

# **Barmah Wetland System Environmental Monitoring Program**

## **Part A: Background Information**



**Bernard McCarthy, Daryl Nielsen,  
Darren Baldwin and Shaun Meredith**

**Report to the Goulburn Broken  
Catchment Management Authority**

**Murray-Darling Freshwater Research Centre**



**Final Report**

**November 2005**

## **Barmah Wetland System Environmental Monitoring Program, Part A: Background Information.**

Report to the Goulburn Broken Catchment Management Authority, P.O. Box 1752, Shepparton 3632

Bernard McCarthy<sup>1</sup>, Daryl Nielsen<sup>2</sup>, Darren Baldwin<sup>2</sup> and Shaun Meredith<sup>1</sup>

<sup>1</sup>Murray-Darling Freshwater Research Centre, P.O. Box 3428, Mildura 3502

<sup>2</sup>Murray-Darling Freshwater Research Centre, P.O. Box 991, Wodonga 3689

### **Report Citation**

McCarthy, B., Nielsen, D., Baldwin, D. and Meredith, S. (2005). Barmah Wetland System Environmental Monitoring Program. Part A: Background Information. Report to the Goulburn Broken Catchment Management Authority. Murray-Darling Freshwater Research Centre.

### **Disclaimer**

The Murray-Darling Basin Commission and CSIRO Land and Water (Trustee and Centre Agent) as joint venture partners in the Murray-Darling Freshwater Research Centre do not guarantee that this publication is without error of any kind, nor do they guarantee the information contained in this report will be appropriate in all instances and therefore, to the extent permitted by law they exclude all liability to any person for any consequences, including but not limited to all losses, damages, costs, expenses and any other compensation, arising directly or indirectly from using this report (in part or in whole) and any information or material contained in it.

### **Cover Photograph**

Wavy Marshwort (*Nymphoides crenata*) at Barmah Forest during a flood event augmented by the release of the Barmah-Millewa environmental water allocation. Photograph: B. McCarthy, MDFRC, Mildura, 16 November 2005.



## Table of Contents

<b>Acknowledgements .....</b>	<b>i</b>
<b>List of Acronyms .....</b>	<b>ii</b>
<b>Introduction.....</b>	<b>1</b>
Purpose, position and scope of this study .....	1
Report structure .....	1
Nomenclature.....	1
Monitoring and research .....	1
Barmah Forest .....	2
<b>Policy and management requirements for environmental monitoring at Barmah Forest .....</b>	<b>3</b>
A. Barmah Forest Management Plans .....	5
Barmah Management Plan .....	5
Mid-Murray Forest Management Plan .....	8
Asset Environmental Management Plan: Barmah Significant Ecological Asset .....	11
Barmah-Millewa Forest Significant Ecological Asset: Asset Environmental Management Plan .....	13
B. Water Management Plans / Strategies .....	15
The Barmah-Millewa Forest Water Management Strategy .....	15
Interim Water Management Strategy for Barmah Forest, Victoria .....	17
Barmah Millewa Forests Water Management Plan .....	18
Barmah-Millewa Forests Water Management Plan: Business Plan Part 1 .....	18
C. Ramsar Documents .....	19
D. Other Strategic and Influential Documents .....	23
Goulburn Broken Regional Catchment Strategy .....	23
Victoria's Biodiversity – Directions in Management.....	24
Sharing the Murray: Proposal for defining people's entitlements to Victoria's water from the Murray.....	25
Murray Valley Area Final Recommendations .....	25
A Directory of Important Wetlands in Australia.....	26
The Wetlands Policy of the Commonwealth Government of Australia.....	26
Register of the National Estate .....	27
E. Other Agreements, Acts and Conventions .....	27
JAMBA and CAMBA.....	27
Flora and Fauna Guarantee Act 1988 .....	28
Convention on the Conservation of Migratory Species of Wild Animals .....	29
Data needs for reporting.....	29
Commonalities.....	29
Ranking of documents.....	30
<b>Environmental monitoring programs at Barmah Forest .....</b>	<b>32</b>
Current and past environmental monitoring programs .....	32
Monitoring of past environmental water allocations.....	38
Proposed monitoring programs at Barmah Forest .....	40
Ecological indicators not currently monitored .....	41
<b>Proposed monitoring programs at other Living Murray SEAs .....</b>	<b>42</b>
<b>References .....</b>	<b>44</b>
<b>Appendices .....</b>	<b>51</b>
Appendix A. Tasks of the consultant brief for Barmah Wetland System Environmental Monitoring Program. ....	51
Appendix B. Diagram highlighting key documents and jurisdictional arrangements influencing the management of Barmah Forest.....	52
Appendix C. Actions for further studies involving environmental monitoring from the Barmah Management Plan.....	53
Appendix D. Research investigations conducted at Barmah Forest. ....	55

## **Acknowledgements**

The authors would like to thank Simon Casanelia (GBCMA Project Manager) and Keith Ward (GBCMA) for assistance throughout the project and for providing critical review of the document. Thanks also to Nick Abel (Sustainable Ecosystems, CSIRO) for kindly providing copies of key documents relating to Barmah Forest.

## **List of Acronyms**

ACRG	Asset Consultation Reference Group
AEMP	Asset Environmental Management Plan
BMF	Barmah-Millewa Forum
CAMBA	China-Australia Migratory Birds Agreement
CAR	Comprehensive, Adequate and Representative (refers to Reserve System)
CC	Coordinating Committee
CFL	Conservation, Forests and Lands
CMS	Conservation of Migratory Species
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DCE	Department of Conservation and Environment
DEH	Department of Environment and Heritage
DNRE	Department of Natural Resources and Environment
DSE	Department of Sustainability and Environment
EA	Environment Australia
ECI	Environmental Condition Indicator
EPBC Act	Environmental Protection and Biodiversity Conservation Act
EPE	Environmental Performance Evaluation
EPT	Environmental Performance Target
ESFM	Ecologically Sustainable Forest Management
EVC	Ecological Vegetation Class
EWA	Environmental Water Allocation
FFG Act	Flora and Fauna Guarantee Act
FMA	Forest Management Area
GBCMA	Goulburn Broken Catchment Management Authority
GL	Gigalitre (=1,000,000,000 or 1 billion litres)
GMW	Goulburn-Murray Water
IBRA	Interim Biogeographic Regionalisation for Australia
JAMBA	Japan-Australia Migratory Birds Agreement
LCC	Land Conservation Council
MDBC	Murray-Darling Basin Commission
MDBMC	Murray-Darling Basin Ministerial Council
MDFRC	Murray-Darling Freshwater Research Centre
ML	Megalitre (= 1,000,000 or 1 million litres)
MWEC	Murray Water Entitlement Committee
OEF	Outcomes and Evaluation Framework
PV	Parks Victoria
SEA	Significant Ecological Asset (or “icon site”)
TAC	Technical Advisory Committee
TLM	The Living Murray
WMA	Water Management Area

## **Introduction**

### **Purpose, position and scope of this study**

The purpose of this project is to develop a comprehensive and flexible environmental monitoring program for Barmah Forest that incorporates adaptive management principles and meets current policy and management requirements. The five tasks of the Consultancy Brief to develop the monitoring program are listed in Appendix A.

This report is an advisory document to the Goulburn Broken Catchment Management Authority. It is intended to inform the Victorian Government's contribution to the development of an environmental monitoring program in future reviews of the Barmah-Millewa Significant Ecological Asset: Asset Environmental Management Plan (MDBC, 2005). It will also inform the development of an updated Water Management Plan for Barmah Forest. The Water Management Plan will also be guided from inputs from three other concurrent studies including a Barmah Forest Issues and Options report (CSIRO Sustainable Ecosystems) that details different water management approaches to sustain the floodplain vegetation communities of Barmah Forest, a Barmah-Millewa Forest Hydrodynamic Model (Water Technology) and a Barmah Forest Community Engagement and Communication Strategy.

The broad scope of the environmental monitoring program is to relate strongly to water management. The monitoring of activities such as logging is considered to be outside the scope of the monitoring program.

### **Report structure**

The Barmah Wetland System Environmental Monitoring Program consists of two stand-alone documents. Part A (this document) provides background information relating to environmental objectives and targets determined for Barmah Forest through the various policies, plans, strategies, agreements and pieces of legislation that govern or influence its management. It also reviews past and current monitoring programs at Barmah Forest.

Part B (separate document) details a comprehensive and flexible environmental monitoring program for the Barmah wetland system that considers the information of Part A and incorporates it into an adaptive monitoring framework.

### **Nomenclature**

Barmah Forest is subject to flooding from the River Murray and is considered a wetland system. Therefore, the term Barmah wetland system will be used interchangeably with Barmah Forest in this report, particularly when referring to the floodplain character of the site.

### **Monitoring and research**

Defining the differences between monitoring and research is required for the objectives of this study to be fulfilled. This is sometimes difficult given the often indistinct boundary between these two activities. For the purposes of this study monitoring was considered to focus on long-term transitions within the forest and where the mechanisms responsible for

## ***Barmah Wetland System Environmental Monitoring Program***

these changes are not necessarily of direct interest (Bren *et al.*, undated). Investigations surrounding specific environmental water allocations (EWAs) to Barmah Forest were also reviewed as part of this document given their direct relevance to the brief.

### **Barmah Forest**

Barmah Forest is a Victorian River Red Gum (*Eucalyptus camaldulensis*) dominated floodplain covering 29,800 ha, located between the townships of Tocumwal in NSW and Echuca in Victoria. Together with the NSW Millewa Forest it forms the largest River Red Gum forest in Australia. Barmah Forest consists of State Forest (21,320 ha, or 72% of area), State Park (7,900 ha, or 26% of area that includes the Reference Areas Top Island (177 ha) and Top End (124 ha)) and Murray River Reserve (580 ha, or 2% of area). The State Park and Murray River Reserve are managed by Parks Victoria under the provisions of the Barmah Management Plan (DCE, 1992), whilst State Forest is managed by the Department of Sustainability and Environment (DSE) under the Mid-Murray Forest Management Plan (DNRE, 2002a) with consideration given to the principles and actions of the Barmah Management Plan (DCE, 1992). In addition to these localised plans, other policies, plans, strategies, agreements and pieces of legislation influence the management of Barmah Forest and are reviewed below.

## **Policy and management requirements for environmental monitoring at Barmah Forest**

A broad range of agreements, legislation, Government strategies and Victorian Government policies and plans control or influence the management of Barmah Forest. Key documents relevant to current policy and management for environmental monitoring at Barmah Forest are listed in Table 1. The ways in which these documents relate to one another are depicted in Appendix B.

### **Legislation**

Principal pieces of legislation considered in the policies and plans governing the management of Barmah Forest include:

- Environmental Protection and Biodiversity Conservation Act 1999 (Commonwealth)
- Flora and Fauna Guarantee Act 1988
- Forests Act 1958
- National Parks Act 1975
- Native Title Act 1993 (Commonwealth)
- Reference Areas Act 1978

Other relevant pieces of legislation include:

- Aboriginal Lands Act 1970
- Archaeological and Aboriginal Relics Act 1972
- Commonwealth Aboriginal and Torres Strait Islander Heritage Protection Act 1984
- Conservation, Forests and Lands Act 1987
- Crown Land (Reserves) Act 1978
- Emergency Management Act 1986
- Fire Authorities Act 1984
- Fisheries Act 1968
- Forest Regulations 1978 and amendments
- Land Act 1958
- Land Conservation Act 1970
- Land Conservation (Vehicle Control) Act and Regulations 1972
- Park Regulations 1992
- River Murray Waters Act 1982
- River Improvement Act 1958
- Vermin and Noxious Weeds Act 1958
- Water Act 1989
- Wildlife Act 1975

These pieces of legislation are considered within the various policies and plans governing the management of Barmah Forest and are not specifically reviewed here with the exception of the *Flora and Fauna Guarantee Act 1988* and the *Environmental Protection and Biodiversity Conservation Act 1999*.

**Barmah Wetland System Environmental Monitoring Program**

**Table 1. Evaluated documents influencing the management of Barmah Forest**

<b>Document</b>	<b>Author and date</b>	<b>Geographical scale (see Key)</b>
<b>A. Barmah Forest Management Plans *</b>		
1. Barmah Management Plan (=Management Plan for Barmah State Park and Barmah State Forest)	DCE (1992)	Local
2. Mid-Murray Forest Management Plan	DNRE (2002a)	Regional
3. Asset Environmental Management Plan: Barmah Significant Ecological Asset (11 May 2005)	DSE and GBCMA (2005)	Local
4. Barmah-Millewa Forest Significant Ecological Asset: Asset Environmental Management Plan 2005-2006 (Draft 22 July 2005)	MDBC (2005)	Regional
<b>B. Water Management Plans / Strategies</b>		
5. Barmah Millewa Forests Water Management Plan	Maunsell Pty Ltd (1992)	Regional
6. Interim Water Management Strategy for Barmah Forest, Victoria	Ward <i>et al.</i> (1994)	Local
7. Barmah-Millewa Forests Water Management Plan: Business Plan Part 1	Maunsell McIntyre Pty Ltd (1999a)	Regional
8. The Barmah-Millewa Forest Water Management Strategy	MDBC and BMF (2000)	Regional
<b>C. Ramsar Documents</b>		
9. Management of Victoria's Ramsar Wetlands: Strategic Directions Statement	DNRE (2002b)	International with State (Vic) Focus
10. Barmah Forest Ramsar Site: Strategic Management Plan	DSE (2003)	International with Local Focus
11. Framework for Describing the Ecological Character of Ramsar Wetlands: Including a description of the ecological character of the Barmah Forest Ramsar Site	DSE (2005)	International with State (Vic) Focus
<b>D. Other Strategic and Influential Documents</b>		
12. Murray Valley Area Final Recommendations	LCC (1985)	Regional
13. Sharing the Murray: Proposal for defining people's entitlements to Victoria's water from the Murray	MWEC (1997)	State
14. The Wetlands Policy of the Commonwealth Government of Australia	EA (1997)	National
15. A Directory of Important Wetlands in Australia	EA (2001)	National
16. Living Murray First Step Decision	MDBMC (2003)	Basin
17. Goulburn Broken Regional Catchment Strategy	GBCMA (2003)	Regional
18. Victorian Biodiversity Strategy	DSE (2004)	State
19. Register of the National Estate	DEH (2005)	National
<b>E. Other Agreements, Acts and Conventions</b>		
20. Japan-Australia Migratory Birds Agreement	JAMBA (1974)	International
21. China-Australia Migratory Birds Agreement	CAMBA (1986)	International
22. <i>Flora and Fauna Guarantee Act 1988</i>	<i>FFG Act 1988</i>	State
23. <i>Environmental Protection and Biodiversity Conservation Act 1999</i>	<i>EPBC Act 1999</i>	National
24. Convention on the Conservation of Migratory Species of Wild Animals	Bonn (1979)	International

\*Includes the Barmah Forest Ramsar Site: Strategic Management Plan (DSE 2003) but this has been included within the Ramsar section.

**Key to geographical scale**

<b>Geographical Scale</b>	<b>Definition</b>
Local	Applicable specifically to Barmah Forest
Regional	Applicable for up to three catchments including the Goulburn-Broken catchment incorporating Barmah Forest
State	Applicable to the State of Victoria
Basin	Applicable to the Murray-Darling Basin
National	Applicable to Australia
International	Applicable to obligations with other countries

**A. Barmah Forest Management Plans**

**Barmah Management Plan (=Management Plan for Barmah State Park and Barmah State Forest) (DCE, 1992)**

The Barmah Management Plan is a Victorian Government plan that forms the basis for managing all aspects of Barmah State Park and Reference areas. Its principles and actions should also be considered for the management of Barmah State Forest although this is primarily achieved through the Mid-Murray Forest Management Plan (DNRE, 2002a). The Barmah Management Plan is an Approved Plan intended to remain in place until replaced by a revised plan.

The document lists 17 Management Objectives for Barmah Forest, with nine chapters addressing specific areas of management (*e.g.* Management of Natural Resources). For each specific area the assets are identified (*e.g.* water) and management aims and actions (actions prioritised as High, Medium, Low, Ongoing and As Needed) are identified. Those objectives and aims related to environmental monitoring at Barmah are copied below directly from DCE (1992). Details of the many identified actions are collated in Section 14 “Further Studies” of the Barmah Management Plan (DCE, 1992) and those relating to environmental monitoring are listed in Appendix C.

**Management objectives**

- Management will protect and conserve natural ecosystems and the natural environment, whilst recognising that such systems are dynamic, that irreversible alterations may have occurred, and that modified systems may have become or are in the process of becoming established
- Management will conserve and where possible rehabilitate wetlands
- Management will maintain the existing diversity of native plant and animal species
- Management will give special protection to significant fauna and flora
- Management will protect the health and viability of River Red Gum forest
- Management will control and where possible eradicate introduced plants and animals
- Management will protect the forest, life and property from fire
- Management will provide adequate opportunities for scientific research, especially that which will provide information of value for future management
- Management will minimise the impact of surrounding land and water uses on the forest

## ***Barmah Wetland System Environmental Monitoring Program***

### **Specific aims for the management of natural resources**

<b>Water</b>
<b><i>Surface water and wetlands</i></b>
To as far as possible recreate the pre-regulation water regimes indicated in Table 14 of DCE (1990)[should read CFL (1990)]
To as far as possible maintain the current [1992] area of each type of wetland
To provide sufficient water to ensure the breeding success of colonial water birds, consistent with the protection of other forest values
To alleviate the adverse effects of altered water regimes on wetlands, timber and conservation values
To monitor wetlands and the effects of applied water regimes
To minimise unnatural river bank erosion and wetland siltation
To ensure disposal of drainage water into the forest does not adversely affect vegetation, wildlife, timber production or recreation values
<b><i>Groundwater</i></b>
To protect the forest against possible adverse effects of rising water tables and salinity
To prevent adverse impacts on the forest arising from salinity mitigation works
<b>Flora</b>
<b><i>Vegetation management</i></b>
To maintain and protect the structural and floristic diversity of natural plant communities
To protect plant species and communities that are threatened or of special significance
To protect and encourage the re-establishment of mature River Red Gum woodland
To promote applied ecological research, particularly to assist future forest management
<b><i>Management of significant plant species</i></b>
To protect significant plant species
To protect significant River Red Gum trees
<b>Fauna</b>
To protect and maintain native fauna by maintaining suitable habitat
To actively manage threatened or significant species
To undertake continuing research and surveys of native wildlife
<b>Geology and geomorphology</b>
To assess and protect sites of geological and geomorphological interest
To interpret geological and geomorphological processes
<b>Reference areas</b>
To as far as possible allow natural processes to continue undisturbed
To as far as possible prevent modifications or intrusions of unnatural origin
To allow for scientific research
To prohibit activities that conflict with the purposes of Reference Areas

## **Barmah Wetland System Environmental Monitoring Program**

### **Specific aims for the management of utilisation**

<b>Timber and wood products</b>
To provide maximum possible protection for all native plants and animals in the State Park
To thin forest where economically viable and environmentally and silviculturally desirable
To minimise the effects of logging on significant plants and animals
<b>Grazing</b>
To determine the effects of herbivores on wetlands, box ridges, native plants (especially significant species), weeds, fuel load and Aboriginal sites
To manage cattle grazing to minimise impacts on forest values as far as is practicable
To manage grazing such that, where consistent with other aims, any contribution cattle may make to reducing fuel loads and controlling weed species is utilised
<b>Apiculture</b>
To minimise the impact of apiculture on conservation and recreation values
<b>Other uses</b>
To provide for and encourage scientific research, especially that oriented towards solving management problems

### **Specific aims for the management of recreation**

<b>Recreation activities</b>
To manage recreation use to prevent conflicts between users, and to protect the forest environment
To minimise the impact of recreational activities on other values
<b>Camping</b>
To minimise degradation to the Murray River environs caused by uncontrolled camping
<b>Fishing and grubbing</b>
To provide opportunities for fishing without adversely affecting native fish populations
To prevent damage to significant areas caused by grubbing
<b>Boating</b>
To protect the values of Barmah Lakes and other waterways within the forest
To minimise bank erosion

### **Specific aims for the management for forest protection**

<b>Fire prevention and suppression</b>
To protect life, property and forest values from fire
To minimise the adverse effects of fire suppression activities on important natural features
<b>Pest plants</b>
To monitor, control and as far as possible eradicate introduced plants
To minimise further establishment of introduced plants
<b>Pest animals</b>
To monitor, eradicate or establish effective control of introduced animals, especially those declared as vermin
To cooperate with adjoining landowners in the control of vermin and other introduced animals
To prevent over-grazing during drought or flood
<b>Invertebrate pests and other threats</b>
To protect the forest against pests and diseases

## **Mid-Murray Forest Management Plan (DNRE, 2002a)**

The State Forest component of Barmah Forest is located within the Mid-Murray Forest Management Area. This Mid-Murray Forest Management Plan replaces, but considers the principles and actions of, the Barmah Management Plan (DCE, 1992) in managing State Forest. The Plan is intended to apply for ten years unless a substantial change of circumstances warrants an earlier review. It has the aim:

**The primary aim of forest management plans is to ensure that State forest is managed in an environmentally sensitive, sustainable and economically viable manner. Forest Management Plans also seek to ensure that planning is a continuing process, responsive to changing community expectations and expanding knowledge of the forest ecosystem.**

Section 12 of the Mid-Murray Forest Management Plan (titled Plan Implementation) contains specific requirements for monitoring and reporting. These requirements are directly relevant to this project and are copied directly.

### **12.3 MONITORING**

Integral to sustainable forest management is the development of criteria and indicators against which the effects of forest management and utilisation activities can be determined.

In response to the *National Forest Policy Statement*, a working party was established to develop a set of national baseline standards against which the criteria for forest management and utilisation activities can be assessed. The working group determined that such standards should be progressively developed and incorporated into codes of practice for forest operations (JANIS 1997).

Monitoring is an integral component of NRE's Ecologically Sustainable Forest Management (ESFM) system.

#### **Monitoring of biodiversity**

ESFM provides information on the relative success of forest biodiversity management programs and provides a basis for review and improvement of these programs.

NRE faces a number of challenges in the design and implementation of biodiversity monitoring programs. These include the need to adopt programs that are:

- related to forest management objectives;
- of known and appropriate statistical power for detecting changes in the condition of forest assets or relationships between planning goals and related outcomes;
- relevant to current management practices and strategies and are able to inform decisions about changes in approach;
- accepted by stakeholders;
- cost-effective and practical to implement.

The currently favoured approach is to select species or processes that allow broader conclusions to be drawn about the condition of forests. Relevant species are identified according to rarity, population dynamics, spatial dynamics and life history parameters. Additionally, consideration needs to be given to habitat requirements at the population level, including the scale at which these operate. Potential candidates for monitoring include:

- large forest owls which range over large areas and which are directly sensitive to changes in the structure of forests and prey on species which may in turn be sensitive to changes in the condition of the forest;
- aquatic invertebrates and vertebrates which may provide an indication of trends in water quality and in turn, the health of aquatic systems;
- arboreal mammals which are relatively easy to survey which are sensitive to changes such as a declining abundance of hollow-bearing trees;
- diurnal birds that may be already in decline although not yet to the level of being classified as threatened and are dependent on a variety of habitat elements in the forest;
- nectarivorous birds that may be dependent on the flowering capacity of large old trees;

## **Barmah Wetland System Environmental Monitoring Program**

- a variety of plant species of different life histories;
- fire and timber harvesting history to ensure the extent and distribution of these processes are maintained within planning parameters;
- pest and weed populations, which may be either a symptom or cause of changes in the condition of the forest, are important but need to be assessed in the context of impact on biodiversity assets;
- common species as surrogates for the range of species in forests used for timber production.

In addition to the general indicators of forest biodiversity, specific monitoring of populations of threatened species should be undertaken to ensure early detection of population trends.

Victoria's Biodiversity Strategy (NRE 1997b) establishes a requirement for monitoring on a bioregional scale. NRE has established a number of Bioregional Networks, which have the task of reporting on the condition of biodiversity assets in each bioregion across all land tenures. Reporting on forest condition will be conducted in this framework.

NRE has a number of processes in place to monitor forest management and utilisation activities in the FMA:

- regular audits of timber harvesting operations in State forest are undertaken to provide information on implementation of the Code;
- water quality in State forest streams is regularly monitored through the Victorian Water Quality network. This data can be used to detect trends in water quality and yield in forest catchments;
- forest areas subject to timber harvesting and other management operations are recorded each year, and timber volume and area harvested are compared to licence commitments and conditions;
- the Statewide Forest Resource Inventory project is establishing a consistent description for forests throughout the State and will provide a baseline for future monitoring changes in the condition of the forests;
- forest sawlog growth and standing sawlog and residual volume are monitored through measurement of the Permanent and Continuous Forest Inventory plots;
- the Integrated Pest Management System provides a means to record pest infestations and to report on the effectiveness of control programs;
- the Wildlife Atlas and Flora Information System provide means of collecting and reporting on flora and fauna data collected by a wide variety of sources;
- Victoria's Biodiversity Strategy establishes a requirement to maintain ecological processes and biodiversity and undertake monitoring activities.

Australia is a signatory to the Montreal Process and has therefore agreed to develop a set of regional indicators, consistent with criteria established under that process for assessing sustainability of forest management.

Geographic Information Systems assist in data recording and storage, and enable analysis of spatial information to examine the effects of proposed forest operations on forest management zones and to determine the area subject to harvesting.

### **ACTIONS**

**Continue existing monitoring activities including, in particular, audits of the Code of Forest Practices for Timber Production, and the collection of data on areas and volumes of timber harvested.**

**In conjunction with other public land managers and private forest owners, establish appropriate monitoring programs for forest biodiversity, water quality and other environmental values at a bioregional scale and progressively monitor appropriate indicators within relevant time scales and in accordance with the Montreal Process.**

### **12.4 REPORTING**

Implementation of this Plan is a vital step in ensuring sustainability of forest management in the FMA. Accordingly, it is important to regularly review and report on its implementation. Reviews will provide the basis for systematically adapting the Plan to changing information and circumstances; thus ensuring it remains relevant.

### **ACTIONS**

**Upon adoption of the Forest Management Plan, the Regional Forest Manager will be responsible for preparing an annual report. This report may include:**

- **implementation of biodiversity management guidelines, new records of threatened species, and any observed responses to management initiatives;**
- **key timber production data such as area and volume harvested by product type, areas thinned or subject to other stand improvement operations critical to the maintenance of**

## **Barmah Wetland System Environmental Monitoring Program**

- |   |
|---|
| <p>sustainable yield, and the outcomes of regeneration and stocking surveys;</p> <ul style="list-style-type: none"> <li>• water quality prescriptions;</li> <li>• implementation of pest plant and animal control guidelines;</li> <li>• recreation and tourism initiatives;</li> <li>• major road maintenance or construction works;</li> <li>• compliance with the Code;</li> <li>• significant research outcomes;</li> <li>• progress on implementation of the Actions and commitments in this Plan;</li> <li>• recommendations for amendments to this Plan where required.</li> </ul> |
|---|

There are also specific Actions in other sections of the Mid-Murray Forest Management Plan that relate to monitoring requirements for State Forests. Those most relevant to the brief are listed below.

### **Research and education (Section 11)**

<b>Research</b>
Encourage research projects that may increase knowledge about forests or assist forest management.
Permit research projects in accordance with the Management Guideline for Assessment of Research Project Proposals.
Maintain a register of research sites in State forest.
Exclude management actions that are incompatible with the objectives for approved research projects, until such time as the areas are no longer required.

### **Biodiversity conservation (Section 3)**

<b>Management of processes affecting the structure and distribution of ecosystems</b>
Monitor harvested areas to assess the implementation of the habitat retention guidelines and associated prescriptions through the Code of Forest Practices for Timber Production audit procedures
<b>Wetlands</b>
Facilitate research to determine the ecological value of the respective water bodies and other open areas in the floodplain forests and an appropriate management regime for each.
Continue to develop and refine the information base on the extent and nature of ephemeral wetlands across the Mid-Murray FMA
<b>Conservation of flora and fauna</b>
Support surveys aimed at increasing knowledge of the location, distribution and abundance of rare and threatened species in the FMA and improving understanding of their habitat requirements.
Continue to record the presence of rare and threatened flora and fauna in the FMA and provide data to maintain currency of the Atlas of Victorian Wildlife and the Flora Information System.
Support research into the role of water, fire and coarse woody debris in the conservation and management of vegetation types and faunal habitat in the FMA.
Manage the habitat for threatened flora and fauna in State forest in accordance with the respective guidelines, relevant legislation and policies and Appendices L and M.
Develop competencies in field staff in the identification of and the management of the habitat for rare or threatened flora and fauna.
Evaluate the effectiveness of the management strategies for State forest and the conservation guidelines through monitoring of either threatened and sensitive faunal populations, or those species that are considered useful indicators of overall forest habitat conditions.
Review the strategies and guidelines for featured species as new information becomes available from survey and research.

**Water management (Section 4)**

**Environmental water management (Actions imply monitoring)**

Ensure that in-stream water quality is not adversely affected by management activities.

Ensure that available water is used to restore and maintain health and vitality of the floodplain ecosystem.

**Other forest uses (Section 6)**

**Grazing**

Encourage research into the combined impacts of introduced and native herbivores on native vegetation and fauna, particularly the impacts on vegetation communities that are threatened or of limited extent, and on the control of fine fuels in relation to fire management. Research should commence within two years of this Plan.

Establish a program to monitor the effectiveness of the grazing strategies and review the grazing strategies as required to incorporate relevant data arising from research.

**Apiculture**

Encourage research aimed at investigating the creation of colonies of feral bee, their activities and at the removal of colonies of feral honeybees from key areas of native forests.

**Forest protection (Section 7)**

**Fire management**

Investigate the ecological value of fire in floodplain forests.

**Pest plants and animals**

Maintain comprehensive records of the occurrences of pest species and control methods taken.

Requirements for environmental monitoring are also specified for several management guidelines (*e.g.* grazing) and conservation guidelines (*e.g.* carpet python) within the Plan but are not listed here.

**Asset Environmental Management Plan: Barmah Significant Ecological Asset (11 May 2005) (DSE and GBCMA, 2005)**

The first step decision of The Living Murray (TLM) identified six significant ecological assets (SEAs, or “icon” sites) to receive improved environmental flows and achieve site-specific ecological objectives (MDBMC, 2003). The Living Murray Business Plan requires the development of a single Asset Environmental Management Plan (AEMP) for each of the six SEAs.

The Barmah and Millewa Forests together comprise one of the six SEAs. This advisory document is the Victorian Government’s contribution to the development of the over-arching document *Barmah-Millewa Significant Ecological Asset - Asset Environmental Management Plan* (MDBC, 2005).

The Victorian vision for the Barmah wetland system is to:

**Restore and maintain a mosaic of healthy wetland communities throughout the floodplain environment representing pre-regulation communities.**

## **Barmah Wetland System Environmental Monitoring Program**

The Murray Darling Basin Ministerial Council set an interim ecological objective and expected outcomes for the Barmah-Millewa SEA as part of the first step decision (MDBMC, 2003), these being:

Enhance forest, fish and wildlife values.

- Successful breeding of thousands of colonial waterbirds in at least three years in ten.
- Healthy vegetation in at least 55% of the area of the forest (including virtually all of the Giant Rush, Moira Grass, River Red Gum forest, and some River Red Gum woodland).

The intention of the Barmah Asset Environmental Management Plan is to refine the interim ecological objective through a more detailed analysis involving local knowledge and stakeholder and community involvement. The refined objectives, together with those developed in NSW for the Millewa Forest, will become the agreed ecological objectives for the whole SEA and will replace the interim ecological objective and expected outcomes detailed by MDBMC (2003).

The document provides a suite of ecological objectives developed specifically for the use of environmental water, as developed through the Barmah Forest Environmental Water Management Program (Victorian State Government and The Living Murray). These include general ecological objectives and objectives pertaining to the current environmental water allocation (EWA) developed through the Victorian Murray Bulk Water Entitlement process.

### **General ecological objectives**

- Protect the ecological character of the floodplain, as required under the Ramsar convention;
- Enhance the ecological functions and diversity of the floodplain by re-instating a more natural flood regime;
- Enhance breeding and recruitment of indigenous floodplain fauna and germination and regeneration of indigenous flora;
- Provide suitable habitat conditions for indigenous flora and fauna;
- Ensure that all natural, flow related ecological functions can occur;
- Protect and restore Moira grass plains; and
- Ensure breeding success of colonial water birds.

### **Ecological objectives for the environmental water allocation (EWA)**

An annual environmental water allocation (EWA), comprising 100 GL high security and 50 GL low security water, is provided to the Barmah-Millewa Forests. The overall ecological objective developed during the Victorian Murray Bulk Water Entitlement process, and pertaining only to those areas where the EWA reaches, is to enhance forest, fish and wildlife values, and:

- Provide successful recruitment of large colonies of colonial water birds at least 3 years in 10;
- Increase the area and quality of Moira Grass plains;

## **Barmah Wetland System Environmental Monitoring Program**

- Provide breeding opportunities for floodplain fish, frogs and tortoises;
- Provide winter-spring floods to 50% of red gum forest; and
- Provide winter-spring floods to a proportion of all Barmah-Millewa wetland communities.

More detailed ecological objectives and the associated hydrological conditions required to achieve these objectives (from p.16) are listed in Table 2.

**Table 2. Ecological objectives and associated hydrological conditions**

<b>Ecological objective</b>	<b>Associated hydrological conditions</b>
Reduce encroachment of giant rush and river red gum onto Moira grass plains	Flow maintained <10,600 ML/day during summer and autumn ( <i>i.e.</i> prevent unseasonal flooding)
Maintain health of sedges, giant rush and wetland communities; assist maintenance of majority of Moira grass; maintain up to half of river red gum forest; provide events suitable for successful waterbird breeding 55% of forest inundated	4-month flood of 400-550GL/month for 4 months in 50% of years (equivalent to average daily flow of 13,135ML/day to 18,330ML/day) Less than 5 years between these events
Maintain health of majority of river red gum forest; maintain some river red gum woodland 66% of forest inundated	760GL/month (equivalent to average daily flow 25,300 ML/day) in 40% of years; any month Aug-Nov, duration 4 months
Maintain up to one half of river red gum woodland communities 75% of forest inundated	912 GL/month (equivalent to average daily flow 30,400 ML/day) in 30% of years; any month Aug-Nov, duration 1-4 months

These objectives are considered a first step in the process of developing a set of ecological objectives for the Barmah SEA. They are based on work undertaken at Barmah Forest in the past but have not been broadly endorsed by other stakeholders. The document specifies that these ecological objectives will require refining so that they encapsulate all key flow-related ecological issues and include targets to inform the development of an appropriate monitoring program.

The Barmah Forest AEMP also highlights a need for “Greater requirement for research and adaptive monitoring: The ability to satisfy ecosystem requirements depends on adequate pure and applied research, and on-going monitoring” (p.11) to address key risks to the identified values of Barmah Forest. The document also recognises that further and refined research and monitoring “will yield improved insights into wetland and species ecology, and thereby better direct water management activities to achieve strategy objectives” (p.21).

### **Barmah-Millewa Forest Significant Ecological Asset: Asset Environmental Management Plan (draft 22 July 2005) (MDBC, 2005)**

The Asset Environmental Management Plan (AEMP) for the Barmah-Millewa SEA, as required under TLM Business Plan, provides a framework for the delivery and management of environmental water. It adopts an adaptive management approach to the whole asset. It contains three main sections: (A) The Strategic Plan, (B) Annual Operating

## **Barmah Wetland System Environmental Monitoring Program**

Plan, and (C) Business Plan. The document is considered the over-arching AEMP for the Barmah-Millewa SEA and has been developed through inputs from the Victorian (*i.e.* the advisory Barmah Forest SEA AEMP: DSE and GBCMA, 2005) and NSW Governments.

The AEMP is considered to be an ongoing document and will be reviewed, reported and updated on an annual basis. The document recognises that considerable work is required to progress certain areas of the document: “In particular the development of a suite of Asset-specific ecological objectives, indicators and targets, and the means to monitor them is very much in its infancy” (p.2).

The environmental water for the Barmah-Millewa SEA managed under this Plan includes the current 100GL/yr high security and 50GL/yr low security environmental water allocations (EWAs) (previously managed through the Barmah Millewa Forum) in addition to any new environmental water allocated to it through TLM Environmental Watering Plan. The existing allocations will be accounted separately to water recovered as part of the first step decision of TLM process and will be managed under the existing interim operating rules and triggers (extended to June 2006) detailed in Appendix C of the Barmah-Millewa SEA AEMP document.

The AEMP will be facilitated through a cross-border Co-ordinating Committee (CC) to which a Technical Advisory Committee (TAC) and Asset Consultation Reference Group (ACRG) will report. An important function of the TAC is to provide advice to the CC to ensure that appropriate monitoring activities are co-ordinated across the Barmah-Millewa Forest SEA. Community involvement and input, including advice on desirable ecological objectives, watering requirements, works and monitoring, is considered a key objective of the community engagement process (Part A Section 3).

Part A Section 4 details the ecological objectives (overall goals of the AEMP) and targets (desired outcomes of specific management actions against which progress can be measured toward objectives) of the Barmah-Millewa SEA AEMP. The document states that the ecological objectives will be refined over the coming years in conjunction with adaptive management principles, advances in knowledge, and with due consideration to existing management obligations. **For 2005-2006, the AEMP will adopt the two interim ecological targets (=desired outcomes) of the first step decision of TLM as listed in DSE and GBCMA (2005).**

The document also considers the various management and planning documents that influence the Barmah-Millewa SEA and identifies **Ramsar obligations** as “the pre-eminent legal obligation and over-arching objective to adopt at the Barmah-Millewa SEA along with TLM ecological objective, which would prevent the existing objectives from being compromised” (Part A Section 4). The Ramsar objective listed is “**to maintain and, where practicable, enhance ecological character of floodplain**”. Note that the wording “and, where practicable, enhance” in this listed objective differs to other listed Ramsar objectives that do not include the word “enhance”.

In Part A Section 4.3 a process for determining and reviewing whole-of-asset objectives and targets is detailed and is here copied directly:

The process to develop and review water-related objectives and targets for the combined asset will be undertaken by the Co-ordinating Committee with community input through the assistance of the ACRG and through the Indigenous consultation process.

To assist this process, the TAC has been asked to develop an environmental performance evaluation (EPE) process. The EPE process will also help guide the formation of a comprehensive monitoring program for future versions of the AEMP. Appendix J outlines the EPE approach taken to date.

Whole-of-asset objectives and targets will be reviewed on an annual basis through the wider AEMP reporting and review process (see Part A, Section 8).

The monitoring activities planned for 2005-2006 are listed in the document. These will be reviewed by the TAC upon receipt of the MDBC's monitoring and evaluation framework, the Outcomes and Evaluation Framework (OEF), to ensure that proposed activities are consistent across SEAs.

This document also highlights previous research, monitoring and evaluation activities within the Barmah-Millewa Forest (Appendix F), relevant legislation and planning instruments influencing forest management (Appendix G), and existing ecological objectives from relevant documents (Appendix I).

## **B. Water Management Plans / Strategies**

### **The Barmah-Millewa Forest Water Management Strategy (MDBC and BMF, 2000)**

The focus of the Barmah-Millewa Forest Water Management Strategy is to maintain or enhance the ecological health of Barmah-Millewa Forest by managing the water regime in a sustainable manner. It recognises the Barmah-Millewa Forest as a single ecosystem, recognises appropriate economic, environmental and social factors, and adapts to advances in knowledge. The Annual Operating Plans prepared by the State managing agencies for the forest come under the umbrella of this Water Management Strategy.

The intrinsic link between the water regime and ecological health of the Barmah-Millewa Forest is recognised in this document. Thus, in designing a monitoring program for the Barmah wetland system it is pertinent to consider the water regime being received by the wetland. This Strategy specifically highlights through Objective 6 the need:

**To monitor, record and evaluate scientific information required to manage water flow operations effectively, and to use that information in assessing the Water Management Strategy's performance and in managing adaptively.**

The seven specific strategies to achieve Objective 6 are listed in Table 3.

**Table 3. Strategies to achieve Objective 6.**

<b>Strategy</b>	<b>Further information</b>
6.1 Develop ecosystem indicators, and inventory and monitoring systems for flora, fauna and ecological processes.	Ecological processes is to include sediment deposition and erosion
6.2 Measure, record and evaluate information required to effectively manage the Barmah-Millewa Forest ecosystem, and report it against specified performance criteria.	Information collected is to encompass wetlands, grasslands, billabongs, effluent channels, trees and grasses, and is to include details of flood mapping; water sources; water quality; groundwater levels; flow path and drainage, including riverbank stability; hydrology and flows in the Forest; watering history, including flood levels and durations, and water use from storage facilities used for environmental flows; operation of water management works; vegetation and wildlife status; and other information as required.
6.3 Evaluate remote sensing of Forest flooding and vegetation health to complement field observations.	It is expected that information collected will enable greater coverage of the Forest and will reduce the requirement for expensive field inspections. It will include data on change in flora and fauna, water use, water deficits, and geomorphic change.
6.4 Develop a database containing a Geographic Information System and other information	
6.5 Specify performance criteria and develop optimum water management options for each water management area, based on information collected.	
6.6 Continue to model flows through regulators, Forest runners and the River Murray, to provide hydraulic knowledge for operating Forest regulators.	
6.7 In response to information required, assess the Water Management Strategy's performance and modify actions progressively in accordance with adaptive management principles.	

The Water Management Strategy also highlights through Objective 8 the need:

**To increase knowledge of the needs of environmental watering regimes and of water management practices, and to apply that knowledge in assessing the Water Management Strategy's performance and in managing adaptively.**

The five specific strategies to achieve this objective are listed in Table 4.

**Table 4. Strategies to achieve Objective 8.**

<b>Strategy</b>	<b>Further information</b>
8.1 Investigate the relationships between water management and environmental factors.	Factors are to include soil moisture, aquifer recharge and groundwater levels, water quality, environmental water requirements and use, water use by flora and fauna and associated flora and fauna health factors.
8.2 Investigate and trial managed floods using releases of water from storages and/or in conjunction with trigger flows from tributaries upstream of the forest.	A set of criteria for trial managed floods are included in the Water Management Strategy p.18. Parameters governing water allocation are listed on p.4 in the Water Management Strategy.
8.3 Further investigate benefits and costs of managing floods with the aim of integrating salinity management (salt export), managed flooding, enhanced downstream environmental water management and dilution of river salinities.	
8.4 Develop and report Managed Flooding Operational and Monitoring Procedures that are integrated with other management plans.	
8.5 In response to advances in knowledge, assess the Water Management Strategy's performance and modify actions progressively in accordance with adaptive management principles.	A coordinated Research Program should be prepared each year, commensurate with available funding, and research and investigations activities conducted should be reported annually.

**Interim Water Management Strategy for Barmah Forest, Victoria (Ward et al., 1994)**

This strategy incorporates the recommendations of Maunsell Pty Ltd (1992) and the Community Reference Group (CRG, 1994) to discuss strategies for water management within Barmah Forest. It uses research findings by Ward (1991, 1994a,b) to develop a water management strategy that reduces the rate of decline in the Moira Grass plains of Barmah Forest, and provides more suitable watering of other open wetland systems and River Red Gum forests. The strategy uses the water management areas (WMAs) A-H adopted by Maunsell Pty Ltd (1992) for forest watering (although WMA H is divided into four sub-sections in this strategy).

The document proposes principles and rules for the operation of regulators and it assesses the proposals of Maunsell Pty Ltd (1992) for the WMAs of Barmah Forest (including proposals for further investigations).

Whilst the document focuses on water management issues (including works), there are some recommendations for environmental monitoring including:

- Salinity and nutrient levels of entering Smiths Creek (WMA C).
- Water quality of ponded water (WMA D).
- Water movement into Black Swamp (WMA E).
- Flow gauging into and out of Barmah Forest to assess volumes actually “lost” to forest.
- Continuation of biological monitoring of Moira Grass, River Red Gum, rushland and billabong vegetation communities using existing field sites and potentially others.

## ***Barmah Wetland System Environmental Monitoring Program***

The document also discussed investigations of:

- Sedimentation rates within Barmah Forest
- The need for incorporating fish passage-ways into existing and new regulators.

## **Barmah Millewa Forests Water Management Plan (Maunsell Pty Ltd, 1992)**

This report details the water management plan for the Barmah-Millewa Forests that involved a six-stage process including (1) Identification of water management areas (WMAs), (2) Determination of water deficits in the Forests, (3) Evaluation of a range of projects to reduce the water deficits identified in Stage 2, (4) Selection of the best strategies to meet water deficits for each WMA, (5) Assigning priorities based on costs and water stress levels, and (6) Developing guidelines to implement the water management plan.

Stage 6 involves the development of guidelines for the implementation, maintenance and monitoring of the water management strategy. Section 7.5 of the document highlights the data and research needs for Barmah-Millewa Forest, and broadly outlines some aspects, including costs, of a proposed monitoring program to monitor water management activities (*e.g.* use of permanent transects and remote sensing).

## **Barmah-Millewa Forests Water Management Plan: Business Plan Part 1 (Maunsell McIntyre Pty Ltd, 1999a)**

The purpose of this document is to develop a detailed plan that integrates environmental, hydrologic, hydraulic, social and economic considerations for the use of the 100GL water allocation and other available flows to benefit Barmah-Millewa forest environmental health. The Barmah and Millewa forests are divided into eleven and eight water management areas (WMAs), respectively, for management and reporting purposes. The location, area, hydrology and ecological features of each WMA are discussed. The document also considers monitoring options for the Forests and discusses the selection of “performance indicators” to assess the effects of environmental watering on the health of the forest, and provides five criteria for selecting useful indicators.

A monitoring program is proposed that focuses on several performance indicators. The most direct indicator of the forest is considered to be the presence or absence of water. Other performance indicators recommended include waterbird breeding, vegetation of wetlands and grass plains, Moira grass plains and understorey vegetation of Site Quality II forests. The document also provides an overview of monitoring types:

- Observational transects and occasional observation points to assess the level of flooding (none, some, lots, complete flooding).
- Understorey vegetation transects to show major changes in understorey communities across WMAs over the medium term
- Bird observation plots at several known major bird sites where the number and relative frequency of bird breeding is tallied
- Biodiversity plots at Douglas Swamp and Moira Lakes involving a complete enumeration of flora and fauna to provide long-term records of forest change

## **Barmah Wetland System Environmental Monitoring Program**

- Grass Plain Extinction plots to monitor vegetation changes on an annual or biannual basis
- Understorey Change Plots involving detailed vegetation mapping at important areas
- Flood Water Height Markers referenced to AHD across the forest to develop the hydraulic knowledge of the forest
- Continuation of Forest Watering Trial Plots at Gulpa Island (Millewa Forest)
- Flood mapping in both winter and summer.

The document also identifies the need for focussed research to provide an improved understanding of the processes that drive the system. It is argued that this research is required in several areas before a monitoring program can be adequately devised. Areas for further research relate to water movement/forest height mapping, episodicity of successful and unsuccessful bird breeding, influence of groundwater on ecosystem health, role of soil cracking in water uptake, understorey vegetation, litter dynamics and effect on biota, seed and egg banks, soil character, and monitoring change in the Moira Grass plain.

## **C. Ramsar Documents**

Australia is a Contracting Party to the Convention of Wetlands (also known as the Ramsar Convention) (Ramsar, Iran, 1971). As such, it has the primary obligation:

**To maintain the ecological character of Ramsar sites through conservation and wise use.**

“Ecological character” has been defined 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” (Ramsar Conference Resolution 7.10; from DNRE, 2002b).

Contracting Parties are also expected to remain informed of any changes to the ecological character of the Ramsar sites (Ramsar Convention 1987). Australia’s legal obligations to Ramsar-listed sites are defined through the Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999*. The EPBC Act introduces an environmental assessment and approval regime for actions that have, may have or are likely to have a significant impact on Ramsar Wetlands and establishes new standards for managing Ramsar wetlands through the Australian Ramsar Management Principles which have been established as regulations under the Act. The *Environment Protection and Biodiversity Conservation Regulations 2000 – Schedule 6* specifically addresses the management of wetlands of international importance and specifies that a management plan should be prepared for each declared Ramsar wetland. Each management plan should, among other things, “provide for continuing monitoring and reporting on the state of its ecological character”. The States and Territories administer the obligations of the Convention in partnership with the Commonwealth Government. The legal obligations concerning activities at Ramsar-listed sites ensures that Ramsar obligations are afforded high priority in the management of these sites.

Barmah Forest is one of 11 sites listed in Victoria as a Wetland of International Significance under the Ramsar Convention. The wetland was listed in 1982 and at that

## **Barmah Wetland System Environmental Monitoring Program**

time met five pre-1999 criteria for Ramsar inclusion. These are listed below along with the current matching criteria (from DSE, 2005):

<b>Pre-1999 criteria</b>	<b>Current matching criteria</b>
1(a) it is a particularly good representative example of a natural or near-natural wetland, characteristic of the appropriate biogeographical region.	<b>Criterion 1:</b> A wetland should be considered internationally important if it contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.
2(b) it is of special value maintaining the genetic and ecological diversity of a region because of the quality and peculiarities of its flora and fauna.	<b>Criterion 3:</b> A wetland should be considered internationally important if it supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.
3(a) it regularly supports 20,000 waterfowl.	<b>Criterion 5:</b> A wetland should be considered internationally important if it regularly supports 20,000 or more waterbirds.
3(b) it regularly supports substantial numbers of waterfowl from particular groups.	<b>No criterion</b>
3(c) where data on populations are available, it regularly supports 1% of the individuals in a population of one species or subspecies of waterfowl.	<b>Criterion 6:</b> A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of waterbird.

The wetland is managed at a state level under the *Management of Victoria's Ramsar Wetlands: Strategic Directions Statement* (DNRE, 2002b). This document establishes ten Management Objectives for Victoria's Ramsar sites and Statewide Management Plans to achieve the primary obligation. The objectives are:

1. Increase the scientific understanding of wetland ecosystems and their management requirements.
2. Maintain or seek to restore appropriate water regimes.
3. Address adverse processes and activities.
4. Manage within an integrated catchment management framework.
5. Manage resource utilisation on a sustainable basis.
6. Protect, and where appropriate enhance, ecosystem processes, habitats and species.
7. Encourage strong partnerships between relevant agencies.
8. Promote community awareness and understanding and provide opportunities for involvement in management.
9. Ensure recreational use is consistent with the protection of natural and cultural values.
10. Develop ongoing consistent programs to monitor ecological character.

The *Barmah Forest Ramsar Site: Strategic Management Plan* (DSE, 2003) applies these Management Objectives and Statewide Management Strategies specifically to Barmah Forest to promote a range of specific Site Management Strategies to achieve the primary obligation. The mechanism used to maintain ecological character is through the management of risks to the identified values of the wetland. For Barmah Forest, risks are identified as altered water regimes, salinity, pollution, pest plants and animals, inappropriate resource utilisation, recreation and erosion. The key environmental values of Barmah Forest include wetland representativeness, flora and fauna and waterbirds.

## **Barmah Wetland System Environmental Monitoring Program**

The Department of Sustainability and Environment has the overall responsibility for ensuring that monitoring programs are established in accordance with the Strategic Directions Statement and Strategic Management Plans for Ramsar Sites. A number of Site Management Strategies have been developed in response to the analysis of risks to the values of the Barmah Forest Ramsar site. These are listed against the Management Objectives detailed above, and those relating to monitoring requirements for Barmah Forest include:

### **Management Objective 1: Increase the scientific understanding of wetland ecosystems and their management requirements**

<b>Site management strategy</b>	<b>Lead agency</b>	<b>Priority</b>
1.1 Seek funding for research needed to determine more appropriate water regimes for the Ramsar site based on the hydro-ecological requirements of the forest	DSE, GBCMA, PV	Higher
1.2 Seek funding for studies which determine the complexity of water movement throughout the forest to assist in the management of environmental water allocations	DSE	Higher
1.3 Complete the program to monitor fish movement in the forest creeks and determine the impact of regulators on fish passage	DSE	Higher
1.4 Seek funding for research into the causes of erosion along the banks of the Murray River and develop strategies to minimise the extent of this erosion	PV	Higher
1.5 Encourage and seek funding for research into the rate and mechanisms of sediment deposition	DSE, PV	Medium
1.6 Assist and encourage surveys and research into natural and cultural values of the Ramsar site	DSE, PV	Medium
1.7 Seek funding for research into the effects of grazing on vegetation communities and its role in reducing fire fuel loads	DSE	Medium
1.8 Initiate research and monitoring of the impacts of apiculture on native flora and fauna within the Ramsar site	DSE	Medium
1.9 Seek funding for an investigation of the extent of wastewater pollution of Barmah Forest	GMW, GBCMA	Lower

### **Management Objective 2: Maintain or seek to restore appropriate water regimes**

<b>Site management strategy</b>	<b>Lead agency</b>	<b>Priority</b>
2.1 Ensure that environmental water allocations are used in accordance with management plans and strategies and that monitoring is undertaken to improve understanding of the effects of water management regimes.	DSE, PV, GBCMA	Higher
2.2 Seek funding for mapping and investigating flows and water quality of formal and informal drainage schemes draining into the Ramsar site.	GBCMA, DSE, GMW	Higher

### **Management Objective 3: Address adverse processes and activities**

<b>Site management strategy</b>	<b>Lead agency</b>	<b>Priority</b>
3.10 Assess impacts of land use and development adjacent to the Ramsar site on Ramsar site values. If necessary, seek planning scheme amendments, such as rezoning or placing an environmental significance overlay on adjacent land to minimise impacts.	DSE, GBCMA, Shire	Lower

**Management Objective 5: Manage resource utilisation on a sustainable basis**

<b>Site management strategy</b>	<b>Lead agency</b>	<b>Priority</b>
5.3 Develop a routine assessment process to assess the ecological condition of the grazing areas to improve the ability to manage stock numbers if seasonal conditions or ecological requirements dictate.	DSE, PV	Higher

**Management Objective 6: Protect and where appropriate enhance ecosystem processes, habitats and species**

<b>Site management strategy</b>	<b>Lead agency</b>	<b>Priority</b>
6.4 Continue monitoring of fish movement in the forest creeks as required to determine the need for fishways or the change in operation of regulators that impede fish movement.	DSE, PV	Medium

**Management Objective 8: Promote community awareness and understanding and provide opportunities for involvement in management**

<b>Site management strategy</b>	<b>Lead agency</b>	<b>Priority</b>
8.4 Identify opportunities and encourage community involvement in ecological monitoring activities.	DSE, PV	Lower

**Management Objective 10: Develop ongoing consistent programs to monitor ecological character**

<b>Site management strategy</b>	<b>Lead agency</b>	<b>Priority</b>
10.1 Seek funding to develop an ongoing consistent program to monitor the ecological character of the Barmah Forest Ramsar Site, measured in a statistically sound way and maintain data in appropriate databases. Factors such as water regime, salinity, nutrients, algae, macroinvertebrates, flora and fauna should be measured.	DSE, PV	Higher
10.2 Encourage and seek funding to monitor the effectiveness of rehabilitation, revegetation and habitat protection works in conjunction with similar works in NSW forest areas. Coordinate work and compare results through the Barmah-Millewa Forum.	DSE, PV	Higher
10.3 Continue to record fauna species usage of the Barmah Forest Ramsar site and provide data to update relevant Victorian databases.	DSE, PV	Higher

Lead Agency Key: DSE=Department of Sustainability and Environment, GBCMA=Goulburn Broken Catchment Management Authority, GMW=Goulburn-Murray Water, PV=Parks Victoria, Shire=Shire of Moira

The document *Framework for describing the ecological character of Ramsar wetlands: Including a description of the ecological character of the Barmah Forest Ramsar Site* (DSE, 2005) provides a framework for managers to prepare a separate ecological character description for new Ramsar sites and those where existing plans or Ramsar Information Sheets (which need to be prepared at the time of listing) are inadequate as a baseline reference. The output of this framework is a formal description of the ecological character for the wetland. This forms a baseline or reference for three main activities:

1. Design of a monitoring program to detect ecological change
2. Assessment of likely impacts on ecological character of proposed actions (required under the Commonwealth EPBC Act).

## **Barmah Wetland System Environmental Monitoring Program**

3. Regular evaluation of results of the monitoring program as a basis for reporting to the Ramsar Convention and for reviewing the management plan.

The Ramsar site tested using this framework (Part B of the document) is Barmah Forest, and information is collated to describe the ecological character of the wetland at the time of listing in 1982.

## **D. Other Strategic and Influential Documents**

### **Goulburn Broken Regional Catchment Strategy (GBCMA, 2003)**

The Goulburn Broken Regional Catchment Strategy (GBCMA, 2003) establishes the planning framework for land, water and biodiversity management in the region. The document supports the objectives of other State Government legislation and also addresses obligations of the catchment under Commonwealth and Murray-Darling Basin legislation. The Regional Catchment Strategy is a broad, overarching document that takes a longer-term view of the challenges and opportunities facing the region.

The strategy does not specifically address Barmah Forest or requirements for its ecological monitoring. However, it does include some general targets for assets of the catchment which apply to Barmah Forest (Table 5).

**Table 5. Resource condition targets for assets of the Goulburn Broken catchment.**

<b>Asset</b>	<b>Resource condition target</b>
Native Vegetation	<ul style="list-style-type: none"><li>• Maintain extent of all native vegetation types at 1999 levels in keeping with the goal of 'net gain' listed in Victoria's Biodiversity Strategy 1997</li><li>• Improve the quality of 90% of existing (2003) native vegetation by 10% by 2030</li><li>• Increase the cover of all endangered and applicable vulnerable EVCs to at least 15% of their pre-European vegetation cover by 2030</li></ul>
Threatened Species	<ul style="list-style-type: none"><li>• Increase 2002 conservation status of 80% threatened flora and 60% threatened fauna by 2030</li></ul>
Wetlands	<ul style="list-style-type: none"><li>• Maintain extent of all wetland types at 2003 levels where the extent (area and number) has declined since European settlement.</li><li>• Improve condition of 70% of wetlands by 2030, using 2003 as the benchmark for condition</li></ul>

The Wetlands Direction Paper for the Goulburn Broken Catchment (Howell and McLennan, 2002) was produced to ensure that every important strategic issue affecting wetlands is addressed in the Regional Catchment Strategy. It outlines a broad process for (1) identifying and prioritising wetland assets and threats, (2) setting goals and targets for wetlands, and (3) identifying actions to achieve these goals and targets following identified standards that build and maintain capacity. It also highlights relevant legislation and policy that relate to the protection and management of aquatic environments in Australia. There are no specific requirements for environmental monitoring of the Barmah wetland system in the Directions Paper.

## **Victoria's Biodiversity – Directions in Management (DSE, 2004)**

Victoria's Biodiversity Strategy forms a key step in meeting the objectives of the *Flora and Fauna Guarantee Act 1988* for the conservation and management of biodiversity in the State. The Strategy comprises three documents (Our Living Wealth, Sustaining our Living Wealth, and Directions for Management) with the third document setting objectives for the Strategy and management approaches to achieve integrated biodiversity conservation throughout each bioregion of the State. Barmah Forest is located within the Victorian Riverina bioregion.

For areas of forest estate not included within the CAR (Comprehensive, Adequate and Representative) Reserve System (includes Barmah Forest), the principles of Ecologically Sustainable Forest Management (ESFM) are applied. The ESFM principles include protecting and maintaining biodiversity, ecological integrity where the health and vitality of the ecosystem are maintained, and invoking the precautionary principle. These principles apply to Barmah Forest through the Mid-Murray Forest Management Plan.

A Key Direction for management approaches in largely natural landscapes includes:

**Continue to promote the investigation of natural ecological processes in these landscapes and adjust management regimes in response (e.g. the role of fire and grazing in the long-term ecological health of the natural systems)**

The Strategy details a Reporting Framework for monitoring achievements using an Adaptive Management Cycle for Biodiversity Conservation. Monitoring plays a key part of this cycle and this section of the Strategy is copied directly.

*Monitoring Actions* – undertaking a strategic selection of monitoring activities which adequately cover the spectrum of management issues, and which use appropriate degrees of sophistication varying as follows:

- Qualitative Monitoring – the unstructured observation of changes in elements of biodiversity (e.g. opportunistic observation of pest plant/animal introduction or disease outbreak), or structured observations without quantitative design or intent (e.g. photopoints or paired plots intended only to visually illustrate changes);
- Surveillance Monitoring – the process of repetitive observations of one or more elements of biodiversity, according to pre-arranged schedules in time and space (e.g. annual population counts of a rare species at a particular locality);
- Research Monitoring – as in surveillance monitoring, but explicitly designed to understand the changes detected in terms of causal links to specific management actions or natural events (e.g. sampling of populations under differing management regimes with the statistical design power to link key factors);
- Risk-Based Assessment – the process of assigning magnitudes and probabilities to the adverse effects of human activities and/or catastrophic natural events; a process which seeks to use unambiguous quantitative endpoints by which to judge results of management. Performance indicators are based on the numbers of management issues with appropriate monitoring programs and the achievement of annual targets for gathering the information required by these programs.

*Environmental Outcomes Monitoring* – including measures of environmental condition with a focus on physical features. Although not actual measures of biodiversity, these outcomes are directly relevant to habitat quality and are often the only features that can be readily assessed across whole systems. Performance indicators are based on some of the established indicators of health (e.g. extent and condition of vegetation cover, Index of Stream Condition, extent of pest plants).

*Biodiversity Outcomes Monitoring* – including measures of biodiversity condition selected from a matrix of features reflecting levels of organisation (landscape, ecological community, population, genetic) and different biodiversity attributes (composition, structure, function). Some measures will only be meaningful for a particular feature at a particular location (e.g. recovery of an individual population), whilst others can be aggregated with similar measures to generate indices (e.g. number of threatened species). Performance indicators are based on a variety of features, for example depletion/rehabilitation of extent and quality of specific vegetation communities or habitat types; population trends of sensitive/threatened/indicator species; retention of specified sites of significance; quantitative assessment of success in managing specific risks.

Two Key Directions for the Reporting Framework as relevant to this brief include:

- Develop practical priorities for monitoring programs and quality assurance guidelines for monitoring techniques.
- Increase the proportion of overall land and water resources directed to monitoring and reporting, and focus the shift of these activities from efficiency to effectiveness measures.

### **Sharing the Murray: Proposal for defining people's entitlements to Victoria's water from the Murray (MVEC, 1997)**

This document highlights Victoria's usage of Murray River water and proposes entitlement options for equitable sharing of water within the bounds of the cap. The document discusses provisions for the environment. It assesses operating rules and requirements for the delivery of environmental flows to restore a more natural flooding regime to Barmah Forest but no specific monitoring requirements for Barmah Forest are stipulated.

### **Murray Valley Area Final Recommendations (LCC, 1985)**

Areas defined as Murray River Reserve and Reference Areas were established in Barmah Forest under recommendations in this document from the Land Conservation Council. The document also recommended that government endorse the nomination of the Barmah and Millewa Forest Group for listing in the National Estate Register. It also recommends that steps be taken to provide adequate winter-spring watering of the River Murray forests and that various engineering and management solutions be pursued to achieve this.

The document also provides recommendations regarding grazing in Barmah Forest, with Recommendation Q15 relating directly to environmental monitoring:

**That the land manager monitor the effects of grazing on both native overstorey and understorey species occurring in the forest and ensure that stocking rates are adjusted to properly reflect the management aims for the forest.**

## **A Directory of Important Wetlands in Australia (EA, 2001)**

The Directory of Important Wetlands in Australia (third edition) is a comprehensive inventory of Australia's nationally important wetlands. It lists 851 wetlands that have met inclusion criteria to qualify as nationally important. For each wetland, information is provided as to the criteria for inclusion, wetland type and area, and its location at State/Territory and regional (as defined by the Interim Biogeographic Regionalisation for Australia; IBRA) scales. A chapter of the report is also dedicated to wetlands listed under the Ramsar Convention (detailed previously).

The document is principally an inventory resource and specific requirements for environmental monitoring are not stipulated for the wetlands listed in the Directory. Exceptions to this are those wetlands that are also listed under the Ramsar Convention. Contracting Parties to the Convention of Wetlands have obligations to protect and maintain the ecological character of listed sites, as recognised in national legislation through the *Environment Protection and Biodiversity Conservation (EPBC) Act 1999* (detailed in the Ramsar section above).

## **The Wetlands Policy of the Commonwealth Government of Australia (EA, 1997)**

The Commonwealth Government developed this policy as a first step toward the development of a national framework of wetland policies and strategies. It was inspired by the Ramsar Convention promoting the wise use principle and is a response to the Governments responsibilities under Agenda 21. The policy has the goal “*to conserve, repair and manage wetlands wisely*” and contains seven objectives and twelve guiding principles to achieve this goal. One of the guiding principles pertains to wetland monitoring requirements:

**Ongoing research into wetland processes, dynamics and management, and the dissemination of these findings in a readily useable form, is important to the conservation and ecologically sustainable use of wetlands.**

The policy also has six strategies to provide for the conservation, repair and wise use of wetlands. Strategy 5 “Ensuring a sound scientific basis for policy and management” specifically addresses the requirement for wetland monitoring and relevant points pertaining to environmental monitoring are copied directly:

### **5.1 Monitoring the state of wetlands**

- Work in partnership with the State-Territory Governments, and private landowners as appropriate, to compile and regularly update a national wetlands inventory which includes the wetland resources on Commonwealth lands and waters.
- In consultation with scientific experts, government agencies, nominated community groups and private landholders, establish national guidelines, protocols and benchmarks for the short and long-term monitoring of Australia's wetlands.
- Seek cooperative arrangements with State/Territory and local Governments and support community groups and the scientific community to ensure regular monitoring of wetlands.
- Provide specific details of the extent and condition of Australia's wetland resource in future State of the Environment Reports.

**5.2 Developing and supporting a strategic and coordinated wetlands research effort**

- Continue to develop a strategic and coordinated approach to Commonwealth funded wetland-related research through, for example, the National Wetlands Research and Development Program. Seek to engage a broad range of joint partners in this Program from other government sectors and the private sector.
- Through the above, foster research into the priority areas to address wetland management issues. This should include, but not be limited to, research to:
  - Identify the full range of threatening processes for wetlands and establish how to manage these and other known threats facing wetlands, such as water flow patterns and water quality, pollution and invasive species;
  - Define the role of wetlands in the hydrologic cycle;
  - Clarify the taxonomy and distribution of wetland dependent species; and
  - Improve information held on the migration and distribution patterns of migratory waterbirds, focusing on the East Asian-Australasian Flyway, through the development of appropriate colour marking protocols and habitat studies, particularly with the assistance of the Australian Bird and Bat Banding Scheme.

**5.3 Supporting mechanisms to encourage the understanding and application of research findings**

- Ensure that results of research are widely disseminated in a user-friendly form to those with wetland management and conservation responsibilities in both government and non-government sectors, here and internationally.
- Monitor international advances in wetland management and draw them to the attention of the Australian research community and others who can apply these locally.

## **Register of the National Estate (DEH, 2005)**

The Register of the National Estate is “Australia’s national inventory of natural and cultural heritage places which are worth keeping for the future” (DEH, 2005). The Register is compiled by the Australian Heritage Commission and registered sites must meet at least one of eight criteria for inclusion. Listing does not directly affect the way that private, State and Local Government owners manage, maintain or dispose of their national estate properties. The Commonwealth Government is the only body whose actions are constrained as a result of a site being listed, where under Section 30 of the *Australian Heritage Commission Act 1975* it is prohibited from taking any action which would adversely affect a place in the Register unless there are no feasible and prudent alternatives to the action.

The Barmah and Millewa Forests are each registered on the Register of the National Estate. There are no specific requirements for environmental monitoring with this listing.

## **E. Other Agreements, Acts and Conventions**

### **JAMBA and CAMBA**

The Japan-Australia Migratory Birds Agreement (JAMBA, 1974) is an agreement between the Government of Australia and the Government of Japan for the protection of migratory birds and birds in danger of extinction. The China-Australia Migratory Birds Agreement (CAMBA, 1986) is an agreement between the Government of Australia and the Government of the People’s Republic of China for the protection of migratory birds and their environment.

## **Barmah Wetland System Environmental Monitoring Program**

For each agreement, the respective governments have agreed to:

- Endeavour to establish sanctuaries and other facilities for the management and protection of migratory birds and also of their environment
- Exchange data and publications regarding research on migratory birds
- Encourage the formulation of joint research programs on migratory birds
- Encourage the conservation of migratory birds

The Victorian Government works in partnership with the Australian Government to conserve Victorian habitats of bird species listed in the agreements. Birds recorded at Barmah Forest that are listed in JAMBA (eight species) or CAMBA (13 species) include Cattle Egret (*Ardea ibis*), Great Egret (*Ardea alba*), Red-necked Stint (*Calidris ruficollis*), Greenshank (*Tringa nebularia*), Sharp-tailed Sandpiper (*Calidris acuminata*), White-throated Needletail (*Hirundapus caudacutus*), Fork-tailed Swift (*Apus pacificus*), Latham's Snipe (*Gallinago hardwickii*), Glossy Ibis (*Plegadis felcinellus*), White-bellied Sea-eagle (*Haliaeetus leucogaster*), Rainbow Bee-eater (*Merops ornatus*) and Caspian Tern (*Hydroprogne caspia*) (data from DCE, 1992; note that MDBC, 2005 also includes Marsh Sandpiper *Tringa stagnatilis* as listed but does not include Rainbow Bee-eater *Merops ornatus*).

## **Flora and Fauna Guarantee Act 1988**

This Act provides for the listing of Victoria's threatened plant and animal species, ecological communities and potentially threatened processes. Under the Act, an Action Statement must be prepared by DSE for each item following its listing. The Action Statements are designed to apply for 3-5 years after which they should be reviewed. Section 19(2) of the Act specifies that:

*The action statements must set out what has been done to conserve and manage the taxon or community or process and what is intended to be done and may include information on what needs to be done.*

Management Plans are also produced under the Act. Section 25(1) of the Act states:

- |  |
|--|
| <p>A management plan must state –</p> <p>(a) the taxon or community of flora or fauna or potentially threatening process to which it applies; and</p> <p>(b) in relation to the flora or fauna conservation and management objectives –</p> <p>(i) the way in which those objectives are to be implemented or promoted for the benefit of that taxon or community or the management of that process; and</p> <p>(ii) the method by which progress towards achieving those objectives can be assessed; and</p> <p>(c) the nature conservation and the social and economic consequences of the plan; and</p> <p>(d) the date by which the management plan should be subject to review by the Secretary</p> |
|--|

Whilst environmental monitoring requirements are not explicitly stipulated in the Act, in practice they form an important component of the conservation objectives and management actions in the individual action statements and management plans.

## **Convention on the Conservation of Migratory Species of Wild Animals (Bonn, 1979)**

Australia is a Range State under the Conservation of Migratory Species (CMS) Convention (Bonn, 1979). The objective of the CMS is to conserve terrestrial, avian and marine species over the whole of their migratory range and arose from a recognition of the need for countries to cooperate in conserving animals that migrate across national borders. Article II of the CMS (titled Fundamental Principles) specifies three fundamental principles for contracting parties. Australia's obligations towards the CMS are administered through the *Environmental Protection and Biodiversity Conservation Act 1999*.

The CMS has two appendices. Appendix I lists migratory species considered at risk of extinction throughout all or a portion of their range, whilst Appendix II lists migratory species considered to have an "unfavourable conservation status and which require international agreements for their conservation and management, as well as those which have a conservation status which would significantly benefit from the international cooperation that could be achieved by an international agreement".

There are strict conservation obligations for parties of the convention that list Appendix I species, whilst there are no direct obligations for Appendix II species (although parties are required to develop further agreements for their protection according to guidelines established by the treaty).

### **Data needs for reporting**

Most of the policies and plans reviewed above specify requirements for environmental monitoring of Barmah Forest. Some documents such as the Barmah Management Plan also specify particular actions (including monitoring) to achieve these objectives. However, the methodologies for environmental monitoring and the data needs required for reporting are not stipulated in these policies and plans.

Exceptions to this are the documents detailing the Ramsar obligations where there exists a specific legislative requirement for reporting on the ecological character of listed sites every three years. To date, much of this reporting has been subjective due to the lack of a framework for describing ecological character. In Australia's National Report to 8<sup>th</sup> Meeting of the Conference of the Contracting Parties to the Convention on Wetlands in November 2002, it was recorded that there had been no detected or predicted change in ecological character at Barmah Forest, and that the monitoring of ecological character was planned for this site.

### **Commonalities**

The identified objectives for environmental monitoring were grouped under several ecological indicators to assess commonalities between the policies and plans influencing the management of Barmah Forest (numbers shown in Table 6 refer to the numbering of documents in Table 1).

**Table 6. Ecological indicators for environmental monitoring and the documents in which they are addressed (numbering of documents as per Table 1).**

<b>Ecological indicator</b>	<b>Documents addressing parameter</b>
General flora and fauna objectives (inc. threatened species)	1, 2, 3, 4, 7, 8, 9, 10, 16, 17, 18, 22
Waterbirds	1, 2, 3, 4, 7, 9, 10, 16, 18, 20, 21
Vegetation	1, 2, 3, 4, 6, 7, 8, 10, 12, 16, 17
Water Regime / Flood mapping	1, 2, 3, 6, 7, 8, 9, 10, 13, 18
“Ecological Character”	3, 4, 9, 10, 11, 17, 23
Water Quality	2, 6, 8, 10, 18
Sedimentation/Erosion	1, 4, 6, 8, 10
Fish	3, 4, 6, 10
Grazing	1, 2, 10, 12
Pest Plants and Animals	1, 2, 10, 18
Apiculture	1, 2, 10
Groundwater and Soil Moisture	1, 7, 8
Logging	1, 2, 10
Frogs	3
Turtles	3
Macroinvertebrates	10
Algae	10

## **Ranking of documents**

A considerable number of policies, plans, strategies, agreements and pieces of legislation influence the management of the Barmah Forest. Whilst the brief stipulates the ranking of these documents in terms of levels of *importance*, this task is difficult because it is a value judgement that changes according to the person making that ranking and the scale at which they operate. However, we consider that documents relating to two areas can be considered to be of high priority: those relating to Ramsar obligations given their legal requirement through the EPBC Act, and those relating to The Living Murray given the governmental support and agreement for assigning future environmental water allocations to the Barmah Forest. The Barmah Management Plan (DCE, 1992) and Mid-Murray Forest Management Plan (DNRE, 2002a) are also important documents because they relate specifically to the management of Barmah Forest and have been endorsed by the State Government.

Instead of ranking in importance all documents reviewed, a more reasonable measure of importance may be applied to the ecological indicators being specified within the documents rather than the documents themselves; for example, numerous documents highlight the importance of waterbirds in the Barmah wetland system (Table 6). Based on this rationale, those ecological indicators most referred to in the various documents, and ranked near the top of Table 6 (*e.g.* waterbirds and vegetation), can be considered important for ecological monitoring under current legislation. Hence, these ecological indicators should be afforded priority in being included in a monitoring program if deemed to be suitable indicators for assessing environmental condition. However, this

***Barmah Wetland System Environmental Monitoring Program***

ranking should not necessarily exclude those ecological indicators listed near the bottom of Table 6. For example, frogs, algae and macroinvertebrates may be considered to have characteristics that are responsive and measurable to the application of environmental water and may therefore be particularly useful in assessing the “success” of applications of EWAs.

The ranking of ecological indicators can therefore be considered a guide.

## **Environmental monitoring programs at Barmah Forest**

Note that many environmental monitoring programs undertaken at Barmah Forest also included monitoring of the Millewa Forest. The titles of the individual programs below highlight where monitoring occurred.

### **Current and past environmental monitoring programs**

Environmental investigations at Barmah Forest were reviewed and classified as either research or monitoring as described in the Introduction. Current and past monitoring investigations were evaluated against the criteria listed in Table 7. Current and past monitoring investigations are reported in Tables 8 and 9, respectively (for those with completed progress or final reports), whilst research investigations are listed in Appendix D.

**Barmah Wetland System Environmental Monitoring Program**

**Table 7. Criteria against which past and current monitoring programs were critiqued**

<b>Criteria for assessment</b>	<b>Details</b>
Scientific Rigour	Classified as high, medium or low based on a qualitative assessment of the monitoring methodologies and scientific rigour employed. For example, were experimental objectives/aims/hypotheses defined? Was the experimental design appropriate (e.g. replication and use of experimental controls where appropriate)? Did the methodologies follow quality assurance and quality control procedures? Over what spatial and temporal scales was the monitoring undertaken? An explanation is provided for those monitoring programs not classified as "high".
Relevance to policy and management needs	Listed as "relevant" if the ecological indicator being monitored is listed in Table 6 of Task 1, otherwise "not listed".
Effectiveness	Listed as "effective" if aims/objectives/hypotheses for the study were both listed <i>and</i> addressed, otherwise listed as "not effective". An explanation is provided for those monitoring programs listed as "not effective".

**Table 8. Current environmental monitoring programs at Barmah Forest**

<b>Document</b>	<b>Details</b>	<b>Scientific rigour</b>	<b>Relevance to policy and management needs</b>	<b>Effectiveness</b>
Jones, M. (2004). Effects of environmental flow allocations on the lateral movements of native fish in the Barmah-Millewa Forest. Progress Report to the Barmah-Millewa Forum and Murray-Darling Basin Commission. Arthur Rylah Institute for Environmental Research, Heidelberg.	Examines fish use of offstream areas of Barmah Forest using several techniques including radiotelemetry. This is a progress report highlighting work completed in this monitoring program. Year 2 of a 3 year monitoring program.	High	Relevant	Effective
Bell, T. and Whyte, K. (2004). Barmah-Millewa Annual Report 2003-2004. Report to the Barmah-Millewa Forum. Forest Science Centre, Creswick.	No title for report but this is the Forest Monitoring Study. The study implements the monitoring program of Bren (2001) with several modifications (e.g. increase in number of plots, changes to techniques, loss of certain forest measurables such as fenced/unfenced areas, tree xylem pressure, and aerial mapping). Reports on the installed infrastructure and data collected	High-Low Some parameters defined and measured, others not done (e.g. initial understorey	Relevant	Effective (although report could be clearer in parts).

**Barmah Wetland System Environmental Monitoring Program**

Document	Details	Scientific rigour	Relevance to policy and management needs	Effectiveness
	from May 2003-March 2004. Examines state of trees and crowns, state of soil, state of understorey, biodiversity and several other variables and provides data for some of these.	transects) or appear abandoned (leaf litter traps at some sites).		
King, A., Mahoney, J. and Tonkin, Z. (2004). Assessing the effectiveness of environmental flows on fish recruitment in Barmah-Millewa. 2003/2004 Annual Progress Report. Report to the MDBC and Barmah-Millewa Forum. Arthur Rylah Institute for Environmental Research, Heidelberg.	Report on the first year of a 3 year fish monitoring program at 14 sites across four main habitat types in the Barmah-Millewa Forests. Significant forest flooding occurred during August to early October. Nine native and five introduced species were collected during 2003/04.	High	Relevant	Effective
King, A., Mahoney, J. and Tonkin, Z. (2005). Assessing the effectiveness of environmental flows on fish recruitment in Barmah-Millewa. 2004/2005 Annual Progress Report. Report to the MDBC. Arthur Rylah Institute for Environmental Research, Heidelberg.	Report on the second year of a 3-year monitoring program at 14 sites across four main habitats in the Barmah-Millewa Forests. Methods are principally designed to capture larval and juvenile fish. Two short duration flood events occurred during September and February. Sampled at least monthly from September 2004 – March 2005. Ten native and five introduced species were collected during 2004/05 with Trout Cod being a new captured species from 2003/04. Reports also on some additional research (e.g. electrofishing) in region.	High	Relevant	Effective
SKM (2005). Barmah Forest groundwater monitoring review to May 2004. Report to Goulburn-Murray Water. Sinclair Knight Merz.	Reviews the current groundwater monitoring program at Barmah Forest and assesses the threat of high watertables and salinity. Updates the groundwater monitoring data since last review in 1995. Since 1995 groundwater levels have declined due to dry climatic conditions to May 2004. The current risk of high groundwater levels and associated salinity problems in Barmah Forest is considered to be low. The current monitoring network of 98 bores and the monitoring program is considered adequate.	High	Relevant	Effective

**Barmah Wetland System Environmental Monitoring Program**

Other monitoring and research investigations being undertaken during 2004/05, but for which reports were not available, include:

- Baseline vegetation mapping of Barmah Forest (specialising in understorey communities) 1999-2005 (DSE)
- Continued monitoring of erosion and silt deposition from the Cutting Creek (DSE)
- Continued stream monitoring at hydrologic monitoring stations and within Barmah Forest (MDBC/Thiess/NSW DPI)

**Table 9. Past environmental monitoring programs at Barmah Forest**

Document	Details	Scientific rigour	Relevance to policy and management needs	Effectiveness
Ife, D. (1987). Progress report on the hydrogeology of the Barmah Forest. Rural Water Commission of Victoria. (Published Report)	Provides information on the hydrogeology of Barmah Forest since monitoring commenced there in 1984. Bores were drilled 1984-1987 and water table levels, salinity, soil composition and aquifers recorded. Salinity did not exceed 500uS/cm in any bore and the mean depth to the water table was 10m.	High	Relevant	Effective
Ife, D. (1988). The hydrogeology of the Barmah Forest. Rural Water Commission of Victoria (Published Report)	Provides results of the hydrogeological investigations at Barmah Forest since the commencement of monitoring from bores in 1984. Provides updated water table level since the Ife (1987) progress report and also includes bore hydrographs including data from earlier investigations in some bores (since 1979).	High	Relevant	Effective
Morison, S. (1988). Monitoring of fish and fish habitat during the trial flooding of Barmah Forest December 1988. Report to the State Working Group on River Murray Wetland and Forest Management. Kaiela Fisheries Research Station, Department of Conservation, Forests and Lands, Shepparton. (Published Report)	A trial flooding of Barmah Forest in December 1988 was conducted to assess fish habitat use and water quality. Water quality was poor with blackwater being created with very low dissolved oxygen. Only a single specimen of golden perch, silver perch and freshwater blackfish were captured (single-winged fyke and drum nets) whilst introduced carp, goldfish and redfin (237 specimens) were captured in higher numbers. (Very stark results to recent fish work).	Medium (limited number of sampling days and sites and limited netting types)	Relevant	Effective
HydroTechnology (1995). Groundwater monitoring in the	Provides 10 years of groundwater monitoring data for Barmah and Gunbower Forests. The first bores were	High	Relevant	Effective

**Barmah Wetland System Environmental Monitoring Program**

Document	Details	Scientific rigour	Relevance to policy and management needs	Effectiveness
Barmah and Gunbower Forests – Progress Report to January 1995. HydroTechnology, Tatura. (Published Report)	drilled at Barmah Forest in 1984. Data used to assess the hydrogeology of each system. Groundwater salinities typically less than 1,000uS/cm. Groundwater levels 5-16m below surface. Some chemical analyses of groundwater also reported from 1989 samples.			
McKinnon, L.J. (1997). Monitoring of fish aspects of the flooding of Barmah Forest. Report to the Murray-Darling Basin Commission. Marine and Freshwater Resources Institute, Queenscliff. (Published Report)	Monitored fish aspects in Barmah Forest from 1990-1993. Captured 13 native and 8 introduced fish species and documented a new crayfish ( <i>Cherax</i> ) species. Also monitored water quality, zooplankton and habitat.	High	Relevant	Effective
Ward, P. (2001). Monitoring frog responses to flooding in Barmah Forest 2000/01. Report to the Barmah-Millewa Forum. (Published Report)	A primary site was selected within each Water Management Area of Barmah Forest and frog responses were noted. Nine species were recorded across 34 sites over a six month period.	High	Relevant	Effective
Ward, P. (2002). Monitoring frog response to flooding in Barmah-Millewa Forest: 2001/02. Report to the Barmah-Millewa Forum. (Published Report)	Extended sites to include the Millewa Forest in addition to Barmah Forest.	High	Relevant	Effective
Stuart, I. and Jones, M. (2002). Ecology and management of common carp in the Barmah-Millewa Forest. Report to Agriculture, Fisheries & Forestry Australia. Arthur Rylah Institute for Environmental Research, Heidelberg. (Published Report)	Sampling from August 1999 – August 2001 revealed that Barmah-Millewa Forest is a major point source of carp in the mid-Murray region. Used radio-telemetry and tagging to monitor carp movement and boat electrofishing. Captured eight native and five introduced species at Barmah-Millewa Forest with carp comprising 86% of biomass.	High	Relevant	Effective
Ward, P.A. (2003). Monitoring frog response to flooding in Barmah-Millewa Forest: 2002/03. Final report prepared for the Barmah-Millewa	Monitored frog responses in Barmah-Millewa Forest at most of the 38 routine study sites on six occasions. Also examined an additional 21 sites on up to 6 occasions. Also recorded the distribution of aquatic invertebrates and	High	Relevant	Effective

**Barmah Wetland System Environmental Monitoring Program**

Document	Details	Scientific rigour	Relevance to policy and management needs	Effectiveness
Forum. (Published Report)	small fish captured during dip netting for tadpoles, and water quality. Main flooding event was an extended low level flood Aug-Dec due to transfer of water from Lake Hume to Lake Victoria. Six frog species were recorded.			
Ward, P.A. (2004). Monitoring frog responses to flooding in Barmah-Millewa Forest: 2003/04. Final report prepared for the Barmah-Millewa Forum, Murray-Darling Basin Commission, Canberra. (Published Report)	Frog responses were monitored at Barmah-Millewa Forest at 38 routine study sites on six occasions from July 2003-June 2004. 11 additional sites were added opportunistically and monitored up to four occasions each. Seven frog species were recorded. Invertebrates, small fish and water quality were also measured and nocturnal wildlife observations made.	High	Relevant	Effective
Webster, R. (2004a). The effect of flooding on waterbirds within Barmah-Millewa Forest: 1999-2003. Report to the Barmah-Millewa Forum. Ecosurveys Pty Ltd. (Published Report)	Examined waterbirds at 12 wetlands for the period November 1999-June 2003. This period included two flood years (with EWAs) and two non-flood years. The sites were not in areas where breeding success was greatest for the 2000/01 flood year (see BMF, 2001) or the flooding of Boals Deadwood (see O'Connor and Ward, 2003) but useful information obtained for the 12 wetlands monitored.	High	Relevant	Effective
Webster, R. (2004b). The influence of flooding and drought on bush birds within Barmah-Millewa Forest 1999-2002. Report to the Barmah-Millewa Forum. Ecosurveys Pty Ltd, Deniliquin. (Published Report)	Surveyed bush birds (terrestrial) once per season at 20 x 2ha plots within five habitat types (20 minute surveys) over a 3 year period. A total of 238 individuals from 88 species were recorded from the plots.	High	Not listed (terrestrial birds not listed specifically but may fall within general fauna)	Effective
Jones, M. and Stuart, I. (2004). Impact of flow regulation structures on fish in the Barmah-Millewa forest. Report to the Barmah-Millewa Forum. Arthur Rylah Institute for Environmental Research, Department of Sustainability and Environment, Heidelberg. (Published Report)	Examined fish movement in Barmah-Millewa Forest and effects of regulators (specifically Gulf Creek regulators) on this movement. Fifteen species of fish were sampled from May 2002-May 2003 using electrofishing and netting techniques. Pump-out technique also used and highlighted stranding of fish behind Gulf Creek regulator.	High	Relevant	Effective

**Barmah Wetland System Environmental Monitoring Program**

The Annual Reports of the Barmah-Millewa Forum also highlight the following funded project for which a report has not been obtained:

- Digital elevation mapping of Barmah Forest and part of Hydraulic Model development

**Monitoring of past environmental water allocations**

Monitoring of ecological indicators has occurred during previous allocations of environmental water to the Barmah wetland system. Reports detailing this monitoring are provided in Table 10.

**Table 10. Monitoring of environmental water allocations to Barmah Forest**

Document	Details	Scientific rigour	Relevance to policy and management needs	Effectiveness
Wood, M. and Parsons, M. (1984). Report on the Barmah-Millewa Red Gum Forest watering trial 20 May to 1 June 1984. Rural Water Commission and Forest Commission of Victoria. (Published Report)	A controlled drawdown of Lake Mulwala for maintenance works provided an opportunity to investigate flow at Barmah-Millewa to assess capacity of Barmah Choke following desnagging (not achieved satisfactorily), flow over the levee banks, extent of flooding in Barmah Forest, and effects of this on soil moisture and groundwater levels at a site in the south-west section of Barmah Forest (which did not flood).	Medium (some objectives not achieved)	Relevant	Effective (although some objectives not met)
Maunsell McIntyre Pty Ltd (1999b). Report on the Barmah Millewa flood of October 1998 and the first use of Barmah-Millewa forest allocation. Report to the Barmah-Millewa Forum. Maunsell McIntyre Pty Ltd. (Published Report)	Utilised the Barmah Millewa Environmental Watering Allocation to sustain a flow of around 16,000ML/d in the River Murray (until the 100GL allocation was exhausted) following the recession of the September/October 1998 flood in the Ovens catchment. This is the first use of the allocation and was viewed as a pilot study for this type of trial. The Barmah-Millewa Forum did not set any ecological objectives for the trial although the effects of flooding on the forests and their ecology were observed. Very few waterbirds were observed and no nesting was observed following an aerial inspection on 30 October 1998. Proposes sites for future waterbird and bushbird monitoring.	Low (only general ecological observations made without objectives being set) to High (operating / accounting of water use)	Relevant	Not effective (no ecological objectives set although general observations – e.g. no waterbird breeding - did provide useful information and highlighted knowledge gaps).

**Barmah Wetland System Environmental Monitoring Program**

Document	Details	Scientific rigour	Relevance to policy and management needs	Effectiveness
<p>BMF (2001). Report on Barmah-Millewa Forest flood of spring 2000 and the second use of the Barmah-Millewa Forest environmental water allocation, spring summer 2000 / 2001. Barmah-Millewa Forum. (Published Report).</p>	<p>Used 341 GL of the Barmah-Millewa EWA to (contributing 8% of the total flow passing Yarrowonga from September 2000 to January 2001) to slow the flood recession of two flood events (Ovens River flooding that peaked in September / October 2000 and Hume catchment flooding that peaked in November 2000). Flooding resulted in 85% and 91% inundation of Barmah and Millewa Forests, respectively, and was a one-in-five year event. Monitoring was conducted on forest flooding (field inspections, aerial photography &amp; data loggers recording water temperature and depth), vegetation (general observations only), colonial waterbird breeding and frogs.</p>	<p>High (waterbirds, flow, frogs) to Low (vegetation).</p>	<p>Relevant</p>	<p>Effective</p>
<p>O'Connor, P.G. and Ward, K.A. (2003). Waterbird monitoring in Barmah Forest 2002-2003. Department of Sustainability and Environment, Tatura. (Published Report)</p>	<p>Report focussed on the monitoring of waterbirds and the delivery of the environmental water allocation (EWA) to the Boals Deadwood wetland complex. The EWA was successfully used to maintain water levels in the Boals Deadwood wetland complex (after the flood conditions from water transfer activities had ceased) and allow successful breeding of Sacred Ibis and Royal Spoonbills. Waterbirds were monitored at Boals Deadwood (following aerial observations of waterbird breeding) by walking to the centre of the breeding colonies noting species, abundance and stage of development.</p>	<p>High</p>	<p>Relevant</p>	<p>Effective</p>
<p>Reid, M.A. and Quinn, G.P. (2004). Hydrologic regime and macrophyte assemblages in temporary floodplain wetlands: Implications for detecting responses to environmental water allocations. <i>Wetlands</i> <b>24</b>, 586-599.</p>	<p>Reports on a pilot study at Barmah Forest for the monitoring of environmental water allocations on macrophytes. Five "impact" wetlands (flooding thresholds of 12,000-13,000ML d<sup>-1</sup>) and four "control" wetlands (flooding thresholds 16,000-20,000 ML d<sup>-1</sup>) were selected for a MBACI design (authors argue that terrain effects do not confound results). Collected two years of "before EWA" data although this occurred two months after the release of the 100GL EWA in 1998, and monitoring ceased several months before the release of the 351GL EWA in September 2000-January 2001. Results suggest that macrophyte differences between control and impact sites reflect cumulative effects of flood events over several years</p>	<p>High</p>	<p>Relevant</p>	<p>Effective</p>

## Proposed monitoring programs at Barmah Forest

Several monitoring programs have also been proposed for environmental monitoring at Barmah Forest (Table 11). These have been reviewed and will inform the development of the environmental monitoring program (Part B).

**Table 11. Proposed monitoring programs at Barmah Forest**

<b>Proposed monitoring program</b>	<b>Details</b>
Bren, L., Keatley, M. and Loyn, R. (undated). Design for installation and monitoring of the Forest Transect Study, Barmah-Millewa Forest.	Proposes various transect and plot investigations to monitor vegetation change as well as biodiversity. (Unclear whether implemented – potentially is the basis for the Forest Transect Study currently underway). See Bren (2001).
Reid, M.A. and Brooks, J. (1998). Measuring effectiveness of environmental water allocations: recommendations for the implementation of monitoring programs for adaptive hydrological management of floodplain wetlands in the Murray-Darling Basin. Cooperative Research Centre for Freshwater Ecology.	Specifies preferred indicator types for monitoring EWAs, and also provides a monitoring program for Barmah Forest. See also Reid and Brooks (2000) below.
Maunsell McIntyre Pty Ltd (1999a). Barmah-Millewa Forests Water Management Plan: Business Plan Part 1. Final Report to the Barmah-Millewa Forum. Maunsell McIntyre Pty Ltd, Canberra.	Reviewed in Part A document. Includes a proposal for a monitoring program at Barmah-Millewa Forest. Proposes a numeric flood scoring protocol for determining prioritisation for watering of the different WMAs. Note that the Barmah-Millewa Forum has adopted this protocol in the 2003/04 and 2004/05 years as a second approach to guide water application.
BMF (2000). Barmah-Millewa Forests: Monitoring needs and program. Barmah-Millewa Forum.	Report focuses on developing a monitoring program for the Barmah-Millewa Forest. Examines policy requirements and current monitoring programs and provides a recommended monitoring program with establishment costs and annual running costs.
Reid, M.A. and Brooks, J.J. (2000). Detecting effects of environmental water allocations in wetlands of the Murray-Darling Basin, Australia. <i>Regulated Rivers: Research and Management</i> <b>16</b> , 479-496.	Authors identified physical, chemical and biological hydrologically-sensitive indicators to environmental water allocations as being wetland depth, wetland area and salinity, aquatic macrophytes and associated assemblage characteristics and variables, and aquatic macroinvertebrates. Other potential indicators (where knowledge of relationships between wetland health and indicator response is more limited) include biofilms, zooplankton, birds, fish, mammals, reptiles, amphibians and fringing vegetation.
Bren, L. (2001). Monitoring plan for the Barmah-Millewa Forest. Forest Science Centre, Creswick.	Proposes monitoring for tree and tree-growth, understorey, biodiversity, soil and groundwater, flood, fuel and fuel load. See Bell and Whyte (2004) for first results.
BMF (2002). Barmah-Millewa Forest fish research and monitoring strategy. Barmah Millewa Forum and Murray-Darling Basin Commission, Canberra.	Objective of Strategy is to establish a set of fish research priorities for focus investment in research to underpin improved management of Barmah-Millewa Forest for native fish. Identifies five research and monitoring priorities.

## Ecological indicators not currently monitored

The status of the monitoring of ecological indicators (parameters) at Barmah Forest is provided in Table 12. Current monitoring of some ecological indicators does not necessarily imply that the monitoring program or methodologies used are adequate. Experimental designs for each ecological indicator will be assessed below.

**Table 12. Current status of environmental monitoring at Barmah Forest**

<b>Ecological indicators</b>	<b>Current monitoring status</b>
Fish	✓
Vegetation (Forest Transect Study)	✓
Groundwater	✓
Erosion/Sedimentation	✓
Hydrographic Monitoring	✓
Hydrologic Stream Monitoring	✓
Grazing Effects	✓
Amphibians	Opportunistic
Waterbirds	Opportunistic
Other Aquatic Vertebrates	✗
Bush Birds	✗
Macroinvertebrates	✗
Microinvertebrates	✗
Algae (biofilm/periphyton/phytoplankton)	✗
Water quality	✗
“Ecological Character”	✗ <sup>1</sup>
Pest Plants and Animals	✗ <sup>2</sup>
Apiculture	✗

<sup>1</sup>Whilst the reporting of “ecological character” is an ongoing Ramsar obligation it has been subjective to date; there is no specific monitoring undertaken to determine whether ecological character has been maintained. A framework that defines ecological character has only recently been completed that uses Barmah Forest as an example site (DSE, 2005).

<sup>2</sup>Except *Sagittaria* mapping

## Proposed monitoring programs at other Living Murray SEAs

There are two TLM monitoring programs that are currently being implemented or are proposed for implementation (Table 13), namely *A monitoring system for the Gunbower Forest* (Crome 2004) and *Living Murray icon site wetlands within the Mallee CMA region: monitoring program designs and the 2004-2005 monitoring results* (Scholz *et al.* 2005). Both of these programs are based at River Red Gum dominated floodplain icon sites and therefore are directly relevant to the development of a monitoring program for Barmah Forest.

**Table 13. Status of asset environmental management plans and monitoring programs for Living Murray significant ecological assets (at 4 August 2005).**

Icon site	Management plan	Monitoring program
Chowilla (S.A)	Incomplete	Incomplete
Lindsay/Walpolla (Vic)	Completed	Scholz <i>et al.</i> (2005)
Barmah (Vic)	Completed	<b>This Report</b>
Barmah-Millewa (Vic & NSW)	Completed	Incomplete*
Gunbower (Vic)	Completed	Crome (2004)
Koondrook-Pericoota (NSW)	Incomplete*	Incomplete*
Hattah	Completed	Scholz <i>et al.</i> (2005)
River Murray Channel	Incomplete	Incomplete
Murray Mouth / Coorong / Lower Lakes	Incomplete	Incomplete

\*Awaiting the development of the Victorian component before being developed.

The two programs place different emphasis on the components of their monitoring program (Table 14). Scholz *et al.* (2005) state hypotheses with concise objectives for all components of the monitoring program and have a clear conceptual model of the wetland system on Lindsay-Walpolla Island. It is unclear in the document if the recommendations are to monitor all of the proposed parameters or whether a subset could be selected.

In Crome (2004) the conceptual model used is less clear and the ability of this program to work within an adaptive management framework is less defined. This program promotes the selection of a suite of indicators within each proposed group which are then monitored over a relevant period (for example, fish populations would be monitored every 2 years). This monitoring program is also aimed at monitoring higher trophic levels ignoring invertebrate groups. Surprisingly, it does not include objectives for monitoring water quality.

**Table 14. Summary of proposed ecological indicators and monitoring framework of current monitoring programs**

<b>Ecological indicator / framework</b>	<b>Crome (2004)</b>	<b>Scholz <i>et al.</i> (2005)</b>
Adaptive Management Framework	x	✓
Hypothesis based	x	✓
Flow/Hydrology	✓	✓
Water quality	x	✓
Microinvertebrates	x	✓
Macroinvertebrates	x	✓
Plants	✓	✓
Fish	✓	✓
Birds	✓	✓
Amphibians	✓	✓

In addition to these monitoring programs above, a draft outline of a monitoring program has been made for the Barmah-Millewa SEA (Appendix J of MDBC, 2005). The program is termed an Environmental Performance Evaluation (EPE) and has been devised by the Technical Advisory Committee under instruction from the Coordinating Committee of the Barmah-Millewa SEA. The framework specifies six Environmental Criteria under which Environmental Condition Indicators (ECIs) are determined. Environmental Performance Targets (EPTs) are then specified for each ECI. It was specified that the development of the Barmah Wetland System Environmental Monitoring Program in this brief need not conform to the framework described in Appendix J of MDBC (2005). This consultancy will inform the Victorian Government and elements of it will likely feed into an agreed monitoring framework for the Barmah-Millewa Forest SEA.

## References

- Abuzar, M. (2002). Mapping of floods in the Barmah-Millewa Forests using remote sensing technology. Report to the Barmah-Millewa Forum. Department of Natural Resources and Environment, Tatura.
- Abuzar, M. and Ward, K.A. (2003). Flood and vegetation mapping in the Barmah-Millewa Forests during October-December 2002 using remote sensing technology. Report to the Barmah-Millewa Forum. Department of Primary Industries, Tatura.
- Bacon, P.E., Stone, C., Binns, D.L., Leslie, D.J. and Edwards, D.W. (1993). Relationships between water availability and *Eucalyptus camaldulensis* growth in a riparian forest. *Journal of Hydrology* **150**, 541-561.
- Bell, T. and Whyte, K. (2004). Barmah-Millewa Annual Report 2003-2004. Report to the Barmah-Millewa Forum. Forest Science Centre, Creswick.
- BMF (2000). Barmah-Millewa Forests: Monitoring needs and program. Barmah-Millewa Forum.
- BMF (2001). Report on Barmah-Millewa Forest flood of spring 2000 and the second use of the Barmah-Millewa Forest environmental water allocation, spring summer 2000/2001. Barmah-Millewa Forum.
- BMF (2002). Barmah-Millewa Forest fish research and monitoring strategy. Barmah Millewa Forum and Murray-Darling Basin Commission, Canberra.
- Bonn (1979). Convention on the conservation of migratory species of wild animals. Bonn, Germany. ([http://www.cms.int/documents/convtxt/cms\\_convtxt.htm](http://www.cms.int/documents/convtxt/cms_convtxt.htm) accessed 4 August 2005).
- Bren, L.J. (1987). The duration of inundation in a flooding river red gum forest. *Australian Forestry Research* **17**, 191-202.
- Bren, L.J. (1988a). Effects of river regulation on flooding of a riparian red gum forest on the River Murray, Australia. *Regulated Rivers: Research and Management* **2**, 65-77.
- Bren, L.J. (1988b). Flooding characteristics of a riparian red gum forest. *Australian Forestry* **51**, 57-62.
- Bren, L.J. (1992). Tree invasion of an intermittent wetland in relation to changes in the flooding frequency of the River Murray, Australia. *Australian Journal of Ecology* **17**, 395-408.
- Bren, L. (2001). Monitoring plan for the Barmah-Millewa Forest. Forest Science Centre, University of Melbourne, Creswick, Victoria.
- Bren, L. and Acenolaza, P. (2002). Impact of burning on red gum regeneration on Moira Grass plains in Barmah Forest. Department of Forestry, University of Melbourne, Creswick.

## ***Barmah Wetland System Environmental Monitoring Program***

Bren, L.J. and Gibbs, N.L. (1986). Relationships between flood frequency, vegetation and topography in a River Red Gum forest. *Australian Forestry Research* **16**, 357-370.

Bren, L.J., Gibbs, N.L. and O'Neill, I.C. (1988a). Changes in the flooding characteristics of the Barmah Forest as a result of the combined river regulation from Hume and Dartmouth dams. In *The hydrology of the Barmah River Red Gum Forests: A collection of works undertaken from 1984-1988*. Forestry Section, University of Melbourne.

Bren, L.J., Gibbs, N.L. and O'Neill, I.C. (1988b). The contribution of River Murray tributaries to the flooding of Barmah Forest. In *The hydrology of the Barmah River Red Gum Forests: A collection of works undertaken from 1984-1988*. Forestry Section, University of Melbourne.

Bren, L.J., Gibbs, N.L. and O'Neill, I.C. (1988c). Soil moisture and groundwater studies in the Barmah Forest. In *The hydrology of the Barmah River Red Gum Forests: A collection of works undertaken from 1984-1988*. Forestry Section, University of Melbourne.

Bren, L., Keatley, M. and Loyn, R. (undated). Design for installation and monitoring of the forest transect study, Barmah-Millewa Forest. FORAD, University of Melbourne, Victoria.

Bren, L.J., O'Neill, I.C. and Gibbs, N.L. (1987). Flooding in the Barmah Forest and its relation to flow in the Murray-Edward River system. *Australian Forestry Research* **17**, 127-144.

Brown, P.R. (1981). Report on the reptiles and amphibians of the Barmah State Forest and the Maramingo and Reedy Creek pulpwood demonstration areas. Unpublished Report.

CAMBA (1986). Agreement between the Government of Australia and the Government of the People's Republic of China for the protection of migratory birds and their environment. Australian Treaty Series 1988 No. 22.

CFL (1986). Defoliation of River Red Gums by gum leaf skeletoniser. Information Notes from the Von Mueller Institute, State Forests and Lands Service, Conservation, Forests and Lands, Victoria.

CFL (1990). Proposed Barmah Management Plan. Department of Conservation, Forests and Lands, Melbourne.

Chesterfield, E.A. (1986). Changes in the vegetation of the river red gum forest at Barmah, Victoria. *Australian Forestry* **49**, 4-15.

Chesterfield, E.A., Loyn, R.H. and Macfarlane, M.A. (1984). Flora and fauna of Barmah State Forest and their management. Forestry Commission of Victoria Research Branch Report 240. Unpublished Report.

Chisholm, L. and Stone, C. (2003). Ground calibration of River Red Gum (*Eucalyptus camaldulensis*) health associated with airborne video imagery. Report to the Barmah-Millewa Forum.

## ***Barmah Wetland System Environmental Monitoring Program***

CRG (1994). Final report on Barmah-Millewa Forest water management plan (WMP) from a local community reference group (CRG). Report to the Murray-Darling Basin Commission, Canberra. ISBN 0-642-21255-4.

Crome, F. (2004). A monitoring system for the Gunbower Forest. Report to the North Central Catchment Management Authority. Francis Crome Pty Ltd.

Crook, D. (2004). Contribution of the Barmah-Millewa floodplain lakes to carp populations in the mid-River Murray. Final report to the Barmah Millewa Forum. Arthur Rylah Institute for Environmental Research, Department of Sustainability and Environment, Heidelberg, Victoria.

DCE (1992). Management plan for Barmah State Park and Barmah State Forest. Department of Conservation and Environment, Victoria. ISBN 0 7306 2248 7.

DEH (2005). Australian Heritage Database. Department of Environment and Heritage. (<http://www.deh.gov.au/cgi-bin/ahdb/search.pl> accessed 23 June 2005).

Dexter, B.D. (1967). Flooding and regeneration of River Red Gum, *Eucalyptus camaldulensis*, Dehn. Bulletin No. 20. Forest Commission of Victoria, Melbourne.

Dexter, B.D. (1978). Silviculture of the river red gum forests of the Central Murray floodplain. *Proceedings of the Royal Society of Victoria* **90**, 175-191.

Dexter, B.D., Rose, H.J. and Davies, N. (1986). River regulation and associated forest management problems in the River Murray red gum forests. *Australian Forestry* **49**, 16-27.

DNRE (2002a). Mid-Murray Forest Management Plan. Department of Natural Resources and Environment, Victoria.

DNRE (2002b). Management of Victoria's Ramsar wetlands: Strategic Directions Statement. Department of Natural Resources and Environment, Victoria.

DSE (2003). Barmah Forest Ramsar Site: Strategic Management Plan. Department of Sustainability and Environment, Melbourne, Victoria.

DSE (2004). Victoria's Biodiversity – Directions in Management. Department of Sustainability and Environment, Victoria.

DSE (2005). Framework for describing the ecological character of Ramsar wetlands: Including a description of the ecological character of the Barmah Forest Ramsar Site. Department of Sustainability and Environment, Melbourne, Victoria.

DSE and GBCMA (2005). Asset Environmental Management Plan: Barmah Significant Ecological Asset. Department of Sustainability and Environment, Victoria and Goulburn Broken Catchment Management Authority, Shepparton (version 11 May 2005).

EA (1997). The Wetlands Policy of the Commonwealth Government of Australia. Environment Australia, Canberra.

## ***Barmah Wetland System Environmental Monitoring Program***

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

Eyles, D. (2004). Understanding fire effects in River Red Gum forest. Department of Sustainability and Environment.

Floodplain Ecology Group (1996). Collated water quality data from Smiths Creek, Barmah Forest 1990-1995. Kaiela Research Station, Department of Conservation and Natural Resources, Shepparton.

Frood, D. and Ward, K. (2001). Mapping of the understorey vegetation in Barmah Forest, Victoria. Report to the Barmah-Millewa Forum.

GBCMA (2003). Goulburn Broken Regional Catchment Strategy. Goulburn Broken Catchment Management Authority, Shepparton, Victoria.

Harris, J.A. (1972). The effect of flooding on population density of the gum leaf skeltonizer moth *Uraba jugens* Walk., in Barmah State Forest. Research Branch Report No. 25, Forest Commission, Victoria.

Howell, M. and McLennan, R. (2002). Wetlands Directions Paper for the Goulburn Broken Catchment. Report to the Goulburn Broken Catchment Management Authority. GBCMA and Rod McLennan & Associates.

Howitt, J., Baldwin, D. and Rees, G. (2004). Blackwater model: A computer model to predict dissolved oxygen and dissolved carbon downstream of Barmah-Millewa Forest following a flood. Report to the Barmah-Millewa Forum. Murray-Darling Freshwater Research Centre, Albury.

HydroTechnology (1995). Groundwater monitoring in the Barmah and Gunbower Forests – Progress report to January 1995. HydroTechnology, Tatura.

Ife, D. (1987). Progress report on the hydrogeology of the Barmah Forest. Rural Water Commission of Victoria.

Ife, D. (1988). The hydrogeology of the Barmah Forest. Investigations Report No. 1988/32. Investigations Branch, Rural Water Commission of Victoria.

JAMBA (1974). Agreement between the Government of Australia and the Government of Japan for the protection of migratory birds in danger of extinction and their environment. Australian Treaty Series 1981 No. 6.

Jones, M. (2004). Effects of environmental flow allocations on the lateral movements of native fish in the Barmah-Millewa Forest. Progress Report to the Barmah-Millewa Forum and Murray-Darling Basin Commission. Arthur Rylah Institute for Environmental Research, Heidelberg.

Jones, M. and Stuart, I. (2004). Impact of flow regulation structures on fish in the Barmah-Millewa forest. Report to the Barmah-Millewa Forum. Arthur Rylah Institute for Environmental Research, Department of Sustainability and Environment, Heidelberg.

## ***Barmah Wetland System Environmental Monitoring Program***

King, A., Mahoney, J. and Tonkin, Z. (2004). Assessing the effectiveness of environmental flows on fish recruitment in Barmah-Millewa. 2003/2004 Annual Progress Report. Report to the MDBC and Barmah-Millewa Forum. Arthur Rylah Institute for Environmental Research, Heidelberg.

King, A., Mahoney, J. and Tonkin, Z. (2005). Assessing the effectiveness of environmental flows on fish recruitment in Barmah-Millewa. 2004/2005 Annual Progress Report. Report to the MDBC. Arthur Rylah Institute for Environmental Research, Heidelberg.

LCC (1985). Murray Valley Area Final Recommendations. Land Conservation Council, Victoria.

Leslie, D. (2001). Effect of river management on colonially-nesting waterbirds in the Barmah-Millewa Forest, south-eastern Australia. *Regulated Rivers: Research and Management* **17**, 21-36.

Loyn, R.H., Lumsden, L. and Ward, K.A. (2002). Vertebrate fauna of Barmah Forest, a large forest of River Red Gum *Eucalyptus camaldulensis* on the floodplain of the Murray River. *Victorian Naturalist* **119**, 114-132.

Mac Nally, R., Ballinger, A. and Horrocks, G. (2002). Habitat change in River Red Gum floodplains: Depletion of fallen timber and impacts on biodiversity. *Victorian Naturalist* **119**, 107-113.

Maunsell Australia Pty Ltd (2003). Development of a hydraulic model of the Gulf water management area in the Barmah Forest. Report to the Barmah-Millewa Forum. Maunsell Australia Pty Ltd, Canberra.

Maunsell McIntyre Pty Ltd (1999a). Barmah-Millewa Forests Water Management Plan: Business Plan Part 1. Final Report to the Barmah-Millewa Forum. Maunsell McIntyre Pty Ltd, Canberra.

Maunsell McIntyre Pty Ltd (1999b). Report on the Barmah Millewa flood of October 1998 and the first use of Barmah-Millewa Forest allocation. Report to the Barmah-Millewa Forum. Maunsell McIntyre Pty Ltd.

Maunsell Pty Ltd (1992). Barmah Millewa Forests Water Management Plan. Report to the Murray-Darling Basin Commission. Maunsell Pty Ltd, Canberra.

McKinnon, L.J. (1997). Monitoring of fish aspects of the flooding of Barmah Forest. Report to the Murray-Darling Basin Commission. Marine and Freshwater Resources Institute, Queenscliff.

MDBC (2005). Barmah-Millewa Forest Significant Ecological Asset: Asset Environmental Management Plan 2005-2006. Draft 22 July 2005.

MDBC and BMF (2000). The Barmah-Millewa Forest Water Management Strategy. Murray-Darling Basin Commission and the Barmah Millewa Forum.

MDBMC (2003). Murray-Darling Basin Ministerial Council Communique.

## ***Barmah Wetland System Environmental Monitoring Program***

Morison, S. (1988). Monitoring of fish and fish habitat during the trial flooding of Barmah Forest December 1988. Report to the State Working Group on River Murray Wetland and Forest Management. Kaiela Fisheries Research Station, Department of Conservation Forests and Lands, Shepparton.

MWEC (1997). Sharing the Murray: Proposal for defining people's entitlements to Victoria's water from the Murray. Murray Water Entitlement Committee, Victoria.

O'Connor, P.G. and Ward, K.A. (2003). Waterbird monitoring in Barmah Forest 2002-2003. Department of Sustainability and Environment, Tatura.

Pamminger, F. (1986). Report on the October-November 1986 flooding of the Barmah Millewa Red Gum Forest. Floodplain Management Unit, Rural Water Commission of Victoria.

Reid, M.A. and Brooks, J. (1998). Measuring the effectiveness of environmental water allocations: Recommendations for the implementation of monitoring programs for adaptive hydrological management of floodplain wetlands in the Murray-Darling Basin. Report to the Murray-Darling Basin Commission. Cooperative Research Centre for Freshwater Ecology.

Reid, M.A. and Brooks, J.J. (2000). Detecting effects of environmental water allocations in wetlands of the Murray-Darling Basin, Australia. *Regulated Rivers: Research and Management* **16**, 479-496.

Reid, M.A. and Quinn, G.P. (2004). Hydrologic regime and macrophyte assemblages in temporary floodplain wetlands: Implications for detecting responses to environmental water allocations. *Wetlands* **24**, 586-599.

Scholz, O., Meredith, S., Sutor, L., Keating, R. and Ho, S. (2005). Living Murray icon site wetlands within the Mallee CMA region: Monitoring program designs and 2004-05 monitoring results. Report to the Mallee Catchment Management Authority. Murray-Darling Freshwater Research Centre, Mildura.

Silvers, L. (1993). The effects of grazing on fuel loads and vegetation in the Barmah Forest, Victoria. Honours Thesis. Charles Sturt University.

SKM (2005). Barmah Forest groundwater monitoring review to May 2004. Report to Goulburn-Murray Water. Sinclair Knight Merz.

Souter, N.J. (1996). The impact of channel outfall drainage on the water quality and benthic macroinvertebrate fauna of Smiths Creek, Barmah Forest. Floodplain Ecology Group, Kaiela Research Station, Department of Conservation and Natural Resources.

Stuart, I. and Jones, M. (2002). Ecology and management of common carp in the Barmah-Millewa Forest. Report to Agriculture, Fisheries & Forestry Australia. Arthur Rylah Institute for Environmental Research, Heidelberg.

## ***Barmah Wetland System Environmental Monitoring Program***

Thoms, M.C. (1995). The impact of catchment development on a semiarid wetland complex: the Barmah Forest, Australia. *Man's Influence on Freshwater Ecosystems and Water Use* **230**, 121-130.

Thoms, M.C. and Walker, K.F. (1990). Sedimentation in Barmah Forest. River Murray Laboratory, University of Adelaide.

Ward, K.A. (1991). Investigation of the flood requirements of the Moira Grass plains in Barmah Forest, Victoria. IWS Report No. 1. Floodplain Ecology Group, Department of Conservation and Environment, Benalla.

Ward, K.A. (1994a). Flooding requirements of vegetation communities in Barmah Forest, Victoria. IWS Report No. 10. Department of Conservation and Environment, Shepparton.

Ward, K.A. (1994b). The effect of trial flooding on the understorey vegetation in Gulpa Island State Forest, New South Wales. IWS Report No. 11. Department of Conservation and Environment, Shepparton.

Ward, K.A. (1994c). Flood requirements of the wetland flora in Barmah Forest, Victoria. Draft Report. Floodplain Ecology Group, Department of Conservation and Natural Resources, Shepparton.

Ward, K.A., Leitch, C., Lloyd, L.N. and Atkins, B.P. (1994). Interim Water Management Strategy for Barmah Forest, Victoria. Floodplain Ecology Group, Department of Conservation and Natural Resources, Shepparton.

Ward, P. (2001). Monitoring frog responses to flooding in Barmah Forest 2000/01. Report to the Barmah-Millewa Forum.

Ward, P. (2002). Monitoring frog response to flooding in Barmah-Millewa Forest: 2001/02. Report to the Barmah-Millewa Forum.

Ward, P.A. (2003). Monitoring frog response to flooding in Barmah-Millewa Forest: 2002/03. Final report prepared for the Barmah-Millewa Forum.

Ward, P.A. (2004). Monitoring frog responses to flooding in Barmah-Millewa Forest: 2003/04. Final report prepared for the Barmah-Millewa Forum, Murray-Darling Basin Commission, Canberra.

Webster, R. (2004a). The effect of flooding on waterbirds within Barmah-Millewa Forest: 1999-2003. Report to the Barmah-Millewa Forum. Ecosurveys Pty Ltd.

Webster, R. (2004b). The influence of flooding and drought on bush birds within Barmah-Millewa Forest 1999-2002. Report to the Barmah-Millewa Forum. Ecosurveys Pty Ltd, Deniliquin.

Wood, M. and Parsons, M. (1984). Report on the Barmah-Millewa Red Gum forest watering trial 20 May to 1 June 1984. Rural Water Commission and Forest Commission of Victoria.

## **Appendices**

### **Appendix A. Tasks of the consultant brief for the Barmah Wetland System Environmental Monitoring Program.**

In consultation with GBCMA staff, the consultant is to undertake and report on the following tasks:

#### **Task 1**

(i). Conduct a search of available literature to determine current policy and management requirements for environmental monitoring in Barmah Wetland and:

- list any identified ecological objectives and targets;
- identify data needs for reporting; and
- identify any commonalities.

(ii). Rank the importance of the current policy and management requirements for environmental monitoring in Barmah Wetland at local, regional, state and national scales.

#### **Task 2**

(i). Assess and document the scientific rigour, relevance to policy and management needs identified in Task 1 and effectiveness of past and current environmental monitoring programs in Barmah Wetland.

(ii). Identify any important physical or biological parameters that are not currently monitored in Barmah Wetland as part of an environmental monitoring program.

(iii). Review current and proposed environmental monitoring programs at Millewa Forest (the New South Wales component of the Barmah-Millewa Forest) and the other five Significant Ecological Assets (Gunbower, including Pericoota-Kondrook Forest; Hattah Lakes; Chowilla Floodplain, including Lindsay and Walpolla Islands; Murray Mouth, Coorong and Lower Lakes; and the River Murray Channel) to identify their transferability and applicability to Barmah Wetland.

#### **Task 3**

(i). In line with the State Government's vision for Barmah Wetland and the priority policy and management requirements for environmental monitoring in Barmah Wetland identified in Task 1, define the scope of the Barmah Wetland environmental monitoring program and its ecological objectives and targets.

(ii). Compare the suitability of different scientifically accepted monitoring options to determine whether the ecological objectives and targets identified above have been met.

#### **Task 4**

(i). Convene a scientific panel comprising experts in floodplain ecology and environmental monitoring to review the Barmah Wetland environmental monitoring program.

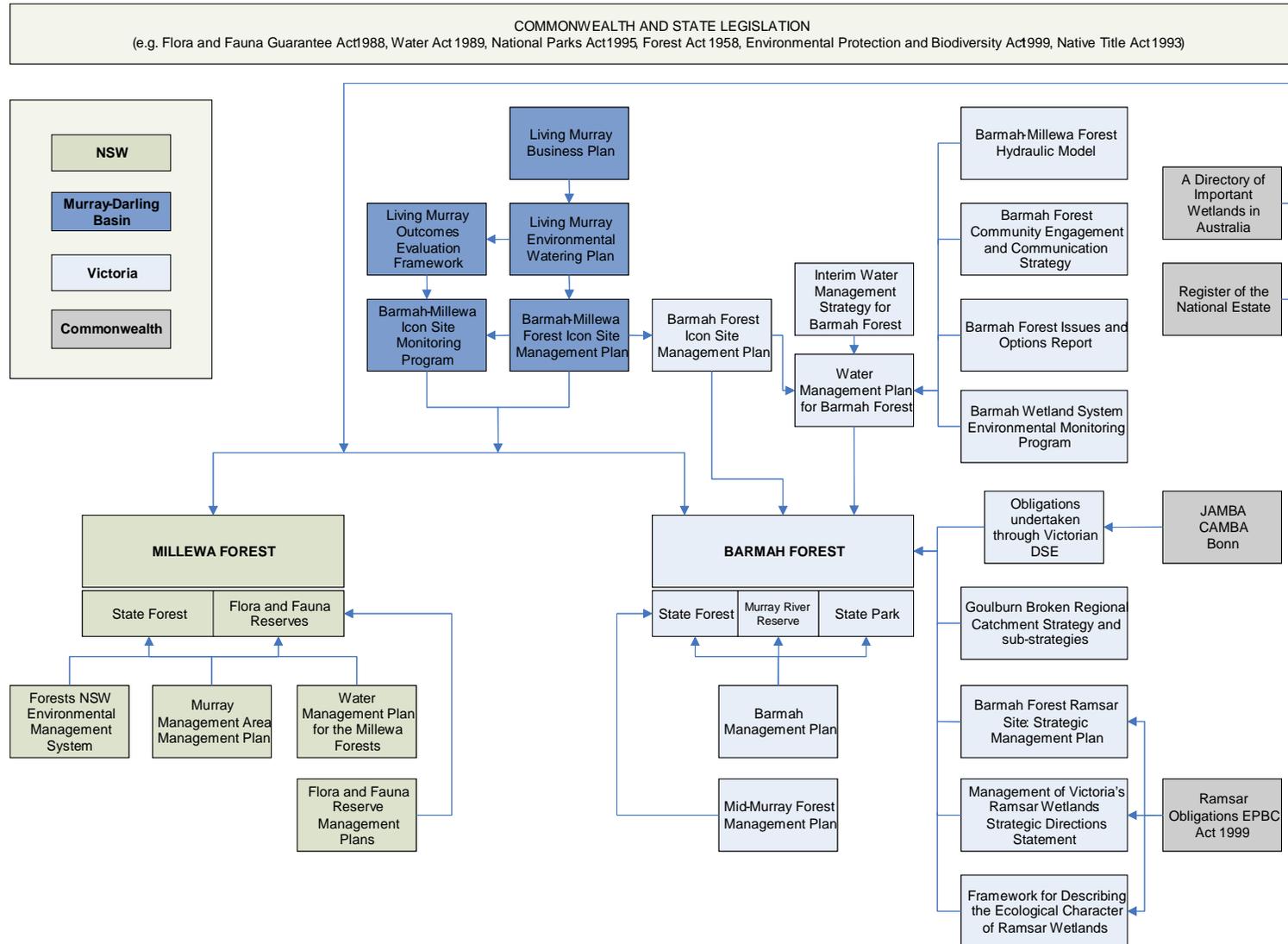
#### **Task 5**

(i). Develop an ongoing environmental monitoring program for Barmah Wetland that:

- incorporates adaptive management principles;
- meets current policy and management requirements (Task 1);
- builds on or is consistent with existing monitoring programs where applicable (Task 2);
- uses scientifically accepted methods;
- is flexible so that new variables can be incorporated as our understanding of the ecosystem improves; and is cost and time efficient.

**Barmah Wetland System Environmental Monitoring Program**

**Appendix B. Diagram highlighting key documents and jurisdictional arrangements influencing the management of Barmah Forest.**



**Appendix C. Actions for further studies involving environmental monitoring from the Barmah Management Plan (DCE, 1992).**

<b>Actions</b>	<b>Priority</b>
<b>Water and wetlands</b>	
Experiment with small barriers across drainage channels to aid spread and retention of water in Boals Deadwoods.	High
Develop and maintain a record of the location and extent of each major wetland type and species, with priority given to the key wetlands at Top Island, Boals Deadwoods, Reedy Lakes and War Plain.	High
Establish procedures for monitoring, reporting and recording water quality and depth, changes in distribution of wetland flora, and the types, numbers and breeding success of water birds.	High
Using funds provided by the Murray Darling Basin Commission, monitor water quality and depth, wetland productivity, wetland flora and fauna, and fish populations. Coordinate this monitoring with other monitoring and research proposed in this Plan.	High
Assist the investigation funded by the Murray Darling Basin Commission to determine the most appropriate method(s) of overcoming the adverse effects of altered water regimes. Incorporate the results of this study into a supplement to this Management Plan.	High
Liaise with the Murray Darling Freshwater Research Centre, Murray Darling Basin Commission, NSW Maritime Services Board and NSW Department of Lands to investigate bank erosion along the Murray River.	Medium
Encourage research into the rate and mechanisms of sediment deposition in the forest	Medium
Examine the feasibility and desirability of undertaking localised excavations in wetlands to improve diversity of habitat for waterbirds.	Medium
Continue to keep a map record of the extent of flooding in the forest.	Ongoing
Liaise with Rural Water Commission and Melbourne University to monitor groundwater levels and movements in and around the forest.	Ongoing
<b>Flora</b>	
Determine specific locations and population sizes of all significant species and maintain a register of this information.	High
Determine distribution and conservation status of Upright Sunray ( <i>Helipterum strictum</i> ), Rish ( <i>Juncus</i> sp. 'O'), and Fairy Spectables ( <i>Menkea crassa</i> ).	High
Prepare improved management prescriptions for significant plants based on detailed ecological study.	Medium
Monitor populations of rare plants at Machonics and Tongalong Ridges, and if necessary institute conservation measures.	Ongoing
Monitor populations of significant plants in Goose Swamp.	Ongoing
Monitor vegetation communities in depressions and floodways and determine the effect of the proposals outlined in Section 5.1.	Ongoing
Monitor encroachment of Moira Grass plains ( <i>Pseudoraphis spinescens</i> ) by rushes and River Red Gum ( <i>Eucalyptus camaldulensis</i> ).	Ongoing
Monitor the extent of Cumbungi ( <i>Typha orientalis</i> ), Common Reed ( <i>Phragmites australis</i> ) and Giant Rush ( <i>Juncus ingens</i> ).	Ongoing
Monitor populations of significant plant species (Table 3), especially with respect to grazing and water regimes (where relevant).	Ongoing
Develop appropriate management actions for any further species identified, through further survey or taxonomic revision, as rare or endangered.	As needed
<b>Fauna</b>	

## Barmah Wetland System Environmental Monitoring Program

<b>Actions</b>	<b>Priority</b>
Conduct surveys to determine whether the Tiger Quoll ( <i>Dasyurus maculatus</i> ) and an unidentified small macropod are present in the forest.	High
Determine locations of nest trees of Superb Parrot ( <i>Polytelis swainsonii</i> ) and determine the importance of box ridges to the species.	High
Encourage systematic survey of reptiles in the forest, and determine the distribution of the Hooded Scaly-foot ( <i>Pygopus nigriceps</i> ) and Carpet Python ( <i>Python spilota variegata</i> ) and whether the Curl Snake ( <i>Suta suta</i> ) and Bandy Bandy ( <i>Vermicella annulata</i> ) are present in the forest.	Medium
Undertake surveys to determine the importance of Barmah Forest for native fish, and investigate favoured water regimes.	Medium
Assess status of Regent Honeyeater ( <i>Xanthomyza phrygia</i> ) and Bush Thick-knee ( <i>Burhinus magnirostris</i> ) in the forest.	Low
Encourage further general surveys of fauna, including invertebrates, and research into the biology and habitat requirements of fauna.	Low
Monitor populations of the Squirrel Glider ( <i>Petaurus norfolcensis</i> ), Tuan ( <i>Phascogale tapoatafa</i> ), Koala ( <i>Phascolarctos cinereus</i> ), Superb Parrot and Eastern Grey Kangaroo ( <i>Macropus giganteus</i> ).	Ongoing
<b>Reference areas</b>	
Undertake a comprehensive survey of the flora and fauna in the Reference Areas and establish an ongoing monitoring program.	High
Prepare Reference Area Management Plans for Top Island and Top End Reference Areas.	Medium
<b>Timber</b>	
Encourage further silvicultural research on topics such as thinning, regeneration, culling unmerchantable trees, and harvesting techniques.	Medium
Encourage research into the effects of timber harvesting on native flora and fauna, and improve management prescriptions as further information becomes available.	Medium
<b>Grazing</b>	
Undertake a research project to assess the effects of cattle on wetlands, native plants, especially those on box ridges, weeds and fuel load and the effects of winter grazing.	High
Monitor the effects of cattle on significant plant species	Ongoing
<b>Apiculture</b>	
Encourage research into the effects of introduced bees on native flora and fauna	Ongoing
<b>Recreation</b>	
Include in the investigation into bank erosion an assessment of the impact of power boats.	Medium
Monitor the use and impact of power boats on wetlands within the forest.	Ongoing
<b>Pests and other threats</b>	
Investigate the opportunities for using the Bradley Method to eradicate introduced species from box ridges.	Medium
Develop strategies to minimise damage to native flora from over-grazing during periods of drought or extended flooding.	Medium
Determine the size of the forest's pig population.	Medium
Monitor weed populations and the effectiveness of control measures.	Ongoing
Monitor populations of pest animals.	Ongoing
Monitor activity of the Gum-leaf Skeletoniser ( <i>Uraba lugens</i> ).	Ongoing
Monitor mistletoe infestations of River Red Gum in State Forest	Ongoing
Conduct tests for Cinnamon Fungus ( <i>Phytophthora cinnamoni</i> )	As needed

**Appendix D. Research investigations conducted at Barmah Forest.**

These documents were reviewed as part of this project but not considered part of an environmental monitoring program. Documents were grouped by main parameter (note that some documents investigated several parameters). These research documents may also inform the development of the monitoring program.

<b>Author and title of research</b>	<b>Document</b>
<b>Vegetation</b>	
Dexter, B.D. (1967). Flooding and regeneration of River Red Gum, <i>Eucalyptus camaldulensis</i> , Dehn. Bulletin No. 20. Forest Commission of Victoria, Melbourne. (Determines environmental factors influencing germination and survival of River Red Gum based on investigations at Barmah State Forest. Germination of River Red Gum is most prolific following flood recession in spring. Also states that cattle assist River Red Gum establishment through the grazing of competing weeds and grasses).	Published Report
Dexter, B.D. (1978). Siviculture of the river red gum forests of the Central Murray floodplain. <i>Proceedings of the Royal Society of Victoria</i> <b>90</b> , 175-191. (Published results stemming from Dexter (1969). Soil moisture and seed-bed conditions are the main determinants in River Red Gum seeding establishment particularly in upon flood recession in spring. Highlights greatest threat is reduced extent and frequency of appropriately timed flooding due to river regulation).	Published Paper
Chesterfield, E.A., Loyn, R.H. and Macfarlane, M.A. (1984). Flora and fauna of Barmah State Forest and their management. Forestry Commission of Victoria Research Branch Report 240. (Considers the flora and fauna of Barmah State Forest in relation to harvesting of timber, grazing and altered flood regimes. Observations made between 1977-1980. Variables of focus include <b>vegetation</b> (>400 species recorded), <b>mammals</b> (26 species recorded) and <b>waterbirds</b> ).	Unpublished Report
Bren, L.J. and Gibbs, N.L. (1986). Relationships between flood frequency, vegetation and topography in a River Red Gum forest. <i>Australian Forestry Research</i> <b>16</b> , 357-370. (Investigates interrelations between <b>vegetation</b> type, forest site quality, topographic position and <b>flood frequency</b> at Barmah Forest using a 22 year sequence (1963-1984) of maps showing annual extent of flooding).	Published Paper
Chesterfield, E.A. (1986). Changes in the vegetation of the river red gum forest at Barmah, Victoria. <i>Australian Forestry</i> <b>49</b> , 4-15. (Effects of river regulation were one of four factors influencing vegetation changes. Changes were deduced from historical and recent evidence. Health of trees affected, area of grassland reduced with areas of Moira grass, common reed and/or cumbungi now covered with river red gum forest of beds of giant rush.)	Published Paper
Bren, L.J. (1988a). Effects of river regulation on flooding of a riparian Red Gum forest on the River Murray, Australia. <i>Regulated Rivers: Research and Management</i> <b>2</b> , 65-77. (Examines relationships between Barmah Forest <b>inundation</b> , River Murray <b>discharge</b> , distribution of <b>vegetation</b> and <b>River Red Gum</b> site quality.)	Published Paper
Ward, K.A. (1991). Investigation of the flood requirements of the Moira Grass plains in Barmah Forest, Victoria. IWS Report No. 1. Floodplain Ecology Group, Department of Conservation and Environment, Benalla. (Examines flooding requirements of Moira Grass plains, of which half have been lost in the past 50 years due primarily to changes to the flow regime. Uses experimental flooding ponds, observational transects, hydrological monitoring of an artificial flooding trial and the effects of grazing and soil type on Moira Grass distribution in 1990-1991 to assess flooding requirements and allow an appropriate water management prescription).	Published Report

## Barmah Wetland System Environmental Monitoring Program

Author and title of research	Document
Bren, L.J. (1992). Tree invasion of an intermittent wetland in relation to changes in the flooding frequency of the River Murray, Australia. <i>Australian Journal of Ecology</i> <b>17</b> , 395-408. (Documents the encroachment of River Red Gum onto Moira grasslands based on historical aerial photographs. Attributes these changes to altered water regime through river regulation and uses simulations that predict the loss of these grass plains under current water regimes).	Published Paper
Silvers, L. (1993). The effects of grazing on fuel loads and vegetation in the Barmah Forest, Victoria. Honours Thesis, Charles Sturt University. (Used fencing in different vegetation communities of Barmah State Park and Barmah State Forest to exclude particular grazers. Showed that some grazers were important for reducing fuel loads in some vegetation types).	Honours Thesis
Bacon, P.E., Stone, C., Binns, D.L., Leslie, D.J. and Edwards, D.W. (1993). Relationships between water availability and <i>Eucalyptus camaldulensis</i> growth in a riparian forest. <i>Journal of Hydrology</i> <b>150</b> , 541-561. (Established twelve 0.8ha River Red Gum plots in Millewa Forest and applied four flooding regimes within the flood runners. For those two plots not underlain by a shallow aquifer, flooding increased significantly the xylem potential pressure and this extended to trees up to 22.5-37.5m from the floodwater. Leaf area and relative growth rates of trees up to 22.5m from the floodwater increased with more regular flooding. Concluded that short-term flooding temporarily increased tree moisture status and resulted in increased tree growth rates up to 70%).	Published Paper
Ward, K.A. (1994c). Flood requirements of the wetland flora in Barmah Forest, Victoria. Floodplain Ecology Group, Department of Conservation and Natural Resources, Shepparton. (Investigates flood requirements for the wetland vegetation communities of Barmah Forest from 1991-1992).	Unpublished Report
Flood, D. and Ward, K. (2001). Mapping of the understorey vegetation in Barmah Forest, Victoria. Report to the Barmah-Millewa Forum. (Defines 66 map units for Barmah Forest. Also relates these to the map units defined by Chesterfield et al. (1983)).	Unpublished Report
Bren, L. and Acenolaza, P. (2002). Impact of burning on Red Gum regeneration on Moira Grass plains in Barmah Forest. Department of Forestry, University of Melbourne, Creswick. (Experiment reintroduced burning of plots of Moira Grass Plain to assess whether fire would kill young River Red Gum plants. Most seedlings were killed by the fire but seedlings at one site survived. Forest flooding during the trial killed all red gum seedlings in burnt and unburnt plots with the exception of one more elevated plot).	Published Report
Mac Nally, R., Ballinger, A. and Horrocks, G. (2002). Habitat change in River Red Gum floodplains: Depletion of fallen timber and impacts on biodiversity. <i>Victorian Naturalist</i> <b>119</b> , 107-113. (Estimates of fallen timber were made in the River Red Gum floodplain forests of the southern Murray Darling Basin. Contemporary fallen timber loads are estimated at around 16% (around 19 tonnes/ha) of the loads prior to European settlement. Loads in Barmah Forest were around 24 tonnes/ha. The relationship between timber loads and biodiversity (both vertebrates and invertebrates) was investigated and the authors indicate that loads of at least twice current levels (restoration targets of 40-50 tonnes/ha) would exert a positive influence on a number of ecologically critical species).	Published Paper
Abuzar, M. and Ward, K.A. (2003). Flood and vegetation mapping in the Barmah-Millewa Forests during October-December 2002 using remote sensing technology. Report to the Barmah-Millewa Forum. Department of Primary Industries, Tatura. (Used remotely-sensed satellite data to map the flood and vegetation status in the Barmah-Millewa Forests during October – December 2002 during a period a sustained high release flows).	Published Report
Chisholm, L. and Stone, C. (2003). Ground calibration of River Red Gum ( <i>Eucalyptus camaldulensis</i> ) health associated with <b>airborne video imagery</b> . Report to the Barmah-Millewa Forum. (Obtained a range of morphological and physiological measures of River Red Gum to determine health levels of trees. Optical filters fitted to an airborne video system successfully produced a three-category canopy moisture stress map. The technology has potential for assessing forest condition and changes due to water allocations).	Published Report

**Barmah Wetland System Environmental Monitoring Program**

<b>Author and title of research</b>	<b>Document</b>
Eyles, D. (2004). Understanding fire effects in River Red Gum forest. (Reviews the effects of fire in Barmah Forest).	Published Report
<b>Waterbirds</b>	
Leslie, D. (2001). Effect of river management on colonially-nesting waterbirds in the Barmah-Millewa Forest, south-eastern Australia. <i>Regulated Rivers: Research and Management</i> <b>17</b> , 21-36. (Established relationship between reproductive performance of colonially nesting waterbirds in the Barmah-Millewa forest and flow variability to determine effects of river management on these waterbirds. Applied relationship to simulated current and natural flow to reveal an 80% reduction in frequency of successful breeding episodes compared to natural).	Published Paper
<b>Fish</b>	
Crook, D. (2004). Contribution of the Barmah-Millewa floodplain lakes to carp populations in the mid-River Murray. Final report to the Barmah Millewa Forum. Arthur Rylah Institute for Environmental Research, Department of Sustainability and Environment, Heidelberg, Victoria. (Used otolith chemical signatures to estimate that approximately 82% of carp captured at Torrumbarry had recruited in the Barmah-Moira lakes)	Published Report
<b>Water mapping</b>	
Abuzar, M. (2002). Mapping of floods in the Barmah-Millewa Forests using remote sensing technology. Report to the Barmah-Millewa Forum. Department of Natural Resources and Environment, Tatura. (Report examines the accuracy of remotely-sensed satellite imagery data with existing ground survey maps of flood distribution for the 1984 and 2000 floods of the Barmah-Millewa forests. Also presents the advantages and limitations of using the technique). See also Abuzar and Ward (2003).	Published Report
Maunsell Australia Pty Ltd (2003). Development of a hydraulic model of the Gulf water management area in the Barmah Forest. Report to the Barmah-Millewa Forum. Maunsell Australia Pty Ltd, Canberra. (This hydraulic model was developed to detail water movement through the 5000ha Gulf water management area of Barmah Forest)	Unpublished Report (Draft Report)
<b>Flow regime</b>	
Dexter, B.D., Rose, H.J. and Davies, N. (1986). River regulation and associated forest management problems in the River Murray red gum forests. <i>Australian Forestry</i> <b>49</b> , 16-27. (Documents changes to the flow regime of Barmah-Millewa Forest by comparing pre-Hume flows (1886-1933) with post-Hume flows (1934-1984)).	Published Paper
Pamminger, F. (1986). Report on the October-November 1986 flooding of the Barmah Millewa Red Gum forest. Floodplain Management Unit, Rural Water Commission of Victoria. (Analyses hydrographic data collected during the October-November 1986 flood and establishes a limiting flow of around 60,000ML/d when any flow balance leaves the system via effluents including Tuppall and Bullatale Creeks).	Published Report
Bren, L.J., O'Neill, I.C. and Gibbs, N.L. (1987). Flooding in the Barmah Forest and its relation to flow in the Murray-Edward River system. <i>Australian Forestry Research</i> <b>17</b> , 127-144. (Examines relationship between historic flow records and the flood maps of 1963-1984 showing annual extent of flooding at Barmah Forest. Reveals that the flow peak in the Murray River at Tocumwal was the best predictor of the extent of flooding. Flooding of the forest commenced at 12,000ML.d <sup>-1</sup> and was effectively fully flooded at 77,000 ML.d <sup>-1</sup> . The relationship allowed changes in the flow regime due to regulation, particularly due to the building of Hume Dam, to be assessed.)	Published Paper

**Barmah Wetland System Environmental Monitoring Program**

<b>Author and title of research</b>	<b>Document</b>
Bren, L.J. (1987). The duration of inundation in a flooding River Red Gum forest. <i>Australian Forestry Research</i> <b>17</b> , 191-202. (Developed the relationship between percentage and forest flooded and peak daily flow in the Murray River at Tocumwal. This relationship was used to estimate the monthly percentage of Barmah Forest flooded from 1895-1984. Independent verification of the inundation model showed it to have a moderate accuracy of prediction. The model reveals that the mean duration of inundation has decreased by one month since river regulation, with gradients of frequency and duration of inundation being present across Barmah Forest.)	Published Paper
Bren, L.J. (1988b). Flooding characteristics of a riparian red gum forest. <i>Australian Forestry</i> <b>51</b> , 57-62. (Uses derived relationships between flooding of Barmah Forest and River Murray flow to generate maps of flooding of Barmah Forest from 1895-1984. Characteristics estimated include distribution of frequency, duration of flooding, and duration of periods between flooding.)	Published Paper
Bren, L.J., Gibbs, N.L. and O'Neill, I.C. (1988a). Changes in the flooding characteristics of the Barmah Forest as a result of the combined river regulation from Hume and Dartmouth dams. (Applies three modelled scenarios to study the likely effects of river regulation on the frequency and duration of flooding of Barmah Forest. Scenarios include no regulation or diversion, Hume Dam regulation and diversion, Dartmouth and Hume Dams regulation and diversion).	Published Report
Bren, L.J., Gibbs, N.L. and O'Neill, I.C. (1988b). The contribution of River Murray tributaries to the flooding of Barmah Forest. (Examines the role of some River Murray tributaries to the flooding of Barmah Forest).	Published Report
<b>Reptiles / amphibians</b>	
Brown, P.R. (1981). Report on the reptiles and amphibians of the Barmah State Forest and the Maramingo and Reedy Creek Pulpwood demonstration areas. (Lists the reptile and amphibian fauna of Barmah State Forest from sampling in February 1981).	Unpublished Report
<b>Groundwater / soil moisture</b>	
Bren, L.J., Gibbs, N.L. and O'Neill, I.C. (1988c). Soil moisture and groundwater studies in the Barmah Forest. (Studied recharge of soil moisture and groundwater at Barmah Forest during two flood years using neutron probes and piezometers)	Published Report
<b>Invertebrates</b>	
Harris, J.A. (1972). The effect of flooding on population density of the gum leaf skeletonizer moth <i>Uraba lugens</i> Walk., in Barmah State Forest. Research Branch Report No. 25, Forest Commission, Victoria. (Examines the relationship between flooding and populations of the gum leaf skeletonizer, concluding that flooding reduces populations of this insect).	Unpublished Report
CFL (1986). Defoliation of River Red Gums by gum leaf skeletoniser. (Information notes on the gum leaf skeletoniser <i>Uraba lugens</i> , its distribution, and options for its population control).	Information Notes
Souter, N.J. (1996). The impact of channel outfall drainage on the <b>water quality</b> and benthic <b>macroinvertebrate</b> fauna of Smiths Creek, Barmah Forest. Floodplain Ecology Group, Kaiela Research Station, Department of Conservation and Natural Resources. (Investigates changes in water quality and benthic macroinvertebrate fauna as a result of drainage into Smiths Creek of Barmah Forest. A major impact was the deposition of sediment into Smiths Creek. This sediment smothered the benthic habitat and altered the macroinvertebrate community structure although species diversity did not change).	Published Report
<b>Water quality</b>	
Floodplain Ecology Group (1996). Collated water quality data from Smiths Creek, Barmah Forest 1990-1995. Kaiela Research Station, Department of Conservation and Natural Resources, Shepparton. (Lists various water quality data collected 1990-1995 but there is no interpretation of the data)	Published Report

**Barmah Wetland System Environmental Monitoring Program**

Author and title of research	Document
<p>Howitt, J., Baldwin, D. and Rees, G. (2004). Blackwater model – A computer model to predict dissolved oxygen and dissolved carbon downstream of Barmah-Millewa Forest following a flood. Report to the Barmah-Millewa Forum. Murray-Darling Freshwater Research Centre, Albury. (Details a process model that predicts dissolved oxygen and dissolved carbon concentrations downstream of Barmah-Millewa Forests. Scenario runs indicate that blackwater events are exacerbated during flooding events where water is allowed to pool on the floodplain and when flooding occurs in late summer).</p>	<p>Published Report</p>
<b>Sedimentation</b>	
<p>Thoms, M.C. and Walker, K.F. (1990). Sedimentation in Barmah Forest. River Murray Laboratory, University of Adelaide. (Used core samples to conclude that deposition of sediment in Barmah Forest is high, and that the source of sediment, the mode of deposition and the composition of sediment have changed).</p>	<p>Published Report</p>
<p>Thoms, M.C. (1995). The impact of catchment development on a semiarid wetland complex: the Barmah Forest, Australia. <i>Man's Influence on Freshwater Ecosystems and Water Use</i> <b>230</b>, 121-130. (Catchment development and flow regulation, particularly over the past 40 years, has increased suspended sediment in the River Murray and increased the supply of sediment to Barmah Forest)</p>	<p>Published Paper</p>
<b>Vertebrates</b>	
<p>Loyn, R.H., Lumsden, L. and Ward, K.A. (2002). Vertebrate fauna of Barmah Forest, a large forest of River Red Gum <i>Eucalyptus camaldulensis</i> on the floodplain of the Murray River. <i>Victorian Naturalist</i> <b>119</b>, 114-132. (Summarises studies of the vertebrate fauna over several decades at Barmah Forest and records 35 mammal, 205 bird, 20 reptile, 10 frog and 28 fish species.)</p>	<p>Published Paper</p>