A REVIEW OF THE STATE SALINITY STRATEGY WETLAND MONITORING PROGRAM 1996 TO 2007

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Introduction

This review of the Wetland Monitoring Program is undertaken as part of a larger review across the Department's salinity programs. Broadly, the present work extends the previous review of 1996-2000 (Wallace 2001) to cover the decade 1996-2007. Commentary is also provided concerning developments to 2009.

Well planned and executed monitoring is essential to assess the efficiency and effectiveness of operational programs. For monitoring to be effective for management, it is important that it is closely linked with management activities and does not become a form of disconnected surveillance monitoring (Nichols and Williams 2006). Therefore, the remainder of this section outlines the context of the monitoring program as a foundation for the section which describes monitoring objectives. The paper then discusses how the program has been implemented before describing the outputs from monitoring together with highlights, challenges and recommendations for future work.

The Salinity Situation Statement (Government of Western Australia 1996a), Western Australian Salinity Action Plan (Government of Western Australia 1996b) and State Salinity Strategy (Government of Western Australia 2000) outlined the threat posed by salinisation in the south-west of Western Australia and proposed actions for management. It was estimated that about 1.8 million hectares in the south-west agricultural region were affected by salinity to some extent, with projections of up to six million hectares at risk of future salinisation without intervention. More recent estimates (McFarlane *et al.* 2004) have revised downwards the area of the State affected by secondary salinity to about 1 million hectares as at 1996. In this later study, the area believed to be at risk was estimated to be up to 5.4 million hectares. Within the conservation estate, McFarlane *et al.* (2004) estimated that about 196,500 ha are affected, with about 764,000 ha at risk.

Biological assets at risk

The south-west of Western Australia, especially the semi-arid inland, is an internationally recognised biodiversity 'hotspot' (see, for example, Beard *et al.* 2000; Belk 1998; Segers 2003) and the Salinity Action Plan and State Salinity Strategy suggested that a substantial proportion of this biodiversity was at risk from salinisation. As a consequence, the Salinity Action Plan proposed a biological survey of the south-western, inland agricultural zone designed to provide quantitative information on the area's biodiversity and its susceptibility to salinisation. The subsequent survey (Keighery *et al.* 2004 and papers therein) revealed 2,878 terrestrial flora and fauna species and 1,887 aquatic fauna and flora (including fringing) species occurring within the region. About half of terrestrial species and almost all of the aquatic species occupied habitats susceptible to salinisation (Lyons *et al.* 2004; McKenzie *et al.* 2004; Walshe *et al.* 2004). Importantly, even those species that inhabit naturally saline areas are at risk of waterlogging and acidification associated with secondary salinisation. Of the aquatic invertebrates, about 750 are essentially freshwater species with very little tolerance to salinity (83% were restricted to salinities <10 g/L) and many of the halophilic species were absent from secondarily salinised wetlands. While most of these have populations outside the wheatbelt about 100 are both at risk of salinisation and known only from the wheatbelt (Pinder *et al.* 2005). Of the 1,436 vascular plants from in and around wetlands at least a third were deemed to be at risk from salinisation. Of the

69 more common waterbird species in the south-west, about 70% are much more common in wetlands with salinity < 50, 000 mg/L and most of those are common only below about 20,000 mg/L. The average richness of waterbirds at wetlands with salinity > 50,000 mg/L is half that of wetlands with salinity < 20,000 mg/L, though slightly saline wetlands often have greater richness than freshwater wetlands.

Thus, the survey provided a snapshot of the extent and distribution of the zone's extant biodiversity. However, it was clear that information on how wetlands and their biotas are changing through time was also needed, and this was recognised under the Salinity Action Plan and later, under the State Salinity Strategy which foreshadowed that the wetland monitoring program established under the Plan would "continue consistent with the overall Monitoring and Evaluation Plan" (page 69). The Government Response to the Taskforce Report (Government of Western Australia 2002) supported monitoring, stating that: "Government will develop and implement a practical and cost effective monitoring and evaluation framework at State, regional and catchment scales by the first quarter of 2003" (page 12). Subsequently additional funds for developing monitoring were allocated through the Natural Heritage Trust and National Action Plan for Salinity and Water Quality, however, none were received by the Department's Wetland Monitoring Program.

Finally, the Government policies outlined above were framed in a situation where, while not explicitly stated, it was envisaged that management action would be implemented by a wide variety of land managers for many catchments and thus it was thought that wetland monitoring would be an important component of assessing achievements.

Objectives

The Salinity Action Plan recommended that:

> "A program to re-establish systematic monitoring of wetlands as an indicator of catchment health is also required. Wetlands provide an important measure of the dynamic changes in salt water loads moving through catchments. Furthermore, changes in flora and fauna due to salinisation will be most pronounced, in the short term, in valley flats and their wetlands. Wetland monitoring will provide a basis for evaluating achievement of biodiversity conservation goals and will focus on both physical and biotic characteristics."

The accompanying action statement was that the Department of Conservation and Land Management will:

> "monitor a sample of wetlands, and their associated flora and fauna, throughout the south-west to determine long term trends in natural diversity and provide a sound basis for corrective action." (Appendix, Salinity Action Plan.)

To implement this action the Department's wetland monitoring program stated specific objectives to:

1. analyse and report on trends in salinity and depth of agricultural zone wetlands monitored by the Department since 1978.
2. monitor depth, salinity and nutrient status of a broad range of wetlands.
3. monitor waterbirds, fish, frogs and aquatic invertebrates in a subset of wetlands to measure any changes in fauna of the wetlands.
4. monitor floristic composition and tree health in the same subset of wetlands to measure change in flora occurring in, and around, the wetlands.

Program Implementation

Objectives (1) and (2) have been addressed through the continuation and re-expansion of the Department's 'South West Wetlands Monitoring Program' (SWWMP; initiated in 1977), while objectives (3) and (4) have been addressed by a multidisciplinary project which commenced in 1997. The latter has three components: fauna and detailed water chemistry, vegetation health and shallow groundwater trends. Summaries of these programs are provided below.

Implementation of wetland monitoring by the Department under the Salinity Action Plan and State Salinity Strategy is based on a project proposal (dated 24 June 1997 and provided in the 2001 review) developed by a team of Departmental officers comprising Ian Herford (Chair) representing Nature Conservation Division, Ken Wallace (then Wheatbelt Regional Manager), and Neil Gibson, Stuart Halse and Jim Lane from the Department's Science Division. The project proposal described the project scope and approach, expected outputs, milestones, actions needed and budget allocations for the first full year (1997-98).

In the early years of monitoring, annual meetings chaired by Science Division *Salinity Action Plan* Project Leader Greg Keighery were held to decide annual budget allocations. Messrs Gibson, Halse, Keighery and Lane also liaised concerning various aspects of the project, particularly selection of wetlands to be monitored, field programs and reporting. In recent years monitoring methods, budget and scope have been stable and run without regular meetings. However, in 2008 a meeting of all staff involved at that time was held to discuss priorities and future directions. It was agreed that while the 2008/9 field program would continue as normal, a priority for the 2008/9 financial year would be publication of all current findings for the 25 biologically monitored wetlands, see recommendations below.

Previous wetland monitoring

It is important to acknowledge that the current monitoring program was built on an existing activity, and a summary of wetland monitoring in the south-west was provided in the Department's 2001 review of its salinity programs (Wallace 2001). In short, a program of monitoring depth, salinity and pH of south-western Australian wetlands was commenced in 1977 to provide data on which to make decisions about duck-hunting seasons and to monitor key variables determining the ecological character of wetlands in Nature Reserves (including Game Reserves). This program, since re-badged as the South West Wetlands Monitoring Program (SWWMP), had included measurements at up to 119 wetlands but almost collapsed with the number of monitored wetlands down to 60 due to funding shortfalls following the banning of recreational duck shooting in 1992 (Lane *et al.* 2004). The Salinity Action Plan[1] recognised the value of this program and provided funding to continue monitoring at an expanded number of wetlands and to establish biological monitoring at a subset of these wetlands in the Wheatbelt.

Personnel

The program has benefited from substantial stability in staff since its inception. Personnel involved in wetland monitoring, with dates and approximate FTE time allocations are as follows:

SWWMP (from 1977): Jim Lane (1977-present, 0.2), Don Munro (1977-1990, 0.6), Grant Pearson (1977-2007, 0.3), Alan Clarke (##xxxx –present, 0.8), Yvonne Winchcombe (2000-present, 0.4).

Wetland fauna monitoring : Stuart Halse (1997-2007, 0.1), David Cale (0.5), Melita Pennifold (2001 – 2008, 0.4), Adrian Pinder (2007-present, 0.1).

Groundwater monitoring: Colin Walker (Geo & Hydro Environmental Management P/L -under contract) (1999 – present).

[1] Unless action relating directly to the Salinity Action Plan is the subject, for the remainder of the document the governing policy referred to is the Salinity Strategy, effectively current policy.

Vegetation monitoring: Michael Lyons (2002- present, 0.2), Neil Gibson (1997-2002, 0.05,), David Mickle (2003-2007, 0.5), Caroline McCormack (2008-present, 0.8). This component contracted to external consultants for 1997 – 2001.

Selection of the wetlands for monitoring

During 1997-2000, a set of 100 wetlands was selected for ongoing physico-chemical monitoring under the Salinity Action Plan and SWWMP. These comprise 58 'continuing' (most of those that were monitored up to and including 1996), 24 'resumed' (a selection of those that had been monitored for a period in the past, but were no longer being monitored in 1996) and 18 'new' (those where monitoring began between 1997 and 2000). The 'new' wetlands that were added to the monitoring program were a selection of previously un-monitored wetlands that the Biological Survey of the Wheatbelt, conducted from 1997 to 2000, showed to be of particular interest from a biodiversity perspective (Pinder *et al.* 2004).

These 100 wetlands represent a broad range of depth and salinity regimes, from shallow to deep, fresh to hypersaline, ephemeral to permanent, and high to low variability in these parameters. The depth and salinity regimes of many have changed since European settlement, as a consequence of land clearing and hydrological disturbances within their catchments. Some are in the process of changing or are considered likely to change in the near future. Some within large conservation reserves are unlikely to change for several decades at least, except perhaps as a consequence of climate change. Not all will change for the worse; some are being rehabilitated through the efforts of government agencies and local communities. Although they have not been selected *a priori* as a representative sample of south-western Australian wetlands, they do present a wide range of types, values, uses, degrees of threat and likely futures. Many have high nature conservation values and a substantial number also have significant recreational and aesthetic values (Lane *et al.* 2004).

Of the 100 wetlands monitored for salinity, water depth, pH and (to 2007) nutrient levels described above, a sub-set of 25 wetlands were selected for intensive biological monitoring. They were selected to represent a range of salinities and past salinisation trajectories and include basin lakes and seasonal wetlands of high conservation value spread across the Wheatbelt. Cale *et al.* (2004) provide a table outlining the reasons each wetland was initially selected. Selection criteria and their current relevance are discussed later in the review.

Data management, custodianship and availability

Data collected by the monitoring program is held within three databases. Fauna and detailed water chemistry data is entered into the Aquatic Projects Database (Microsoft Access) of A. Pinder's wetlands group in Science Division. The vegetation and groundwater data is stored in a project-specific MS Access database and MS Excel respectively, maintained by M. Lyons. The SWWMP data is also maintained in a project specific MS Access database (linked to Excel graph templates) maintained by Y. Winchcombe and managed by J. Lane. The data are actively exchanged and shared by all project participants and the Department of Environment and Conservation is the official custodian. The fauna, detailed water chemistry and SWWMP data is also available on the publicly accessible WetlandBase, maintained by the Department of Environment and Conservation and hosted by the Department of Agriculture and Food on the SLIP NRM portal (http://www.dec.wa.gov.au/management-and-protection/wetlands/wetland-base/view-wetlandbase-online.html).

Summaries of the fauna collected at the biologically monitored wetlands prior to about 2002 are available in Cale *et al.* (2004). Lane *et al.* (2004, 2009a and 2009b) present in graphical and summary form almost all of the SWWMP data collected between 1977 and 2008 (some seasonal data have yet to be reported). Vegetation methodology and data up to 2001 are available in Ogden and Froend, (1998), Gurner *et al.* (2000), Franke *et al.* (2001) and Kabay (2002). A priority of the 2009/2010 financial year will be to prepare summaries of all available data for the 25 biologically monitored wetlands.

Expenditure, Outputs and Outcomes

Expenditure

The budget expenditure under Wetland Monitoring is described in Table 1.

Table 1: Budget expenditure by the Wetland Monitoring Program, 1996-2006 financial years.

1996/97	1997/98	1998/99	1999/00	2000/01	2001/02	2002/03	2003/04	2004/05	2005/06	Total
18,930	259,939	229,287	216,135	250,000	232,334	275,213	249,736	246,681	264,664	2,242,919

Over the decade, expenditure exceeded the total budget allocation by about $4,400 (0.2%).

Outputs

Physico-chemical monitoring of surface waters

Selection of SWWMP wetlands

Since the 1996-2000 review, the only change to the list of 100 wetlands monitored under the physico-chemical monitoring program (SWWMP) has been the addition in 2001 of Collets Road Swamp, a small wetland in the southern part of Fitzgerald River National Park. This was added because it is close to, and contains water more frequently than, Pabelup South Swamp, which has rarely contained water during the months of monitoring.

Output
- List of currently and historically (pre-1997) monitored wetlands in Appendix 1 of Lane *et al.* (2004) and Tables 1 and 2 of Lane *et al.* (2009a, 2009b).

Gauge maintenance, installation and benchmarks

Since 2000, the depth gauges on all 101 currently-monitored wetlands have been maintained as necessary to ensure readability and accuracy.

The depth gauges at the 51 ‘historical’ wetlands (those monitored at some time in the past by SWWMP personnel, but not monitored currently under the State Salinity Strategy) are not being maintained. However, Landgate (formerly the WA Department of Land Administration) benchmarks have been installed near the gauge clusters of all SWWMP wetlands (except Colletts) and all gauges have been surveyed to them, thus facilitating re-installation of gauges and resumption of monitoring at ‘historical’ wetlands at any time in the future should this be required.

The program of installing Landgate benchmarks and reference marks near the depth gauges of all 152 (current and historical) SWWMP wetlands is very near completion, with only the Colletts Road Swamp depth gauges not having bench and reference marks. Most of the benchmarks have also been surveyed to Australian Height Datum (mean sea level) by Landgate.

Outputs
- Depth gauges maintained on 101 ‘current’ SWWMP wetlands to 2009.

- Program of installing Department of Land Administration benchmarks near gauge clusters on all 152 current and historical SWWMP wetlands very near completion (2009).
- Program of surveying all 152 SWWMP benchmarks to Australian Height Datum very near completion (2009).

Monitoring of SWWMP wetlands

Since the 1997-2000 review, all 101 SWWMP wetlands have continued to be monitored for water depth, salinity/conductivity, pH, total phosphorous and total nitrogen (both filtered and unfiltered) in the standard monitoring periods of September and November each year, except in 2008 when water samples were not analysed for nutrients due to funds being re-allocated to other SWWMP-related 2008/09 priorities. Note that the current September and November SWWMP monitoring maintains continuity with the monitoring of the past, provides more data confidence and analytical power than would be obtained from either month alone, and adds usefully to, rather than duplicates, the August, October and April monitoring of the Fauna and Water Chemistry component of the wetland monitoring program (see below).

Output

- Physico-chemical data collected from 100-101 SWWMP wetlands in September and November each year to 2008 (except nutrients in 2008).

Design, construction and maintenance of SWWMP database

In 2008 the SWWMP (formerly referred to as SWALMP) database, designed and constructed in 1998, was modified to the minimum extent necessary to make it compatible with the current version of Microsoft Access. Microsoft Excel software is used to graph SWWMP data.

Output

- SWWMP database maintained and software updated to 2008. All field data to 2008 entered onto database.

Prepare salinity and water level data for analysis

Since the 1997-2000 review, all water level recordings made using temporary markers have been converted by survey or other measurement to SWWMP depth gauge readings. All water level data have also been checked by visual comparison of same-year September and November and other recordings, assisted in some cases by the use of nearest-station rainfall data. A routine procedure of photographing all depth gauges at the time of taking depth gauge readings has applied since 2007, in order that all subsequent water level readings may be checked, corrected where necessary and verified.

The intensive, wetland-by-wetland review of salinity instrumentation and salinity data that was begun in 2000 was not continued as it proved too time-consuming for the small gains in precision achieved. Instead, all salinity data have been adopted ‘as is’, except in the case of a small number of obvious errors, which have been corrected. Standardized conductivity-salinity conversion formulae have been adopted for all more-recent salinity determinations. The conductivities of all routine SWWMP water samples continue to be tested both by SWWMP (DEC) technical staff and the WA Chemistry Centre in order that measurement errors may be detected and corrected. The exception to this was in 2008 when samples were double-tested by two DEC staff working independently, rather than tested separately by the WA Chemistry Centre, due to cost considerations.

Output

- A high quality SWWMP dataset through adoption of procedures to check, and correct where necessary, all routine depth and conductivity / salinity recordings.

Salinity, rainfall and water level trends analyses

Water level, salinity and rainfall data (nearest Bureau of Meteorology site) of all SWWMP wetlands monitored for 20 or more years to 2000 have been analysed for long term trends. All water level, salinity, pH and rainfall data to 2008 for the 25 biological monitoring wetlands has also been analysed for trends in preparation for a joint publication in 2009/10.

Output

- Depth and salinity trends reported in Lane *et al.* (2004).

Bathymetric mapping, water volume and salt load calculation

Since the 1997-2001 review, the bathymetries of 17 SWWMP wetlands and six other wetlands of the inland agricultural area have been mapped. Bathymetric mapping of Dumbleyung Lake, commenced in 1998, has also been completed. Depth-volume calculators and, in some cases, depth-surface area calculators have also been prepared. These are necessary for hydrological (water balance and salt balance) modelling of individual wetlands.

Progress with bathymetric survey is behind that envisaged in the June 1997 Science Division proposal. It was originally thought that 40 wetlands would be mapped by June 2001. Rapid survey techniques are currently being trialled (6 wetlands to date) with a view to increasing the rate of mapping in coming years.

Outputs

- Bathymetric maps of 18 SWWMP wetlands (16 currently monitored wetlands, of which 6 are also biological monitoring wetlands, plus 2 historically monitored wetlands) and 6 other wetlands have been prepared.
- Depth-volume and depth-surface area calculators have been prepared for most of the SWWMP wetlands bathymetrically mapped under this program.

Long term changes in habitat suitability and waterbird use of selected SWWMP wetlands

During 2008/09 intensive waterbird surveys were undertaken of nine SWWMP wetlands, seven of which were known to have been important for waterbirds during the 1980s and early 1990s and to have since experienced major changes in water levels and or salinities, or to be showing early signs of possible change. Only one of these nine wetlands, which are situated mainly near the south coast, is in the set of 25 'biological monitoring' wetlands monitored since 1997. Some major changes in waterbird habitats and use by waterbirds were recorded. These 'case studies' dramatically illustrate some of the changes that have occurred to south-west wetlands and their nature conservation values over the past 2-3 decades, that is, over a longer period than the 1997-2008 biological monitoring. Further work is proposed in 2009/10 on these and possibly several other SWWMP wetlands in order to more fully document these changes.

Outputs

- The 2008/09 work has been reported in Jaensch *et al.* (2009).

High resolution aerial oblique photography of SWWMP wetlands

Aerial oblique photography substantially improves interpretation of routinely acquired vertical photography. For example, it is very useful in assessing the species composition, arrangement, structure and health of wetland vegetation (see Gibson and Keighery 1999). This type of photography, which can be captured by DEC at relatively low cost, is also useful for communication activities, such as formal and informal presentations. During 2008 and 2009, 86 of the 152 current and historical SWWMP wetlands were flown to obtain multiple, high resolution, colour, digital, aerial oblique photographs of each. It is proposed to photograph the remaining 66 SWWMP wetlands during the next 2-3 years if funding permits, and it is envisaged that this work will be repeated at 20-30 year intervals (a smaller number of these wetlands were also photographed in the late 1970s and early 1980s). This photography is being made widely available for public use.

Outputs
- A list of the 86 SWWMP wetlands that were photographed in 2008 and 2009 has been reported in Lane *et al.* (2009b).

Hydrological modelling

Hydrological modelling is required in order to better determine the likely impacts of saline water disposal, freshwater extraction, changes in catchment management and climate change on the nature conservation and other values of specific, high value SWWMP wetlands. During 2008/09, the possibilities of developing suitable hydrological (salt and water balance) models and collecting additional physico-chemical data to input into those models and to assist in model development were explored in collaboration with the Department's supervising hydrologist. Training courses were attended and a small amount of equipment (rainfall and water level recorders) was purchased and installed. Catchment and subcatchment boundaries and flow lines of a selection of SWWMP wetlands were mapped and relevant GIS layers acquired. This work will be progressed in 2009/10.

Outputs
- None to date, apart from digital maps of catchment and subcatchment boundaries and flow lines of a small number of SWWMP wetlands.

Reporting

Since the 1997-2000 Review, progress in the physico-chemical monitoring program has been reported in Lane *et al.* 2004, 2009a, 2009b, in scientific publications in refereed journals (for example, Gibson *et al.* 2004, Lyons *et al.* 2007), in Annual Research Activity Reports of the Science Division, at an April 2005 workshop hosted by the Department's Natural Resources Branch and at the July 2008 Science Division Biennial Conference in Fairbridge.

A format has been developed for annual reporting of SWWMP results, with reports to be distributed in PDF or hardcopy format to all relevant DEC Regions, Districts and Branches and made publicly available through the DEC Wildlife Sciences Library and readily-locatable by internet search engines.

Outputs
- Several reports, publications and presentations referred to above, including the 1977-2007 and 1977-2008 annual reports (Lane *et al.* 2009a, 2009b).
- This report of 2009.

Data supply

Since the 1997-2000 review, data from SWWMP have continued to be used by departmental personnel and other organisations and individuals for a variety of purposes such as identifying changes in wetland character; assessing the potential impacts of proposals to divert, drain or input saline waters to or from wetlands; salt balance and water balance modelling, and management investigation and planning (see section 7 of Lane *et al.* 2004). Requests for SWWMP data may be e-mailed to jim.lane@dec.wa.gov.au.

Outputs
- Timely supply of latest data to a variety of users.

Fauna and water chemistry

Ongoing monitoring

The suite of 25 wetlands for biological monitoring was established such that fauna sampling commenced at 13 in 1998 and a further 12 in 1999. Fauna monitoring has continued with each wetland sampled every second year. Sampling occurs three times over the annual hydrological cycle of the wetlands. In August, when wetlands are in a filling phase, waterbirds and a set of water-chemistry parameters are sampled. Waterbirds, an extended set of water-chemistry parameters and aquatic invertebrates are sampled in October when wetlands are near maximum water levels and there has been time since filling to allow invertebrate communities to develop. Finally, the restricted set of water-chemistry variables and waterbirds are again sampled in early autumn during the period when wetlands are generally in a drying (reducing water depth) phase.

Since 2000 there have been 302 wetland visits to the 25 wetlands (Table 1), although no data were collected for the 73 occasions for which no water was present.

Water-chemistry parameters measured on each visit are: electrical conductivity, pH, water depth, concentrations of chlorophyll and total (filtered) persulphate nitrogen and phosphorus. These parameters are measured from a single sub-site (designated sub-site A) in August and April and from two sub-sites (A and B) in October. In October, to aid interpretation of invertebrate data, additional variables (ionic composition, total dissolved solids, turbidity, colour, alkalinity, and hardness) are measured at sub-site A.

The invertebrate sampling protocol of two 50m net sweeps (1 with a net of 50µm mesh and 1 with a net of 250µm mesh), at each of two sub-sites within the wetland, collects in excess of 60% of all invertebrate species larger than 50µm in size (Halse *et al.*2000). Recent studies by Pinder *et al.* (unpublished) suggest that a similar sampling effort collected 75 to 85% of species present at a site in the Pilbara. Collections of this detail are uncommon, with most studies concentrating on larger organisms (>250µm) and/or not identifying such a large range of organisms to species level. Research by the Department has consistently shown that about half of wetland invertebrate biodiversity is represented by micro-invertebrate species – such as ostracods, copepods, cladocera and rotifers – that are most efficiently collected with a fine net (for example, Halse *et al.* 2000, Pinder et al, 2004).

Waterbird counts record species, abundance and a measure of breeding activity for all waterbirds on the wetland. More than 36,000 invertebrates and 210,000 waterbirds have been counted and identified, yielding approximately 619 invertebrate taxa and 60 species of waterbirds.

Over the 10 year period 1997 to 2008, data have been collected during 5 years at most wetlands and for 6 years at Lakes Bryde, Logue, Towerrining, Coyrecup and Wheatfield (Table 1). Some wetlands are data deficient because rainfall has been insufficient to fill them. These include: Toolibin Lake which has not yet been sampled as part of the program (but see Halse *et al.* 2000), Lake Dumbleyung which was first sampled in 2003, Lake Altham which has dried before October sampling in most years and Lake Fraser which has filled only five times in the last ten years (and sampled only three times).

Outputs*:*
- Water-chemistry, including ionic composition, chlorophyll and nutrients (TN and TP) turbidity and colour for 24 monitoring wetlands.

- Invertebrate community composition for 5 sampling years at each of 10 wetlands, 4 sampling years at 10 wetlands, 3 sampling years at 3 wetlands and 2 sampling years at 1 wetland.
- Waterbird community composition three times per sampling year for between 3 and 6 sampling years at 24 wetlands.

Sample sorting, identification and curation

The monitoring protocol involves identifying invertebrates to species level for all groups where this is possible given the available taxonomic literature. While the taxonomy of macroinvertebrates has developed substantially in the last 20 years, progress on micro-invertebrate groups has been much slower. As a consequence, the processing of micro-invertebrate samples has been much slower than planned. Significant staff turnover in 2006 exacerbated this problem reducing access to skills for the identification of groups such as the Ostracoda and Copepoda. The skills shortage has been rectified by in-house training and it is again possible to identify these groups using departmental staff, however, sample processing is behind schedule with samples collected in 2006 almost completed and samples from 2007 and 2008 as yet unprocessed.

Collaboration with Dr Russ Shiel of the University of Adelaide has been crucial in the identification of Rotifera and Cladocera. His involvement has revealed a number of previously un-described species amongst these micro-invertebrate groups. These new species will periodically be formally described by Dr Shiel or his colleagues. Training sessions with Dr Shiel have also increased the capacity of monitoring staff to identify described species of Cladocera and to a lesser extent Rotifera.

Currently (2008) invertebrate data are complete for all wetlands up to 2003. Samples from more recent dates (up to 2006) are also complete with the exception that some groups, for example, Ostracoda, Harpacticoida and Oligochaeta, have yet to be identified to species. Efforts are being made to complete identifications to the lowest possible level for all samples up to and including 2006 by the end of the 2008 calendar year.

All fauna and water-chemistry data are held on the Aquatic Projects Database situated at the Department’s Woodvale centre. This database enables simple data outputs of all parameters by wetland and date. All data, other than invertebrate identifications, are added to the database within weeks of collection.

Invertebrate data have been added to the database at the lowest level of identification possible; which in most cases is species. However, where insufficient material is available a higher level of taxonomy has been recorded (for example most dytiscid beetles can only be identified to species where adult males are present). This continues to cause some difficulties in reporting invertebrate composition data for wetlands since some expertise is required to cross-match taxa between wetlands or between samples within a wetland to produce consistent species lists. As a result, some requests for invertebrate data must be handled individually and require the development of a unique dataset with consequent time costs.

Output

- All water-chemistry and waterbird data and invertebrate data up to 2006 added to the Wetland Projects Database.

Analysis, Data supply and Reporting

Since the 1997-2000 review a detailed report including site descriptions, sampling methodologies and initial documentation of monitoring data to 2000 (April 2001) has been written by Cale *et al.* (2004).

A pamphlet series was trialled in 2004 as a means of advertising the existence of the program and availability of the dataset; and to provide a limited interpretation of the waterbird community data for individual wetlands. The pamphlet series had a limited distribution list including Regional Managers, Nature Conservation Leaders and Recovery Catchment Officers. However, its distribution elicited numerous requests from other government agencies (Department of Water in Geraldton) and NGOs (NACC, Birds Australia). Following the popularity of these pamphlets a second series was produced in 2006.

Detailed wetland by wetland accounts incorporating data from all three monitoring program components, together with climate and other data from the catchments and sites, are planned for 2008/10 to summarise existing data for the 25 wetlands. It is clear already, however, that faunal diversity is strongly dependant on hydrological and chemical conditions within the wetlands and that the data will allow some biological effects of altered wetland conditions resulting from management actions to be predicted and monitored.

Contributions to other projects from the above work have been numerous. Invertebrate data from the fauna monitoring program were used by Pinder *et al.* (2004, 2005) in analyses of the biodiversity and invertebrate salinity tolerances of the Wheatbelt fauna. Sim *et al.* (2008) used invertebrate, water chemistry and waterbird data to test the utility of wetland condition indicators as part of the federally funded project "Development of National Indicators for Wetland Ecosystem Extent, Distribution and Condition". Several requests for data have been made by departmental hydrologists dealing with drainage applications, for example, at Coyrecup and Coomelberrup. Waterbird data was provided to an investigation of preferred lake depths for waterfowl in the Lake Warden Recovery Catchment by Robertson and Massenbauer (2005). Similarly, waterbird and water chemistry data have been provided for the Ecological Character Description of Lake Warden (Gareth Watkins).

A major analysis of data collected to date is the current priority.

Outputs:

- Report on initial data and detailed methodology published in Conservation Science.
- Pamphlets documenting an interpretation of waterbird community data have been published separately for each wetland for the period 1997-2003 (Cale and Halse, 2004) and the period 1997-2005 (Cale and Halse, 2006).
- Data made available to researchers and departmental personnel as requested.
- Data provided to WetlandBase.

Lake Bryde and adjacent wetlands study

In 2006, following late summer flooding rains in the Lake Bryde Recovery Catchment, the Recovery Catchment Team funded additional sampling in wetlands surrounding Lake Bryde. This project aimed to document the fauna and water chemistry at wetlands in the catchment other than Lake Bryde. This has allowed improved understanding of three aspects of the catchment: the spatial and temporal variability in the catchment; the changes in wetlands as they dry; and the implications of this for interpreting long term datasets. At Lake Bryde itself sampling during the 12 months following flooding revealed 30 invertebrate species not previously collected and indicated that this lake was a major repository of invertebrate and waterbird diversity within the Recovery Catchment (Cale, 2008). While a report on the spatial and temporal patterns has been completed, a more detailed analysis of this data in the context of monitoring is still to be completed.

Output:
An unpublished report on biodiversity of the Lake Bryde suite of wetlands (Cale, 2008).

Table 1 Individual fauna sampling visits to Wheatbelt Biological Monitoring wetlands. The three symbols per cell represent the three consecutive site visits per year in which the site was due to be sampled. ● denotes waterbird and water chemistry collected, ○ waterbird, water chemistry and invertebrate data collected, D wetland dry (no data collected), NS wetland not sampled.

Wetland	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
BRYDE	●○●		●○●		●○D		●○D		DD●	NS○○*	●○D
LOGUE	●○D		●○●	●○●		●○D		●DD		DDD	
TOWERRINING	●○●		●○●		●○●		●○●		●○●		●○●
COYRECUP	●○●		●○●		●○●		●○D		●○●		●○D
WHEATFIELD	●○●		●○●		●○●		●○●		●○●		●○●
ALTHAM		●○●		●○D		●○D	●DD	●DD		●DD	
NOOBIJUP		●○●		●○●		●○●		●○NS		●○D	
BENNETT'S		●○●		●○●	●○●		●○●		●D●		●DD
ARDATH		●○●		●○●		●○●		●○D		●○●	
BLUE GUM		●○●		●○●		●○D		●○D		●○D	
KULICUP		●○●		●○●		●○D		●DD		●○D	
CAMPION		●○●		●○●		●D●		●○D		●○D	
GOONAPING		●○●		●○●		●○D		●DD		●○D	
COOMELBERRUP		●○●		●○●		●○●		●○●		●○D	
WALYORMOURING		●○●		●○●		DDD	●○D	●○D		●DD	
EGANU		●○●		●○●		●○D		●○●		●○D	
FRASER		●○D	●○●	●○●		DDD	●○D	DDD		●○D	
PAPERBARK			●○●		●DD		●○●		●○●		●DD
COOMALBIDGUP			●○NS		●○●		●○●		●○●		●○●
DUMBLEYUNG					DDD	●DD	D○D		●○●		●○●
YAALUP			●○●		●○●		●○●		●○●		●○D
PARKEYERRING			●○●		●○●		●○D		●○●		●○●
PLEASANT VIEW			●○●		●○●		●○●		●○●		●○●
RONNERUP			●○●		●○●		●○D		●○●		●DD

* Additional data were collected at Lake Bryde in 2006, using equivalent protocols, as part of the Lake Bryde Natural diversity Recovery Catchment Survey

Drummond Nature Reserve Survey

A survey of two vegetated swamps in Drummond Nature Reserve was undertaken in 2004 to document their aquatic invertebrates and water chemistry. This was funded by the Drummond Recovery Catchment. Although not intended to be part of the ongoing monitoring program the data will be useful as a baseline snapshot of the lakes' faunal diversity and water chemistry.

Output:
An unpublished report (Cale, 2005).

Vegetation Monitoring

Ongoing monitoring

Vegetation monitoring at the 25 biological monitoring wetlands commenced in 1997 with eight wetlands sampled. A further eight were sampled in 1998 and the remaining seven in 1999. This three year cycle has continued such that currently all 25 wetlands have been monitored four times. Each annual round of sampling is typically conducted between October and December, although some measurements have been made in early January of the following year.

Monitoring of vegetation and floristic composition is based on multiple fixed transects at wetlands that capture the major vegetation types and riparian topographies. Transects are contiguous 20 x 20 m quadrats and may be 20-80 m in total length.

For overstorey taxa, measurements are made of height and diameter at breast height (dbh), with each individual also scored for vigour/health. Counts of seedlings for each species are also undertaken. These data provide an insight into stand age structure/recruitment, growth rates and overall stand health. Additionally, foliage canopy cover of the overstorey has been collected beginning with the 2001 round of sampling. This technique collects canopy foliage intercepts at 100 points within each 20 x 20 m quadrat.

Understorey floristic composition has been monitored concurrently with the overstorey data collection. Percentage cover is scored for all perennial understorey taxa within contiguous 4 x 4 m quadrats located on one side of the vegetation transect.

Soil salinity of transects has been monitored concurrently with vegetation sampling for the duration of the project. EM 38 measurements are made at 15 fixed points within each quadrat. This has been coupled with soil profile sampling at selected points to determine profile structure and salinity.

For overstorey taxa, the original methodology prescribed that all individuals are marked with uniquely numbered tags. These were affixed with either nails or galvanized tie-wire. After 2002 significant problems were encountered with the loss of tags across many transects due to corrosion, particularly during wetland fill events. All tags have been progressively replaced with stainless steel and affixed using stainless steel wire.

During the 2002 sampling round it was recognized that some overstorey taxa were not included in the earlier overstorey data collection rounds. These taxa were typically large overstorey shrubs such as *Melaleuca atroviridis* and *M. halmaturorum*. At transects where this was encountered all such taxa have subsequently been marked and included in routine overstorey data collection.

Additional data collection

To provide an historical perspective on wetland vegetation changes in the context of salinisation, historical aerial photography has been acquired for all 25 biological monitoring wetlands, based on searches of all photography held by the Central Map Agency, Department of Land Information. These 1200 dpi images have subsequently been geo-registered and are available in ArcGIS 9.

Transect survey data were upgraded by Geodetic Survey, Department of Land Information during 2004 by the use of RTK GPS. This provided data to accurately locate the horizontal and vertical positions of all quadrat transect markers. This has enabled the vegetation transects to be accurately located relative to the bench mark and associated depth gauge network of the SWWMP.

Data compilation

A major undertaking since the 1997-2000 review has been the compilation of data sets that preceded the Department resuming direct responsibility for the vegetation component in 2002, in addition to data collected in subsequent years. Prior to 2002 data sets collected by external consultants were stored in individual spreadsheets with multiple data structures. Presently (2008) all vegetation data sets from 1997 -2007 are stored in a dedicated database that includes direct data export functionality to analysis software.

Output

- All wetland vegetation and associated environmental data up to 2007 compiled in wetland vegetation database.

Analysis, Data supply and Reporting

Preliminary data analysis has been undertaken for all wetlands at whole of wetland and individual transect scales. To date this analysis has focused on overstorey taxa in terms of temporal changes in stand basal area, stand vigour/health and stand age structure (using size classes). The occurrence or absence of seedlings and subsequent recruitment into adult size classes has been summarized for all wetlands.

Since the 1997-2000 review, a case study paper, integrating all aspects of the monitoring programme at two wetlands has been published (Lyons *et al.* 2007).

Several requests for data and interpretation have been made by departmental hydrologists dealing with drainage applications, for example, at Coomelberrup and Parkeyerring.

Outputs

- Refereed paper integrating monitoring data for two wetlands (Lyons *et al.* 2007)
- Data made available to researchers and department personnel as requested.

Shallow groundwater monitoring

Ongoing monitoring

A total of 164 monitoring bores have been established adjacent to the 82 vegetation monitoring transects at the 25 biological monitoring wetlands. These were progressively established from autumn 1999 to winter 2001. Locations and elevations of all monitoring bores were included in the 2004 RTK GPS survey work undertaken for the vegetation transects.

Manual groundwater measurements have continued every two years at all bores since bore establishment, and include depth to groundwater using manual dipper tape, groundwater pH and conductivity. Measurement rounds are timed to maximize the chance of recording seasonal minima and maxima.

During 2003 the decision was made to install data loggers to record twice daily depth to groundwater at a subset of monitoring bores at all wetlands. Currently 97 loggers are in service. These data have been used to validate the representativeness of the manual data across the seasonal cycle and to capture shorter term groundwater movements associated with major rainfall events.

Currently all data pertaining to the shallow groundwater monitoring component is stored in an Excel spreadsheet. The spreadsheet records all data relating to bore location, technical details of bore dimensions, logger and probe installation data, battery voltages, data collection times and the manual and logged groundwater measurements.

All aspects of the shallow groundwater monitoring are carried out under contract to Dr. Colin Walker, Geo & Hydro Environmental Management P/L.

Output

- All data incorporated into dedicated Excel application for sampling up to and including autumn 2008.

Outcomes: Achievement of the original objectives

Objective 1: "Analyse and report on trends in salinity and depth of agricultural zone wetlands monitored by The Department since 1978."

Lane et al. (2004) analysed trends in salinity and depth of 41 wetlands monitored for 20 or more years since 1977. Seventeen showed no significant trends in depth or salinity; nine increased in depth but not salinity; three increased in salinity but not depth; three (Bryde, Crackers and Yarnup) increased in both depth and salinity, suggesting a substantial increase in their salt loads.

Probable causes of statistically-significant, long term increases or decreases in depths and/or salinities include secondary salinisation (Bryde, Toolibin, Yarnup), excess surface and groundwater inputs (Warden), surface water diversion (Crackers, Towerrinning), trends in local rainfall (Dulbinning, Eganu, Muir), a multitude of human interventions (Thomsons) and 'cause unclear' (Bambun, Chandala, Nine Mile, Poorginup, Unicup, Warrinup, Yealering). Several of these wetlands and their catchments are the subject of detailed hydrological and related investigations by the Department and others. Some, particularly Crackers and Nine Mile, warrant further investigation.

All water level, salinity, pH and rainfall data to 2008 for the 25 biological monitoring wetlands has also been analysed for long term trends in preparation for publication with biological monitoring results in 2009/10. Data from 9 other SWWMP wetlands that, in most cases, are showing substantial changes or early signs of change in salinity and water level, have also been analysed to 2008. Depth, salinity and pH trends and other changes of particular interest or concern in any of the 101 SWWMP wetlands to 2008 have also been reported in Lane *et al.* (2009b). Additional methods of trends analysis of salinity data are currently being explored by the Department's statistician.

Based on the above outcomes, Objective 1 is being met.

Objective 2: "Monitor depth, salinity and nutrient status of a broad range of wetlands."

The SWWMP has involved monitoring depth, salinity, pH and nutrients at 101 wetlands since 1997. These 101 State Salinity Strategy wetlands present a wide range of types, values, uses, degrees of threat and likely futures. They are also broadly distributed across coastal and inland agricultural areas of south-western Australia. Because of the origins of the program, many of the monitored wetlands are important for waterbirds. Nonetheless most are also important for other biota, while some are only important for other biota. A substantial number have significant recreational values, both passive (nature walks) and active (for example, boating activities) as well as philosophical/spiritual and other values, including infrastructure protection through flood mitigation.

Thus, Objective 2 has been achieved.

Objective 3: "Monitor waterbirds, fish, frogs and aquatic invertebrates in a subset of wetlands to measure any changes in fauna of the wetlands."

Waterbirds and aquatic invertebrates have been monitored at 25 wetlands since 1997. Most wetlands have been sampled biennially but some have been dry occasionally, or mostly dry since commencement of the program (Toolibin Lake, Lake Dumbleyung). Some of these data and analyses have been made available (see references) but a greater emphasis on analysis and communication of results is required (see recommendations). Fish and frogs were never included in the program. There is a very limited diversity of fish in the inland agricultural zone and surveying frogs has logistical difficulties that do not fit within the current field work schedule (unreliable detection, long periods required at wetlands, strong seasonal presence). It is not recommended that fish or frogs be part of any future program for these reasons. Furthermore, measurements of water chemistry, waterbirds and aquatic invertebrates are sufficient and more efficient indicators of wetland condition.

Objective 3 has been met except that a decision not to monitor fish and frogs, due to resource constraints and the difficulty of using frogs and fish as indicators of change, was made before the program commenced.

Objective 4: "Monitor floristic composition and tree health in the same subset of wetlands to measure change in flora occurring in, and around, the wetlands."

Tree health and floristic composition (overstorey and perennial understorey species) have been monitored at 25 wetlands since 1997. Soil salinity measurements have been taken at the time of vegetation sampling along with continuous logged depth to shallow groundwater, and biennial manual groundwater depth, pH and conductivity measurements. The composition and health of riparian vegetation at most wetlands appears relatively stable. Some secondarily saline wetlands have shown rapid decline and death of riparian vegetation (for example, Lake Eganu, Ardath), while other secondary saline wetlands are fringed by stands that appear stable but lack any recruitment and are likely to decline. At declining wetlands an increasing dominance of more inundation and salt tolerant taxa has been observed. For most other wetlands, both fresh and naturally saline, the vegetation is healthy and characterized by episodic recruitment events associated with wetland filling.

Objective 4 has been met except to date analysis of vegetation data has been confined to overstorey tree and shrub species.

Additional achievements

The program has made six other notable achievements:

1. Drummond Recovery Catchment: Two claypans within the Drummond Recovery Catchment were surveyed for water chemistry and aquatic invertebrates (Cale *et al.* 2002). Keighery *et al.* (2002) also carried out surveys of the vegetation of the Drummond Nature Reserve, including quadrats in the same two claypans. This work resulted in the "wandoo woodland over sedges" being recognised as a Priority Ecological Community. This data provides a baseline picture of water chemistry, aquatic invertebrates and floristics as a basis for future monitoring.

2. Lake Bryde Survey: A survey of several wetlands within the Lake Bryde Recovery Catchment contributed to an understanding of the spatial and seasonal variability of the catchment's wetlands and documented changes in community composition following an extreme summer rainfall event (and freshening). It also allowed the biodiversity values of the long term monitoring site (Lake Bryde) to be put into a catchment perspective.

3. To provide an historical perspective on wetland vegetation changes in the context of salinisation, historical aerial photography has been acquired for all 25 biological monitoring wetlands, based on searches of all photography held by the Central Map Agency, Department of Land Information. These 1200 dpi images have subsequently been geo-registered and are available in ArcGIS 9.

4. Bathymetric maps of 18 SWWMP wetlands (16 currently monitored wetlands, of which 6 are also biological monitoring wetlands, plus 2 historically monitored wetlands) and 6 other wetlands have been prepared. Depth-volume and depth-surface area calculators have been prepared for most of the SWWMP wetlands bathymetrically mapped under this program. This mapping will be an important component of planned hydrological modelling.

5. Intensive surveys of a small group of SWWMP wetlands known to have been important for waterbirds in the 1980s - early 1990s and to have since experienced major changes in water levels and or salinities, or to be showing early signs of such change, has shown that substantial changes in habitats and use by waterbirds have occurred. These case studies dramatically illustrate the impacts of altered hydrology on many south-west wetlands and their nature conservation values over the past 2-3 decades, that is, over longer periods than the 1997-2008 biological monitoring.

6. Prior to the current monitoring program there was very little understanding of the ecological functioning of wetlands in the agricultural south-west. In addition to simply monitoring trends, this program has had a strong research element, though that wasn't implicit in the program objectives. In particular, the program has provided substantial insights into the long-term variability and dynamics of the biological and physico-chemical components of a range of different types of wetlands. This knowledge is critical to understanding the likely outcomes of management initiatives.

Challenges

Reflection on experience to date raises two questions that need to be addressed before making recommendations for the future. These are:

- How relevant are the original criteria for selecting wetlands, and should they be either amended or added to?
- Are the original monitoring objectives still important and are there more important objectives?

Relevance of the original selection criteria

Salinisation was the primary focus of the monitoring program when it commenced. Wetlands were selected for biological monitoring largely on the basis of their current salinity, whether that salinity was primary or secondary, and whether condition of the wetland was perceived to have been declining or improving. There was also a desire to achieve a broad geographic spread of wetlands, and to select wetlands of high conservation value that have a history of data collection. Below, we briefly review the extent to which the currently monitored wetlands meet the original selection criteria and comment on their possible future application.

Wetlands referred to in Government of Western Australia (1996b)

Three wetlands (Toolibin Lake, Noobijup Swamp and Lake Wheatfield) were pre-selected to be included in the biological monitoring program because they were well known high conservation value wetlands within Natural Diversity Recovery Catchments (Government of Western Australia 1996b). This recognized that Recovery Catchments were the focus of the State's response to the need to protect biodiversity from salinisation in the region and that the effectiveness of their management needed to be monitored. Since the original wetlands were chosen three more recovery catchments have been established (Lake Bryde, Buntine-Marchagee and Drummond). Lake Bryde, within the Lake Bryde Natural Diversity Recovery Catchment, was one of the originally selected wetlands but none have been selected within the Drummond and Buntine-Marchagee catchments. There is already an intensive wetland monitoring program within the Buntine-Marchagee catchment (Storey *et al.* 2004, Lynas *et al.* 2006, Richardson *et al.* 2005). Two claypans in the Drummond NDRC have been sampled twice for aquatic invertebrates using the same methods (Cale *et al.* 2005 and DEC unpublished data) and Keighery *et al.* (2002) have good floristic data for these sites. The current fauna, vegetation and water chemistry program at Buntine-Marchagee may be adequate and is largely compatible with the State Salinity Strategy monitoring. However, the addition to the program reviewed here of key Drummond and Buntine-Marchagee wetlands (one each) that are subject to management actions should be considered.

Adherence to overall monitoring design

This criterion referred specifically to the need to include a range of salinities, salinity histories and expected salinisation trajectories in order to determine the effects of salinisation. Five water quality categories were used: primary saline, secondarily saline, fresh, declining, and improving. All of these categories were included in the biological monitoring program.

The selected wetlands also represent a wide range of biophysical wetland types, from sedge swamps (Lake Pleasant View, Noobijup Swamp), shrub and tree swamps (Goonaping, Toolibin) to more open fringed freshwater (Lake Logue) and naturally saline (Lake Campion, Lake Ronnerup) wetlands. The major types of wetlands not included in the biological monitoring program are naturally turbid claypans, near-coastal wetlands, granite rock holes and palaeodrainage flats. Considering the dominance of primary saline wetlands, their variety and geographic spread is also under-represented, being focused on quite large wetlands in the eastern Avon rather than the more numerous small playas which tend to have quite a different fauna and flora.

Naturally turbid claypans support an array of distinctive and endemic crustaceans and annual plants, but since they are mostly fed by local rainfall they can be isolated from rising groundwater by their clay sediments. However, some occur on the edges of areas affected by salinisation and may be inundated by overflow. They are also threatened by grazing and climate-change.

Near-coastal wetlands include large lagoons like those near Leeman and Hutt Lagoon and associated wetland complexes but also some along the south coast. While most are not imminently threatened by salinisation they may be affected by hydrological disturbance and other processes. Note that physico-chemical parameters of a significant number of high value, near-coastal wetlands, for example Lakes Clifton, Jasper, Maringup and Moates, are already being monitored under SWWMP and some, particularly Clifton, are showing increases in salinity.

Granite rock holes (mostly seasonal to ephemeral freshwater pools on granite outcrops) are not directly affected by salinisation but the rock hole communities may be affected in the long term by a reduction in the regional species pool that provides sources for aerial and passive recolonisation. The endemic component of granite rock hole faunas is adapted to ephemerality but this probably changes along the rainfall gradient and species composition may change if climate changes.

Palaeodrainage flats, containing many thousands of playas and intermittent drainage lines are a dominant feature of the zone of ancient drainage. However, the flats themselves and slightly elevated fringes contain a very diverse array of vegetation and include many ephemerally inundated areas not included in the monitoring program. These areas certainly are affected by salinisation.

The biological monitoring program could be made more comprehensive and representative by including some of these wetland types. However, this would need to be considered in conjunction with other existing and potential criteria, especially the need to align monitoring with management activities, as discussed below.

Wetlands with high conservation value

Wetlands were selected partly on the basis that they were of high conservation value for at least one of the following biological components: vegetation, waterbirds or aquatic invertebrates. Only two (Coomelberrup and Blue Gum) of the wetlands selected for biological monitoring were deemed not to meet this criterion. Now that the Biological Survey of the Wheatbelt is complete (Keighery *et al.* 2004) the relative value of the 25 biologically monitored wetlands, all of which were selected prior to its completion, can be re-assessed. The recovery catchment program is identifying new catchments based, in part, on the results of the survey, and additional high conservation value wetlands will probably be identified by that process. It would be beneficial to include these and other wetlands known to be of high conservation value in an expanded monitoring program if they represent conservation values poorly represented in the current set of wetlands.

It would be preferable not to discontinue monitoring of wetlands already in the program in order to fund the inclusion of additional wetlands as this would be wasteful of effort and resources already expended and would reduce the value and usefulness of the overall program. Very few wetlands in Western Australia have been intensively and systematically monitored for their biophysical attributes for periods as long as ten or more years. Nevertheless, given the likely scenario of static or declining resources for monitoring (K.J. Wallace pers. comm.), it is recognised that it might be necessary to transfer monitoring resources in order to ensure that a satisfactory outcome for biodiversity conservation is achieved.

Geographic spread

Biological monitoring wetlands have been selected mainly east and north of the 600mm annual rainfall isohyet, from Lake Logue and Lake Eganu in the north, to Noobijup and Kulicup in the south-west and to Coomalbidgup and Wheatfield near Esperance . There are also many wetlands through the central and southern areas of the Avon catchment extending inland to Lake Campion and Bennett's Lake near the eastern extent of clearing. There are purely geographic gaps in the central-western Avon (between York, Merredin, Narrogin and Corrigin) and in the western half of the Mallee IBRA region (between Cranbrook and Jerramungup). However, spatial distribution is probably the least important of the original selection criteria, other than when considering climate change, which will be uneven in its impacts across the region. In any case, all IBRA sub-regions are well represented in the sampled wetlands.

Long record of data

Twenty of the wetlands selected in 1997 had a significant history of data collection, including the SWWMP program and waterbird and vegetation surveys during the 1980s (for example, Lane *et al*. 2004; Jaensch *et al.* 1988a,b,c; Halse *et al.* 1993). This would be an important criterion in the selection of additional wetlands and is a strong argument against ceasing monitoring of any of the current wetlands. One of the greatest strengths (and necessary attributes) of this wetland monitoring program is its long term (multi-decadal) nature.

Landcare activities in local catchments

This criterion influenced the selection of several wetlands, including those that were, or now are, in recovery catchments: Lake Bryde, Noobijup Swamp, Toolibin Lake and Lake Wheatfield. The existence of local landcare activity that has the potential to significantly affect wetland hydrology should also be an important consideration in the selection of any wetlands for addition to the monitoring program.

Size

Very large wetlands were generally avoided except where this would compromise meeting other selection criteria. Very large wetlands in the region are generally naturally saline playas, although the secondarily saline Lake Dumbleyung is an exception. Lake Dumbleyung and Lake Campion were the only wetlands in the biological monitoring program that could be classed as ‘very large’. Particularly large wetlands tend to have more influences from different parts of the catchment. In general, smaller wetlands with simpler or more discrete threats are more suitable for investigating cause-effect relationships.

Summary

These criteria are all still relevant, but there may be a need to change their emphasis when considering whether to continue monitoring at currently included wetlands, or if selecting additional wetlands. The following section suggests that there should be an emphasis on monitoring wetlands that are a focus of management activities and that threatening processes other than salinisation should also be considered. This may require additional or modified selection criteria.

Are the original monitoring objectives still important?

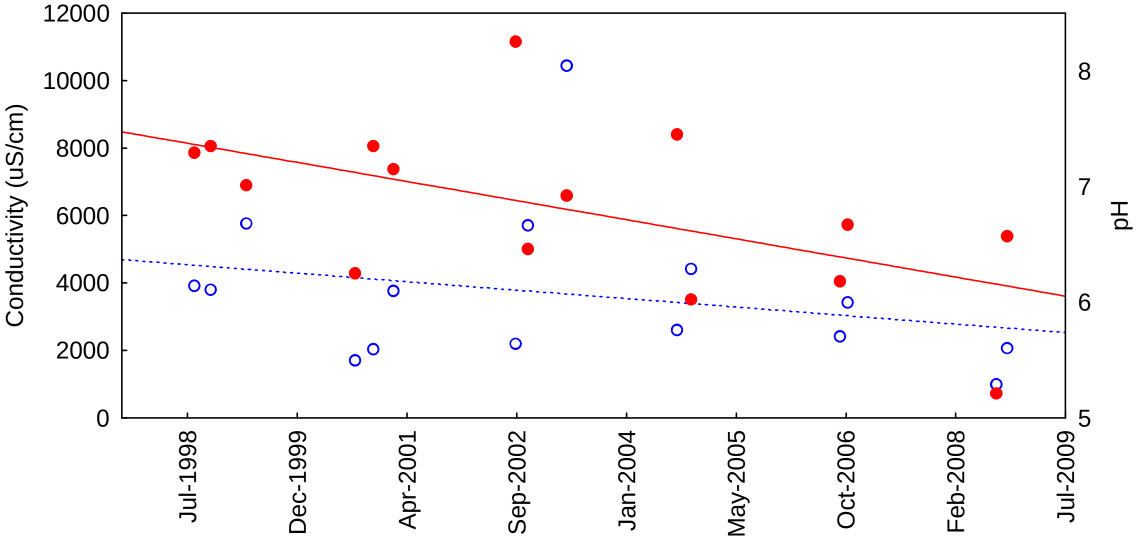
Relevance to management activities

The original objectives largely addressed the need for data on trends in the biota and physico-chemical environments of wetlands across the region. While this type of monitoring is still important, there is also a need to provide information on the effects of catchment management on wetland biodiversity, a requirement acknowledged in the previous review. All wetlands are affected by what is happening in their catchments but we do not adequately understand the specific linkages between catchment processes, management activities and monitored wetland attributes for many of the monitored wetlands. In general, biennial sampling of fauna and triennial sampling of flora is probably sufficient to detect long term trends at wetlands. However, those wetlands where we are trying to monitor the biological effects of management actions may need to be monitored more frequently and/or differently if cause-effect relationships are to be determined. Trends in the biota may be in response to short term changes in environmental attributes of wetlands not captured by the frequency of current monitoring.

Examples of wetlands at which we are beginning to link catchment processes and activities to changes in wetland ecosystems are provided below. Conceptual models, with some quantitative components, could be produced for many of the wetlands.

Noobijup Swamp

Noobijup Swamp in the Muir-Unicup recovery catchment is experiencing problems with vegetation decline, falling water levels and acidification as a result of hydrological change. This is potentially going to worsen in the near future as extensive blue-gum plantations are harvested which could result in water tables rising through iron-rich soil profiles with consequent further acidification of the wetland (Roger Hearn, pers comm.). The graph below shows a mild trend towards decreasing pH (closed circles, solid line) and conductivity (open circles, dashed line) at this wetland and analyses in 2009 will show whether this has affected the biota. Continued monitoring at Noobijup will help to determine the effects of these processes on the flora, fauna and water chemistry of the wetland. This will have application to other, similar non-monitored wetlands and will potentially assist in their conservation management.



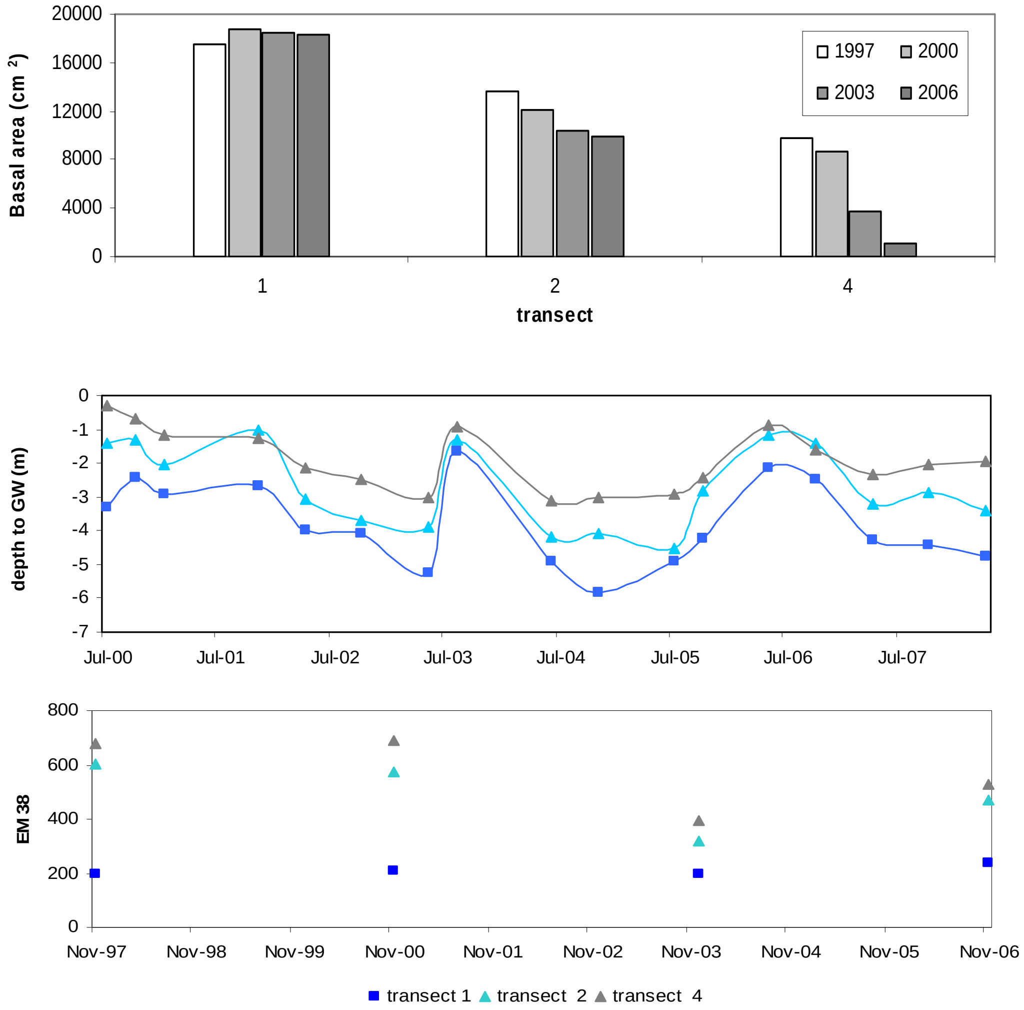
Toolibin Lake

Toolibin Lake and its catchment have been very actively managed for more than a decade (Toolibin Lake Recovery Team and Toolibin Lake Technical Advisory Group, 1994). Current management actions, which include by-passing saline flows around the lake, have reduced the impact of saline surface water flows on the lake biota. Low rainfall combined with by-passing of significant volumes of water is reducing the frequency with which the lake fills. Most importantly, however, the woodland vegetation across the lake bed has been retained alive, although its condition is spatially very variable as illustrated by the graphs below.

The upper graph shows the basal area (total cross-sectional area at breast height) of *Casuarina obesa* stands at three locations on the bed of the lake. Transect 1 has remained stable, while transect 4 has collapsed. Transect 2 has declined by ca. 30% from 1997 to 2006. Note that the area of vegetation recovery on the lake floor is not included in this data. This illustrates an unavoidable consequence of a limited vegetation monitoring program – that is, that, by chance, monitoring plots might not be established in some areas that later prove critical in reflecting some changes brought about by management.

The central graph plots depth to groundwater at transects from 2000, and the lower graph shows mean surface soil ECa (EM 38) values from 1997 to 2006. Transect 4, where the *Casuarina* stands have collapsed, shows the shallowest groundwater and highest soil electrical conductivity. The persisting stand at transect 1 shows low soil salinity and groundwater at the greatest depth. Transect 2 is intermediate.

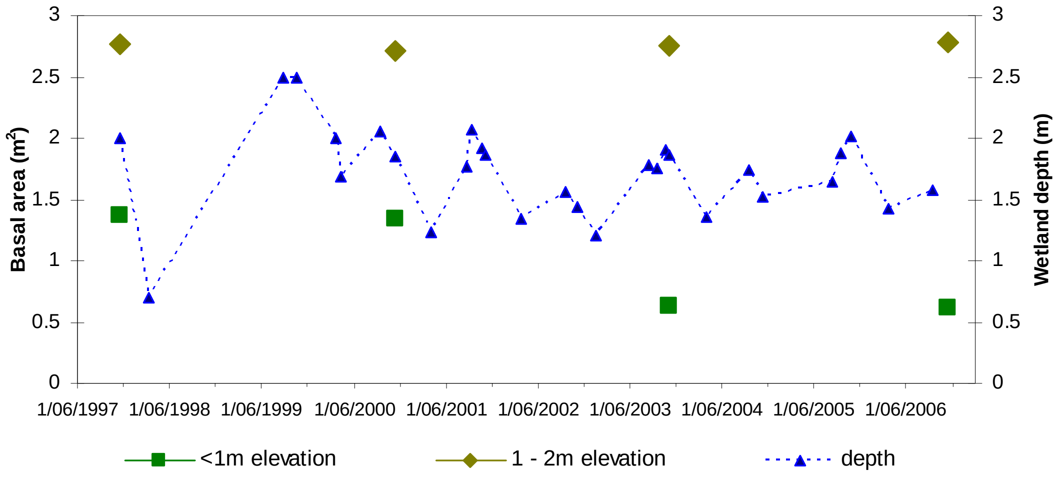
These data show significant variability across the bed of the lake and highlight the need for more detailed ecophysiological studies to understand the interaction between groundwater depth, soil type and soil salinity as they relate to the tolerance limits of *Casuarina obesa*. Such studies have recently (February 2009) begun at Toolibin.



Lake Wheatfield

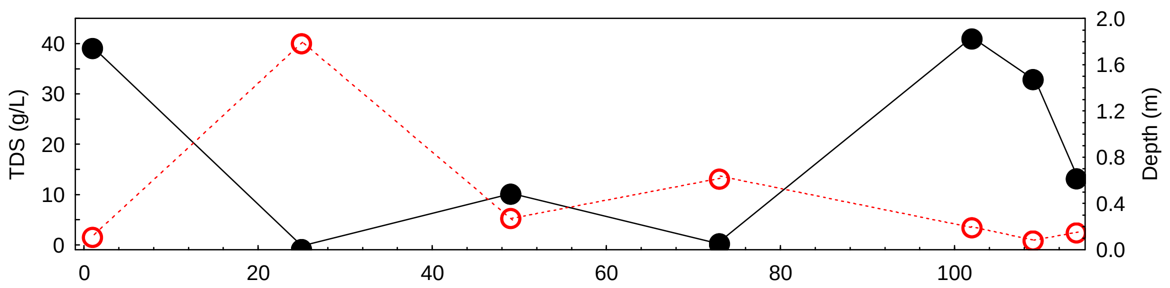
As with other wetlands in the Lake Warden Natural Diversity Recovery Catchment (LWNDRC), Lake Wheatfield has elevated water levels with reduced summer drying. Engineering intervention to increase discharge of water from the system's wetlands will be taking place from 2008. However, the Lake Warden system is very diverse in the variety of wetland types and water qualities and is affected by different management actions in different parts of the catchment. Wheatfield is thus a representative only of the central hydrological suite of the Lake Warden wetland system. From 2009, the Recovery Catchment Team intends to monitor the response of riparian vegetation, aquatic invertebrates and waterbirds to planned lower water levels at Wheatfield and a number of other wetlands in the system (John Lizamore, LWNDRC, pers comm.). The fauna component of this monitoring will be undertaken by State Salinity Strategy staff (David Cale, Adrian Pinder and an additional 0.25 FTE technical officer). Several wetlands in the catchment, in addition to Wheatfield, are already included in SWWMP.

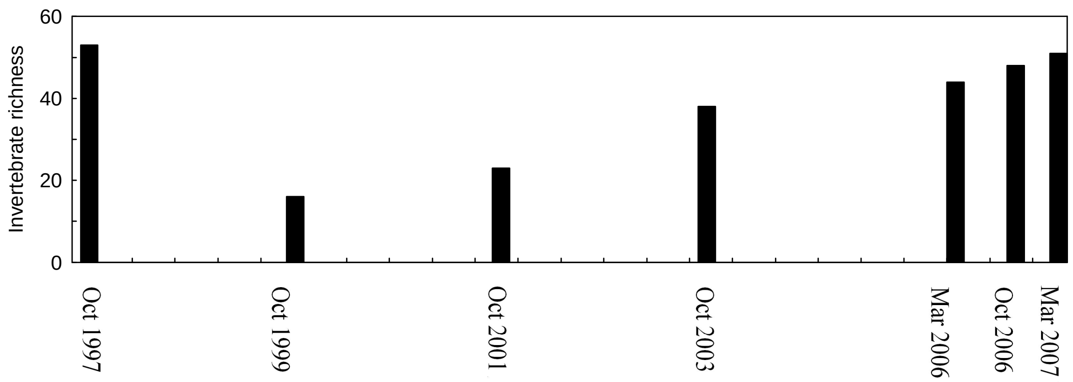
The plot below shows the basal area (total cross-sectional area at breast height) of *Melaleuca cuticularis* stands at two elevation bands at Lake Wheatfield plotted with wetland water depth. Trees below 1 metre elevation have been inundated since 1998 and have shown a 55 % reduction in basal area between 1997 and 2006 due to death of individuals. Stands of trees at higher elevations appear stable. Salinity levels in the wetland are relatively unchanged although a dilution effect was observed after the large rainfall of 1999/2000.



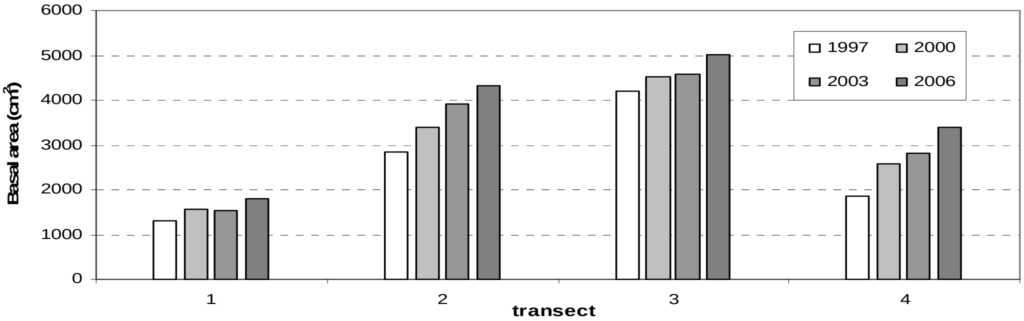
Lake Bryde

Significant engineering works are being undertaken within the Lake Bryde Recovery Catchment to control surface water flows. Future stages of these works are planned, and these will allow redirection of highly saline, low to intermediate flows away from Lake Bryde but allow fresher high volume flows into the lake (Natalie Nicholson, pers. comm.). The plot below shows that aquatic invertebrate richness (bottom graph) is strongly related to salinity (red open circles) and to a lesser extent depth (black circles). There is some decoupling of depth and salinity – probably related to different salinities of inflows. Data collected following the early 2006 flooding (Cale 2008) suggest that the invertebrate community of Lake Bryde has retained a capacity to bounce-back when it gets a large fresh filling. This resilience is important for understanding the long term prospects for the lake and for justifying intensive management.





Populations of *Melaleuca strobophylla* on the margin of Lake Bryde are healthy with no significant change in vigour scores from 1997-2006. Stands have also accumulated basal area (see plot below). It may be concluded from this that the current hydrological regime of the wetland appears to remain within thresholds for the persistence of *M. strobophylla*.



Basal area of *Melaleuca strobophylla* at transects on the margin of Lake Bryde.

The need to monitor threatening processes other than salinisation

In 1996, salinisation and associated hydrological disturbance were justifiably considered the major broadscale threats to wetlands of the Wheatbelt. The current monitoring program was a component of the State Salinity Strategy, specifically designed to address the need to determine the "long term responses of wetland ecosystems to salinisation". Now that this program is well established and collecting quality information on wetland condition in relation to salinity, it is opportune to consider how the program could be adapted to include other threatening processes. Three processes recommend themselves as candidates for additional monitoring.

<u>Drainage and Acidification</u>: The extensive occurrence of acid groundwater in parts of the Wheatbelt, coupled with the growth in farmland drainage, poses a major threat to wetland biodiversity in the region (Halse, 2004). More than 45% of base-flows in drains in the central eastern Wheatbelt (east of a line from Dumbleyung to Dalwallinu) have been found to have pH < 4.5 (Shand and Degens, 2008). Drainage will also affect the hydrology of wetlands receiving water. Of the 25 biologically monitored wetlands none directly receive local drainage although Coomelberrup, Parkeyerring and Ardath have significant current or proposed drainage/groundwater pumping disposal within their wider catchments. Understanding the impacts of drainage may require augmenting the current suite of measured biophysical attributes, especially of drainage inputs, and at least some hydrological modelling.

Acidification of wetlands may occur from direct drainage inputs but also in the absence of drainage via alterations in groundwater levels that intersect acidic soils. This is predicted to occur at Noobijup Swamp within Muir-Unicup NDRC in response to mass removal of plantation eucalypts with consequent groundwater rise. Where acidification is likely, additional measured parameters would include acidity and metals in water, sediments and fauna. Pre-drainage monitoring data would allow cause-effect relationships to be more easily established.

<u>Eutrophication</u>: Introduced livestock and the use of agricultural fertilizers have undoubtedly resulted in nutrient enrichment of agricultural zone groundwater and wetlands. However, in many districts, this threat has received very little attention. The interaction of nutrient enrichment and salinisation is also an issue, whereby increased salinity may have reduced the more obvious signs of eutrophication (altered patterns of primary productivity). To better understand nutrient dynamics and primary productivity on biodiversity in wetlands, a broader range of nutrient parameters (e.g. total nutrients rather than just soluble nutrients) will need to be measured. Measures of algal biomass, composition and productivity would also be desirable.

<u>Climate-change</u>: Climate change is affecting, and is likely to increasingly affect, many wetlands in the south-west of WA to varying degrees. Due in large part to its long term nature, the current monitoring program has the capacity to provide insights into the probable future effects of climate change if coupled with local rainfall data, catchment hydrology and climate modelling. Monitoring of wetlands

with minimal other disturbances, such as Goonaping Swamp, may allow the effects of climate change to be isolated for some wetlands. Some wetland types not currently monitored (damplands, granite vernal pools) will be particularly vulnerable to climate-change. Some currently monitored parameters would be useful for measuring effects of climate change, especially surface and groundwater monitoring, but additional parameters (for example, soil moisture in damplands and local weather monitoring) would be required. Predicted changes in rainfall patterns may call for additional or modified seasonal timing of monitoring activities.

The above examples show that monitoring is providing data that is relevant to management activities at some wetlands. The additional monitoring of the Lake Warden system starting in 2009 is an example of how the program can be expanded or modified to focus on adaptive management. At other wetlands, monitoring has provided data important for specific proposals that were not under consideration when the program was first established (for example, the provision of data for assessing likely impacts of drainage waters into Lake Parkeyerring and Cowcowing Lake). These are just two of the benefits of a long-term monitoring program.

Recommendations

1. Support the continuation of the program, recognising that one of its greatest strengths is its long term (multi-decadal) nature, bringing greater understanding of long-term multiscale trends and the complex dynamics of representative wetlands.

2. As opportunities and budgets allow, broaden the focus of the present monitoring program so that it is able to more effectively inform managers about past, present and potential effects of catchment processes, management and climate change on wetland ecosystems. This may, for example, involve more intensive or additional parameter monitoring of existing wetlands and/or selecting new wetlands with more of a management focus or subject to different threats. It may also involve medium term intensive monitoring at wetlands where substantial management actions, particularly actions aimed at recovery are proposed. In the short term, consider including an additional wetland within each of the Recovery Catchments not already included in the wetland monitoring program (Drummond and Buntine-Marchagee).

3. Assess the efficiency of the current sampling program in the light of the first ten years of biological data collection and analysis. For example, do all current groups of aquatic invertebrates need to continue to be identified or can a subset provide adequate information, thereby allowing more frequent sampling or more wetlands to be sampled or information to be provided in a more timely manner? Similarly, can the number of trees per vegetation quadrat or number of quadrats be reduced without unacceptable loss of information?

4. Increase funding to cover increased costs. The budget for the wetland monitoring program has remained unchanged over the past 10 years despite greatly increased costs. These costs have been absorbed by the program, albeit with some reduced spending on chemical analyses (particularly nutrients) and casual technical assistance, the latter with adverse consequences in terms of keeping up to date with laboratory work. Maintenance and replacement of equipment is also constrained. Additional funding will certainly be needed for expansion of the program.

5. Although very high quality data has been produced by the program, integrated analyses and dissemination of biological monitoring results have been delayed due to funding in recent years only being sufficient to keep up to date with field and laboratory work and data entry for the intensive monitoring. While some valuable and high quality publications have been produced by program staff, it is recommended that additional funding be provided to 1) analyse and disseminate findings of the program for the 25 biologically monitored wetlands and 2) rapidly disseminate new information in the context of previous data. Documents analysing all of the data collected to date for the biologically monitored wetlands are currently being prepared and some of

these are nearing completion. However, this is occurring at the expense of keeping up to date with processing new samples and data.

6. A workshop is convened by the Manager, Natural Resources Branch, to review the objectives of the Monitoring Program and recommend priorities for expenditure.

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