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Index of Wetland Condition

Conceptual framework and selection of measures

Victoria
The Place To Be

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Australian Governments and local communities working together to prevent repair and manage rising salinity and declining water quality across Australia.

Natural Heritage Trust
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The Index of Wetland Condition

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Contents

Executive summary

This project has resulted in the development of an Index of Wetland Condition (IWC) for use as a rapid assessment technique to assess wetland condition in Victoria. The project has focused on the conceptual framework that underpins the method and the selection of suitable measures for inclusion in the IWC, as described in this report. The development of the IWC has involved consultation with natural resource managers and policy officers from a range of natural resource management (NRM) agencies in Victoria as well as wetland experts from Victoria and other Australian states. The status of the IWC is currently as a provisional method that requires systematic use and testing as part of a continuing process of development.

There is an identified need for a standard method in Victoria for assessing wetland condition. The assessment and monitoring of wetland condition is an important component in the wise use of wetlands under the Ramsar Convention, to which Australia is a party. A method to measure wetland condition is needed to address National Action Plan for Salinity and Water Quality (NAP) and the Natural Heritage Trust (NHT) requirements to set and evaluate wetland resource condition targets for wetlands. Information on wetland condition is also required for State of the Environment and catchment condition reporting in Victoria.

Wetland condition has been defined for the IWC as the state of the '*biological, physical, and chemical components of the wetland ecosystem and their interactions*'. The definition is based on the Ramsar Convention definition of ecological character. The method aims to differentiate natural from human-induced changes in condition. It applies to naturally occurring, non-flowing wetlands, which do not have a marine hydrological influence. The IWC is one of a suite of rapid assessment methods designed to measure condition of natural assets in Victoria. Other methods include the Index of Stream Condition (for rivers and streams) and Habitat Hectares (for terrestrial vegetation).

The requirements that guide the selection of measures for the IWC are derived from the policy and practical considerations associated with the natural resource management (NRM) framework in Victoria and from an understanding of wetland ecology. The following requirements were agreed upon in consultation with stakeholders.

1. The IWC will be suitable for use at all naturally occurring, non-flowing wetlands without a marine hydrological influence in Victoria.
2. The IWC will be a tool for the surveillance of wetland extent and condition over a 10-20 year timeframe.
3. The IWC will be suitable for use at a wetland at any time of year.
4. The IWC will be designed to assess wetland condition in a single visit.
5. The IWC will be a rapid assessment tool.
6. The IWC will be simple, straightforward and inexpensive.
7. The IWC will be easy to interpret.
8. The form of the IWC will be based on the key ecological components of the wetland and its catchment.
9. The level of discrimination for the IWC must be sufficient to determine significant human-induced change in the state of the wetland.
10. The reference benchmark for condition assessment in the IWC wetland is the wetland unmodified by human impact associated with European settlement.

The IWC takes the form of a hierarchical index. The index has six sub-indices based on the characteristics that define wetlands: wetland catchment, physical form, hydrology, soils, water properties and biota. The components within each characteristic form the basis for the determination of possible measures to include in the IWC. The possible measures are evaluated against the IWC requirements to determine whether they should be included in the index. Selected measures are either the components themselves, impacts on the component

or threats to the component (the latter two are a type of surrogate measure). The component and measures selected for inclusion in the IWC are shown in the following table.

IWC sub-index	Key ecological component	Measure	Measure type
Wetland catchment	Wetland catchment	Percentage of land in different land use intensity classes adjacent to the wetland	Threat
	Wetland buffer	Average width of the buffer	Component
		Percentage of wetland perimeter with a buffer	Component
Physical form	Area of the wetland	Percentage reduction in wetland area	Component
	Wetland form	Percentage of wetland where activities (excavation and landforming) have resulted in a change in bathymetry	Threat
Hydrology	Water regime	Severity of activities that change the water regime	Threat
Water properties	Macronutrients (such as nitrogen and phosphorus)	Activities leading to an input of nutrients to the wetland	Threat
	Electrical conductivity (salinity)	Factors likely to lead to wetland salinisation • input of saline water to the wetland • wetland occurs in a salinity risk area	Threat
Soils	Soil physical properties (structure, texture, consistency and profile)	Percentage and severity of wetland soil disturbance	Impact
Biota	Wetland plants	Wetland vegetation quality assessment based on: • critical lifeforms • presence of weeds • indicators of altered processes • vegetation structure and health	 Component Impact Impact Component

The application of the measures and field assessment sheets for the IWC are in a separate report: 'Index of Wetland Condition Methods Manual. Preliminary Draft – November 2005' (Department of Sustainability and Environment unpublished). The Manual has been prepared as a draft to provide the basis for initial testing of the IWC by selected NRM stakeholders in Victoria. It is proposed that the manual will then be revised and considered for publication.

Wetland vegetation quality assessment is one of several measures of wetland condition included in the IWC. The approach to the assessment of wetland vegetation quality in wetlands is set out in 'Index of Wetland Condition. Assessment of wetland vegetation' (Department of Sustainability and Environment 2005a). This report also describes wetland ecological vegetation classes (EVCs) and provides guidance on the identification of EVCs at individual wetlands. A benchmark description has been developed for each wetland EVC as the reference for assessing vegetation quality.

Aspects of the IWC such as accuracy, precision and practicality have not been systematically tested to date. Research may also be warranted to improve existing measures or add new measures. Future testing and periodic revision of the IWC is considered essential to continue to develop the IWC as a robust and credible method. It is proposed that the IWC now be used in a provisional sense and that its use incorporates a program of testing. It is proposed that the IWC be reviewed within five years.

1. Introduction

1.1 Purpose of the document

This document has been prepared for a project to develop 'Core indicators for biodiversity for wetland ecosystem extent and distribution and wetland ecosystem condition'. The project was undertaken by the Department of Sustainability and Environment (DSE) with funding assistance from the National Action Plan for Salinity and Water Quality (NAP) and the Natural Heritage Trust (NHT). The principal project output is a method to assess the condition and extent of wetlands in Victoria.

There has been an increasing need for a standard, relatively simple and rapid statewide method for determining wetland condition in Victoria. The factors driving development of such a method are discussed in detail in Section 2 of the report.

The term 'condition' is widely used with respect to wetlands but is less often defined. In some wetland studies, condition has been used synonymously with 'ecosystem health' (e.g. Spencer et al. 1998). For the purposes of this project, 'wetland condition' has been defined as the state of the '*biological, physical, and chemical components of the wetland ecosystem and their interactions*'. This definition is based on the Ramsar Convention definition of ecological character and has been used by Butcher (2003). The Ramsar Convention defines ecological character as: "the sum of the biological, physical, and chemical components of the wetland ecosystem, and their interactions, which maintain the wetland and its products, functions, and attributes. Change in ecological character is the impairment or imbalance in any biological, physical or chemical components of the wetland ecosystem, or in their interactions, which maintain the wetland and its products, functions and attributes." (Ramsar Convention 1999). In this project, wetland extent refers to the area of a wetland and is considered to be one of the physical components included in the definition of wetland condition above.

The conceptual framework that underpins the development of the condition assessment method includes both the policy and natural resource management (NRM) and ecological frameworks relating to wetlands. The policy and NRM framework is defined by wetland policy in Victoria, the assets-based approach to NRM in Victoria and the practical requirements for wetland condition assessment by NRM practitioners. It also takes account of national NRM requirements. The ecological framework is based on current knowledge of wetland structure, function and condition based on measuring the components of structure and function. The state of the components may be determined by directly measuring a component or, alternatively by measuring the impact on the component or the activity causing the impact.

The wetland condition assessment method has been termed the Index of Wetland Condition (IWC). This document sets out the rationale and requirements for development of the IWC, the form of the IWC and the condition measures that make up the IWC.

1.2 Stakeholder engagement

The development of the IWC has involved consultation with natural resource managers and policy officers in Victoria as well as wetland experts from Victoria and other Australian states. Agencies consulted include the Department of Sustainability and Environment, Parks Victoria, Victoria's ten catchment management authorities, the Victorian Environment Protection Authority, Goulburn Murray Water, Southern Rural Water and the Australian Government Department of Environment and Heritage. Project governance includes a steering committee and expert technical panel that meet regularly. Meetings have also been convened to present and discuss project progress and seek input from regional natural resource managers in regional Victoria.

1.3 The importance and status of wetlands

The Ramsar Convention defines wetlands as 'areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres' (Ramsar Convention, n.d.). The scope of the IWC is naturally occurring, waterbodies with static water and without a marine hydrological influence.

Methods are under development for assessing condition of other types of waterways such as artificial wetlands (R. Coleman, Melbourne Water Corporation pers. comm.), estuaries (D. Hough, DSE pers. comm, D. Tiller, Victorian EPA pers. comm.) and floodplains (L. Smith, DSE pers. comm.). The Index of Stream Condition (ISC) is used to report on stream condition in Victoria (Ladson et al. 1999). The IWC is designed for determining the condition of natural areas of non-estuarine marsh, fen, peatland or water, permanent or temporary, with water that is static and fresh, brackish or salt. This includes depressional areas on floodplains that retain water, at least temporarily, after filling but not areas that drain freely immediately after flooding.

Wetlands provide important ecosystem services or values to the community (Appendix 1). These services include supporting, provisioning, regulating and cultural services, using the terminology of the Millennium Ecosystem Assessment (2003). In Victoria, there are approximately 16,700 non-flowing wetlands covering 540,900 hectares, of which 12,800 (covering 432,800 hectares) are natural and the remaining 3,900 wetlands are artificial (Figure 1) (Department of Sustainability and Environment 2005b). Eleven wetland systems are Ramsar sites of international importance and 159 are wetlands of national importance. The majority of these wetlands are inland wetlands, although some large wetlands, such as the Gippsland Lakes and Corner Inlet are marine or estuarine, and are therefore not covered by the IWC.

Wetlands are among the most impacted and degraded of all ecological systems. A global overview indicates that massive losses of wetlands have occurred worldwide and that the majority of the remaining wetlands are degraded, or under threat of degradation (Finlayson and Spiers 1999). In Victoria, almost 4,000 natural wetlands (191,000 hectares) have been lost since European settlement. This assessment is based on comparison of two geospatial coverages for Victoria (Department of Sustainability and Environment 2005b). These were based on air-photo interpretation and ground survey. One coverage estimates the extent of wetlands at the time of European settlement and the second the extent of wetlands in the period 1975-1994. The coverages do not include wetlands less than one hectare in area as it was not possible to adequately determine the original extent of small wetlands because of the lack of large scale air photos and subsequent clearing and drainage of wetlands leading to poor shoreline definition. (A. Corrick pers. comm.). Loss of wetlands in Victoria is attributed primarily to drainage for agricultural purposes (Department of Conservation and Environment and Office of the Environment 1992).

Threats and impacts on Victorian wetlands have been reviewed in Department of Conservation and Environment and Office of the Environment (1992) and Department of Conservation, Forests and Lands et al. (1988). Wetlands are significantly impacted in Victoria by physical loss, salinisation, changed water regimes and changed water quality (e.g. salinity and nutrients). Activities causing such impacts are believed to be large-scale clearing of native vegetation in wetland catchments, use of fertilisers and erosion of agricultural land and regulation of rivers for water supply and irrigation (Department of Conservation and Environment and Office of the Environment 1992). Other activities that potentially threaten wetlands are infilling, over-grazing by livestock, littering and pollution (Department of Conservation, Forests and Lands et al. 1988). In urban areas, human activity in and around wetlands may lead to damage of vegetation and disturbance to wetland fauna. Invasive species have also been identified as a problem in wetlands (Department of Conservation, Forests and Lands et al. 1988).

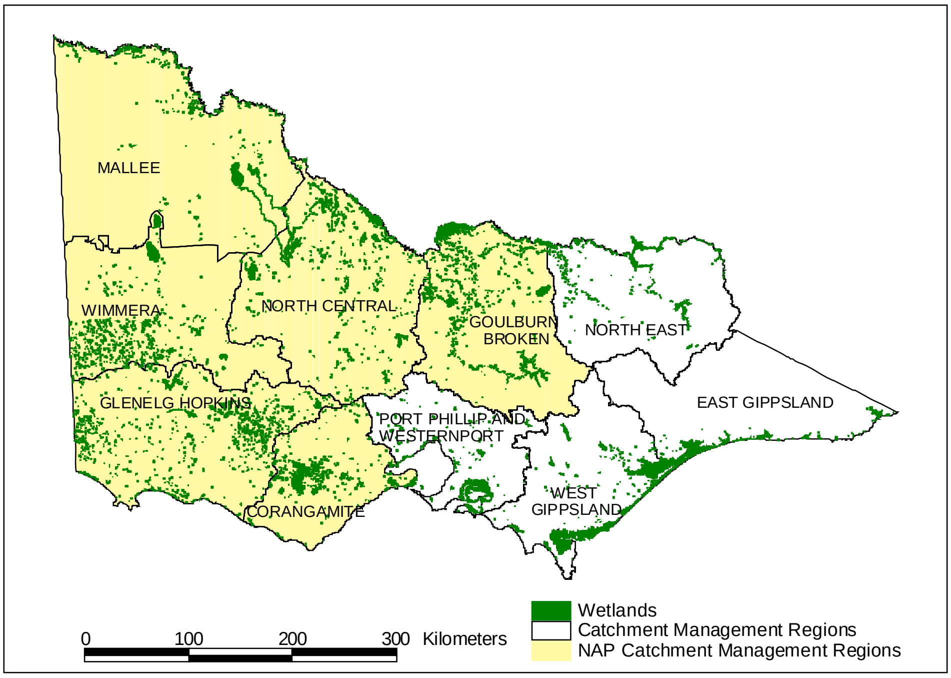

Figure 1. Victoria, showing the distribution of wetlands and catchment management regions.

2. Policy and natural resource management framework

Wetland policy and the NRM framework in Victoria and nationally, provide significant direction for the development of the IWC.

2.1 International and national wetland policy

Australia is a contracting party to the Ramsar Convention on Wetlands and, therefore, has an obligation to promote the conservation and wise use of wetlands. Victoria has adopted a policy on wetlands, as described in 'Victoria's Biodiversity: Directions in Management' (Department of Natural Resources and Environment 1997), to address this goal.

The assessment and monitoring of wetland condition is an important component in the wise use of wetlands as recognised in the Ramsar Strategic Plan 2003-2008 (Ramsar Convention 2002a). Operational Objective 1.2 of the plan is to 'assess and monitor the condition of wetland resources, both globally and nationally (or, where appropriate, provincially), in order to inform and underpin implementation of the Convention and in particular the application of the wise use principle' (Ramsar Convention 2002a).

2.1.1 National NRM framework

At the national level, the NAP and NHT provide the framework for integrated natural resource management. The goal of NAP is to prevent, stabilise and reverse trends in salinity and improve water quality. There are six NAP catchment regions in Victoria: Mallee, North Central, Wimmera, Glenelg-Hopkins, Corangamite and Goulburn-Broken (Figure 1). The goal of NHT is to achieve the conservation, sustainable use and repair of Australia's natural environment. All ten catchment regions in Victoria have access to NHT programs. Funding for both programs is provided on the basis of the 2001 bilateral agreement between Victoria and the Australian Government.

Under NAP and NHT, natural resource assessment is required to provide "a continuing reference point against which the appropriateness and effectiveness of national policies, strategies and programs may be judged" (Australian Government unpublished a). National outcomes, resource condition matters for targets, indicator headings and indicators, either "agreed" or "for advice", have been established (Australian Government unpublished b). Resource condition indicators are to be addressed at the regional level in setting regional " (Australian Government unpublished c). Table 1 shows those of relevance to inland wetlands. Estuarine, coastal and marine habitats and rivers are separate matters for targets with different indicators. In line with the NAP/NHT framework, the IWC will apply to inland, non-flowing wetlands, without a marine influence and must be suitable for use at all such wetlands in Victoria.

The wetland indicators (Table 1) are 'for advice', that is, in the process of being finalised (Australian Government unpublished b). Protocols for these indicators have been developed (Australian Government unpublished b). An assessment of protocols found significant shortcomings, either with the indicators themselves, or the protocols (Beaten Track Group unpublished). These indicators are considered for their usefulness in the IWC, together with other potential measures of wetland condition.

Table 1. NAP/NHT outcomes relevant to wetlands (Natural Resource Management Standing Committee unpublished b) and resource condition matters for targets, indicator headings and indicators (not finalised) for wetlands (Australian Government unpublished b)

Resource condition outcomes	Resource condition matter for targets	Indicator headings	Indicators
1 Biodiversity and the extent, diversity and condition of native ecosystems are maintained or rehabilitated. 2 Populations of significant species and ecological communities are maintained or rehabilitated. 3 Ecosystem services and functions are maintained or rehabilitated.	Inland aquatic ecosystems integrity	Wetland ecosystem condition	• colour • dissolved oxygen and temperature • extent of inundation • macroinvertebrate diversity and community composition • macroinvertebrate index • macroinvertebrate indicator species • nutrients (Phosphorus and Nitrogen) • transparency • vegetation • phytoplankton
		Wetland ecosystem extent and distribution	• extent of regionally significant wetlands

Regional catchment strategies, the key planning documents underpinning the implementation of catchment management programs in Victoria, are also required under NAP and NHT. They guide the investment of funds from State, Commonwealth and other sources. Monitoring and evaluation frameworks in regional catchment strategies address NAP and NHT outcomes. Resource condition targets for wetlands, based on the NAP/NHT indicator headings, have been set by several CMAs in regional catchment strategies. Others are yet to develop wetland targets. The timeframe for targets is 10-20 years (Natural Resource Management Standing Committee unpublished b) with reports on resource condition trends and associated measures to be provided at least every five years (Natural Resource Management Standing Committee unpublished a). The IWC is needed to assist with setting resource condition targets required under NAP and NHT and assessing management effectiveness in meeting such targets (Figure 2).

To detect trends over a 10-20 year timeframe, condition assessments may be made several times over this period, for example every 1-5 years, depending on the rate of degradation of a wetland or the rate of response to management intervention. The level of discrimination required for the IWC must be sufficient to determine significant changes in the state of the wetland. It is not designed to detect fine-scale changes in condition that would require continuous or detailed monitoring. The IWC is required as a surveillance tool, which in the context of definitions of wetland inventory, assessment and monitoring adopted by the Ramsar Convention (Ramsar Convention 2002b), refers to the collection of time-series information that is not hypothesis-driven.

The Victorian Catchment Management Council is required, under the *Catchment and Land Protection Act 1994*, to report to Parliament through the Minister for Environment every five years on the condition and management of Victoria's land and water resources. Wetland condition assessment is recognised as an important aspect of natural resource management in Victoria. The Victorian Catchment Assessment Council (2002) noted that "currently there are no indicators which directly measure the impacts of threats on inland, marine or coastal wetlands or estuaries. These are urgently needed. The *Commissioner for Environmental Sustainability Act 2003* requires a State of the Environment Report for Victoria every five years. The IWC will provide a means for reporting of wetland condition to fulfil these obligations.

2.2 Victoria's NRM framework

In Victoria, the concept of integrated catchment management underpins sustainable development of land and water resources. Management of natural resources recognises the linkages between land and water and that the management of one component can impact on the other. Victoria has established an integrated catchment management system under the *Catchment and Land Protection Act 1994.* The State is divided into ten catchment regions and a Catchment Management Authority (CMA) is established for each region (Figure 1). Each CMA prepares a regional catchment strategy (RCS), which provides the integrated planning framework for land, water and biodiversity management in the catchment region. Investment proposals are developed annually in regional catchment investment plans (RCIPs) which evaluate investment options for projects. Regional management plans (RMPs) document the programs and projects funded and provide a 12-month schedule of activities.

2.2.1 The assets-based approach to NRM

Victoria has adopted an assets-based approach to NRM, which is implemented through the regional NRM framework (RCSs, RCIPs and RMPs). Natural assets are tangible physical elements of environment. Wetlands are recognised as a secondary asset class under the primary asset 'water' (Department of Sustainability and Environment unpublished a).

The Victorian landscape comprises a diversity of natural resources, including wetlands, which society uses, appreciates or values in a variety of ways. The term 'services' applies to the uses and values related to an asset (Department of Sustainability and Environment unpublished a). For wetlands these are summarised in Appendix 1. Assets and their services are threatened and impacted by changing environmental, social and economic conditions. Threats are potential causes of degradation to the natural asset base. They threaten the quality (or condition) of an asset and/or the level of services that the asset provides (Department of Sustainability and Environment unpublished a).

The assets-based approach is guided by the RCS and any regional sub-strategy relating to wetlands. In relation to wetlands, the approach involves identifying a region's wetlands (assets) and setting outcomes, objectives and targets for them. Wetlands are prioritised based on the value of their services. Threats are identified and management actions to mitigate threats are identified and prioritised. Implementation of priority actions at priority wetlands is based on an annual investment cycle (through RCIPs and RMPs). Management actions are designed to address threats and thereby secure or improve the level of the service by producing the greatest possible benefit for a given cost. Management effectiveness is evaluated against targets.

The IWC will assist CMAs and other NRM agencies that manage wetlands with implementation of the assets-based approach to NRM as outlined below and shown in Figure 2. It is important to note, however, that condition measurement is only one of several tools needed for the overall assessment and management of wetlands.

The IWC will assist in:

- assessing the condition of wetlands in a catchment region and setting resource condition targets;
- identifying wetlands where threats are operating;
- assisting with the assessment of management options by comparing the relative effectiveness of different options in improving condition; and
- evaluating management effectiveness against resource condition targets.

Figure 3 illustrates the way in which condition relates to factors of interest to wetland managers, namely the threats to the wetland, the services or values which the wetland supports and the likely effect of management intervention. For example, human-induced changes to the wetland and its catchment cause threats which may change the wetland from an unmodified state to some impaired or unbalanced state. This in turn, is reflected in the change in the ecosystem services supported by the wetland. Management intervention attempts to identify threats and reduce risks to the ecological integrity of the wetland. Such action should be reflected by an improvement in the condition of the wetland leading to an improvement or restoration of wetland ecosystem services.

Although the IWC is not designed to systematically assess wetland threats or ecosystem services, it will have value as a diagnostic tool where relationships between threats and condition or service level and condition are known.

Information about wetland condition is only one of several types of information that direct management decisions about wetlands. For example, the decision on whether or not to restore a wetland to its natural state will also include consideration of issues such as the relative value of particular wetland services to the community, the availability of sufficient knowledge and the feasibility and the cost of restoration.

2.3 Practical considerations for development of the IWC

The IWC must be designed to meet the practical needs of CMAs and other agencies or managers undertaking wetland condition assessment. The three most significant likely requirements are those relating to program delivery timelines, financial resourcing and the expertise of people undertaking assessments.

Temporal variation in the hydrological cycle is characteristic of Victorian wetlands. To enable NRM managers to meet program timelines, the IWC must be designed, as far as possible, to be useful at any time of year, regardless of the phase of the hydrological cycle in the wetland. The selection of measures should therefore consider wet and dry phases.

To overcome financial resourcing constraints which are likely when large numbers of wetlands need to be assessed, it is desirable that the IWC assessment is able to be completed in a single visit rather than requiring successive visits. The assessment of condition should not take more than a few hours. In addition, the cost of sampling equipment and sample analysis needs to be considered. The methods required to undertake assessment should not require expensive equipment or laboratory analysis.

It is envisaged that staff likely to be undertaking wetland condition assessments will have general expertise in NRM but may not have specialist skills in wetland ecology. The IWC must be designed to suit this level of expertise, with training provided where a greater level of skill and expertise is required.

Another important factor is that the IWC should be easy to understand and interpret. The results of a condition assessment should be understood by natural resource managers and planners who may not be experts in wetland assessment, as well as by the community. The structure of the IWC into sub-indices and the measures used should aid in the interpretation of the wetland condition results.

These practical considerations lead to a number of requirements, which guide the development of the IWC (see Section 4).

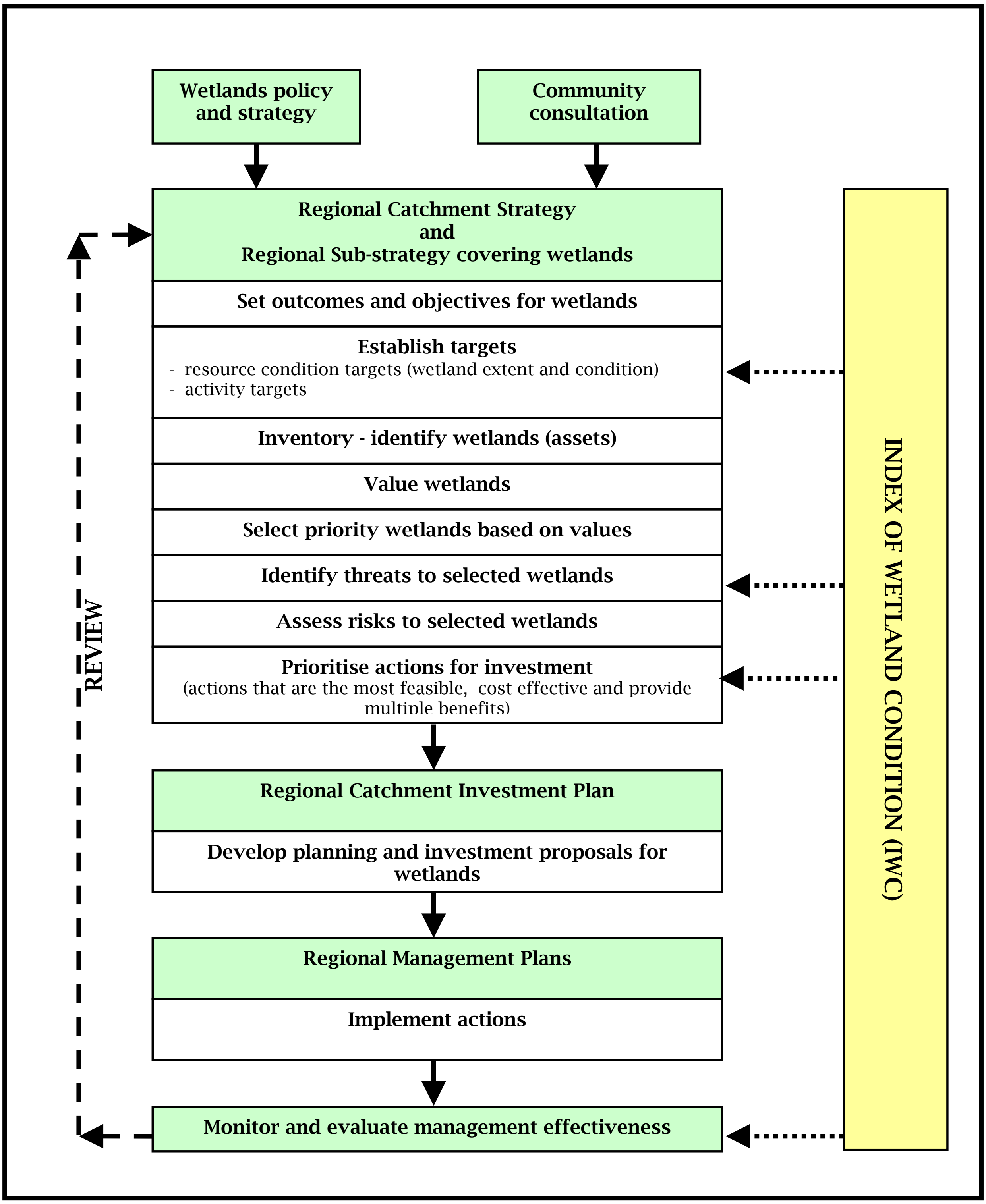

Figure 2. The assets-based approach to NRM as it relates to wetlands and the potential use of the IWC in several steps of the process. Arrows indicate the steps where the IWC can be used.

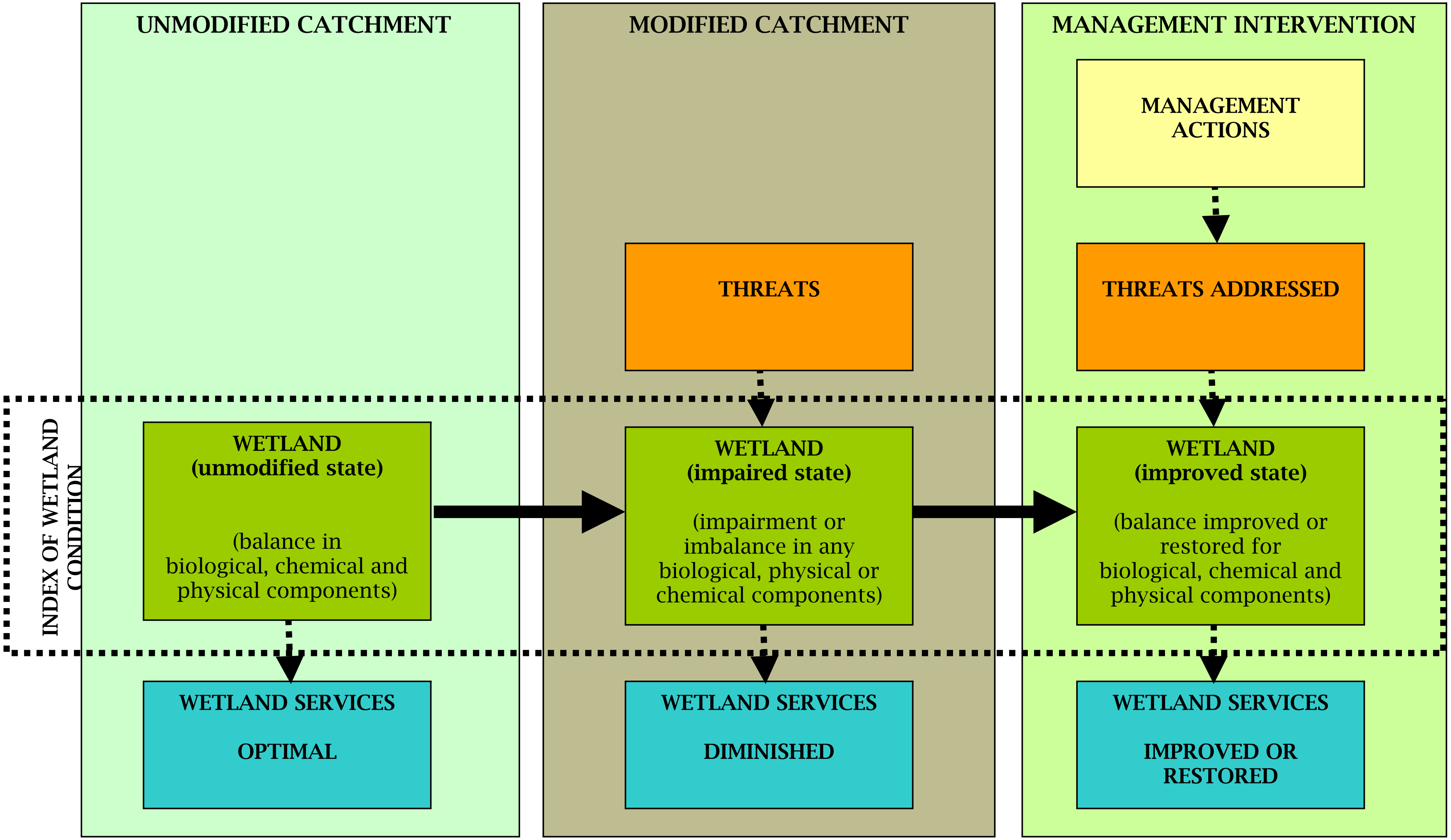

Figure 3. Figure depicting the relationship between the condition of wetlands, threats to wetlands and wetland services. A wetland in an unmodified catchment supports an optimal range of ecosystem services characteristic of that particular wetland type (left box). Human activities that modify the catchment and/or wetland cause threats, which lead to a change in the condition of the wetland and to a diminished level of wetland services (centre box). Managers address threats to the wetland, improving or restoring wetland condition. This leads to a restoration or improvement in the level of wetland services (right box). The IWC will be designed to measure changes in the condition but may also be useful in as a diagnostic tool for threats and service levels.

3. Ecological framework

The ecological framework provides the ecological context for selection of wetland components and measures that form the IWC. Wetland ecology is discussed with reference to the common characteristics that all wetlands possess and the interactions between them both generally and with particular reference to Victorian wetlands. The measurement of wetland condition with reference to managing spatial and temporal variability and selecting an appropriate reference condition is presented. Approaches adopted in other wetland condition assessment methods are outlined.

3.1 Wetland ecology

Wetlands generally occur where there are closed depressions in the landscape where water can collect (Paijmans et al. 1985). Geomorphology and climate are considered key wetland drivers that determine the location of wetlands across the landscape. They play an important role in determining characteristics of the wetland catchment and the characteristics of the wetland, such as its physical form, hydrology, water properties, biota and soils (Johnson and Gage 1997, Mitsch and Gosselink 2000).

Wetlands themselves are distinguished by three characteristics: the presence of water for all or part of the hydrologic cycle, unique soil conditions (hydric soils) and vegetation adapted to wet conditions (hydrophytes) (Mitch and Gosselink 2000) (Figure 4). Hydrology is considered a key variable of wetland ecosystems, driving the development of wetland soils and leading to the development of the biotic communities (Mitsch and Gosselink 2000). Other features that all wetlands have in common include a physical form (area and shape) and their water properties (i.e. physical and chemical properties). Wetland characteristics are described in Section 3.1.3.

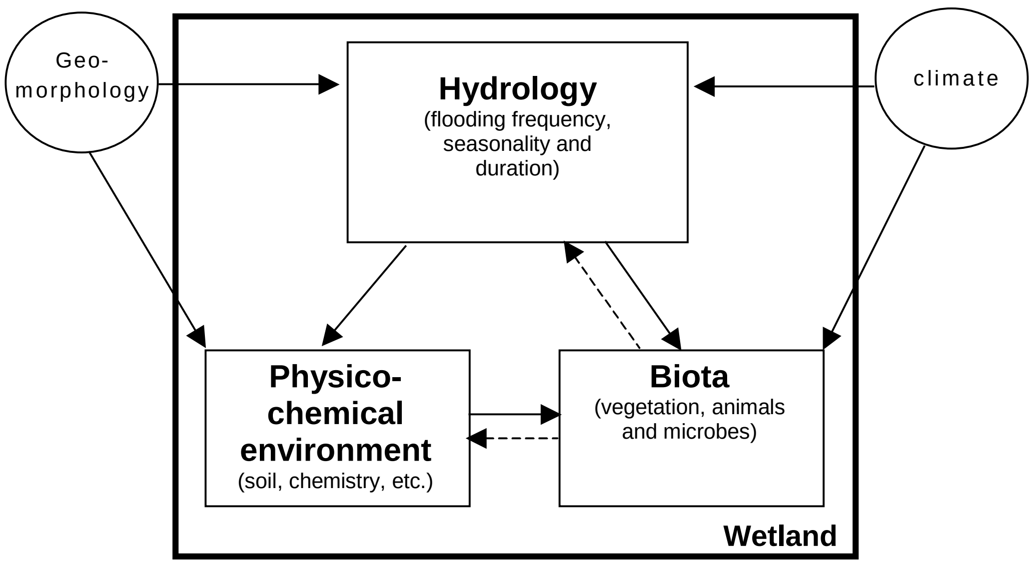

Figure 4. Conceptual diagram showing the key characteristics of all wetlands (hydrology, physico-chemical environment and biota), key wetland drivers, geomorphology and climate and the relationships between them. Reprinted and adapted with permission from National Research Council (1995) by the National Academy of Sciences, courtesy of the National Academies Press, Washington, D.C.

3.1.1 Wetland drivers

Climate

Climate has an overriding influence on the distribution and abundance of wetlands globally. Generally, wetlands are more numerous in humid environments and become less common in drier climates (Semeniuk and Semeniuk 1995). Climate also has a major influence on wetland hydrology (flooding duration, seasonality and frequency). Hydrological variability in wetlands is closely associated with rainfall patterns. Over the year these patterns influence the seasonal cycle of filling and drying. Over several years there may be periods that are wetter or drier than average which lead to longer-term changes in wetland filling frequency and duration of inundation. Diurnal and seasonal temperature fluctuations cause variations in daily and seasonal wetland water temperature. Temperature also affects hydrology through evaporation and transpiration.

Geomorphology

Geomorphic setting is a key factor that determines the water source of wetlands, the size and shape of wetlands, their location, their hydrology, physico-chemical properties of the water and soils (Figure 4) (Semeniuk and Semeniuk 1995, National Research Council 1995, Mitsch and Gosselink 2000). A number of wetlands classification schemes are based on geomorphic setting. Examples of such categories are as follows (modified from Brinson 1993, Semeniuk and Semeniuk 1995):

- depressional wetlands/basins that occur in depressions and are maintained predominantly by overland flow, groundwater and precipitation;
- riparian (also known as riverine) wetlands that are adjacent to rivers and maintained predominantly by periodic pulses of water from overbank flows;
- flats that occur in many settings but are principally maintained by precipitation and contain organic soils;
- slope wetlands that are usually located on a slope where groundwater reaches the surface and is relatively constant; and
- highlands or hill wetlands that principally occur in wet areas, maintained by precipitation (e.g. alpine bogs).

3.1.2 Wetland catchment

The wetland's catchment is defined by its geomorphic setting and determines the water source, which may be from two principal sources: surface water and groundwater. Paijmans et al. (1985) describe four main inflow systems in Australian wetlands.

- Regional runoff inflow. These are wetlands that are dependent on water flow from high in the catchment through stream channels.
- Local runoff inflow. Wetlands derived from runoff generated by precipitation close to the wetland.
- Regional groundwater inflow systems. Wetlands derived from groundwater discharge zones in the topographic lows at the edges of large aquifers.
- Local groundwater inflow systems. Wetlands derived from discharge zones on minor topographic lows.

The land use within the wetland catchment is likely to have an influence on wetland condition. Relationships between stream condition and land use have been well documented (Roth et al. 1996, Johnson et al. 1997, Gergel et al. 2002). Relationships between wetland condition and catchment characteristics are, however, less documented. Nevertheless, land use is considered to be a factor influencing wetland condition and hence is a commonly used measure in wetland rapid assessment methods (e.g. Hicks and Carlisle 1998, Miller and Gunsalus 1999, Mack 2001, United States Environment Protection Agency 2002).

The wetland buffer is a commonly-recognised component of the wetland catchment. It can be defined as the natural terrestrial vegetation upslope of the wetland-dependent vegetation (Davies and Lane 1995) or more simply as a 'zone' around the wetland that extends outwards from the wetland to a human land use (Castelle et al. 1992, 1994; Boyd 2001).

The wetland buffer can provide the following functions (Castelle et al. 1994, Davies and Lane 1995, Boyd 2001):

- attenuation of nutrients, pollutants and sediments;
- protection of groundwater quality;
- feeding and breeding habitat and shelter for wetland fauna;
- contribution to wildlife corridors between the wetland and adjacent wetlands or bushland;
- reduction in disturbance of native fauna from surrounding development (e.g. noise, movement and light from residential development);
- minimisation of invasion by exotic species; and
- provision of a source of carbon to the wetland.

It should be noted that exotic vegetation such as grass filter strips can also be effective in trapping sediments and nutrients (Hairsine 1997).

The width of the buffer required to achieve the functions outlined above is dependent on a number of factors. These include: slope of the land and how significant it is for sediment erosion, type and amount of vegetation and how effective it is in stabilising the ground, soil types and how far the surface water infiltrates the soil and the requirements of the biota that inhabit the buffer (Castelle et al. 1994, Davies and Lane 1995, Boyd 2001). The intensity of the land use adjacent to the buffer may also be a factor in the determination of effective buffer widths (Castelle et al. 1992). Buffer widths suggested for various buffer functions are included in Table 2. Wetland assessment methods typically assess buffer widths to a maximum of 50 m. For example a 30 m maximum width is used in the Murray-Darling rapid assessment method (Spencer et al. 1998), a 30 m width is used in the Washington (USA) method (Castelle et al. 1992) and 50 m width is used in the Ohio (USA) method (Mack 2001).

Table 2. Buffer widths suggested for various buffer functions (from Castelle et al. 1992,1994; Davies and Lane 1995; Water and Rivers Commission Western Australia 2000; Boyd 2001, Hairsine 1997).

Purpose	Buffer width needed to perform function (m)
Protection of inflowing surface water quality (sediment and nutrient trapping)	As little as 6 m for low overland flow rates
Maintenance of ecological processes and major food-webs	20-50
Protection of inflowing groundwater quality	250
Protection from rising salinity	2000

3.1.3 Wetland characteristics

Physical form

Wetland physical form relates to the wetland's shape and bathymetry (depth and underwater topography). It includes the extent (area) of the wetland at maximum inundation level. The shape of a wetland is often determined by the process that formed the wetland. For example, wetlands formed by volcanic activity are often round and wetlands on floodplains (billabongs) often have a characteristic ox-bow shape (Boulton and Brock 1999).

A wetland's physical form influences the flooding depth and duration of inundation. It also influences biological components and physical processes. The bathymetry of a wetland is a determinant of the biotic habitats present in a wetland.

Different habitat areas are often identified in a wetland with different plant and animal assemblages occupying these areas (Boulton and Brock 1999):

- the littoral zone (the edge of the shore at the highest watermark to a depth where light becomes limiting to aquatic plant growth);
- the profundal zone (the poorly lit bed of the wetland with fine sediments, usually only found in deeper systems);
- the water surface; and
- the open water column.

The area and shape of the wetland determines the amount and type of available habitat for the different plant and animal assemblages, for example, irregularly shaped wetlands have a higher proportion of littoral zone compared to the open water than round or oval-shaped wetlands.

Wetland depth and shape are factors that affect the mixing regime of the wetland and the type and stability of stratification (Boulton and Brock 1999). Stratification is the separation of layers of water due to different densities, through differences in salinity or temperature with depth. Stratification often causes the bottom layer to become deoxygenated, increasing the risk of stress on aquatic biota. Shallow wetlands are much less likely to become stratified, as are wetlands with their maximum length coinciding with the prevailing wind direction (Boulton and Brock 1999).

Hydrology

A wetland's hydrology is determined by precipitation, evapotranspiration, and surface and groundwater inflows and outflows (Mitsch and Gosselink 2000). Precipitation is controlled by climate, evapotranspiration is controlled by both climate and plant communities. Geomorphology and geology control inflows and outflows.

Inundation frequency, duration and seasonality are components of wetland hydrology. Frequency of inundation refers to the average number of times a wetland is filled in a given period of time. Duration is the length of time surface water is present and seasonality refers to the season in which inundation typically occurs.

Wetland hydrology is likely to be the single most important determinant for the establishment and maintenance of specific types of wetlands and wetland processes (Mitsch and Gosselink 2000). A wetland's hydrology both modifies and determines wetland characteristics (such as soil and biota) and, in turn, is affected by these characteristics (i.e. through a build up of materials which leads to a change in wetland morphology) (Breen 1989, Mitsch and Gosselink 2000).

Wetland hydrology influences the chemical and physical aspects of the wetland, which in turn, affect the biotic components. Hydrology affects the oxygen concentration in the soil, redox potential and availability of nutrients and toxicants. A longer duration of inundation will result in longer periods of anaerobic and/or reduced conditions that generally limit the plants that can survive. Consequently, wetlands with longer flooding durations generally have lower plant species richness than do less frequently flooded wetlands (McKnight et al. 1981). Hydrology also affects the accumulation of organic matter. Longer hydroperiods inhibit the breakdown of organic matter. Longer flooding periods will lead to the development of hydric soil properties and an accumulation of organic material (Tiner 1993).

Water properties

Water properties discussed in this section may be either physical or chemical. Physical properties include temperature, turbidity and suspended solids. Chemical properties include macro nutrients (e.g. phosphorus, nitrogen, sulfur, potassium, magnesium and calcium), micro nutrients (trace elements), cations (sodium, calcium, magnesium and potassium), anions (chloride, carbonate and sulfate), metals (iron, manganese), silicon, colour (gilvin), dissolved gases (e.g. hydrogen, nitrogen, oxygen, carbon dioxide and methane), electrical conductivity, alkalinity, pH, redox potential and dissolved organic carbon.

The water in the wetland, when present, has a number of physico-chemical properties that are influenced by the wetland's geomorphology, catchment characteristics (including its geology), soils and biota. For example, wetland vegetation can affect water pH, nutrient cycling and colour. The water properties will influence many of the biotic components of wetlands and their processes (e.g. feeding, growth and reproduction of fauna and growth of flora). Examples of the influence of water properties on biota are listed below.

- Nutrients present in water are essential for growth of phytoplankton and floating macrophytes. Excess amounts of nutrients such as phosphorus and nitrogen may lead to high growth rates and biomass of phytoplantkon and benthic algae including toxic species (Boulton and Brock 1999).
- Water chemistry (ionic composition) is a determinant for biota that are dependent on trace elements/metals for their physiology (e.g. microcrustacea such as ostracods and some zooplankton, diatoms and insects) (Radke et al. 2003).
- Seasonal changes in water properties (such as temperature) provide cues for fish spawning.
- Water colour (gilvin) is a determinant for aquatic invertebrate composition in south west Australian wetlands (Davis et al. 1993) and limits the growth of phytoplankton (Wrigley et al. 1988, Jackson and Hecky 1980).
- Dissolved organic carbon is the primary food source for bacteria, which form the basis of wetland food webs (Boon 1999).
- The tolerances/thresholds of biotic communities and species to many water properties (such as salinity, nutrients, dissolved oxygen and temperature) are amongst the key determinants in the presence or absence and distribution of biota in wetlands.

Wetland soils

Wetland soils (often termed 'hydric' soils) are characterised by periodic saturation leading to anaerobic conditions and the inhibition of oxygen diffusion in the soil (Brady and Weil 2000). For anaerobic conditions to develop, the following factors are necessary: saturation of soil pores with water, the presence of heterotrophic microorganisms, the presence of a source of oxidisable organic matter and temperatures sufficiently warm for microbial activity (Mid-Atlantic Hydric Soils Committee 2004). The majority of hydric soils have a wet period and a dry period in most years but remain wet enough close to the surface to have an aquic moisture regime (Soil Survey Staff 1999). Spatial variability is common as oxygen levels are usually higher near the surface and alternating oxidized and reduced zones may be associated with structural units. Even saturated zones have very small aerobic sites. Hence, both aerobic and anaerobic respiration can occur concurrently in hydric soils (Mid-Atlantic Hydric Soils Committee 2004).

Soils have physical, chemical and biological components. Physical components include the soil structure, texture and consistency; chemical components include the soil's redox potential, salinity, acidity, dissolved organic carbon, nutrients, trace elements and others. The biological components of soils are its biota and include microorganisms, invertebrates and plants.

Based on their organic content, wetland soils can be considered to be of two broad types: organic (with an organic content greater than 35%) and mineral (an organic content less than 20-35%) (Mitsch and Gosselink 2000). The organic content of the soil is affected by the period of inundation (anaerobic period) and the availability of organic material. There is a greater accumulation of soil organic matter under very poorly drained conditions, leading to the formation of a thicker, darker A or O horizon (the surface soil layer). This effect is most pronounced in cases where the anaerobic conditions exist within the uppermost horizons for extended periods (i.e. very poorly drained soils) (Mid-Atlantic Hydric Soils Committee 2004).

Wetland soils are important ecologically as they:

- favour the development of some hydrophytic plants, which require anaerobic conditions (Tiner 1993);
- provide a physical substrate for aquatic plants including macrophytes and algae and habitat for benthic aquatic invertebrates, soil micro-organisms (microbes, bacteria and fungi);
- store nutrients that are important for primary production (Mitsch and Gosselink 2000);
- store moisture;
- bind toxicants such as heavy metals; and
- provide a site for many chemical transformations and nutrient cycling.

Wetland biota

Wetland biota are characterised by their dependence on water and/or hydric soils for habitat or food source for at least part of their lifecycle. They include phytoplankton, wetland plants (such as herbs, ferns, shrubs, trees), aquatic invertebrates, vertebrates (such as fish, amphibians, birds, mammals and reptiles) and microorganisms (such as fungi, diatoms and microbes). The types of biota in a wetland will be influenced by the wetland's soils, hydrology, water properties, geology, morphology, connectivity with other wetlands and ecosystems and species biogeography.

Relationships exist between biotic groups. For example, there are associations between wetland vegetation and aquatic invertebrates and fish. Biotic components of wetland may have a considerable impact on a wetland's hydrology, geomorphology, water properties, soils and processes such as nutrient cycling. Some examples that the role wetland biota play in the functioning of the wetland include:

- binding and trapping of sediments by vegetation, which reduces erosion;
- provision of fauna habitat by wetland vegetation;
- transpiration by vegetation, which influences wetland hydrology;
- breakdown and decomposition of vegetation that leads to the development of wetland soils (e.g. peat);
- shading of water by vegetation, which influences water temperature and light intensity and quality;
- breakdown of organic matter by detrital feeders and grazers (invertebrates) that assists in development of wetland soils and availability of nutrients to microorganisms;
- chemical transformations by microorganisms, that play an important role in nutrient cycling; and
- transport of invertebrate eggs and aquatic plant seeds between wetlands by birds.

3.1.4 Wetland processes

Processes in wetlands include physical processes such as stratification, sedimentation and erosion, ecological processes such as energy dynamics and nutrient cycling and processes which maintain populations of biota and species interactions (Boulton and Brock 1999). Wetland processes operate between multiple wetland characteristics, for example, nutrient cycling involves water, soils and wetland biota and these can be viewed at many scales or hierarchies. An example of a nutrient cycling hierarchy is provided in Figure 5. Biological processes can also be described at several scales and at different levels of organisation that include processes related to individuals (e.g. movement, reproduction, growth and respiration), populations and communities (e.g. colonisation, trophic responses) and ecosystems (e.g. production, respiration) (Boulton and Brock 1999).

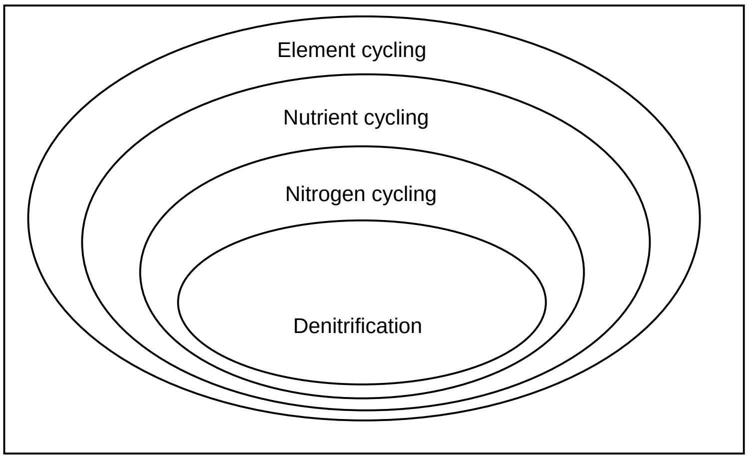

Figure 5. Example of a wetland process hierarchy (adapted from Smith and Wakeley 2001).

3.2 The ecology of wetlands in Victoria

3.2.1 Wetland drivers in Victoria

Climate

Victoria's climate varies spatially. North-western Victoria has hot dry summers and cold winters. Southern, western and north-eastern Victoria have a temperate climate with warm summers and cool to cold winters. Rainfall generally increases with altitude and decreases inland (Figure 6). Rainfall variability is classified as high to very high in summer and autumn especially in the north of the state, low in winter and spring in southern Victoria and moderate in northern Victoria in winter to spring (Bureau of Meteorology Website 2005a). There has been little overall change in average annual rainfall over the period 1900-2004, however there is significant variability over a 10-20 year time frame (Bureau of Meteorology Website 2005b).

Temperature varies seasonally. In northern Victoria the mean maximum temperature ranges from 30-33°C in February to 15-18°C in July. In southern and mountain Victoria, it ranges from 21-27°C to 8-15°C (Bureau of Meteorology Website 2005a). Over the period 1900-2004, temperature in Victoria has increased slightly (Bureau of Meteorology Website 2005b).

Higher rainfall totals tend to occur in winter and spring over all but the north west of the State (Bureau of Meteorology Website 2005a and 2005c). Thus wetlands are most likely to fill in winter and spring and semi-permanent wetlands are most likely to dry over summer and autumn.

In semi-arid regions (e.g. north-west Victoria), climate has been identified as the major regional determinant of whether wetlands fill predictably or unpredictably (Williams 1985). Rainfall is a major determinant of the water regime. Rainfall affects wetland hydrology directly in wetlands that rely on precipitation on or close to the wetland and indirectly in wetlands that rely on riverine floods (i.e. floodplain wetlands) or groundwater recharge.

Geomorphology

In Victoria, geomorphology is generally more important than climate in determining wetland location. Wetlands are generally most extensive in areas of low relief (in the west, north and south-east of Victoria). They are much less common in the Eastern Highlands and dunefields of the Mallee (Environment Australia 2001) (Figure 1). Wetlands have been formed by geomorphic features such as barriers leading to the containment of surface waters, depressions associated with volcanic plains, groundwater discharges and riverine floodplain complexes (Norman and Corrick 1988). The geomorphic wetland classes discussed in section 3.1.1 that are represented in Victoria include: depressional wetlands, riparian (also known as riverine) wetlands, highland/hill wetlands, flats wetlands and slope wetlands.

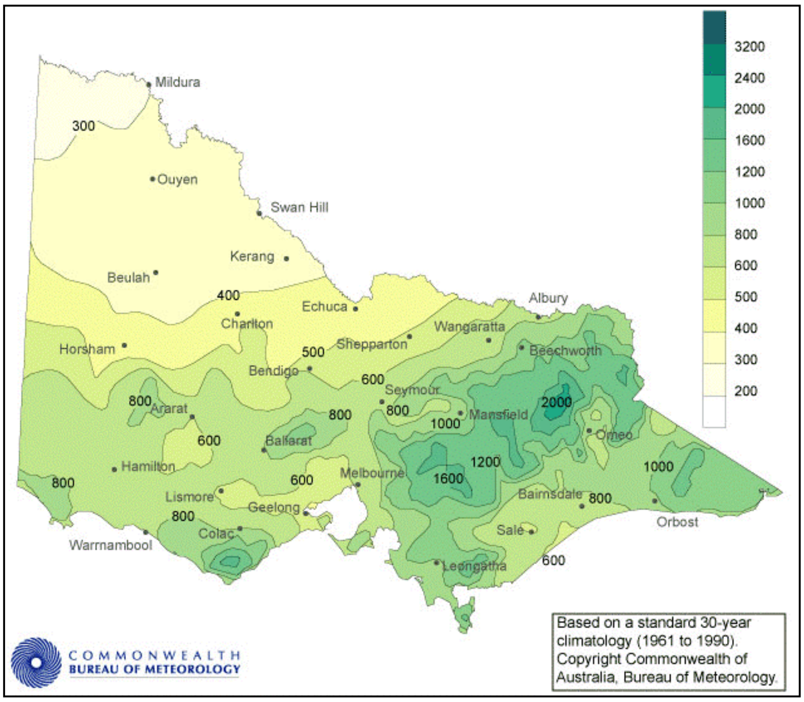

Figure 6. Average annual rainfall in Victoria (Bureau of Meteorology Website 2005a)

3.2.2 Wetland catchments in Victoria

Wetland catchments in Victoria are defined by their water source. The water source categories discussed in Section 3.1.2 as described by Paijmans et al. (1985) are applicable to Victorian wetlands, i.e. wetlands may be fed by local runoff (precipitation directly on or near the wetland), regional surface runoff (i.e. floodplain wetlands), or by groundwater from local aquifers (including interdunal wetlands in the Wimmera region) or regional aquifers (including wetlands at the edge of the Murray Basin, e.g. in north-central Victoria). The catchment can range in size from a few hectares for wetlands fed by local runoff to thousands of square kilometres for wetlands fed by large rivers such as the Goulburn or Murray.

The importance of buffers, as outlined in Section 3.1.2, also applies to wetlands in Victoria. The native terrestrial vegetation adjacent to the wetland which defines the buffer may be difficult to identify on floodplains where wetlands are surrounded by vegetation that tolerates inundation. On floodplains, the buffer may not be composed of strictly terrestrial vegetation and therefore should be considered as any native vegetation extending outwards from the defined boundary of the wetland.

3.2.3 Characteristics of Victorian wetlands

Physical form

Wetland area and bathymetry are the principal components of physical form. The ecological role of these components is discussed in Section 3.1.3.

There is considerable spatial variability in wetland area and bathymetry between wetlands across Victoria. The variation is associated with the topography of the land, climate, available water sources (surface and groundwater) and the history of formation of the wetland. Depths of wetlands in Victoria range from less than 30 cm to greater than 2 m. Depth has been used to characterise wetland types used in Corrick and Norman (1980) and Corrick (1982) (Table 3).

The shape of wetlands and their shoreline morphology are influenced by geological and climatic events and the degree of energy associated with them. For example, wetlands with highly irregular outlines generally reflect low energy and are systems that have changed little since their time of formation (Wimmera Catchment Management Authority unpublished). There is often an evolutionary sequence embedded in the development of a basin's shape. In Victoria, prevailing westerly winds have led to the development of smooth eastern margins and, in areas where there is an abundant supply of sand and clay, the formation of lunettes on the eastern margins of wetlands (Wimmera Catchment Management Authority unpublished). Ovoid wetlands with lunettes on their eastern margins are common in the Wimmera and north-central regions of Victoria.

Table 3. Victorian wetland classification (Corrick and Norman 1980). Only categories covering naturally occurring wetlands are shown.

Category	Sub-category	Depth (metres)
Freshwater meadow These include shallow (up to 0.3 m) and temporary (less than four months duration) surface water, although soils are generally waterlogged throughout winter.	Herb-dominated Sedge-dominated Red gum-dominated Lignum dominated	< 0.3
Shallow freshwater marsh Wetlands that are usually dry by mid-summer and fill again with the onset of winter rains. Soils are waterlogged throughout the year and surface water up to 0.5 m deep may be present for as long as eight months.	Herb-dominated Sedge-dominated Cane grass-dominated Lignum dominated Red gum-dominated	< 0.5
Deep freshwater marsh Wetlands that generally remain inundated to a depth of 1 – 2 m throughout the year.	Shrub-dominated Reed-dominated Sedge-dominated Rush-dominated Open water Cane grass-dominated Lignum-dominated Red gum-dominated	< 2
Permanent open freshwater Wetlands that are usually more than 1 m deep. They can be natural or artificial. Wetlands are described to be permanent if they retain water for longer than 12 months, however they can have periods of drying.	Shallow Deep Impoundment Red gum Cane grass Dead timber Black box Rush Reed Sedge Shrub Lignum	<2 >2
Semi-permanent saline These wetlands may be inundated to a depth of 2 m for as long as eight months each year. Saline wetlands are those in which salinity exceeds 3,000 mg/L throughout the whole year.	Salt pan Salt meadow Salt flats Sea rush Hypersaline lake Melaleuca Dead timber	< 2
Permanent saline These wetlands include coastal wetlands and part of intertidal zones. Saline wetlands are those in which salinity exceeds 3,000 mg/L throughout the whole year.	Shallow Deep Intertidal flats	< 2 > 2

The size of individual mapped wetlands greater than one hectare has been determined in Victoria. Two thirds of these wetlands are less than ten hectares in area (Table 4).

Table 4. Range of sizes for wetlands (Department of Sustainability and Environment 2005b).

Size class (ha)	Percentage of wetlands
>1 - <10	67
>=10 and <100	29
>=100 and <1000	3
>=1000	1

Hydrology

The flooding duration, frequency and seasonality are the principal components of hydrology. The ecological roles of these components are discussed in Section 3.1.3.

Many of Victoria's wetlands are semi-permanent or ephemeral. Wetlands that usually fill in winter or spring may remain dry in years of drought and wetlands that usually dry in summer or autumn may remain inundated for longer in wet years. Water may not always be present, even in winter or spring and the hydrologic conditions in a wetland may not be the same at the same time every year. The hydrologic variability (seasonality and flooding duration) is evident in the wetland types identified by Corrick and Norman (1980) and Corrick (1982) (Table 3).

Freshwater meadows are common on the floodplains of the Victorian Riverina bioregion, particularly along the Murray, Ovens and Goulburn rivers and in the Kerang–Echuca area. They are also common in the south-west of the State, particularly near Edenhope, Hamilton and Camperdown. Shallow and deep freshwater marshes also occur in these areas and in the Gippsland Plain bioregion. Saline wetlands are a feature of the southern Victorian Volcanic Plain near Colac, the drier parts of the State, and the Wimmera River, Mildura, Lake Tyrrell and Kerang areas, the Gippsland coast and Port Phillip Bay and Western Port.

Wetland complexes in the alpine areas of Victoria are dominated by alpine bogs (also termed mossbeds and peatlands). In the Bogong High Plains area of north-east Victoria, approximately 10% of the alpine and upper subalpine landscapes are covered by these wetlands (McDougall 1982). They occur in shallow stream headwater basins where the water table is at or near the surface due to a combination of high annual precipitation, gentle slope and the underlying geology leading to impeded drainage. They also occur around seepage areas on sheltered aspects (Tolsma et al. 2005). Hydrologically, these wetlands are significant as they have a significant water-holding capacity and regulate the flow of water into streams (Costin 1957, Carr and Turner 1959, Ashton and Williams 1989). These wetlands were not mapped during the statewide surveys in the period 1975-1994.

Water properties

The physical, chemical and biological properties of the water are the components of the water in the wetland. The ecological role of these components is discussed in Section 3.1.3.

Variations in geomorphology, geology, climate, water source and degree of anthropogenic disturbance lead to a high degree of spatial variability in the properties of water in wetlands across Victoria. Temporal variability within wetlands of many water properties is also high, associated with climate and water regime seasonality and variability over larger time scales. Examples of temporal changes include concentration of salts and increased turbidity (re-suspension of sediments) with decreasing water levels. Section 3.1.3 details the influence that water properties have on wetland biota. These are also relevant to wetlands in Victoria. Changes in the concentration of nutrients and organic carbon in wetlands also act as spawning cues for fish in riverine channels following floods (Murray-Darling Basin Commission 2001).

Water quality data has been collected in some Victorian wetlands (Appendix 2). Sampling periods and frequency between wetlands has been variable, ranging from measurements taken monthly to quarterly.

There is a high degree of temporal variability (within a wetland) and spatial variability (between other wetlands) in many of the parameters measured including nutrients, electrical conductivity, dissolved oxygen and turbidity. The variability may be caused by many factors, including climate, the presence of anthropogenic inputs (e.g. stormwater) and variations in the quality of the wetland's water source (e.g. groundwater, river or stream or inlet water quality).

Wetland soils

The wetland soil components are comprised of physical, chemical and biological elements. The ecological role of these components is discussed in Section 3.1.3.

In Australia, wetland soil texture ranges from river-derived silts in floodplain wetlands, through to sands and peats of interdune, beachplain and sandstone plateau depressions. Soil texture is usually heaviest in the middle of the wetland and lighter towards the edge. Often, clayey soils dominate the middle of the wetland with sands towards the outer edge (Paijmans et al. 1985).

Information on wetland soils in Victoria is limited to the Wimmera and northern part of the North Central catchment management regions (Figure 1) and the alpine region. In the former areas dark silt/clay soils predominate (Wimmera Catchment Management Authority unpublished). Some of the larger wetlands in the western Wimmera region have sandy shores (Wimmera Catchment Management Authority unpublished). Wetlands in alpine regions are characterised by organic-rich soils (peat) formed by the breakdown of *Sphagnum* sp. moss. Organic soils may also be formed from the breakdown of plant fragments from reeds such as *Typha* and *Phragmites* in freshwater marshes.

Soil pH values in Victoria are variable but are naturally low for wetlands with peat soils. These include alpine bogs where pH values of 4 are common (Paijmans et al. 1985). In wetlands with mineral soils or peat soils (not derived from moss), pH ranges from slightly acidic to alkaline (Breen 1989). Soil pH (and consequently the pH of the water) can be affected by the disturbance and exposure of acid sulfate soils to air. Such soils contain significant amounts of iron sulfides. In Victoria, most acid sulfate soils occur in coastal locations (Department of Primary Industries 2003). Recently, acid sulfate soils have been found to occur in the Murray Darling Basin (Baldwin et al. 2005) and therefore there is a possibility that they may also occur in other inland locations.

Temporal change in wetland soils occurs at varying scales. Drivers of change include climate changes (wet and dry periods), wind (erosion) and salinity of the groundwater. For example, in the western Wimmera and North Central CMA regions of Victoria, the clayey wetland soils are thought to have formed over dry periods (over the past 500 000 years) from dust blown into the region (Wimmera Catchment Management Authority unpublished). Over shorter temporal scales, wetland soil characteristics can change due to local rainfall (e.g. salts can be washed down the soil profile) and water regime (e.g. soils will lose their hydric properties when dry).

Wetland biota

The ecological components and role of biota in wetlands are discussed in Section 3.1.3. Features of the biota in Victorian wetlands are presented in this section. A summary of the number of native species of some wetland biota in Victoria is presented in Table 5.

Table 5. Summary of numbers of wetland species in various groups in wetlands in Victoria (source: Department of Natural Resources and Environment 1997, Department of Sustainability and Environment 2005c).

Group	Number of species recorded in Victoria's wetlands
Aquatic macroinvertebrates	>300*
Fish	25**
Reptiles	15
Amphibians	27
Waterbirds	119
Mammals	3
Aquatic macrophytes***	21
Ferns	29
Grass-like plants	301
Herb-like plants	384
Shrubs	75
Trees	31

*Data from south-west Wimmera wetlands only (Butcher unpublished a)
** Some uncertainty with two species as to whether they can breed in wetlands.
*** Macrophytes in this context include rushes, sedges and reeds.

Aquatic macroinvertebrates

Aquatic macroinvertebrates in Victorian wetlands form a significant component of the biodiversity. More than 300 species were recorded in 16 wetlands in the west Wimmera alone (Butcher unpublished a). It is likely there are considerably more species across the state. The variability in invertebrate composition between temporary wetlands is high and the number of species found in these wetlands may continue to increase for three months after the wetlands fill (Butcher unpublished a).

Fish

The majority of fish species that inhabit wetlands (approximately 25 species) require permanent water for survival and reproduction. Of these, four species require connectivity with streams and the sea to spawn and six species prefer flowing waters but are occasionally found in wetlands (Department of Sustainability and Environment 2005c). Species which inhabit temporary wetlands include the short-finned eel *Anguilla australis* and long-finned eel *A. reinhardtii*, that are able to move across land looking for water after the wetland has dried and the Australian mudfish *Neochanna cleaveri* and dwarf galaxias *Galaxiella pusilla* that are known to aestivate (i.e. the adults are able to survive out of free water in moist conditions for some period of time) and survive periods of drying (Cadwallader and Backhouse 1983). Floodplain wetlands are an important habitat for the larvae of a number of fish including the western carp gudgeon *Hypseliotris klunzingeri*, Australian smelt *Retropinna semoni*, flathead gudgeon *Philypnodon grandiceps* and flat headed galaxias *Galaxias rostratus* (A. King, DSE pers. comm.).

Reptiles

Reptiles that utilise Victorian wetland habitat include three tortoise species. Two species are largely restricted to Murray River floodplain wetlands: the broad-shelled tortoise *Chelodina expansa* and the Murray River tortoise *Emydura macquarii*). The third, the common long-necked tortoise *C. longicollis*, is widely distributed. The common long-necked tortoise is found in many wetland types including temporary wetlands. A number of skink species (such as the swamp skink *Egernia coventryi* and alpine water skink *Eulamprus koscioskoi*) utilise wetlands as habitat. Snake species that utilise wetlands for food (frogs constitute a major components of their diet) include the eastern (or mainland) tiger snake *Notechis scutatus* and the red-bellied black snake *Pseudechis porphyriacus* (G. Brown, DSE pers. comm.). The Gippsland water dragon *Physiganthus lesurii howittii* is found in wetland habitats and some other reptiles utilise wetlands at the extremes of their distribution (N. Clemann, DSE pers. comm.).

Waterbirds

Waterbirds use wetlands in many different ways, for feeding, nesting and roosting (Frith 1986, Marchant and Higgins 1990, Marchant and Higgins 1993, Higgins and Davies 1996). For example, cormorants and diving ducks can use deep open water, whereas dabbling ducks prefer to feed in shallow water or among vegetation. Herons, egrets and spoonbills search for food while wading in shallow water, ibis probe for food in wet mud or nearby grassland, and Whiskered Terns take insects from the water surface. Some waterbirds can nest in bare treeless wetlands (e.g. Australian Pelican) but most nest in trees or dense aquatic vegetation. Several species of duck nest in tree hollows (Frith 1982, Marchant and Higgins 1990), and cormorants and large wading birds usually nest in trees, often colonially in flooded swamp forest.

Shorebirds forage on mudflats and shores of both tidal and inland wetlands. Most of these species are long-distance migrants, nesting in the tundras of Arctic Siberia or Alaska and migrating to Australia for the southern summer.

Because waterbirds can fly long distances, they are uniquely adapted to exploiting temporary wetlands that fill and then dry on an erratic or seasonal basis. The Australian environment contains many such temporary wetlands that provide flushes of nutrients and food for waterbirds when they flood. Floodwaters can originate hundreds of kilometres away across the continent, flowing via floodplains and rivers such as the Murray-Darling system. Many waterbird species are quick to exploit these new habitats when they form, and rely upon them as their main source of breeding habitat. When the wetlands dry out, these species congregate on more permanent wetlands in the more temperate parts of Australia, including Victoria. In these temperate areas, the paradoxical situation arises where more waterbirds can be found in a dry year following good seasons inland than in a wet year when birds are dispersed over inland areas). However, wet conditions are more favourable for the birds themselves (Norman and Nicholls 1991, Loyn et al. 1994, Roshier et al. 2002).

Frogs

Most frog species require water for part of their life cycle and hence are likely to utilise wetlands. There is a high degree of variability and diversity in life histories across species in Victoria (e.g. burrowing frogs, tree frogs, mostly aquatic species and frogs that lay their eggs on land) (M. Smith, DSE pers. comm.). Frogs utilise habitat around wetlands as well as the wetland itself. Common and widespread frog species that inhabit Victorian wetlands and near-wetland habitats include the eastern common froglet *Crinia signifera* and the southern brown tree frog *Litoria ewingi*. Species with a restricted distribution include the Baw Baw frog *Philoria frosti* and the Booroolong frog *Litoria booroolongensis*. A landscape scale analysis of the relationship between frog species richness and physical and chemical variability in wetlands and their surrounding environments in the Wimmera region is the focus of current research (M. Smith, DSE pers. comm.).

Wetland plants

Plants inhabiting wetlands have some tolerance to inundation. These range from obligate aquatic species and wetland habitat-specific opportunistic species to species which are more amphibious (Department of Sustainability and Environment 2005a). They may also include species which have some tolerance for intermittent inundation and/or water-logging, but whose distributions are not characterized by such habitat features (Department of Sustainability and Environment 2005a).

In Victoria, wetland plant communities have been identified and described as ecological vegetation classes (EVCs) progressively following a statewide survey of wetland vegetation in the early 1990s and regional vegetation surveys such as that in north west Victoria (Arthur Rylah Institute 2003). As part of this project, existing wetland EVCs were revised and additional EVCs identified and described to cover the full range of wetland vegetation in the State (Department of Sustainability and Environment 2005a). Eighty three wetland EVCs have been identified (Appendix 3).

3.2.4 Agents of change

Wetland condition (as defined by our definition) can be influenced by natural events such as floods and droughts and by human activities (intentional and unintentional). As discussed in Section 1.3, there are multiple human-induced threats to Victoria's wetlands leading to the manifestation of multiple potential impacts on wetland condition. The nature of the relationships between the human activities and environmental response may not be known and identifying the effect of one human activity among many is difficult (Downes in press, Downes et al. 2002). In some cases, the general relationships between particular impacts, threats and condition are known, although generally more so in flowing waters than non-flowing wetlands (Gergel et al. 2002, Ortega et al. 2004). For the IWC, the assumption is made that the threats to wetlands lead to specific impacts, which have a negative correlation with wetland condition. We cannot confidently quantify this relationship, however.

3.2.5 Reference condition for wetland condition assessment

To assess condition a reference condition is needed. Approaches include selecting sites that are not impacted (or minimally impacted) by human activities (Reynoldson et al. 1997, Norris and Thoms 1999) and using 'best professional judgment' (Reynoldson et al. 1997) to determine the reference state against which condition is assessed (e.g. Ladson et al. 1999). There are problems associated with poorly defined terms that are often used in condition assessment methods, e.g. 'pristine', 'minimally impacted' or 'natural' (Downes in press). The reference condition for a wetland may be its 'natural' state or some other defined state. A natural condition or state may be defined as a process, situation or system that is free of human (including indigenous people) disturbance (Anderson 1991). This is problematic in that often this condition is unknown. Another definition of 'natural' used in condition assessment methods is the condition thought to have existed before European settlement (i.e. within the last 200 years) (Ladson et al. 1999, Downes in press). This does not take into consideration disturbance by indigenous people and there is evidence to suggest that indigenous people brought about large changes to the landscape (Downes in press).

A pragmatic decision was made to adopt the reference condition for the IWC as the condition of the wetland at the time of European settlement. The reference condition for component-based measures will be established through an examination of literature and data. For threat-based measures, the reference condition will be the absence of the activity causing the impact. The scoring in the IWC will be based on the departure from the reference condition.

3.2.6 Issues of spatial and temporal variability

The variation in climate, geology, topography, geomorphology and species distributions across Victoria results in natural spatial variation in the physical features, hydrology, water chemistry, soils and biotic communities of wetlands. Many wetland components exhibit a large degree of spatial variability, as described in Section 3.2.3. The IWC must take account of the spatial variability in wetlands across the State, making it suitable for use at the range of inland wetland types in Victoria.

Classifications can assist in managing spatial variability. They are generally simple representations of spatial and temporal complexity (Kingsford et al. 2004). A review of wetland classification systems in Australia is provided by Pressey and Adam (1995). The review highlights a diversity of approaches used for different objectives and across the different states. For example, early systems were primarily based on waterbird habitat (e.g. Riggert 1966, Goodrick 1970 and Corrick and Norman 1980), a Western Australian system uses a geomorphic approach (Semeniuk 1987) and a Queensland system draws on the Cowardin et al. (1979) system based on soils developed in the United States (Pressey and Adam 1995). In Victoria, the system devised by Corrick and Norman (1980) has recently been used to classify wetlands in some wetland condition methods (e.g. Butcher unpublished b, Ecos Consulting unpublished).

The classification developed by Corrick and Norman (1980) was developed to provide a distribution map of wetlands, to categorise wetlands, to examine utilisation by waterbirds and to determine threats (Corrick and Norman 1980). Consequently, the classification does not cover all wetland components and is of limited usefulness for the IWC. For the IWC, classification needs to be tailored to the actual measures used in the index. Therefore, classification systems will be discussed in relation to the individual measures (Section 5).

Temporal variation in many components is linked to hydrology. Hydrological variation is linked to seasonal patterns or longer-term cyclic variations in rainfall. For some components, such as dissolved oxygen, fish and invertebrate abundance, temporal variability is linked to air and water temperatures, which vary seasonally.

Temporal variability is an important consideration in the selection of measures, as the range and pattern of variability of the component must be known in order to use it as a measure. Components that exhibit temporal variation require sufficient data to explain the variation. In Victoria, for most components, such datasets are limited. One way of building up such datasets is to sample a subset of wetlands frequently over a long time period.

3.2.7 Approaches to measuring condition

There are a number of different approaches to wetland condition assessment that vary according the specific objectives of the associated programs (Table 6). Approaches may involve an assessment of the whole wetland or specific biotic groups. Types of assessments include the following:

- condition of wetland: techniques primarily based on characteristics and components that define wetlands (e.g. Spencer et al. 1998, Ladson et al. 1999, Bolton 2003, Washington State Department of Ecology unpublished);
- condition of wetland: techniques based on impacts or threats known to damage wetlands (e.g. Brooks et al. 2002, Clarkson et al. 2003);
- condition of wetland: techniques that measure biotic groups as a surrogate for wetland condition (e.g. Davis et al. 1999, Chessman et al. 2002); and
- condition of biotic groups: techniques based on indices that measure the state of wetland biotic groups (such as fish or amphibians) or combinations of groups rather than wetland condition (e.g. United States Environmental Protection Agency 2002, Mack 2001, Mack 2004).

Approach adopted in the IWC

The condition of the wetland, based on the definition adopted for the IWC, implies that all components and interactions are important in determining condition and should be considered for selection in wetland assessment. Due to the constraints imposed by practical considerations relating to NRM (Section 2.3) this will largely be unachievable. As a consequence, the IWC will be based on the principal structural characteristics of wetlands (and their associated components) and the wetland catchment. The assumption used in the IWC is that the components and interactions assessed will collectively represent wetland condition.

For the components and interactions selected for wetland condition assessment, ideally the measure would be the component or interaction itself. In many cases, however, there is insufficient knowledge of reference condition and the way the component or interaction responds to human-induced change. Additionally, the measuring techniques for many components are not suited to a rapid assessment approach. Therefore, in the IWC, in some instances, it is more appropriate to include a measure of impact or threat. In selecting and evaluating measures for the IWC (Section 5), commonly-accepted and well-recognised threats and impacts in Victoria that affect wetland condition are identified and related to the key ecological components identified in Section 3.1.

There are few studies that examine the actual relationship between threats and impacts and the condition of wetlands and therefore ability to quantify the threat and impact-based measures is problematic. The assumption is made in the IWC that there is a negative correlation between the threats and impacts and condition. Section 5.2 details the selection of possible measures for the IWC based on this approach.

Table 6. Examples of wetland condition assessment methods and their indicators in Australia and New Zealand. C=method based on wetland characteristics and components, I=method based on impacts, B=method based on a surrogate biotic group for measuring condition.

Location/ Purpose	Indicators used
Australia-wide (C) Purpose: State of The Environment Report Australia 2001 (Ball et al. 2001).	• Decline in wetland extent • Waterbird species status • Abundance and distribution of frogs
New Zealand (I) Purpose: Monitoring of condition in palustrine and lacustrine wetlands (Clarkson et al. 2003)	• Change in hydrological integrity: impact of manmade structures, water table depth, dryland plant invasion, change in physico-chemical parameters, fire damage, degree of sedimentation/erosion, nutrient levels, von Post index • Change in ecosystem intactness: loss in area of original wetland, connectivity barriers • Change in browsing, predation and harvesting regimes: damage by domestic or feral animals, introduced predator impacts on wildlife, harvesting levels • Change in dominance of native plants: introduced plant canopy cover, introduced plant understorey cover
Victorian Index of Stream Condition (C) Purpose: Assessing the condition of homogenous river reaches to assist with the delivery of stream management programs in Victoria. In particular, for use in priority setting, resource allocation, assessing management effectiveness and setting benchmarks.	Sub-indices relating to five stream components. Indicators for each sub-index: • Hydrology (hydrologic deviation, percentage of catchment urbanised, presence of hydropower stations that cause water surges) • Physical form (bank stability, bed aggradation and degradation, presence and influence of artificial barriers, density and origin of coarse woody debris) • Streamside zone (width of vegetation, longitudinal continuity of vegetation, proportion of vegetation cover that is indigenous, presence of regeneration of indigenous species, condition of wetlands and billabongs) • Water Quality (Total phosphorus concentration, turbidity, electrical conductivity, pH) • Aquatic Life (presence of macroinvertebrate families using the SIGNAL index)
Murray-Darling Basin (C,I) Purpose: Monitoring condition of floodplain wetlands in the Murray-Darling Basin (Spencer et al. 1998). Rapid assessment method.	• Soils: bank stability, pugging by livestock, soil organic content • Fringing vegetation: width, continuity, height diversity • Aquatic vegetation: cover, spatial heterogeneity, attached algae • Water quality: turbidity, conductivity, colour, algal bloom frequency
Gippsland Lakes, Victoria (C) Purpose: Assess wetland condition in wetlands of the Gippsland Lakes.	Sub-indices relating to wetland complex and sub-categories: • Landscape sub-index (man made structures, loss of original extent, connectivity, grazing impact, adjacent and upstream land use, exotic species) • Vegetation sub-index (vegetation zone shift, species richness, significant species, significant class, weed species) • Bird sub-index (diversity of feeding groups, species diversity within feeding groups, listed migratory species, threatened species, introduced species) Total Condition Score = Landscape sub-index + Vegetation sub-index + Bird sub-index
Dowds Morass, Victoria (C) Purpose: Assess wetland condition. Agency: Monash University/Victoria University.	• Swamp paperbark condition indicators: overstorey cover, understorey cover, number of plant species, visually estimated index of health, measures of *Melaleuca* recruitment

Table 6. (continued).

Location/ Purpose	Indicators used
Wimmera Wetlands (C,I) Purpose: To inform Wimmera CMA and aid decision-making. Rapid assessment method. Broad rating of condition applied which considers risk Agency: Wimmera CMA (Butcher unpublished b)	• Measures of condition were developed and trialed for hydrological integrity, geomorphological integrity, land use, riparian vegetation, wetland vegetation, water quality. • Based on key system drivers of wetland ecology and includes biological, physical and chemical components
Swan Coastal Plain, Western Australia (B) Australian Wetlands Assessment and Monitoring Program (AUSWAMP). Purpose: Method to assist in the assessment of wetland condition of wetlands on the Swan Coastal Plain, Western Australia (Davis et al. 1999).	• Model based on the Australian River Assessment System (AUSRIVAS). • Model developed using macroinvertebrate data from wetlands on the Swan Coastal Plain.
Swan Coastal Plain, Western Australia (B) Swan Wetlands Aquatic Macroinvertebrate Pollution Score (SWAMPS). Purpose: Method to assist in the assessment of wetland condition of wetlands on the Swan Coastal Plain, Western Australia. Chessman et al. (2002).	• Biotic index based on macroinvertebrate data. • Macroinvertebrate taxa assigned numerical grades to reflect sensitivity to anthropogenic disturbance (primarily nutrient enrichment). • Family and species level grades and scores developed.
South Australian River Murray Wetlands (C) Purpose: Assess wetland condition. Agency: River Murray Water Catchment Management Board. River Murray Catchment Water Management Board (unpublished).	• Indicators comprised of habitats essential to the specific wetland type character and function. • Indicators comprised of characteristic species and processes and species and processes indicative of low disturbance and exceptional diversity.
North Coast Wetland Assessment Technique, New South Wales (C,I) Purpose: Assess wetland condition in fresh water wetlands and farm dams. Bolton (2003). Rapid assessment method.	• Connectivity: proximity to natural ecosystems, corridors, area of wetland, adjacent land use • Human disturbance • Bank condition: erosion, pugging, bank gradient • Habitat • Fringing vegetation: width, diversity, species number, weeds • Aquatic vegetation: diversity, species number, cover, weeds • Water quality: pH, EC, nitrate, ammonium, phosphate, turbidity, attached biofilm, blue-green algae, water odour • Macroinvertebrates

4. IWC requirements

A number of key requirements have been identified to guide the development of the IWC (Table 7). These are derived from the policy and NRM framework (Section 2) and the ecological framework (Section 3). The section that relates to each requirement is indicated in Table 7.

Table 7. Requirements that dictate the development of the IWC.

Requirement	Conceptual framework dictating requirement	Section
1. The IWC will be suitable for use at all naturally occurring, non-flowing wetlands without a marine hydrological influence in Victoria.	Policy & NRM	2.1.1
2. The IWC will be a tool for the surveillance of wetland extent and condition over a 10-20 year timeframe.	Policy & NRM	2.3
3. The IWC will be suitable for use at a wetland at any time of year.	Policy & NRM	2.4
4. The IWC will be designed to assess wetland condition in a single visit.	Policy & NRM	2.4
5. The IWC will be a rapid assessment tool.	Policy & NRM	2.4
6. The IWC will be simple, straightforward and inexpensive.	Policy & NRM	2.4
7. The IWC will be easy to interpret.	Policy & NRM	2.4
8. The form of the IWC will be based on the key ecological components of the wetland and its catchment.	Ecological	3.1, 3.2
9. The level of discrimination for the IWC must be sufficient to determine significant human-induced change in the state of the wetland.	Policy & NRM Ecological	2.3 3.2.4
10. The reference benchmark for assessing condition will be the condition of the wetland at the time of European settlement.	Ecological	3.2.5

5. IWC structure and measures

5.1 Structure of the IWC

The IWC is designed as a hierarchical index. The sub-indices form the top-level of the hierarchy and are based on the wetland catchment and the fundamental characteristics of the wetland: physical form, hydrology, water properties, soils, biota (discussed in Section 3). The key components, identified in the discussion on wetland ecology in Victoria (Section 3.2), form the next level in the hierarchy followed by the actual measures (Figure 7). Measures may be based on the components themselves or threats or impacts to the components. A summary of catchment and wetland characteristics and their key components and processes, discussed in Section 3, are shown in Table 8.

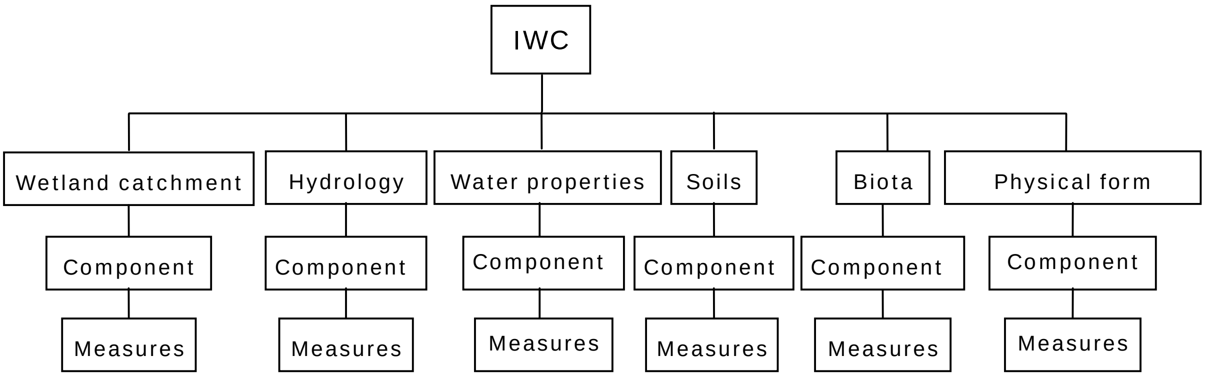

Figure 7. Structure of the IWC.

Table 8. The wetland catchment and wetland characteristics forming the sub-indices of the IWC and their components (B=biological, P=physical, C=chemical) and interactions (where relevant).

Wetland catchment	**Catchment components**
	Wetland catchment (P)
	Wetland buffer (P)
Wetland characteristic	**Principal wetland components or interactions**
Physical form	Wetland area (area or extent of wetland when fully inundated) (P)
	Bathymetry (P)
Hydrology	Frequency of inundation (P)
	Duration of inundation (P)
	Seasonality of inundation (P)
Water properties	Physical properties (temperature, dissolved oxygen, suspended solids, turbidity, light availability, stratification and mixing) (P)
	Chemical properties (nutrients, metals, trace elements, dissolved organic carbon, redox potential, pH, alkalinity) (C)
Soils	Physical properties (structure, texture, consistency, profile) (P)
	Chemical properties (redox potential, salinity, acidity, dissolved organic carbon, nutrients, trace elements) (C)
	Biological properties (soil biota) (B)
Biota	Wetland plants (B)
	Phytoplankton, including diatoms (B)
	Aquatic macroinvertebrates (B)
	Vertebrate fauna (fish, amphibians, reptiles, waterbirds, mammals) (B)
	Processes which maintain species populations (reproduction, regeneration, dispersal, migration, pollination) (I)
	Species interactions (competition, predation, succession, herbivory, diseases and pathogens) (I)

5.2 Possible measures for the IWC

For the wetland catchment and each wetland characteristic, the threats that are thought to affect each of the key ecological components (identified in Section 3) and the likely impacts on wetland condition are discussed in this section. Possible measures of condition are also identified. These may be either the catchment or wetland component itself, threats to the component or the impact on the component. Many of the threats to wetland physical form, hydrology, water properties and soils arise in the catchment of the wetland, including the buffer; these measures are dealt with collectively in Section 5.2.1.

5.2.1 Wetland catchment

The main components of the wetland catchment include the catchment itself and the wetland buffer. The state of the catchment influences the amount and pattern of flow of the surface water that feeds the wetland. Water flowing into the wetland carries carbon, sediment and nutrients to the wetland. In modified catchments, runoff may contain excessive amounts of sediments and nutrients as well as pollutants, propagules of invasive species or water of a low pH derived from areas affected by soil acidification. These factors can lead to a decline in wetland condition. In the case of wetlands fed by groundwater, clearing of the aquifer catchment can lead to a rise in the water table, mobilisation of salts stored in soil and salinisation of groundwater and the wetland. The catchment can be altered by clearing of native vegetation and adoption of various land use practices.

The functions of the wetland buffer are discussed in Section 3.1.2. The effectiveness of the buffer in providing these functions depends on the width of the buffer and the percentage of the wetland perimeter with a buffer. Modification of the buffer can result from land clearing or livestock grazing.

Table 9 lists the main catchment components, the activities with the potential to cause changes in these components and the likely impact on the wetland.

Table 9. Components of wetland catchment, activities with the potential to cause changes to these components and the resultant impacts that are likely to affect wetland condition.

Key ecological component	Potentially threatening activities	Potential impacts
Wetland catchment	Clearing of the natural[1] vegetation, land uses or fire in the catchment that lead to a change in the pattern or amount of runoff	Changes in the natural[1] amount or pattern of flow of the water that feeds the wetland can lead to changes in wetland hydrology.
	Clearing of the natural[1] vegetation and land uses in the catchment that lead to an increase in the amount of sediments, nutrients or pollution in catchment runoff.	Increases in the level of nutrients, sediments or pollutants in catchment runoff can lead to increases in the availability of nitrogen and phosphorus in the wetland's soil and water.
		Increases in the level of sediments or pollutants in catchment runoff can lead to increases in turbidity.
		Increases in the level of sediments in catchment runoff can lead to changes in the physical form of the wetland due to sedimentation
	Land uses that lead to soil acidification in the catchment resulting in lowered pH of runoff.	A decrease in water pH can lead to changes in wetland biota abundance, diversity and richness
	Introduction and/or poor control of invasive weed species in the wetland catchment	Invasive weeds can lead to changes in wetland vegetation and fauna habitat.

Table 9. (continued).

Key ecological component	Potentially threatening activities	Potential impacts
Wetland buffer	Modification of the buffer (reduction in width and continuity of natural[1] vegetation surrounding the wetland)	Changes in the ability of the buffer to filter out sediments can lead to changes in the physical form of the wetland due to sedimentation
		Impairment of the ability of the buffer to filter out nutrients and pollutants can lead to increases in the availability of nitrogen and phosphorus in the wetland's water and nutrient enrichment of wetland soils.
		Impairment of the ability of the buffer to filter out sediments and pollutants can lead to increases in turbidity.
		Modification of the buffer can lead to decrease in the quality of groundwater flowing into the wetland.
		Changes in the amount of sunlight reaching the water can lead to changes in productivity and average water temperature.
		Modification of buffer can lead to reduction in habitat quality for wetland fauna.
		Modification of buffer can lead to increased exposure of wetland fauna to disturbance from human activity
		Impairment of the ability of the buffer to filter out weed propagules can lead to the establishment of invasive species in the wetland
		Reduction in the ability of the buffer to lower water tables near the wetland can lead to changes in hydrology and salinisation.

[1] The term 'natural' is used here to mean a state unmodified by human activities associated with European settlement.

Changes to the catchment of the wetland can be assessed by measuring aspects of the catchment and wetland buffer (Table 10).

Table 10. Possible measures of the wetland catchment relating to wetland condition.

Key ecological component	Possible measure	Type of measure
Wetland catchment	Percentage of native vegetation cover in the catchment.	Threat
	Percentage of land in different land use intensity classes in the catchment	Threat
	Percentage of soil affected by acidification in the wetland catchment	Threat
	Percentage of land in different land use intensity classes adjacent to the wetland	Threat
Wetland buffer	Average width of the buffer	Component
	Percentage of wetland perimeter with buffer	Component

5.2.2 Physical form

Changes to the physical form of the wetland are likely to result in changes in wetland condition, as physical form of the wetland is an important factor in determining the availability of habitat for biota and the duration of inundation.

The physical form of the wetland can be altered in several ways (Table 11). In the most extreme scenario, a wetland or part of a wetland may be completely destroyed through activities such as drainage or infilling. An enlargement in wetland area may occur, for example, through construction of a dam wall that raises the water level of the wetland as undertaken for several swamps in northern Victoria to create Lake Mokoan in 1971 (Goulburn-Broken Catchment Management Authority 2003). An enlargement of a wetland, however, is considered as an aspect of altered hydrology for the purposes of the IWC.

Changes in the physical form can result from activities in the wetland that involve excavation or landforming of the wetland or from an accumulation of sediments in the wetland. In these cases, the depth and overall form of the wetland can be changed.

Table 11. Components of physical form, activities with the potential to cause changes to these components and resultant impacts that are likely to affect wetland condition.

Key ecological component	Potentially threatening activities	Potential impacts
Area of the wetland	• Physical conversion of wetland into dryland (land filling, drainage)	A reduction in wetland area results in loss of habitat for wetland biota.
Wetland form (depth, shape and bathymetry)	• Activities that change the wetland form (excavation and landforming)	Changes in the physical form of the wetland can lead to changes in habitat for biota and affect duration of inundation.
	• Activities in the wetland catchment that lead to an increase in the amount of sediments in catchment runoff (clearing of native vegetation, overstocking, urbanisation). • Modification of the wetland buffer that decreases its ability to filter out sediments in catchment runoff.	Sedimentation of the wetland causing changes in wetland depth can lead to changes in habitat for biota and affect duration of inundation.

Changes to the physical form of the wetland can be assessed by measuring any reduction in the area of the wetland, its depth or bathymetry and comparing the results to data on the unmodified form of the wetland, if such data is available. Alternatively, the presence of any activities likely to change the physical form of the wetland can be measured (Table 12). Measures based on threats that arise in the wetland catchment and buffer and lead to an increase in wetland sedimentation are covered in Section 5.2.1.

Table 12. Possible measures of physical form relating to wetland condition**.**

Key ecological component	Possible measure	Type of measure
Area of the wetland	Percentage reduction in wetland area	Component
Wetland form	Wetland bathymetry	Component
	Depth of wetland (maximum water depth)	Component
	Percentage of wetland where activities have resulted in a change in bathymetry	Threat

5.2.3 Hydrology

Most chemical and biological processes in wetlands are controlled by the water regime (Boulton and Brock 1999). Therefore changes in hydrology are almost certain to result in changes in wetland condition. One of the more obvious of the many changes that result from a change in water regime is a change in vegetation patterns over time.

Change in hydrology can result from a change in any of the three hydrological components: the frequency with which the wetland is filled; the period of inundation; and the season in which filling occurs (Table 13). Activities with the potential to cause a change in water regime are those that:

- change the flow regime of the water source of the wetland;
- interfere with the natural connectivity of flow to and from the wetland;
- involve disposal of water into the wetland or extraction of water from the wetland; and
- change wetland depth and, therefore, alter the duration of inundation by changing the rate of evaporation.

Climate change has the potential to change the flow regime of the water source of the wetland. In Victoria to date, the effects of climate change on temperature or rainfall are not significant (Section 3.2.1). Therefore, climate change is not included as a potentially threatening activity.

Table 13. Components of wetland hydrology, activities with the potential to cause changes to these components and the resultant impacts that are likely to affect wetland condition.

Key ecological component	Potentially threatening activities	Potential impacts
Frequency of inundation Duration of inundation Seasonality (timing) of inundation	Activities that change the flow regime of the water source: • River regulation (water source: river or stream) • Activities that change surface drainage patterns (water source: surface water) • Activities that change groundwater levels[3] (water source: groundwater) • Regulation not associated with maintaining or restoring reference condition (water source: artificial channel)	Change to the wetland water regime can lead to changes in almost all aspects of wetland ecology, including changes in vegetation patterns.
	Activities that interfere with natural[1] connectivity of flow to and from the wetland: • obstruction or regulation of natural[1] water inlets • obstruction or regulation of natural[1] water outlets[3] • drainage of water from the wetland[3]	
	• Disposal of wastewater into the wetland • Extraction of water directly from the wetland[3]	
	Activities which change the natural[1] depth of the wetland: • Activities that permanently raise the water level (eg. damming the wetland or constructing levees to restrict the spread of water)[3] • excavation[3] (covered under physical form Table 11).	

[1] The term 'natural' is used here to mean a state unmodified by human activities associated with European settlement.

[2] Potentially threatening activities affecting frequency and duration of inundation, but not seasonality.

[3] Potentially threatening activities affecting duration of inundation, but not frequency or seasonality of inundation.

The hydrology of a wetland can be determined by regularly measuring the water depth and/or the extent of surface water in the wetland to establish the frequency, duration and seasonality of flooding. Changes can be detected by comparing the observed hydrological regime to the unmodified hydrological regime for the wetland, where known. Alternative measures of change are the presence and severity of activities thought to be responsible for hydrological change (Table 13) or impacts thought to be a direct consequence of hydrological change, such as change in vegetation patterns (Table 14). Measures based on threats that arise in the wetland catchment and lead to a change in the amount or pattern of flow of the water to the wetland are covered in Section 5.2.1.

Table 14. Possible measures of hydrology relating to wetland condition.

Key ecological component	Possible measure	Type of measure
Frequency, duration and seasonality of inundation	Water depth and/or surface water extent over time (to establish frequency, seasonality and duration of inundation)	Component
	Severity of activities that change the water regime	Threat
	Distribution/health of vegetation species or communities	Impact

5.2.4 Water properties

Changes in a wetland's physico-chemical components are likely to result in changes in wetland condition due to the relationship between water properties and the wetland's ecological processes as outlined in Section 3.1. Table 15 lists the main physico-chemical components of the water of wetlands, the activities with the potential to cause changes in these components and the likely impact on the wetland.

Poor water quality can be attributed to a range of land use activities in the wetland and its catchment and may be may be manifested by changes in several physical and chemical water properties. Nutrient enrichment, salinisation and turbidity are of particular concern in

Victoria's wetlands. Impacts may also arise from the exposure of sulfidic soils. Sulfidic soils are enriched in sulphide minerals such as monosulfides (FeS) and pyrtite (FeS_2). It has been recognised recently that such soils exist in inland wetland systems (Baldwin et al. 2005). The oxidation of sulfidic soils can lead to a decline in wetland condition through: the generation of noxious (and potentially toxic) gasses, deoxygenation of the water column and acidification. Changes in the vegetation in and around wetlands can lead to changes in the input of organic material and changes in water temperature and mixing regimes.

Table 15. Physico-chemical water components, activities with the potential to cause changes to these components and the resultant impacts that are likely to affect wetland condition.

Key ecological component or process	Potentially threatening activities	Potential impacts
Nutrients • Nitrogen • Phosphorus	• Activities in the wetland that lead to an increased input or release of nutrients (input of nutrient-rich water to the wetland, livestock grazing and feral animals in the wetland, aquaculture). • Activities in the wetland catchment that lead to an increase in the amount of nutrients in catchment runoff (clearing of vegetation, land uses such as agriculture or urbanisation, fire). • Modification of the wetland buffer that decreases its ability to filter out nutrients in catchment runoff. • Addition of nutrient-rich water into the wetland.	Increases in the availability of nitrogen and phosphorus can lead to an increase in primary productivity and subsequent changes in food webs and (especially for Phosphorus), algal blooms.
Electrical conductivity	• Excessive clearing of native vegetation in the wetland catchment or poor irrigation practices that lead to raised water tables and wetland salinisation. • Input of saline water into the wetland.	Salinisation can lead to changes in wetland biota abundance, diversity and richness, increases in water clarity and, potentially, salinity gradations in the water column
Turbidity	• Activities in the wetland that cause disturbance to soils or sediments (clearing of vegetation, excavation, landforming, cultivation, fire, livestock grazing, presence of carp or aquaculture). • Activities in the wetland catchment that lead to an increase in the amount of sediments or pollutants in catchment runoff (clearing of vegetation, land uses such as agriculture or urbanisation, fire). • Modification of the wetland buffer that decreases its ability to filter out sediments or pollutants in catchment runoff. • Direct discharge of wastes (industrial waste, effluent or sewage) into the wetland.	Changes in turbidity affect light penetration in the water column and can lead to changes in primary productivity (plant growth) and subsequent changes in food webs as well as changes in water temperature.
Temperature	• Activities in or adjacent to the wetland that modify vegetation and affect the amount of sunlight reaching the water surface such as clearing or harvesting of vegetation or establishment of non-indigenous plant species in or around the wetland. • Activities that change the turbidity of water (see above).	Changes in average temperature can lead to changes in the availability of oxygen, salinity levels and the susceptibility of the wetland to eutrophication affecting wetland biota abundance, diversity and richness and the cues for movement and reproduction of fish.

Table 15. (continued.)

Key ecological component or process	Potentially threatening activities	Potential impacts
Dissolved oxygen	• Same as activities that affect water temperature, nutrients and salinity (see above).	Low dissolved oxygen concentrations can lead to fish kills, promote the growth of anaerobic bacteria and the release of nutrients from the sediments (Australian Government unpublished b).
pH	• Activities involving disturbance of acid sulfate soils in the wetland. • Factors resulting in lowered pH of runoff from the wetland catchment (soil acidification or disturbance of acid-sulfate soils in the wetland catchment). • Acid or alkaline industrial waste discharges to the wetland. • Atmospheric acid deposition (sourced from vehicles, factories, smelters and power stations that burn fossil fuels).	Change in water pH can lead to changes in wetland biota abundance, diversity and richness.
Nutrient cycling	• Activities that affect all of the above components.	Changes in nutrient cycling can lead to changes in primary and secondary productivity and subsequent changes in wetland food webs.

The physico-chemical water properties of a wetland can be determined by directly measuring the components in Table 15. Changes in the water properties can be detected by comparing the results to reference data relevant to the wetland for these parameters, where known. Alternative measures of change are the presence or absence of threats thought to be responsible for changes to the water properties or impacts thoughts to be a direct consequence of water quality change, for example, the composition of macroinvertebrate assemblages (Table 16). Measures based on threats that arise in the wetland catchment and buffer and lead to wetland salinisation, an increase in nutrients, sediments or pollutants entering the wetland or lowered pH of runoff entering the wetland are in Section 5.2.1.

Table 16. Possible measures of physico-chemical water properties relating to wetland condition.

Key ecological component	Possible measure	Type of measure
Nitrogen	Nitrogen	Component
Phosphorus	Phosphorus	Component
	Frequency of algal blooms in last five years	Impact
Macronutrients (such as nitrogen and phosphorus)	Aquatic macroinvertebrate indicator species or index	Impact
	Activities leading to an input of nutrients to the wetland	Threat
Electrical conductivity	Electrical conductivity	Component
	Aquatic macroinvertebrate abundance and diversity	Impact
	Diatom abundance and diversity	Impact
	Vegetation indicator species or communities	Impact
	Factors likely to lead to wetland salinisation • input of saline water to the wetland • wetland occurs in a salinity risk area	Threat
	Groundwater levels at wetland	Threat
Turbidity	Turbidity	Component
	Percentage and severity of wetland soil disturbance (covered under soils Table 18).	Threat

Table 16. (continued).

Key ecological component	Possible measure	Type of measure
Temperature	Temperature	Component
	Vegetation cover over water surface (amount of shading)	Threat
Dissolved oxygen	Dissolved oxygen	Component
pH	pH	Component
	Presence/absence of activities involving disturbance of acid sulfate soils in the wetland	Threat
	Presence/absence of acid or alkaline industrial waste discharges to the wetland	Threat
	Presence/absence of source of atmospheric acid deposition (traffic, factories, smelters, power stations burning fossil fuels)	Threat
Nutrient cycling	Macroinvertebrate index	Impact

5.2.5 Soils

Changes to wetland soils are likely to result in changes in wetland condition as soils are important for nutrient storage, as a substrate and seed store for wetland plants and as habitat for benthic aquatic invertebrates and soil micro-organisms.

Wetland soils can be altered and degraded by activities in the wetland that disturb the soil structure or add nutrients. Activities in the wetland catchment can lead to wetland soil salinisation, contamination or nutrient enrichment, altering the chemical properties of wetland soils. Impacts such as soil salinisation and nutrient enrichment are also likely to be reflected in increased levels of salinity and nutrients in the water. Changes to the physical and chemical properties of soils are likely to result in changes to the soil biota. Table 17 lists the components of wetland soils, the activities with the potential to cause changes in these components and the likely impacts on the wetland.

Table 17. Components of wetland soils, activities with the potential to cause changes to these components and the resultant impacts that are likely to affect wetland condition.

Key ecological component or process	Potentially threatening activities	Potential impacts
Soil physical properties (structure, texture, consistency and profile)	• Cultivation in the wetland • Livestock grazing in wetland. • Trampling and vehicle tracks in the wetland associated with recreational use. • Carp mumbling.	Soil disturbance which can lead to reduced water storage capacity of soil (Bacon et al. 1994), negative impacts on some invertebrates (Seddon and Briggs 1998), propagules, egg and seed banks and increased turbidity during filling.

Table 17. (continued).

Key ecological component or process	Potentially threatening activities	Potential impacts
Soil chemical properties (organic content, nutrients, metal oxides, silica clays, salts and pH)	• Excessive clearing of native vegetation in wetland catchment leading to raised water tables and wetland soil salinisation. • Disposal of saline water into the wetland.	Soil salinisation can lead to changes in benthic biota and wetland vegetation and fauna abundance, diversity and richness.
	• Activities in the wetland that lead to an increased input or release of nutrients (Table 15). • Activities in the wetland catchment that lead to an increase in the amount of nutrients in catchment runoff (clearing of vegetation, land uses such as agriculture or urbanisation, fire). • Modification of the wetland buffer that decreases its ability to filter out nutrients in catchment runoff.	Soil nutrient enrichment can lead to changes in benthic biota and macrophyte abundance, diversity and richness.
	• Direct discharge of wastes (industrial waste, effluent or sewage) into the wetland leading to soil contamination.	Soil contamination can lead to changes in benthic biota and abundance, diversity and richness of vegetation communities.
Soil biological properties (soil organisms such as bacteria and fungi, protozoans, nematodes, mites and worms)	• Activities that affect the soil physical and chemical components (above) causing changes in benthic fauna communities.	Changes in benthic fauna communities lead to changes in secondary productivity and nutrient cycling, leading to changes in wetland food webs.

The condition of wetland soils can be measured by directly measuring the soil components and comparing against the reference condition, where known. Alternative measures are the presence or absence of threats thought to be responsible for changes to the soil components or impacts thoughts to be a direct consequence of change to these components (Table 18). Measures based on threats that arise in the wetland catchment and buffer and lead to soil salinisation or nutrient enrichment are covered in Section 5.2.1.

Table 18. Possible measures of wetland soils relating to wetland condition.

Key ecological component	Possible measure	Type of measure
Soil physical properties (structure, texture, consistency and profile)	Soil physical properties	Component
	Percentage and severity of wetland soil disturbance	Impact
	Presence of activities that cause soil disturbance	Threat
Soil chemical properties (organic content, nutrients, metal oxides, silica clays, salts and pH)	Soil pH	Component
	Soil salt levels	Component
	Soil nutrient levels	Component
	Presence of toxicants	Impact
	Activities leading to an input of nutrients to the wetland (covered in water properties Table 16)	Threat
	Factors likely to lead to wetland salinisation • input of saline water to the wetland; • wetland occurs in a salinity risk area (covered in water properties Table 16)	Threat
Soil biological properties (soil organisms such as bacteria and fungi, protozoans, nematodes, mites and worms)	Abundance, diversity and richness of benthic biota	Component
	Benthic fauna index	Impact

5.2.6 Biota

As outlined in Section 3.1, wetland biota can influence many of the other non-biotic components of a wetland through their role in wetland processes. Therefore, changes in wetland biota are likely to result in changes in wetland condition. In addition, wetland biota are affected by the wetland characteristics of form, hydrology, water properties and soils. Therefore, changes in wetland biota provide additional evidence for changes in wetland condition brought about by changes to other characteristics. Table 19 lists the main biotic components of the wetland, the activities with the potential to cause changes in these components and the likely impact on the wetland.

Table 19. Components of wetland biota, activities with the potential to cause changes to these components and the resultant impacts that are likely to affect wetland condition.

Key ecological component or process	Potentially threatening activities	Potential impacts
Wetland plants	Activities that result in change to natural[1] wetland form (Table 11), hydrology (Table 13), physico-chemical properties of the water (Table 15) or to wetland soils (Table 17) and lead to changes in wetland vegetation health and distribution.	Changes in wetland vegetation health and distribution can lead to changes in fauna habitat, wetland transpiration rates, average water temperatures, the rate of binding and trapping of sediments and soil formation.
	Clearing or harvesting of indigenous vegetation or establishment of non-indigenous plant species in or around the wetland.	
	Introduction and/or poor control of invasive species.	
Phytoplankton, including diatoms	Activities that result in changes to the natural[1] physico-chemical properties of the water (Table 15).	Changes in primary productivity can lead to changes in wetland food webs.
Aquatic macroinvertebrates	Activities that result in changes to natural[1] wetland vegetation (listed above).	Changes in secondary productivity and nutrient cycling can lead to changes in wetland food webs.
	Activities that result in changes in natural[1] physico-chemical properties of the water (Table 15) or in wetland soils (Table 17).	
Vertebrate fauna (fish, amphibians, reptiles, waterbirds, mammals)	Activities that result in changes to natural[1] wetland vegetation (listed above).	Changes in vertebrate fauna abundance, diversity and richness can lead to changes in species interactions (e.g. competition, predation, herbivory), nutrient cycling and wetland food webs.
	Activities that result in change to natural[1] wetland form (Table 11), hydrology (Table 13) or physico-chemical properties of the water (Table 15).	
	Activities that result in changes to natural phytoplankton and invertebrate communities (listed above).	
	Introduction and/or poor control of invasive fauna species.	
	High level of human activity in and around the wetland.	
	Activities that interfere with natural[1] connectivity of flow to and from the wetland.	Loss or impairment of habitat connectivity for species requiring the presence of water for movement can lead to changes in migration and dispersal.

[1] The term 'natural' is used here to mean a state unmodified by human activities associated with European settlement.

The status of wetland biota can be assessed by directly measuring the abundance of particular species (e.g. an indicator species) or the parameters that describe particular communities or groups of biota. Changes in biota can be detected by comparing the results to the reference data for the wetland for these parameters, where known. Alternative measures of change are the presence or absence of threats thought to be responsible for changes to the biota or impacts thought to be a direct consequence of change to a species or community, for example, primary productivity or vegetation quality (Table 20).

Table 20. Possible measures of wetland biota relating to wetland condition.

Key ecological component	Possible measure	Type of measure
• Vertebrate fauna (fish, amphibians, reptiles, waterbirds) • Aquatic invertebrates • Aquatic microinvertebrates • Phytoplankton • Diatoms	Abundance measures or presence/absence for individual species or indicator (keystone) species.	Component
	Measures of species abundance, richness and diversity for particular groups	Component
	Measures of habitat quality for particular groups	Impact
Vertebrate fauna (fish, amphibians, reptiles, waterbirds, mammals)	Abundance of pest species	Impact
	Activities that interfere with natural connectivity of flow to and from the wetland (covered in hydrology Tables 13 and 14).	Threat
	Level of human activity in and around the wetland	Threat
	• Average width of the buffer • Percentage of wetland perimeter with buffer (covered under wetland catchment Table 10)	Threat
Wetland plants	Individual species cover or biomass	Component
	Vegetation community attributes such as species richness, critical species or lifeform presence, cover, structure and health	Component
	Weeds	Impact
	Indicators of altered processes	Impact

[1] See Section 3.2 for a description of wetland ecological vegetation classes

5.3 Evaluation of measures

The possible measures selected for use in the IWC (Section 5.2) have been evaluated against the IWC requirements with the exception of .Requirement 8 which guided the selection of key components on which the measures are based (Section 5.1). The measures recommended for inclusion in the IWC are identified and the main reasons given for the inclusion or rejection of each measure. A detailed evaluation for each measure is provided in Appendix 4 (Tables A4.1-4.6).

5.3.1 Wetland catchment

Measures relating to the entire wetland catchment are of limited use, primarily because of the practical difficulty of defining a wetland catchment. This practical difficulty can be overcome by measuring land use intensity in the area adjacent to the wetland within the surface water catchment. This requires definition of the adjacent area and categorising various land uses according to intensity. Buffer width and the percentage of wetland perimeter with a buffer are considered useful measures as they meet all IWC requirements (Table 21, Appendix 4: Table A4.1).

Table 21. Evaluation of possible measures of wetland catchment.

Key ecological component	Possible measure	Comment on measure	Include in IWC
Wetland catchment	Percentage of native vegetation cover in the catchment.	The limitations of these measures are the difficulty in defining the wetland catchment, the possible lack of current data on native vegetation cover and land use and the skills and time required to interpret air photos, satellite imagery and/or GIS vegetation layers.	NO
	Percentage of land in different land use intensity classes in the catchment		NO
	Percentage of soil affected by acidification in the wetland catchment	The availability of data on soil acidification in Victoria is limiting.	NO
	Percentage of land in different land use intensity classes adjacent to the wetland	This measure meets all of the requirements.	YES
Wetland buffer	Average width of the buffer	This measure meets all of the requirements.	YES
	Percentage of wetland perimeter with buffer	This measure meets all of the requirements.	YES

5.3.2 Physical form

Two measures are recommended for physical form: the percentage reduction in wetland area and the percentage of the wetland where activities have resulted in a change in bathymetry. Activities such as excavation of the wetland bed (e.g. excavating channels or dams in the wetland or dredging) and landforming (eg. raised-bed cropping, laser-levelling and building of mounds) are likely to cause a significant change in wetland bathymetry. To better estimate the effect on condition, it is considered necessary to record the percentage of the wetland bed where activities occur. Direct measurement of depth or bathymetry has major limitations as outlined in Table 22 and Appendix 4: Table A4.2.

Table 22. Evaluation of possible measures of physical form.

Key ecological component	Possible measure	Comments on measure	Include in IWC
Area of the wetland	Percentage reduction in wetland area.	This measure meets all of the IWC requirements.	YES
Wetland form	Wetland bathymetry	Wetland bathymetry is expensive and time-consuming to capture and process and can only be undertaken when wetlands are dry. Reference data are unlikely to be available for most wetlands.	NO
	Depth of wetland (maximum water depth)	This measure can only be determined easily when the wetland is full (using a depth gauge) or dry (using survey or remote sensing techniques). The reference depth is only known as a depth class for most wetlands.	NO
	Percentage of wetland where activities (excavation and landforming) have resulted in a change in bathymetry	This measure is considered the only practical measure of bathymetry for use in a rapid assessment technique. It meets the IWC requirements.	YES

5.3.3 Hydrology

The hydrological regime can only be determined accurately by regular monitoring over a time period that encompasses seasonal and inter-annual variability. Reference data on the hydrological regime are unlikely to be available for most wetlands, making it difficult to interpret results. Therefore, direct measures of hydrology components are not suitable for a rapid assessment technique. Threat-based measures are considered the only practical measures for indicating a change in hydrology, given the requirements of the IWC (Table 23, Appendix 4: Table A4.3).

Table 23. Evaluation of possible measures of hydrology.

Key ecological component	Possible measure	Comments on measure	Include in IWC
Water regime	Water depth and/or surface water extent over time (to establish frequency, seasonality and duration of inundation)	These measures are not suitable for a rapid assessment technique because they require regular monitoring throughout the year over many years before a change in condition could be detected. Reference data is unlikely to be available for most wetlands for frequency and seasonality of inundation. Reference data is available for duration of inundation but only in general terms. The interpretation of results may be confounded by the lack of reference data and lack of knowledge about effects of climate change due to human-induced factors.	NO
	Distribution/health of vegetation species or communities	This is not considered a suitable measure for detecting changes in wetland hydrology because of the high level of specialist knowledge required to interpret change and the lack of a ready reference for the distribution of vegetation.	NO
	Severity of activities that change the water regime (see Table 13 for a list of activities)	This measure is considered the only practical hydrology measure for use in a rapid assessment technique. Within the practical constraints of the IWC requirements, severity can only be estimated subjectively. Guidance is required to maximise consistency between assessors. It is likely that the presence of activities will signal a change in hydrology. The nature of the relationship between an activity and the degree of change however, is difficult to quantify. However, noting the presence of activities and their estimated severity provides evidence about likely changes to wetland hydrology.	YES

It is recommended that the IWC measure of hydrology be based on assessing the severity of activities that change the water regime as outlined in Table 13.

5.3.4 Water properties

Measurements of the water components (pH, salinity, nutrients, dissolved oxygen and turbidity) can only be taken when water is present in the wetland. Frequent measurements are required to account for the temporal variability exhibited by these parameters (several times a year to monthly) and as such, long-term frequent monitoring is usually recommended. Interpretation of results requires information about the natural range of variation, which is lacking for many wetlands. Events, such as sudden wetland filling, or the final phases of drying out, may produce atypical readings, also making interpretation of results difficult. Recent salinity research in wetlands in Victoria has shown that spatial variability of salinity (within a wetland) and temporal variability within a two-month period when the wetland is full or close to full are relatively low (M. Smith, DSE pers. comm.).

Frequent measures of a range of water components are collected for a few wetlands in Victoria (Appendix 2). Where such data are collected, it may be possible in the future to incorporate the results into the IWC. This would require guidance on the acceptable quality of a data set and establishment of a reference for the water properties incorporated.

The reference condition for many water components will not be known for the majority of wetlands in Victoria. To develop suitable reference benchmarks for water components would require the classification of wetlands in relation to the component. To date the only such statewide classification is that of Corrick and Norman (1980) for salinity, which separates wetlands into two broad categories: fresh and saline (Table 3). These limitations render the use of water components unsuitable for inclusion in the IWC at present.

Indirect measures of water quality parameters such as macroinvertebrate and diatom assemblages require water to be present and analysis (identification of samples) requires specialist knowledge and is relatively time-consuming. The use of such biota as surrogates for water quality in Victoria requires further investigation. Consequently, indirect measures such as macroinvertebrate and diatom assemblages are not suitable for a rapid assessment technique.

Threat-based measures are considered the only practical measures. Threat-based measures for salinity and nutrients have been included as changes in these components are considered to have significant impacts on wetlands in Victoria, even though the measures have recognised deficiencies, particularly in interpretation of results. They will be useful only to indicate the likelihood of nutrient enrichment or salinisation, which might then require further investigation. Water pH is also considered important but the possible threat-based measures are considered to have too many limitations. The threat-based measure for turbidity is covered under soil disturbance (Table 25). See Table 24 and Appendix 4: Table A4.4 for more detail on the assessment of measures.

Table 24. Evaluation of possible measures of water properties.

Key ecological component	Possible measure	Comments on measure	Include in IWC
Nitrogen	Nitrogen	Measurements can only be taken when water is present in the wetland. Frequent (several times a year) and long-term monitoring is usually recommended to take account of seasonal and inter-annual climatic variation. Interpretation of results requires information about the natural range of variation at a reference site. Certain events (e.g. sudden wetland filling, or the final phases of drying out) may produce atypical readings, also making interpretation of results difficult. Reference condition will not be known for the majority of wetlands in Victoria.	NO
Phosphorus	Phosphorus		
Electrical conductivity	Electrical conductivity		
Turbidity	Turbidity		
Temperature	Temperature		
pH	pH		
Dissolved oxygen	Dissolved oxygen		
Phosphorus	Frequency of algal blooms in last five years	Assessment is dependent on having reliable records of algal blooms for the region where the wetland is located. This may not be the case. Several factors can be involved in triggering an algal bloom, so interpretation of results is not straightforward. The assumed reference is that algal blooms do not occur in wetlands where the wetland and its catchment are unmodified, but this is not known definitely to be the case.	NO
Macronutrients (such as nitrogen and phosphorus)	Aquatic macroinvertebrate indicator species or index	Measurements can only be taken when water is present in the wetland. Interpretation relies on establishing the relationships between components and the aquatic macroinvertebrate indicator species, index or abundance and diversity and on establishing reference benchmarks. This would require a significant research effort.	NO
Nutrient cycling			
Electrical conductivity (salinity)	Aquatic macroinvertebrate abundance and diversity		NO
	Diatom abundance and diversity		

Table 24. (continued).

Key ecological component	Possible measure	Comments on measure	Include in IWC
Macronutrients (such as nitrogen and phosphorus)	Activities leading to an input of nutrients to the wetland (Table 15)	Activities are only likely to be present or obvious when the wetland is dry or partially dry. Interpretation of results may be difficult, due to the uncertainty of the relationship between the various activities and nutrient levels. However, noting the presence/absence of such activities will be useful as evidence about the likely nutrient enrichment of the water.	YES
pH	Presence/absence of sulfidic soils in the wetland and activities involving disturbance of such soils	Not all wetlands have or may have the potential to develop sulfidic soils. There would be a need to confirm that the wetland had acid-sulfate soils and the degree to which the activity disturbed those soils. It might be difficult to detect degrees of change in condition using this measure.	NO
	Presence/absence of acid or alkaline industrial waste discharges to the wetland	The nature of the effect of these factors will be difficult to quantify because it depends on many variables such as the volume and pH of the discharge or deposit, for atmospheric deposition, the rate of deposition on and the natural pH of the wetland. Therefore, results will be difficult to interpret.	NO
	Presence/absence of source of atmospheric acid deposition (traffic, factories, smelters, power stations burning fossil fuels)		
Electrical conductivity (salinity)	Factors likely to lead to wetland salinisation • input of saline water to the wetland • wetland occurs in a salinity risk area	Interpretation of results may be difficult, due to the uncertainty of the relationship between the factors and salinisation. However, noting the presence/absence of such factors will be useful as evidence about likely salinisation.	YES
	Vegetation indicator species or communities	This measure is not suitable at present but may be useful with further research on suitable indicator species and their salinity tolerances. Information on the salinity tolerances of some species is already available.	NO
	Groundwater levels at wetland	This measure is not suitable for a rapid assessment technique. Groundwater levels may vary naturally throughout the year in some aquifers. Setting up bores may be expensive. To detect changes in condition and interpret results will require data collection over the range of time that reflects natural variability. The interpretation of results may be confounded by the lack of knowledge about the range of natural variability and the effects of climate change due to human-induced factors.	NO

5.3.5 Soils

Multiple measurements will be required to account for spatial variability in the wetland (making sampling time consuming) for direct measures of soil physical and chemical properties. Reference data are unlikely to be available for many of these parameters, making interpretation of results difficult. Specialist knowledge is needed for analysis of soil biota and this is also likely to be relatively time-consuming. The soil disturbance impact measure is considered the only practical measure for indicating a change in soil physical properties, given the requirements of the IWC. Activities leading to an input of nutrients to the wetland

and factors likely to lead to wetland salinisation are covered in water properties (Table 24.). See Table 25 and Appendix 4: Table A4.5 for more detail on the evaluation of possible measures for soils.

Table 25. Evaluation of possible measures of wetland soils.

Key ecological component	Possible measure	Comments on measure	Include in IWC
Soil physical properties (structure, texture, consistency and profile)	Soil physical properties	This measure is considered to be unsuitable. Measurements will be impractical when the wetland is inundated. Multiple measurements will be required to account for spatial variability in the wetland (making sampling time-consuming). Reference data are unlikely to be available making interpretation of results difficult.	NO
	Percentage and severity of wetland soil disturbance	This measure meets most of the IWC requirements. Different comparable sampling methods are required for measuring soil disturbance at different degrees of inundation.	YES
	Presence of activities that cause physical disturbance	This measure has limitations. Activities are only likely to be present or obvious when the wetland is dry or partially dry. Interpretation of results will be difficult, due to lack of understanding of the relationship between the various activities and soil disturbance. Noting the presence/absence of such activities will be useful as additional evidence about likely disturbance to wetland soil.	NO
Soil chemical properties (organic content, nutrients, metal oxides, silica clays, salts and pH)	Soil pH Soil salt levels Soil nutrient levels	These measures are considered to be unsuitable. Multiple measurements will be required to account for spatial variability in the wetland (making sampling time-consuming). Reference data are unlikely to be available making interpretation of results difficult.	NO
	Presence of toxicants	This measure is not suitable because sampling and analysis is likely to be time-consuming and relatively expensive.	NO
Soil biological properties (soil organisms such as bacteria and fungi, protozoans, nematodes, mites and worms)	Abundance, diversity and richness of benthic biota Benthic fauna index	These measures are considered to be unsuitable. Measurements can only be taken when water is present in the wetland. Analysis is likely to require specialist knowledge and be relatively time-consuming. Reference data are unlikely to be available making interpretation of results difficult.	NO

5.3.6 Biota

Two of the threat measures relating to fauna are covered elsewhere. Activities that interfere with natural connectivity of flow to and from the wetland are covered under hydrology (Tables 13, 14 and 23) and the average width of the buffer and percentage of wetland perimeter with buffer are covered under wetland catchment (Table 21). Other measures of fauna are not recommended for inclusion in the IWC. The assessment of wetland fauna (including the identification of taxa) is not likely to be rapid for most groups and in many cases will require specialist knowledge. Some groups such as frogs and waterbirds may be easier to identify in the field and hence more rapid to assess. The appropriateness of frogs as measures of wetland condition has not been assessed for many wetland types. Waterbirds are likely to be heavily influenced by factors external to the wetland such as the area and availability of water across the species range. The presence of water is required for the assessment of invertebrates, fish and diatoms, which is a limiting factor. Adequate data is not available to determine reference conditions for fauna at most wetlands.

Four measures of wetland vegetation have been combined into a method to assess wetland vegetation quality for the IWC (Department of Sustainability and Environment 2005a). An existing rapid assessment method for terrestrial vegetation quality, habitat hectares (Parkes et al. 2003, Department of Sustainability and Environment 2004) was considered unsuitable for assessment of wetland vegetation due to the high degree of variation in wetland vegetation and the frequent domination by non-woody species (Department of Sustainability and Environment 2005a). The method developed for the IWC assesses the quality of wetland vegetation based on four attributes: critical lifeforms, lack of weeds, indicators of altered processes and vegetation structure and health. Benchmark descriptions for each wetland EVC have been prepared. The method is described in Department of Sustainability and Environment (2005a). See Table 26 and Appendix 4: Table A4.6 for more detail on the evaluation of measures.

Table 26. Evaluation of possible measures of wetland biota.

Key ecological component	Possible measure	Comments on measure	Include in IWC
• Vertebrate fauna (fish, amphibians, reptiles, waterbirds, mammals) • Aquatic invertebrates • Phytoplankton • Diatoms	Abundance measures or presence/absence for individual species or indicator (keystone) species	For some groups, particularly vertebrates, there are unlikely to be species or even groups present and obvious at all wetlands. Multiple samples are generally recommended for some species. Analysis is generally relatively time-consuming and identification of some biota (such as diatoms and macroinvertebrates) requires specialist knowledge. Reference data are unlikely to be available making interpretation of results difficult.	NO
	Measures of species abundance, richness and diversity for particular groups	Multiple samples are generally recommended. Analysis is relatively time-consuming and requires specialist knowledge. Reference data are unlikely to be available making interpretation of results difficult.	NO
	Measures of habitat quality for particular groups	This measure has limitations. The habitat requirements differ for species or faunal groups and are not likely to be consistent across all wetlands. The reference condition will vary for each fauna group. The measure is not currently considered appropriate for the IWC.	NO
Wetland fauna Vertebrates (fish, amphibians, reptiles, waterbirds, mammals)	Abundance of pest species	Multiple samples are generally recommended. Analysis is relatively time-consuming and requires specialist knowledge.	NO
	Level of human activity in and around the wetland	This measure has promise as it meets most of the requirements. There are limitations, however as the relationship between level of human activity and condition of vertebrate fauna is largely unknown.	NO
Wetland plants	Individual species cover or biomass	This measure has many limitations. Assessment is not likely to be rapid and will require expert knowledge. The measure is not considered appropriate for the IWC	NO
	Vegetation community attributes such as species richness, critical species or lifeform presence, cover, structure and health	These measures have been combined into a wetland vegetation quality assessment method that meets the IWC requirements. Some specialist knowledge or training is likely to be required to undertake assessments.	YES
	Indicators of altered processes		
	Weeds		

5.4 Summary of recommended measures for the IWC

Measures identified for inclusion in the IWC for each sub-index, as evaluated in section 5.3 (Tables 21-26), are summarised in Table 27. Methods for collecting measurements are covered in a draft methods manual (Department of Sustainability and Environment unpublished b).

Table 27. Measures identified for inclusion in the IWC.

IWC sub-index	Key ecological component	Measure	Measure type
Wetland catchment	Wetland catchment	Percentage of land in different land use intensity classes adjacent to the wetland	Threat
	Wetland buffer	Average width of the buffer	Component
		Percentage of wetland perimeter with a buffer	Component
Physical form	Area of the wetland	Percentage reduction in wetland area.	Component
	Wetland form	Percentage of wetland where activities (excavation and landforming) have resulted in a change in bathymetry	Threat
Hydrology	Water regime	Severity of activities that change the water regime (see Table 13 for a list of activities)	Threat
Water properties	Macronutrients (such as nitrogen and phosphorus)	Activities leading to an input of nutrients to the wetland (Table 15)	Threat
	Electrical conductivity (salinity)	Factors likely to lead to wetland salinisation: • input of saline water to the wetland • wetland occurs in a salinity risk area	Threat
Soils	Soil physical properties (structure, texture, consistency and profile)	Percentage and severity of wetland soil disturbance	Impact
Biota	Wetland plants	Wetland vegetation quality assessment based on: • critical lifeforms • presence of weeds • indicators of altered processes • vegetation structure and health	 Component Impact Impact Component

5.5 Scoring and reporting

5.5.1 Scoring of sub-indices and the IWC

Equal scores were assigned to each sub-index as there is insufficient evidence to apply weightings. All sub-indices have an equal maximum possible score of twenty points. The vegetation quality assessment method has a maximum possible score of 100 points as this method was developed in a similar way to the Habitat Hectares approach, which scores out of 100 points (Parkes et al. 2003) For the IWC, the vegetation quality score is divided by five to match the totals of the other sub-indices. The maximum total score for wetland condition is therefore 120 (Table 28).

Table 28. Maximum scores for the sub-indices in the IWC.

Sub-index	Total score
Physical form	20
Hydrology	20
Water properties	20
Soils	20
Biota (wetland vegetation)	20
Landscape context	20
Total ⇒	**120**

5.5.2 Scoring of individual measures

Within a sub-index, where there is more than one measure, each measure is weigh has equal weighting. There is insufficient information to assign a different weighting to the measures, hence a pragmatic decision was made to weight equally and ensure the total of the measures for each sub-index was twenty points. The guiding principal behind the scoring of each measure is the comparison with reference condition. For each component-based measures, the greater the departure from the reference condition the lower the score. For threat-based measures, the reference condition will be the absence of the activity with the potential to cause a change in condition or in some cases, the absence of a risk factor like to cause a change in condition.

5.5.3 Reporting results of IWC assessments

The IWC is designed for the general surveillance of wetland condition. It is designed to be useful for assigning wetlands to general condition categories and detecting significant changes in wetland condition. Therefore it is considered more appropriate to report sub-indices and overall wetland condition in the form of categories, rather than actual scores. Proposed condition categories (Table 29) are based on the concept of departure from the reference condition (discussed in Section 3.2.5). Four reporting categories are proposed at this stage based on scoring classes that are equally distributed across the total scoring range. These categories and scoring classes are untested and provisional. Testing and use of the IWC may result in a change to the number of reporting categories or changes to the scoring system.

The overall condition for a wetland is best suited to general reporting, such as State of the Environment or catchment condition reporting. Detailed information, not presented in the overall rating, is useful to managers in implementing the assets-based approach to NRM (Figure 2). For this purpose, it is considered useful to report the categories for each sub-index as well as the overall scoring category.

Table 29. Provisional condition categories for reporting sub-index and overall wetland condition based on the sub-index and total IWC scores.

Sub-index condition category	Sub-index score
Well below reference	<5
Moderately below reference	>5-10
Slightly below reference	>10-15
Reference	>15-20

Wetland condition category	IWC wetland score
Well below reference	<30
Moderately below reference	>30-60
Slightly below reference	>60-90
Reference	>90-120

6. Future development

6.1 Status of the IWC

This project has resulted in the development of an IWC for use as a rapid assessment technique to assess wetland condition in Victoria. The project has focused on the conceptual framework that underpins the method and the selection of suitable measures for inclusion in the IWC. There has been minimal testing of the IWC to date. The ability of the method to accurately measure condition has not yet been systematically tested and the measures have not been tested for their precision. There has been limited practical testing of the IWC by the project team as part of the development process but no widespread testing by potential users of the method.

Future testing and periodic revision of the IWC is considered essential to continue to develop the IWC as a robust and credible method. It is proposed that the IWC now be used in a provisional sense and that its use incorporates a program of testing for accuracy, precision and practicality. It is proposed to review that IWC within five years.

6.2 Future testing

Testing the accuracy of the IWC will involve assessing wetlands of known condition across the state. Such wetlands will likely be those that have comprehensive datasets, those for which condition has been previously assessed by other methods or those where the condition can be determined subjectively by a panel of discipline experts. Comparison with other condition assessment methods will be possible in parts of Victoria, i.e. the Gippsland Lakes, the Wimmera and the Alps, however the accuracy of these methods should be considered before doing so. The IWC should also be tested for consistency across different hydrological phases at a wetland. Testing may demonstrate that the scoring system should be refined. Testing for consistency between users is also required.

The practical application of the IWC also needs to be tested. Feedback on the draft field assessment sheets and draft methods manual (Department of Sustainability and Environment unpublished b) will be sought from those using the IWC, to facilitate the continued development and improvement of the IWC.

6.3 Implementation

Several issues require consideration in implementing the IWC. Training will be required to familiarise users with the IWC. It is likely that a low level of training will be required for most elements of the IWC and higher-level training will be required for the wetland EVC assessment. The training requirements and nature of such a program is currently being investigated by the Department of Sustainability and Environment. An initial round of practical testing is proposed as a way of identifying the level of training required.

Stakeholder engagement will continue to be an important consideration in the future development of the IWC. It is planned to consult NRM agencies that will be using the IWC as part of the testing process and the ongoing development of the IWC. It is also considered important to continue to engage wetland experts in implementation and testing.

Scoring and reporting considerations were briefly outlined in Section 5.5. The scoring system and condition categories proposed for reporting may be revised if testing results indicate this is necessary. The reporting of wetland condition results may need to be tailored to the needs of individual assessment programs across Victoria.

Data quality assurance, data analysis and data management need to be addressed before assessments begin to be undertaken.

6.4 Knowledge gaps

During the development of the IWC and an analysis of the information available on Victorian wetlands, a lack of information and knowledge was evident in some areas. The following were identified as issues, which may require further investigation:

- identifying wetland boundaries and buffers (especially on floodplains);
- assessing large wetlands;
- identifying wetland catchments;
- distinguishing wetland vegetation from terrestrial vegetation; and
- mapping wetlands smaller than one hectare.

A number of issues regarding the IWC components and measures have arisen from the consultative process undertaken throughout the development of the IWC. These issues, resources and research required to address them and other areas of research that can 'add-value' to the IWC are discussed below.

Use of threat and impact based measures

Only about half the IWC measures are direct measures of components. The others are indirect measures based on threats to wetlands or impacts on them. The use of threat and impact measures arises for a number of reasons. Limitations in time, resources and skill levels for undertaking an assessment meant that direct measures were impractical for some components. There is often insufficient data to determine the type of relationship between components and threats or components and impacts. Therefore, the use of threat-based measures is potentially unreliable.

The lack of data and/or ecological knowledge about the component has meant it has not been possible to identify the reference condition for many components. For example, there is water quality data for less than 100 wetlands in Victoria, most of which is short-term (less than ten years).

Options to address these issues include:

- an in-depth review of literature to investigate evidence for quantitative relationships between threats and impacts and condition; and
- targeted research into the nature of the relationships between threats, impacts and wetland condition to identify (whether or not these relationships are linear or of some other form).

Comprehensiveness of measures

Within the requirements of the IWC, some key ecological components could not be measured using direct or indirect measures. Notable gaps include the lack of measures for water property components such as pH and turbidity and for biotic components such as vertebrate fauna and macroinvertebrates. There is presently no accurate and straightforward method for determining a wetland catchment (due to different water sources) and the current catchment measure relates only to land adjacent to the wetland.

Options to address these issues include those listed below:

- scoping of the feasibility of developing better measures for water properties and vertebrate fauna to include in the IWC;
- scoping of the feasibility of developing biotic indices such as a macroinvertebrate index;
- investigation of wetland catchment delineation methods.

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Appendix 1. Wetland ecosystem services

Wetland ecosystem services adapted from the Millennium Ecosystem Assessment (2003), the definition of ecological character (Ramsar Convention 1996) and Ramsar Convention (undated). The column headed EC shows how the 'products, functions and attributes' in the ecological character definition equate to specific ecosystem services.

Ecosystem service	Examples	EC
Provisioning services		
Wetland products	Drinking water for humans and for livestock Water for irrigated agriculture Water for industry Sustenance for humans (e.g. fish) Timber Livestock fodder Storage and delivery of water as part of water supply systems	Product
Regulating services		
Maintenance of hydrological stability	Flood control Replenish groundwater	Function
Coastal shoreline and river bank stabilization and storm protection	Reduce impacts of wind and wave action and currents Prevent erosion by holding sediment with plant roots	Function
Sediment and nutrient retention	Flood retardation and sediment and nutrient deposition	Function
Local climate regulation	Local climatic stabilization, particularly in relation to rainfall and temperature.	Function
Climate change mitigation	Sequester carbon	Function
Water purification	Removal and dilution of wastewaters from irrigation areas, urban areas and sewage treatment plants	Function
Biological control of pests and diseases	Support of predators of agricultural pests (e.g. ibis feeding on grasshoppers)	Function
Cultural services		
Recreation and tourism	Recreational fishing and hunting Water sports and activities Picnics, outings, touring Nature observation	Attribute
Cultural value	Inspiration Aesthetic values Cultural heritage (historical and archaeological) Spiritual and religious Sense of place Educational values Knowledge systems	Attribute
Supporting services		
Food web support**	Nutrient cycling Primary production	Function
Ecological value	Reservoirs of biodiversity in relation to: • supporting an abundance of individuals of particular species or groups • supporting significant proportions of particular species populations supporting a high diversity of species • maintaining bioregional biodiversity • representing a rare or threatened wetland type • being a unique wetland type • being representative of a bioregion • being important as habitat for animal taxa at a particular stage of their life cycle • being important as habitat for animal taxa at a vulnerable stage of their life cycle or as a refuge during adverse conditions • supporting threatened species or threatened ecological communities.	Attribute

Appendix 2. Water quality programs for Victorian wetlands

Table A2.1 Water quality monitoring programs for Victorian wetlands. Where data for parameters other than water quality is collected as part of a program, the measures are included in the table.

Region	No. of wetlands monitored	Wetlands	Parameters measured	Sampling frequency	Period of data set	Reference
Mallee	16	Lake Carpul, Bullock Swamp, Callander Swamp, Karadoc Swamp, Psyche Bend Lagoon, Cardross Basin, Lake Ranfurly (West and East), Wargan Basin (Two and Three), Bottle Bend Billabong, Lake Hawthorn, Lake Hattah, Dry Lakes (Hattah), Raak Plain, Lake Agnes	Total Phosphorus, Nitrogen, Salinity, Turbidity, Dissolved Oxygen, Temperature, pH.	Seasonally	From 1995 (some measures) - 2001. Program is ongoing.	Earth Tech Engineering (unpublished).
Wimmera	12	Boyeo Swamp, Nhill Lake, Collins Lake, Lake Charlegrark, Lake Wallace, Lake Bringalbert, Lake Wyn Wyn, Lake Ratzcastle, Maryvale Swamp, Lake Albacutya, Lake Hindmarsh, Mitre Lake	EC, pH, Temperature, metals, herbicides and pesticides.	Monthly	July 2003 - present	Wimmera CMA
Northern Victoria	3	Gaynors Swamp, Reedy Swamp and Kinnairds Swamp	Nutrients (Phosphorus & Nitrogen)	Seasonally	1995- present	http://www.dpi.vic.gov.au/dpi/vro/gbbregn.nsf/pages/gb_lwm_environmental?OpenDocument
			Salinity (EC), pH, Dissolved Oxygen, Temperature, Turbidity	Seasonally		
			Invertebrate community composition	Yearly		
			Weed invasion and regeneration	Seasonally		
			Macrophytes	Seasonally		
			Vegetation health	Annually		

Region	No. of wetlands monitored	Wetlands	Parameters measured	Sampling frequency	Period of data set	Reference
North Central Victoria	19	Lake Buloke, Lake Cope Cope, Box Swamp, Lake Boort, Lake Lalbert, Repper Swamp, Merin Merin Swamp, Tang Tang Swamp, McDonalds Swamp, Johnson Swamp, Two Mile Swamp, Cullen Lake, Woolshed Swamp, Third Marsh, Second Marsh, Great Spectacle Lake, Lake Yando, Lake Murphy, Lake Elizabeth	Nutrients (Phosphorus & Nitrogen)	Quarterly	1990-1997 (depending on measure) - present	http://www.dpi.vic.gov.au/dpi/vro/nthcenregn.nsf/pages/nthcen_enviro_monitoring_sites?OpenDocument
			Physico-chemical (ie EC, pH, Temperature)	Monthly		
			Macroinvertebrates	Annually		
			Depth to Groundwater	Monthly		
			Groundwater EC	Annually		
			Vegetation health	Annually		
			Bird surveys	Annually		
			Adjacent land use	Annually		
West Gippsland	3	Clydebank Morass, Dowd Morass, Heart Morass, Lake Kakydra, Curtains Flat, Victoria Lagoon, Lake Betsy, Snipe Wetland, Morley's Swamp	Nutrients (TKN, NOx, TP)	Seasonally	From early or mid 1990s to late 1990s some continuing.	Department of Natural Resources and Environment. 2001.
			Physico-chemical (EC, pH, Temperature, Turbidity, DO, AHD)	Monthly		
			Invertebrates (community composition (RBA)	Annually		
			Depth to Groundwater	Monthly		
			Groundwater EC	Quarterly		
			Vegetation health	Bi-annually		
Corangamite	9	Wetlands in the Western District Lakes Ramsar Site	Dissolved Oxygen, Electrical Conductivity, pH, Turbidity, Temperature, Soluble Orthophosphorus	Monthly	2004-2005	Barwon Water program

Region	No. of wetlands monitored	Wetlands	Parameters measured	Sampling frequency	Period of data set	Reference
North East Victoria	3	Dowdles Swamp Tabilk Lagoon Nagambie Wetland	Nutrients (TKN, NOx, TP)	Seasonally	NA	Reported in an unpublished draft 2001 discussion paper by the Victorian Environmental Monitoring Working Group, Department of Natural Resources and Environment.
			Physico-chemical (EC, pH, Temperature, Turbidity, DO)	Monthly		
			Invertebrates (community composition (RBA)	Annually		
			Vegetation health	Annually		
			Macrophytes abundance and composition	Annually		
East Gippsland	1	Bekta Swamp	Air temperature, Electrical Conductivity, pH, Turbidity, Temperature, Reactive Phosphorus	Quarterly	June-December 2004	Pers. comm. Becky Van Der Heyden, Waterwatch Facilitator, East Gippsland Waterwatch
East Gippsland	1	McGees Gully	Air temperature, Dissolved Oxygen, Electrical Conductivity, pH, Turbidity, Temperature, Total Phosphorus	< monthly from 16/6/97 - 15/9/97, then a single reading in 2001.	1997-2001	
East Gippsland	1	Macleod Morass	Air temperature, Dissolved Oxygen, Electrical Conductivity, pH, Rainfall, Turbidity, Temperature, Reactive Phosphorus, Total Phosphorus	< monthly	1996-present	
			Bore water EC	< monthly	26/2/2001 – 12/7/2001	
Glenelg-Hopkins	Mandatory Environmental Monitoring Program may cover some wetlands. Details not available					

Appendix 3. Wetland ecological vegetation classes

EVC Number	EVC name	EVC Number	EVC name
171	Alpine Fen	107	Lake Bed Herbland
1008	Alpine Relic-bog Dwarf Heathland	104	Lignum Swamp
905	Alpine Short Herbland	823	Lignum Swampy Woodland
288	Alpine Valley Peatland	966	Montane Bog
306	Aquatic Grassy Wetland	318	Montane Swamp
653	Aquatic Herbland	185	Perched Boggy Shrubland
308	Aquatic Sedgeland	125	Plains Grassy Wetland
334	Billabong Wetland Aggregate	755	Plains Grassy Wetland/Aquatic Herbland Complex
369	Black Box Wetland	767	Plains Grassy Wetland/Brackish Herbland Complex
875	Blocked Coastal Stream Swamp	958	Plains Grassy Wetland/Calcareous Wet Herbland Complex
537	Brackish Aquatic Herbland	959	Plains Grassy Wetland/Sedge-rich Wetland Complex
934	Brackish Grassland	960	Plains Grassy Wetland/Spike-sedge Wetland Complex
538	Brackish Herbland	961	Plains Rushy Wetland
636	Brackish Lake Aggregate	888	Plains Saltmarsh
539	Brackish Lake Bed Herbland	647	Plains Sedgy Wetland
947	Brackish Lignum Swamp	1010	Plains Sedgy Wetland/Sedge Wetland Complex
13	Brackish Sedgeland	292	Red Gum Swamp
973	Brackish Shrubland	975	Riverine Ephemeral Wetland
656	Brackish Wetland	804	Rushy Riverine Swamp
591	Calcareous Wet Herbland	842	Saline Aquatic Meadow
291	Cane Grass Wetland	717	Saline Lake Aggregate
602	Cane Grass Wetland/Aquatic Herbland Complex	648	Saline Lake-verge Aggregate
606	Cane Grass Wetland/Brackish Herbland Complex	101	Samphire Shrubland
284	Claypan Ephemeral Wetland	136	Sedge Wetland
976	Coastal Ephemeral Wetland	963	Sedge Wetland/Aquatic Sedgeland Complex
11	Coastal Lagoon Wetland	883	Sedge Wetland/Calcareous Wet Herbland Complex
949	Dwarf Floating Aquatic Herbland	281	Sedge-rich Wetland
678	Ephemeral Drainage-line Grassy Wetland	707	Sedgy Swamp Woodland
721	Fern Swamp	964	Shell Beach Herbland
809	Floodplain Grassy Wetland	908	Sink-hole Wetland
172	Floodplain Wetland Aggregate	819	Spike-sedge Wetland
810	Floodway Pond Herbland	857	Stony Rises Pond Aggregate
945	Floodway Pond Herbland/Riverine Swamp Forest Complex	210	Sub-alpine Wet Heathland
723	Forest Bog	221	Sub-alpine Wet Heathland / Alpine Fen Mosaic
728	Forest Creekline Sedge Swamp	917	Sub-alpine Wet Sedgeland
718	Freshwater Lake Aggregate	918	Submerged Aquatic Herbland
954	Freshwater Lignum-Cane Grass Swamp	920	Sweet Grass Wetland
968	Gahnia Sedgeland	821	Tall Marsh
124	Grey Clay Drainage-line Aggregate	990	Unvegetated (open water / bare soil / mud)
708	Hypersaline Inland Saltmarsh Aggregate	12	Wet Swale Herbland
813	Intermittent Swampy Woodland	932	Wet Verge Sedgeland
822	Intermittent Swampy Woodland/Riverine Grassy Woodland Complex		

Appendix 4. Evaluation of possible IWC measures against the requirements of the IWC

Table A4.1. Evaluation of wetland catchment measures against the IWC requirements.

Key ecological component	Possible measure	Type of measure	IWC requirements: 1. Suitable for use at all wetlands	2. Measure repeatable (for surveillance)	3. Suitable for use at any time of year	4. Can be assessed in a single visit	5. Rapid to measure	6. Simple and inexpensive	7. Easy to interpret	9. Detects human-induced changes in condition	10. Reference condition known
Wetland catchment	Percentage of native vegetation cover in the catchment.	Threat	1	✓	✓	✓	2	2	✓	✓	✓
	Percentage of land in different land use intensity classes in the catchment	Threat	1	✓	✓	✓	2	2	✓	✓	✓
	Percentage of soil affected by acidification in the wetland catchment	Threat	1	✓	✓		3	3	4	✓	✓
	Percentage of land in different land use intensity classes adjacent to the wetland	Threat	✓5	✓	✓	✓	✓	✓	✓	✓	✓
Wetland buffer	Average width of the buffer	Component	✓	✓	✓	✓	✓	✓	✓	✓	✓6
	Percentage of wetland perimeter with buffer	Component	✓	✓	✓	✓	✓	✓	✓	✓	✓

Notes.
1. The wetland catchment may be difficult to determine, especially for wetlands fed by groundwater.
2. The catchment of wetlands varies significantly in size. Current data may not be available to assist with the assessment, particularly for very large catchments and those that extend interstate. For large catchments, specialist knowledge may be required to interpret GIS layers, air photos or satellite imagery.
3. Soil acidification and/or presence of acid sulfate soils information may not be available for all catchments.
4. The relationship between catchment soil acidification and lowered pH in wetlands is not well understood.
5. The adjacent area needs to be defined in a consistent way for each wetland and should lie inside the surface-water catchment of the wetland.
6. Buffer widths based on buffer functions may be used (Section 3.3.1)

Table A4.2. Evaluation of physical form measures against the IWC requirements.

Key ecological component	Possible measure	Type of measure	IWC requirements: 1. Suitable for use at all wetlands	2. Measure repeatable (for surveillance)	3. Suitable for use at any time of year	4. Can be assessed in a single visit	5. Rapid to measure	6. Simple and inexpensive	7. Easy to interpret	9. Detects human-induced changes in condition	10. Reference condition known
Area of the wetland	Percentage reduction in wetland area	Component	✓	✓	✓	✓	✓	✓1	✓	✓	✓2
Wetland form	Wetland bathymetry (3)	Component	✓	✓	4	✓	5	5	✓	✓	
	Depth of wetland (maximum water depth)	Component	✓	✓	6	✓	✓	✓	✓	✓	7
	Percentage of wetland where activities (excavation and landforming) have resulted in a change in bathymetry	Threat	✓	✓	✓	✓	✓	✓	✓8	✓	✓

Notes
1. Measuring wetland area may require acquisition of air photos or satellite imagery and require skills in their use and interpretation.
2. Reference condition is known for most wetlands in Victoria which are mapped on a DSE GIS layer showing the extent of these wetlands at the time of European settlement.
3. Methods for capturing bathymetry include surveying and remote sensing technologies for high-resolution terrain mapping such as Light Detection and Ranging (LIDAR) and photogrammetry. Results are usually stored in a digital elevation model.
4. Impractical or technically limited when water is present in the wetland.
5. Data capture of bathymetry using LIDAR or photogrammetry is rapid, but processing is lengthy. Methods involving survey would be relatively time-consuming.
6. Using a depth gauge, the maximum depth can only be read when the wetland is full. Methods involving surveying would be impractical when water is present in the wetland.
7. The reference condition is known only in very broad terms for wetlands mapped on a DSE GIS layer of most wetlands in Victoria at the time of European settlement. These wetlands have been classified into categories, which specify their depth classes.
8. Activities such as excavation of the wetland bed (e.g. excavating channels or dams in the wetland or dredging) and landforming (e.g. raised-bed cropping, laser-levelling and building of mounds) are likely to cause a significant change in wetland bathymetry. To better estimate the effect on condition, it is considered necessary to record the area of the wetland affected by such activities.

Table A4.3. Evaluation of hydrology measures against the IWC requirements.

Key ecological component	Possible measure	Type of measure	IWC requirements									
			1. Suitable for use at all wetlands	2. Measure repeatable (for surveillance)	3. Suitable for use at any time of year	4. Can be assessed in a single visit	5. Rapid to measure	6. Simple and inexpensive	7. Easy to interpret	9. Detects human-induced changes in condition	10. Reference condition known
Change in wetland water regime	Water depth and/or surface water extent over time (to establish frequency, seasonality and duration of inundation)	Component	✓	✓					1	1	✓2
	Severity of activities that change the water regime	Threat	✓	✓3	✓	✓4	✓	✓	5	✓	✓
	Distribution/health of vegetation species or communities	Impact	✓	✓	✓6	✓	✓	✓	7	✓	8

Notes
1. To detect changes in condition and interpret results will require data collection over the range of time that reflects natural variability. The interpretation of results may be confounded by the lack of knowledge about the range of natural variability and any future effects of climate change due to human-induced factors.
2. The reference condition with respect to duration of inundation is known in broad terms for wetlands mapped on a DSE GIS layer showing most wetlands in Victoria at the time of European settlement. These wetlands have been classified into categories which specify their typical duration of inundation (Table 3).
3. Within the practical constraints of the IWC requirements, severity can only be estimated subjectively. Guidance is required to maximise consistency between assessors.
4. The presence or absence of such activities would not necessarily be assessed on site.
5. It is likely that the presence of activities will signal a change in hydrology. The nature of the relationship between an activity and the degree of change however, is difficult to quantify.
6. Vegetation patterns can be assessed at most times of year, however, there are likely to be changes in vegetation communities between wetland phases.
7. Interpretation of hydrological condition in terms of changed vegetation patterns may be difficult as specialist knowledge would be required. In addition, vegetation response times are likely to be delayed and vegetation change may also be due to other factors.
8. The distribution of vegetation in an unmodified landscape may be able to be reconstructed from the current distribution of EVCs and from air photos and/or reports.

Table A4.4. Evaluation of water properties measures against the IWC requirements.

Key ecological component	Possible measure	Type of measure	IWC requirements								
			1. Suitable for use at all wetlands	2. Measure repeatable (for surveillance)	3. Suitable for use at any time of year	4. Can be assessed in a single visit	5. Rapid to measure	6. Simple and inexpensive	7. Easy to interpret	9. Detects human-induced changes in condition	10. Reference condition known
Nitrogen	Nitrogen	Component	✓	✓	1	2	✓	✓	3	✓2	4
Phosphorus	Phosphorus	Component	✓	✓	1	2	✓	✓	3	✓2	4
	Frequency of algal blooms in last five years	Impact	✓	✓	✓	5	✓5	✓	✓6	✓6	✓7
Macronutrients (e.g. nitrogen and phosphorus)	Aquatic macroinvertebrate indicator species or index	Impact	✓	✓	1	✓			8	8	8
	Activities leading to an input of nutrients to the wetland	Threat	✓	✓	✓	✓	✓	✓	9	9	✓
Electrical conductivity (salinity)	Electrical conductivity	Component	✓	✓	1	2	✓	✓	3	✓	✓ 10
	Aquatic macroinvertebrate abundance and diversity	Impact	✓	✓	1	✓			8	8	8
	Diatom abundance and diversity	Impact	✓	✓	1	✓			8	8	8
	Vegetation indicator species or communities	Impact	✓	✓	✓ 11	✓	✓	✓	✓ 12	✓. 12	12
	Factors likely to lead to wetland salinisation • input of saline water to the wetland	Threat	✓	✓	✓	✓ 14	✓ 14	✓	15	15	✓
	Factors likely to lead to wetland salinisation • Wetland occurs in a salinity risk area	Threat	✓	✓ 16	✓	✓ 17	✓	✓ 16	18	✓ 18	✓
	Groundwater levels at wetland	Threat	✓	✓	19		✓	✓ 20	21	21	
Turbidity	Turbidity	Component	✓	✓	1	2	✓	✓	3	✓2	4
	Percentage and severity of wetland soil disturbance (covered under soils Table 25).	Threat	See Table A4.5								
Temperature	Temperature	Component	✓	✓	1	2	✓	✓	3	✓2	4
	Vegetation cover over water surface (amount of shading)	Threat	✓	✓	✓	✓	✓	✓	22	22	
Dissolved oxygen	Dissolved oxygen	Component	✓	✓	1	2	✓	✓	3	✓2	4

Table A4.4. (continued).

Key ecological component	Possible measure	Type of measure	IWC requirements: 1. Suitable for use at all wetlands	2. Measure repeatable (for surveillance)	3. Suitable for use at any time of year	4. Can be assessed in a single visit	5. Rapid to measure	6. Simple and inexpensive	7. Easy to interpret	9. Detects human-induced changes in condition	10. Reference condition known
pH	pH	Component	✓	✓	1	2	✓	✓	3	✓2	4
	Presence/absence of sulfidic soils in the wetland and activities involving disturbance of such soils	Threat	23	✓	✓	✓	✓	✓	24	✓ 23	✓
	Presence/absence of acid or alkaline industrial waste discharges to the wetland	Threat	✓	✓	✓	✓ 17	✓	✓	25	25	✓
	Presence/absence of source of atmospheric acid deposition (traffic, factories, smelters, power stations burning fossil fuels)	Threat	✓	✓	✓	26	26	26	25	25	✓
Nutrient cycling	Macroinvertebrate-based index	Impact	✓	✓	1	✓			27	27	27

Notes
1. Measurements can only be taken when water is present in the wetland and it is preferable to take successive readings at same hydrological phase and, for aquatic invertebrates, the same season.
2. Frequent (several times a year) and long-term monitoring is recommended to take account of seasonal and inter-annual climatic variation (Australian Government, unpublished b).
3. Interpretation of results requires information about the natural range of variation at a reference site. Certain events (e.g. sudden wetland filling, or the final phases of drying out) may produce atypical readings, making interpretation of results more difficult. These issues may be overcome if successive readings are taken at the same hydrological phase or, for aquatic invertebrates, the same season.
4. Reference condition is not known for the majority of wetlands in Victoria.
5. Assessment is dependent on having reliable records of algal blooms for the region where the wetland is located. This may not be the case.
6. Several factors can be involved in triggering an algal bloom, so interpretation of results is not straightforward.
7. It is assumed that algal blooms do not occur in wetlands where the wetland and its catchment are unmodified, but this is not known definitely to be the case.
8. Interpretation and detection of change in condition relies on establishing relationships between water quality variables and aquatic macroinvertebrate indicator species, index or abundance and diversity and establishing reference benchmarks. This also applies to diatoms.
9. It is likely that the presence of activities will signal a change in nutrients. The nature of the relationship between an activity and the degree of change however, is difficult to quantify.
10. The reference condition is known in broad terms for wetlands mapped on a DSE GIS layer showing most wetlands in Victoria at the time of European settlement. These wetlands have been classified into the categories: fresh and saline (Table 3).

Table A4.4 Notes (continued).

11. This would depend on the indicator species selected.
12. Salinity tolerance of indicator species will need to be investigated and documented. Some information is already available. Reference benchmarks would need to be established for different wetland types.
13. To detect changes in condition and interpret results will require data collection over the range of time that reflects natural variability. The interpretation of results may be confounded by the lack of knowledge about the range of natural variability and the effects of climate change due to human-induced factors.
14. Assessment is dependent on having reliable records of saline water input. The presence of such activities would not necessarily be assessed on site.
15. It is likely that the presence of this factor will contribute to salinisation. The nature of the relationship between an activity and the degree of change however, is difficult to quantify because it depends on many factors such as the salinity of the wetland and that of the inflowing water and the volume of the wetland and whether or not the wetland is subject to periodic flushing.
16. Maps showing salinity risk have been prepared for Victoria. More detailed information may be available for particular regions of the State. Repeating the measure will be reliant on the regular upgrade of mapping or local surveys.
17. The presence or absence of such activities would not necessarily be assessed on site.
18. It will usually not be known in specific terms if and to what extent a wetland will become salinised if it is located in an area identified as being at risk of dryland salinity.
19. Groundwater levels may vary naturally throughout the year in some aquifers.
20. Setting up bores may be expensive.
21. To detect changes in condition and interpret results will require data collection over the range of time that reflects natural variability. The interpretation of results may be confounded by the lack of knowledge about the range of natural variability and the effects of climate change due to human-induced factors.
22. Interpretation and detection of change in condition relies on establishing relationships between water temperature and shading.
23. Not all wetlands have or may have the potential to develop sulfidic soils.
24. There would be a need to confirm that the wetland had acid-sulfate soils and the degree to which the activity disturbed those soils. It might be difficult to detect degrees of change in condition using this measure.
25. The nature of the effect of these factors will be difficult to quantify because it depends on many variables such as the volume and pH of the discharge or deposit, for atmospheric deposition, the rate of deposition on and the natural pH of the wetland. Therefore, results will be difficult to interpret.26. Assessment is dependent on identifying the source/s of atmospheric acid deposition and having information about the nature of the discharge source (volumes and concentration). This may not be the case.
27. Interpretation and detection of change in condition relies on establishing relationships between nutrient cycling and the aquatic macroinvertebrate index and establishing reference benchmarks.

Table A4.5. Evaluation of soil measures against the IWC requirements.

Key ecological component	Possible measure	Type of measure	IWC requirements								
			1. Suitable for use at all wetlands	2. Measure repeatable (for surveillance)	3. Suitable for use at any time of year	4. Can be assessed in a single visit	5. Rapid to measure	6. Simple and inexpensive	7. Easy to interpret	9. Detects human-induced changes in condition	10. Reference condition known
Soil physical properties (structure, texture, consistency and profile)	Soil physical properties	Component	✓	1	✓1	✓					
	Percentage and severity of wetland soil disturbance	Impact	✓	✓2	✓2	✓	✓	✓	✓3	✓3	✓
	Presence of activities that cause soil disturbance	Threat	✓	✓2	✓2	✓	✓	✓	4	4	✓
Soil chemical properties (organic content, nutrients, metal oxides, silica clays, salts and pH)	Soil pH	Component	✓	1	1	✓	5	✓	6	6	
	Soil salt levels	Component	✓	1	1	✓	5	✓	6	6	
	Soil nutrient levels	Component	✓	1	1	✓					
	Presence of toxicants	Impact	✓7	✓	✓	✓	8		✓	✓	✓
	Activities leading to an input of nutrients to the wetland (covered in water properties Table 24)	Threat	See Table A4.4								
	Factors likely to lead to wetland salinisation (covered in water properties Table24)	Threat									
Soil biological properties (soil organisms such as bacteria and fungi, protozoans, nematodes, mites and worms)	Abundance, diversity and richness of benthic biota	Component	✓	9	9	✓			10	10	
	Benthic fauna index	Impact	✓	9	9	✓			10	10	

Notes
1. Soil sampling will be impractical on areas of the wetland that are inundated. The measure will not be repeatable if the extent of water in the wetland is different from that at the time of the previous assessment.
2. Soil disturbance or activities causing it may not be detectable in inundated parts of the wetland. Measure may not be repeatable if the extent of water in the wetland is different from that at the time of the previous assessment. This limitation may possibly be overcome by designing different comparable methods of taking the measure for different degrees of inundation.
3. The nature of the relationship between soil disturbance and condition will be difficult to quantify. To better estimate the effect on condition, it is considered necessary to record the percentage of the wetland affected by soil disturbance the severity of disturbance.

Table A4.5 Notes (continued).

4. Presence of these activities is assumed to lead to soil disturbance, which, in turn, is assumed to lead to changes in soil condition. The nature of the relationship between these activities and soil condition will not usually be quantifiable. Therefore, interpretation of the results will not be straightforward.
5. pH or salt levels in the wetland soil are likely to vary spatially, requiring multiple samples within the wetland.
6. The soil pH or salt levels are likely to vary considerably depending on whether the soil is inundated or dry.
7. Contaminants of wetland soils are likely to be different for different wetlands. A standard method would need to test for the presence of all expected toxicants.
8. Many samples may be required to account for possible spatial variability in the presence of toxicants.
9. Measurements can only be taken when water is present in the wetland. The measure will not be repeatable if there is no water present on successive visits.
10. Interpretation relies on establishing relationships between benthic abundance and diversity or an index of benthic fauna and the condition of soil biota.

Table A4.6. Evaluation of biota measures against the IWC requirements.

Key ecological component	Possible measure	Type of measure	IWC requirements								
			1. Suitable for use at all wetlands	2. Measure repeatable (for surveillance)	3. Suitable for use at any time of year	4. Can be assessed in a single visit	5. Rapid to measure	6. Simple and inexpensive	7. Easy to interpret	9. Detects human-induced changes in condition	10. Reference condition known
• Vertebrate fauna (fish, amphibians, reptiles, waterbirds, mammals) • Aquatic invertebrates • Phytoplankton • Diatoms	Abundance measures or presence/absence for individual species or indicator (keystone) species	Component	1	2	2	✓	✓	✓	3	3	
	Measures of species abundance, richness and diversity for particular groups	Component	4	2	2	✓	✓5	✓5	3	3	
	Measures of habitat quality for particular groups	Impact	6	7	7	✓	✓	✓	8	8	
Vertebrate fauna (fish, amphibians, reptiles, waterbirds, mammals)	Abundance of pest species	Impact	✓	✓	✓	✓	✓	✓	9	9	9
	Activities that interfere with natural connectivity of flow to and from the wetland (covered under hydrology Tables 13, 14 and 23)	Threat	See Table A4.3								
	Level of human activity in and around the wetland	Threat	✓	✓	✓	10	✓	✓	11	11	✓
	• Average width of the buffer • Percentage of wetland perimeter with buffer (covered under wetland catchment Table 21)	Threat	See Table A4.1								
Vegetation (aquatic macrophytes, other vegetation)	Individual species cover or biomass	Component	1	12	12	✓	✓	✓	3	3	
	Vegetation community attributes such as species richness, critical species or lifeform presence, cover, structure and health	Component	✓ 13	✓ 12	✓ 12	✓	✓	✓ 14	✓ 15	✓ 15	✓ 16
	Indicators of altered processes	Impact	✓ 13	✓	✓	✓	✓	✓	✓ 15	✓ 15	✓ 16
	Weeds	Impact	✓ 13	✓	✓	✓	✓	✓	✓ 15	✓ 15	✓ 16

Table A4.6 Notes

1. There are unlikely to be species that are known to be present at all wetlands.
2. Measurements are unlikely to be repeatable unless conditions are similar at the wetland when the assessment is repeated. Depending on the species or group, factors that may cause numbers to vary, independent of wetland condition include hydrological phase, season, temperature, time of day and status of wetlands elsewhere in species range.
3. Interpretation relies on knowing or establishing relationships between wetland condition and species or groups.
4. Aquatic macroinvertebrates, phytoplankton and diatoms are likely to be present at all wetlands. Of the vertebrate fauna groups, only waterbirds are likely to be present and obvious at all wetlands.
5. Aquatic macroinvertebrates, phytoplankton, diatoms and fungi will not be rapid or inexpensive to measure.
6. Only suitable for use at all wetlands if the flora and fauna group is present at all wetlands.
7. Some habitats may vary with hydrological phase or season. Measurements would not be repeatable unless conditions are similar at the wetland when the assessment is repeated.
8. Interpretation will be dependent on having sufficient knowledge to define the habitat for a particular flora or fauna group and the relationship between habitat quality, state of the biotic group and wetland condition.
9. Interpretation relies on knowing or establishing relationships between wetland condition and presence of particular pest species.
10. Activity would need to be monitored over a period of time to assess its average level.
11. Interpretation relies on knowing or establishing relationships between human disturbance and presence of vertebrate fauna. This would be difficult as different species and individuals have different requirements.
12. These measures may not be able to be assessed in all hydrological phases.
13. Application at all wetlands is dependent on the development of a suitable classification system. This has been done through the identification and description of wetland EVCs.
14. Specialist knowledge or training would be required.
15. Interpretation relies on knowing or establishing relationships between wetland condition and the measure. This has been done by establishing benchmarks for each measure.
16. Reference benchmarks have been determined for each wetland ecological vegetation class.

Acronyms

CMA	Catchment Management Authority
DSE	Department of Sustainability and Environment
EVC	Ecological vegetation class
ISC	Index of Stream Condition
IWC	Index of Wetland Condition
NAP	National Action Plan for Salinity and Water Quality
NHT	Natural Heritage Trust
NRM	Natural Resource Management
RCS	Regional Catchment Strategy
RMP	Regional Management Plan
RCIP	Regional Catchment Investment Plan

Glossary

Aestivate: (with reference to fish) Fish that are able to survive out of free water in moist conditions for some period of time) and survive periods of drying (Cadwallader and Backhouse 1983).

Aquic: A moisture condition associated with a seasonal, reducing environment (see Redox Potential) that is virtually free of dissolved oxygen because the soil is saturated by ground water or by water of the capillary fringe as in soils in aquic suborders and aquic subgroups.

Bathymetry: Underwater topography defined by patterns in depth.

Ecological character: The sum of the biological, physical, and chemical components of the wetland ecosystem, and their interactions, which maintain the wetland and its products, functions, and attributes. Change in ecological character is "the impairment or imbalance in any biological, physical or chemical components of the wetland ecosystem, or in their interactions, which maintain the wetland and its products, functions and attributes." (Ramsar Convention 1999).

Ecological Vegetation Class (EVC): The concept of an EVC was introduced in the *Old Growth Study of East Gippsland* (Woodgate et al. 1994). EVCs are a type of native vegetation classification described through a combination of floristics, life forms and ecological characteristics, and through an inferred fidelity to particular environmental attributes. Each EVC includes a collection of floristic communities that occur across a biogeographic range, and although differing in species, have similar habitat and ecological processes operating.

Ecosystem services: The benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services, such as nutrient cycling, that maintain the conditions for life on Earth (Millennium Ecosystem Assessment (2003).

Environmental assets: Tangible physical elements of environment. Wetlands are recognised as a secondary asset class under the primary asset 'water' (Department of Sustainability and Environment unpublished).

Functions: Activities or actions, which occur naturally in wetlands as a product of the interactions between the ecosystem structure and processes. Functions include flood water control; nutrient, sediment and contaminant retention; food web support; shoreline stabilization and erosion controls; storm protection; and stabilization of local climatic conditions, particularly rainfall and temperature (Ramsar Convention 1999).

Gilvin: Soluble humic substances that are often the major single component absorbing light in inland waters. Wetlands with low concentrations of gilvin are clear (i.e. low in colour); wetlands with high concentrations of gilvin are dark coloured (brown to black).

Hydric soils: Soils that are characterised by periodic saturation leading to anaerobic conditions and the inhibition of oxygen diffusion in the soil (Brady and Weil 2000).

Hydrophyte: A plant that is adapted to wet conditions (Gosselink and Mitsch 2000).

Indicator: An expression of the environment that estimates the condition of ecological resources, magnitude of stress, exposure of a biological component to stress, or the amount of change in a condition (Breckenridge et al. 1995).

Impact measure: Measure of condition based on the impact on the wetland component.

Inventory: The collection and/or collation of core information for wetland management, including the provision of an information base for specific assessment and monitoring activities (Ramsar Convention 2002).

Monitoring: Collection of specific information for management purposes in response to hypotheses derived from assessment activities, and the use of these monitoring results for implementing management. (Note that the collection of time-series information that is not hypothesis-driven from wetland assessment should be termed surveillance rather than monitoring, as outlined in Resolution VI.1.) (Ramsar Convention 2002).

Mumbling: Feeding behaviour of carp that involves sucking in sediment and expelling the inedible sediment through the gill openings.

Natural: The term 'natural' refers to a state unmodified by human activities associated with European settlement.

Phase: See Wetland Phase.

Products: Generated by wetlands include: wildlife resources; fisheries; forest resources; forage resources; agricultural resources; and water supply. These products are generated by the interactions between the biological, chemical and physical components of a wetland (Ramsar Convention 1999).

Rapid assessment: For the scope of the IWC, rapid assessment implies an assessment of wetland condition can be undertaken at a wetland in less than three hours.

Redox potential: (in relation to soils) A measure of the degree of aeration in a soil. High redox potential indicates a high oxygen level. Low redox values may provide an indication that conditions are conducive to anaerobic microbiological activity.

Surveillance: the collection of time-series information that is not hypothesis-driven (Ramsar Convention 2002a)

Threats: Activities that lead to impacts on wetlands.

Values: See Ecosystem services.

Wetland: For the scope of the IWC, wetlands are naturally occurring, waterbodies with static water and without a marine hydrological influence.

Wetland assessment: The identification of the status of, and threats to, wetlands as a basis for the collection of more specific information through monitoring activities (Ramsar Convention 2002).

Wetland attributes: Include biological diversity and unique cultural and heritage features. These attributes may lead to certain uses or the derivation of particular products, but they may also have intrinsic, unquantifiable importance (Ramsar Convention 2000).

Wetland characteristics: The features that all wetlands have in common, i.e. hydrology, water properties, soils, biota and landscape context.

Wetland classification: Simple representations of spatial and temporal complexity (Kingsford et al. 2004). Classification systems group wetlands on the basis of similarities in characteristics and/or components.

Wetland components: Specific elements of wetland characteristics. For example, soil biota, soil physical properties and soil chemical properties are components of the characteristic soils.

Wetland condition: The state of the 'biological, physical, and chemical components of the wetland ecosystem and their interactions'. Synonymous with the Ramsar definition of ecological character (Ramsar Convention 1999).

Wetland extent: The area of an individual wetland or collectively, the total area of wetlands in a given region.

Wetland phase: The hydrologic state of the wetland with respect to flooding. Wetland phases include 'full', 'filling', 'drying', 'dry'.