweed *Centipeda cunninghamii*
Common Spike-rush *Eleocharis acuta*
Couch *Cynodon dactylon*
Cumbungi *Typha* spp.
Drain Flat-Sedge *Cyperus eragrostis* (*)
Drooping Cassinia *Cassinia arcuata*
Hairy Carpet-weed *Glinus lotoides*
Lesser Joyweed *Alternanthera denticulata*
Marsh Yellow-Cress *Rorippa palustris* (*)
Pale Knotweed *Persicaria lapathifolia*
Pigweed *Dysphania glomulifera*
Plains Rush *Juncus semisolidus*
Poong'ort *Carex tereticaulis*
Poplar *Populus sp*. (*)
Red Water-milfoil *Myriophyllum verrucosum*
River Red Gum *Eucalyptus camaldulensis*
Southern Cane-grass *Eragrostis infecunda*
Spear Thistle *Cirsium vulgare*
Spreading Sneezeweed *Centipeda minima*
Spiny Sedge *Cyperus gymnocaulos*
Star Cudweed *Euchiton sphaericus*
Stinkwort *Dittrichia graveolens* (*)
Tall Flat-Sedge *Cyperus exaltatus*
Weeping Lovegrass *Eragrostis parviflora*
Willow *Salix* sp. (*)

Appendix 2: Water level history

Mokoan Levels: 1 Jan 1970 to 31 Dec 1979



1 Jan 1980 to 31 Dec 1989



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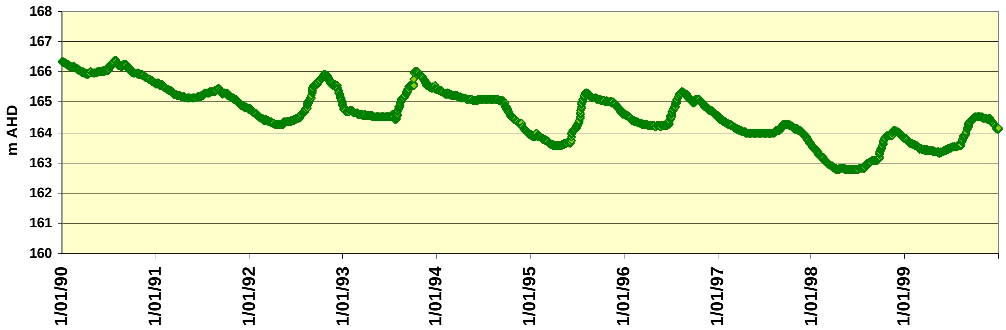
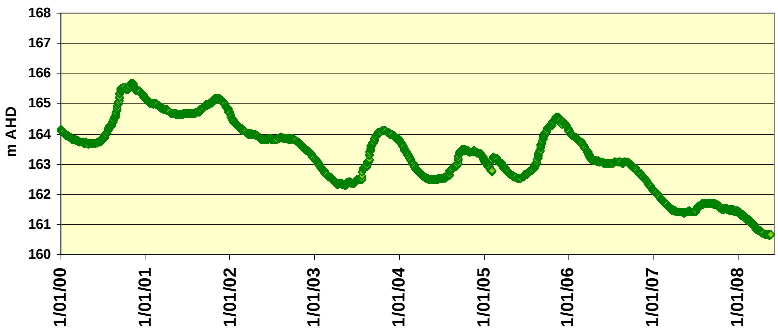


1 Jan 2000 to 23 May 2008



Water level history, 1 July 1970 to 23 May 2008 (data provided by Goulburn Murray Water)