

RESOURCES AND VALUES OF JERRABOMBERRA WETLANDS

**Report prepared for the
Jerrabomberra Wetlands Nature Reserve Concept Plan**



**Prepared by the
Jerrabomberra Wetlands Nature Reserve
Board of Management 2013**

Resources & Values of Jerrabomberra Wetlands

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Executive Summary

Jerrabomberra Wetlands is a landscape and resource which was initially shaped by the forces of landform development, water and wind, and later by layers of human use.

The area has come to be valued for its wetlands and waterbirds, even though these are largely viewed as an artefact of urban development, sustained as backwaters of Lake Burley Griffin. Paradoxically, it is the on-going urban development that has the potential to compromise these values. Managing ecological values in the context of urban development poses significant challenges.

The preparation of a draft Master Plan in 2012 drew attention to these challenges, and prompted the Board of Management to reconsider not only the Master Plan but also the nature and future of Jerrabomberra Wetlands Nature Reserve.

A fresh perspective came largely from studies and reviews undertaken in 2012-2013. These generated new understandings of natural and cultural resources that broadened and enriched appreciation of the area.

A new vision of the Jerrabomberra Wetlands in the 21st century was then forged. This recognises a much greater suite of possibilities, yet still works within existing objectives and acknowledged constraints. The outcome is a substantial repositioning of Jerrabomberra Wetlands in terms of its ecological and cultural values, and as a resource for the Canberra community.

This document is a record of the thinking and re-positioning undertaken by the Board of Management over six intensive months in 2013. It is intended as a reference and source document for the Board of Management. It is not confidential, and is open to interested parties and members of the public.

Our Challenge

In the past, management of the area has been focused on its more evident ecological values, in wetlands and waterbirds, and has suffered from a relatively low level of scientific input and understanding. To contemporary eyes, waterbirds and wetlands are part of the values, and bird study is one of several activities to be encouraged.

Being a floodplain, the area has been protected from urban building development. However, it has been incrementally encroached upon to meet the demands of the city growing around it. This indicates that it has not always been appropriately understood or valued.

The area has been portrayed as a refuge area within an interconnected system of corridors, although in ecological terms it has become increasingly and irreversibly isolated by urban development. As a result, these corridors have become largely notional, and most valuable for visual amenity. This has serious implications for sustaining populations of biota.

There is a risk now that the combined effects of encroachment and isolation could diminish the future ecological value of Jerrabomberra Wetlands. It may become reduced to a backdrop to views from the west and a scenic outlook and recreational space for intensified urban residential and commercial development in the south and south-east.

Enhancing its value as a floodplain wetland landscape and habitat refuge have long been treasured ideals, but these are increasingly constrained by concern about aircraft bird strikes as traffic grows at Canberra International Airport.

The landscape and ecology of the area are products of past decisions, increasingly at risk in the present from growing urban development pressures and diminishing investment in management, and into the future from intensified climatic variability.

These challenges mean that it will become increasingly difficult to protect Jerrabomberra Wetlands from degradation. Attempts to prolong patterns of the past in a future changing environment may perpetuate ill-informed, even misleading, treatment of the area.

The Board resolved that the best approach is to develop some long-sighted ideas and a clear vision of Jerrabomberra Wetlands in a future Canberra. These represent a substantial repositioning of Jerrabomberra Wetlands in terms of valuation, conservation and presentation. They target our most significant challenges, and are essential for developing community appreciation and support.

Resources & Values of Jerrabomberra Wetlands

Our Response

We accept a duty of care to minimise adverse impacts on neighbours and the broader Canberra-Queanbeyan community that could arise from management of the Reserve. This includes a specific duty of care to minimise risk of aircraft bird strike at Canberra International Airport.

We are reshaping the nature of management of the area, founded in a more holistic and ecological approach, informed by evolving scientific understanding and robust decision-making, and adaptive to changing circumstances and to new information that arises from structured and focused survey, monitoring and research.

At the same time, in the face of immediate and growing pressures, we are taking a firm stance on appropriate access, use and development within the Reserve, and on impacts imposed on the area from outside its boundaries. This is to avoid further encroachment on, or degradation of, its values, with decisions informed by the principle that safeguarding the ecology of the Reserve is paramount.

From this point, we are exploring options to develop more diverse wetland, riparian and terrestrial habitat types within the floodplain landscape, and to redress unwise or ill-informed decisions of the past. This includes re-establishing disrupted hydrological and ecological connections in the landscape, and removing or relocating connections and developments that compromise ecological diversity and integrity, or which increase safety concerns.

We are presenting the Reserve in a new light, as a floodplain landscape, cultural landscape and novel ecosystem, with values arising from historical use and a novel mix of habitat elements. These afford Jerrabomberra Wetlands a special place in the spectrum of reserves in Canberra Nature Park.

We recognise Ngunnawal people as the Traditional Custodians of the area, and their presence here for at least 25,000 years. We are exploring options to strengthen continuing cultural and spiritual connections with Country through management practices, programs and facilities in the Reserve.

And we have built a new understanding and appreciation of the layers of European historical use of the evolving landscape over the past two hundred years.

These new understandings will enable us to communicate a more diverse range of values, developing enhanced stories about the place in Aboriginal cultural landscape practices, interpretation/education materials and programs, and in broader planning and development decision-making processes.

We are operating well beyond the traditional (and now highly constrained) focus on waterbirds, to encompass non-avian and terrestrial fauna, a broader and richer view of the area's environmental and cultural history, continuing cultural and spiritual connection for Aboriginal people, and new interactions with the local arts community.

We are responding to changing urban communities by providing and facilitating a dynamic program of opportunities for community participation in caring actively for the area, and in collective building of cultural, historical and ecological knowledge and understanding.

This is complemented by an approach to sustained resource development and management through new and innovative partnership approaches across multiple sectors, harnessing diverse options for collaboration, contribution and financial investment.

Exploring and developing further these new possibilities will bring about significant changes in how we work with and strengthen Jerrabomberra Wetlands, so that the Reserve can continue to provide a diverse suite of benefits to the communities of Canberra and the surrounding region, well into the future.

Our Vision

***A diverse and dynamic floodplain landscape and wetland resource,
inspiring the community to enjoy and appreciate its natural
and cultural values, and to participate actively
in its care and management.***

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Preamble

Purpose

This Report seeks to:

- inform and influence policy, planning and management decision-making which may have an impact on resources and values of the Jerrabomberra Wetlands Nature Reserve
- broaden and strengthen community connection with the Reserve, and participation in its care and management

It is written as guidance for the Board of Management and for policy and planning decision-makers and their agents

It is available to the broader community, although it has not been developed specifically for this audience

It addresses these aims by:

- summarising new information and understanding about resources and values of the Reserve, which has become available or accessible since production of the Plan of Management 2010 and the Draft Master Plan 2012
- communicating a vision for the Reserve, and guiding principles for decision-making
- indicating opportunities to strengthen ecological and cultural management of the Reserve, based on new information and new understanding about resources and values, and about potential threats to those resources and values

Scope

The Report addresses Jerrabomberra Wetlands Nature Reserve (‘Jerrabomberra Wetlands’ or ‘the Reserve’), as declared in 1990 under the *Nature Conservation Act 1980* and in 1993 under the *Land (Planning and Environment) Act 1991*, as well as the former education site used by Birrigai Outdoor School that adjoins the Reserve on Dairy Road.

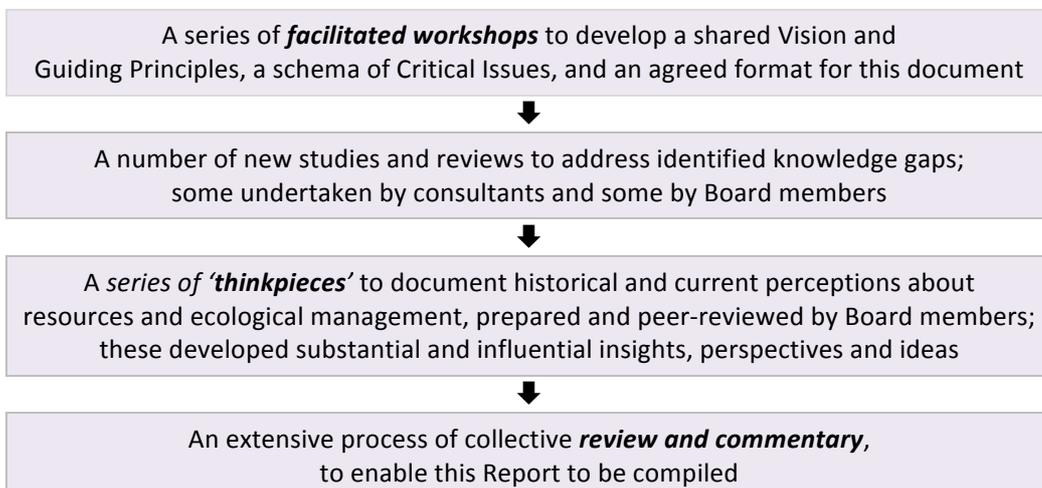
Attention is also paid to areas and activities outside the Jerrabomberra Wetlands which may affect values of the Reserve.

Process

The Board of Management prepared this Report in response to the Draft Master Plan 2012 and public submissions on that document.

The Board was concerned to define a coherent direction, which addresses significant issues and knowledge gaps, and to rectify inaccuracies and ill-informed conceptions regarding the Reserve.

The iterative process included:



Planning and Legislative Context

This Report operates within the context of overlapping Federal and Territory policies, legislation and plans.

The ***Australian Capital Territory (Planning and Land Management) Act 1988*** (Commonwealth) establishes a planning framework for the Territory

- o The National Capital Plan considers national significance and sets out planning principles and policies for the Territory.
- o The Territory Plan addresses planning for the needs of ACT residents

The Act defines two categories of land in the ACT:

- o National Land managed by the Commonwealth.
- o Territory Land managed by the ACT Government on behalf of the Commonwealth.

Jerrabomberra Wetlands Nature Reserve is located on Territory Land, within a Designated Area under the National Capital Plan. This means it is subject to planning controls of the National Capital Authority (NCA), and proposed plans or 'works' must be approved by the NCA.

The **National Capital Plan** contains a number of policies and conditions that are directly or indirectly relevant to the Reserve. These are outlined in the Draft Master Plan 2012 and in additional detail below.

The **Lake Burley Griffin Management Plan** 1995 & 2011 recognises the integral relationship between the Reserve and Lake Burley Griffin, which is National Land managed by the NCA.

The Reserve is part of the **National Capital Open Space System**, which protects the open space framework, visual backdrop, and landscape setting for Canberra.

The **Jerrabomberra Wetlands Nature Reserve Plan of Management** 2010 sets out how the Reserve's values will be protected and recreational opportunities will be promoted. The Plan of Management is a statutory document required under the *ACT Planning and Development Act 2007*.

Additional Federal and Territory policies, legislation, plans and strategies that underpin or influence management of the Reserve are outlined in the Plan of Management, along with international agreements that are relevant to the wetlands.

The Plan of Management 2010 determined that a **Master Plan** should provide a coordinated and strategic approach for capital works in the Reserve.

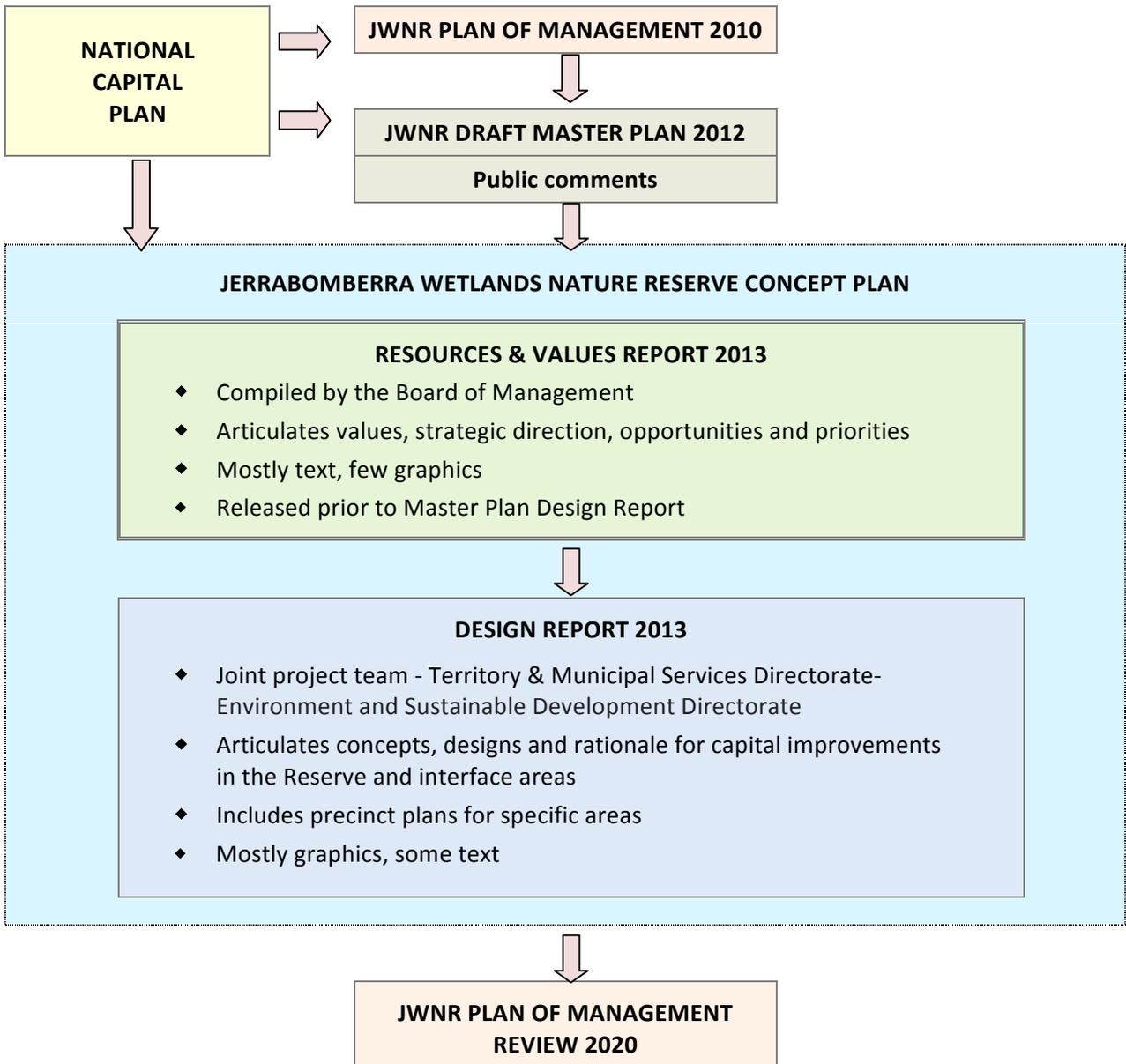
The ACT Government charged the Board of Management with preparation of the Master Plan, and a Draft was released in 2012.

A Concept Plan is now being prepared, based on a refined draft plan, public comments and new information developed through studies, reviews and 'thinkpieces'.

This Resources and Values Report will complement and help to shape a Design Report for capital improvements in the Reserve and its interface with proposed urban redevelopment.

The interaction between key Plans is shown in Figure 1.

Figure 1: Interaction with Other Plans



Governance

The ACT Government established a Board of Management for the Jerrabomberra Wetlands in 2010. It comprises community members with a range of skills in natural resource management, and an officer from the Territory & Municipal Services Directorate (TAMS). See Table 1 for Terms of reference.

In appointing the Board, the then Chief Minister stated the intention of the ACT Government that the natural and cultural values of Jerrabomberra Wetlands will 'be managed in partnership between the community, government and private sectors in a way that achieves enhanced ecosystem restoration and through educational and eco-tourism opportunities, inspires conservation values within the community of the Capital Region'.

The ACT Parks and Conservation Service will continue to own and manage the Reserve, with stewardship provided through partnership with the Board of Management. This aims to deliver best practice management for nature conservation, research, recreational and educational outcomes.

In 2011 the ACT Government established the Capital Woodland and Wetlands Conservation Trust (the Trust) to generate community funding for Board initiatives in both Jerrabomberra Wetlands and Mulligans Flat Nature Reserves. A Memorandum of Understanding is being developed between the Trust and Jerrabomberra Wetlands Nature Reserve Board.

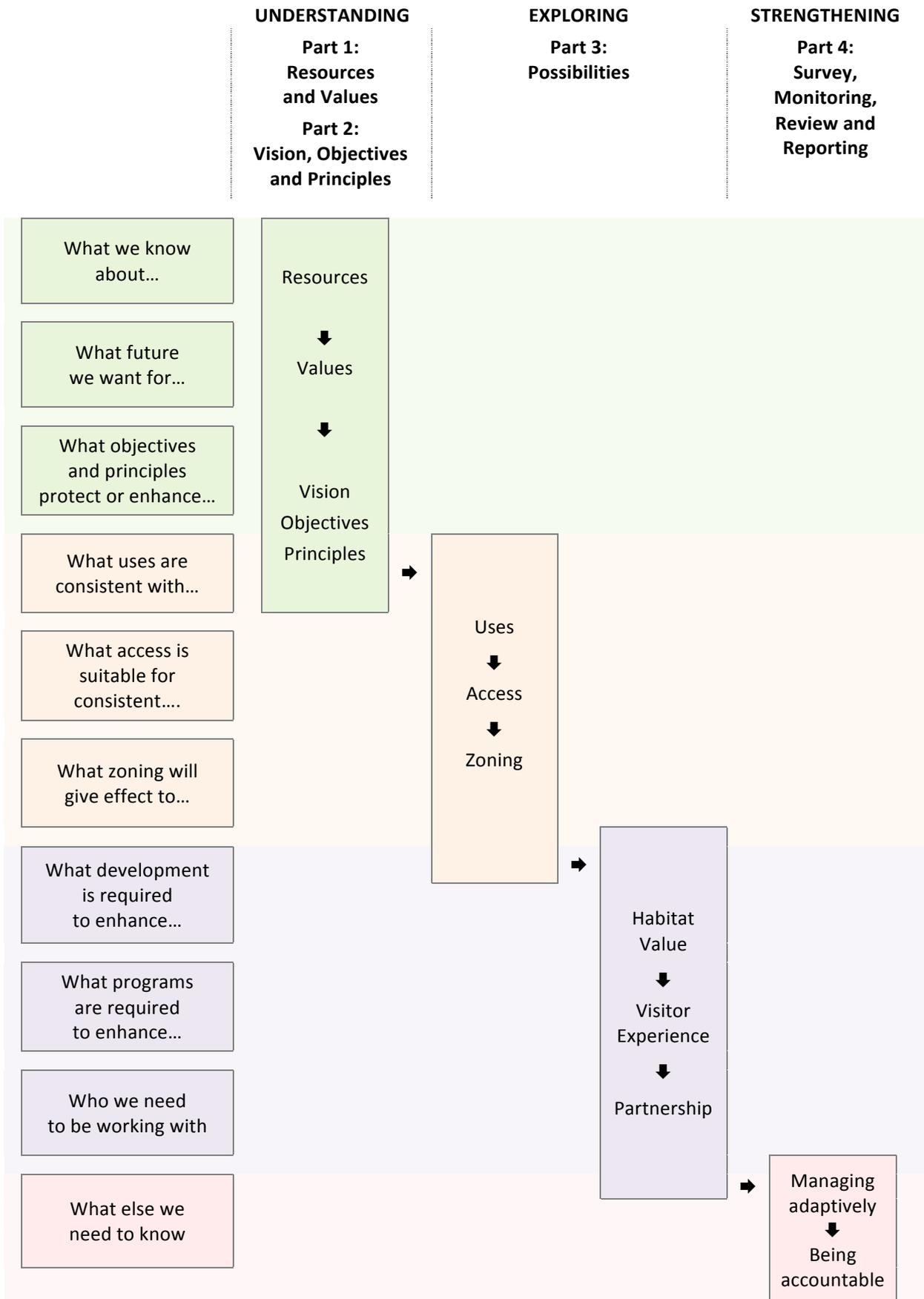
Table 1: Terms of Reference for the Jerrabomberra Wetlands Board of Management

- ◆ Oversee, guide and support strategic management and development of the Jerrabomberra Wetlands Reserve and its programs, including input to, and approval of, Annual Operations and Works Programmes, as well as Business Plans, that are designed to achieve delivery of the objectives outlined in Plans of Management or Master Plans.
- ◆ Foster a spirit of partnership with Parks, Conservation and Lands (PCL) and other stakeholders (including community groups, business, research organisations and ACT Government agencies) in delivering the programs for the Reserve.
- ◆ Provide direction, expert advice and support to the Executive Manager of the Reserves (whether employed directly by the Board, or as the senior PCL manager).
- ◆ Harness wide community support for and participation in the Reserve and its programs (including contributions to the Trust, voluntary (or in-kind) support, and sponsorships).
- ◆ Monitor the effectiveness of conservation, management and other programs delivered in the Reserve to meet defined objectives.
- ◆ Undertake review and assessment of development and management proposals on lands adjacent to the Reserve (which may have implications for the conservation of the natural and cultural values of the Nature Reserve), and make submissions and representations to relevant decision-making authorities.
- ◆ Oversee production and implementation (including prioritisation of activities) of Plans of Management and/or Master Plans.
- ◆ Provide advice to the Minister, TAMS and Parks Conservation and Lands (as the Territory's land owner and public land manager) on progress in delivering Plans of Management and/or Master Plans, and other matters as required.

This Report will assist the Board to translate its brief into a set of agreements and processes necessary to realise the Vision. This will include:

- legislative, administrative, and regulatory powers necessary to implement actions or programs;
- allocation of authority and/or agreements with Government agencies in relation to resourcing or implementing management and operational measures/programs;
- the scope of sponsorship projects and processes required in relation to the Trust, to resource the development, management, interpretive and educational resources of the Reserve; and
- process agreements required in relation to the Trust.

Conceptual Structure of this Report



Part 1: Resources and Values

This Part describes ‘*what is*’ – the current state of natural and cultural resources and some implications.

Jerrabomberra Wetlands is a floodplain landscape that has been shaped both directly and indirectly by water, and its dominant values continue to be related primarily to water availability, movement and quality, and the life supporting role that water plays.

This Part begins with an overview of the Jerrabomberra Wetlands landscape as it is today.

This is followed by descriptions of interactions between landforms and water (above and below the ground surface), in turn shaping patterns of vegetation, wildlife habitat, ecological processes, and human use.

For the purposes of presenting information, it is convenient to separate these features and interactions into categories such as natural and cultural resources or landscapes. However, this tends to blur the essential relationships and inter-dependencies between biophysical elements, and between these and human use/ connection (Fig.2).

The descriptions in this Part form a basis for subsequent exploration of opportunities for these resources and values.

Figure 2: Simplified Model of Interaction of Natural and Cultural Landscapes

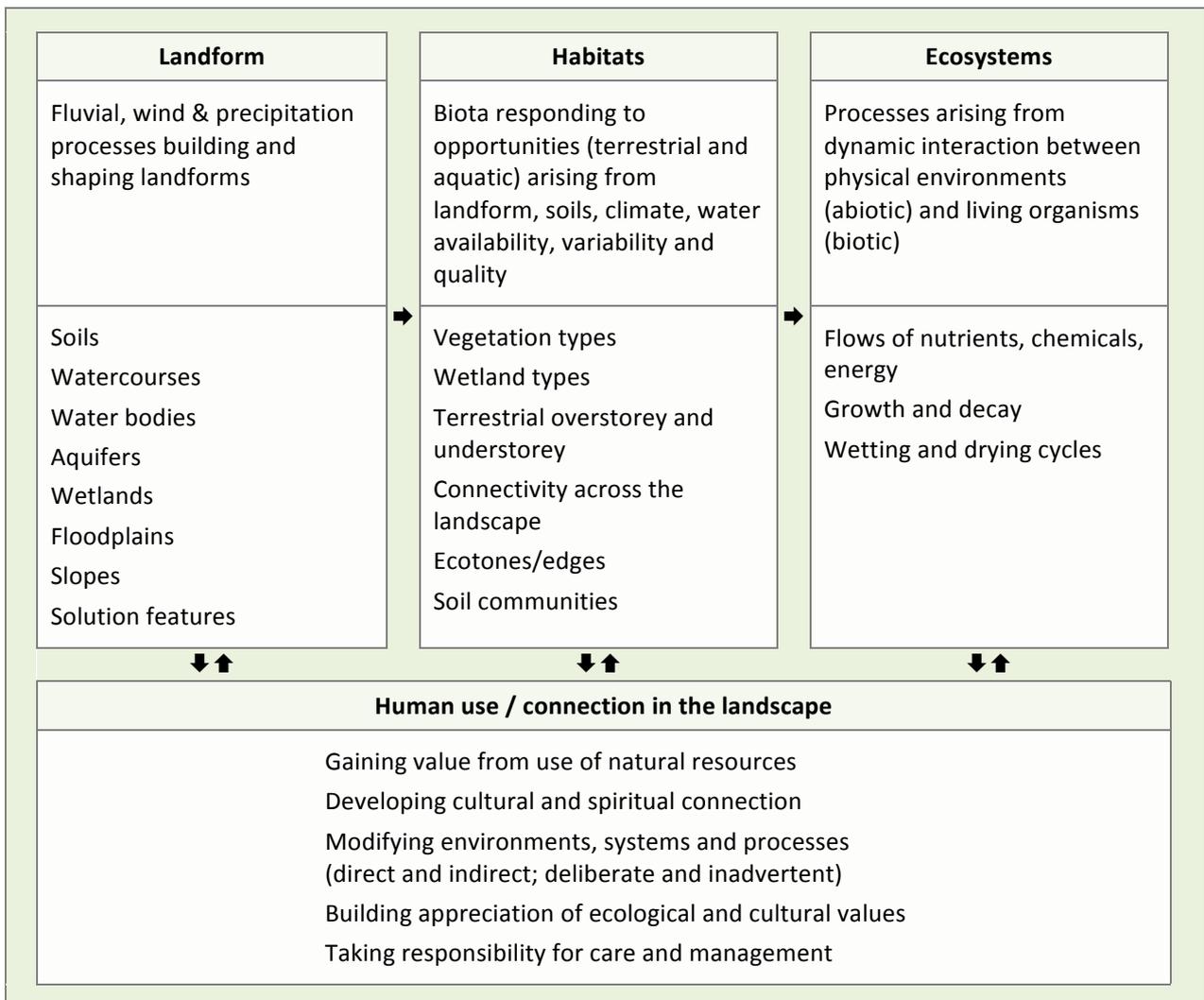




Figure 3: Jerrabomberra Wetlands
Reserve boundary in yellow. Aerial photography 2012

Landscape

The Reserve covers about 201ha of land, shaped by the Molonglo River which lies to the north, and Jerrabomberra Creek entering from the south.

Each of these watercourses has associated floodplains and secondary channels. The Molonglo River has created a broad expanse of low relief floodplain (Dairy Flat) with a series of scroll bars and former flood channels, some of which are palaeochannels. The floodplain of Jerrabomberra Creek is smaller, with notable features including a billabong and a cutoff meander shaping Kellys Swamp.

Both watercourses flow into Lake Burley Griffin, and backwaters form the Molonglo Reach and Jerrabomberra Reach. Lake waters also back up into a constructed channel (Causeway channel) and inundate lower reaches of some palaeochannels on the Dairy Flat floodplain. The only wetlands in the Reserve that are permanently inundated are those connected to lake backwaters.

Shallow depressions in the floodplain form areas of impeded drainage or ephemeral wetlands, all of which are subject to periodic drying. Some of these features were formed by fluvial processes (river flow) and some are a result of recent human activities in the landscape.

Wetlands that are 'perched' in the upper mantle of silty clay on the floodplain are periodically inundated with surface water flows, and (rarely) by over-bank flow from the Molonglo River or Jerrabomberra Creek during periods of extreme rainfall. Others (such as Kellys Swamp and the Jerrabomberra Creek Billabong) are connected with the underlying groundwater aquifer, and carry water for longer periods.

The low divide between the two floodplains is marked by an ancient sand dune system. More elevated ground is found on the southern boundary of the Reserve. Some of this is landfill e.g. along the left (southern) bank of Jerrabomberra Creek, and some is formed by a ridge of weathered rock and surface gravels on the south-eastern boundary towards Fyshwick.

Past land uses, works undertaken to shape the national capital, and more recent management activities related to improvement of waterbird habitat and recreation, have shaped three main components:

- terrestrial – mostly floodplain dominated by exotic pasture, and some native tree/shrub plantings;
- aquatic – water bodies, stream channels, and wetlands (some dry at most times); and
- riparian – including areas of invasive exotic trees.

Cultural Landscape Approach

This Report considers Jerrabomberra Wetlands Nature Reserve within biophysical and cultural landscape settings. It identifies both natural heritage elements and cultural heritage elements, and considers the interaction of these as an expression of continuity and change in the landscape.

Country is an area to which Aboriginal...people have a traditional attachment or relationship. It includes the plants, animals, water, air, earth, rocks, stories of their ancestors, and the persona of that landscape - people speak on Country and visit, care for and long for Country. Connecting to Country refers to Aboriginal...people being on or remembering Country, acknowledging the specific localised knowledge of that area's natural and cultural landscape and ancestral stories
(ACT Government 2013)

The cultural landscape is fashioned out of a natural landscape by a culture group. Culture is the agent, the natural area is the medium, the cultural landscape is the result. Under the influence of a given culture, itself changing through time, the landscape undergoes development, passing through phases...

(Sauer 1929, cited by Lennon & Mathews 1996)

A cultural landscape is a physical area with natural features and elements modified by human activity resulting in patterns of evidence layered in the landscape, which give a place its particular character, reflecting human relationships with and attachment to that landscape.

(Lennon & Mathews 1996)

In cultural landscape terms, the meaning and significance of the Reserve derives not only from the individual cultural and biophysical elements within it, but also from relationships between the landscape and those elements (spatial context and connections). This approach offers potential to communicate or demonstrate a number of connected themes and periods simultaneously. So the significance of an individual element may lie not only in its individual qualities but in what it contributes to understanding of continuity and change.

An additional key concept in a cultural landscape approach is that evolution of a landscape does not stop, and new layers of cultural meaning and natural form are being created all the time.

There is no conflict inherent in this approach between cultural (archaeological/historical) resources and natural heritage (biophysical) resources. Both are heritage in the sense of our common inheritance. Cultural influences have shaped elements of the floodplain landscape, which are now considered to have natural heritage values.

These elements need to be managed for cultural and natural conservation objectives simultaneously. They need to be managed in both in physical terms (e.g. position relative to access), and functionally (e.g. as a component of a larger system).

Accordingly this report addresses:

- cultural elements, which represent layers of history and biophysical elements, which indicate change in the landscape;
- elements which demonstrate the dependence of historic activities on biophysical systems;
- elements which relate to regional connectivity; and
- thematically linked elements, and elements representing multiple themes or multiple values.

Values

The National Capital Plan (Appendix I) sets out an objective ‘to maintain and enhance the rural and floodplain landscape character, and strengthen the perception and appreciation of the Jerrabomberra Wetlands and its surroundings as an integral part of the landscape of Lake Burley Griffin and the setting for the National Capital’.

Table 2: Summary of Landscape Values

Visual and functional connection:	<p>The Reserve is a crucial part of the National Capital Open Space System, as part the Molonglo River Corridor and as part of the foreshores of Lake Burley Griffin.</p> <p>It is a conspicuous pocket of open, non-urban landscape in the heart of the city.</p> <p>The informal nature of its vegetation and floodplain landscape provides a sense of spaciousness and remoteness from development.</p> <p>It has significant landscape and visual links with surrounding hills (including Mount Ainslie, Mount Pleasant, Red Hill) and with elements of the national capital landscape (Parliament House), as well as the corridors of the Molonglo River and Jerrabomberra Creek.</p> <p>Its location and ‘unbuilt’ nature assist in communicating stories of multilayered historic use from Aboriginal use, through European settlement of the Limestone Plains, to selection and development of the National Capital.</p>
Landforms:	<p>The stream channels, wetlands, and floodplain landforms are varied and notable elements in the local landscape, with significant scenic amenity value.</p>
Habitat:	<p>The varied landforms provide a mosaic of habitat types, with visual and functional connections to adjacent water bodies.</p>
Cultural connection:	<p>Ngunnawal people have a continuing cultural and spiritual connection to Country, in biophysical elements, stories and pathways, and cultural knowledge, science and practices within the landscape.</p>

Natural Resources

This section contains consideration of ecosystem components in geomorphic units and hydrology, how the interaction of these provides wetlands and other habitat for elements of biodiversity, implications of ecological connectivity and disturbance, and how ecosystems are valued.

Under the Australian Natural Heritage Charter 2002, natural significance includes the importance of ecosystems, biodiversity and geodiversity for their existence value, or for present or future generations, in terms of their scientific, social, aesthetic and life-support value.

The natural resource values of Jerrabomberra Wetlands area have been recognised over a long period, and this has been acknowledged in policy and planning (Table 3).

Table 3: Recognised Natural Resource Values and Related Objectives

- ◆ The Jerrabomberra Wetlands area is classified by the National Trust (1997) and listed on the ACT Heritage Register (1998) for its natural heritage values, specifically for wetland habitats for birds and other wildlife, and as the only extensive area in the ACT of riverine floodplain with extant palaeochannels.
- ◆ The ACT Heritage Register requires that the area be maintained and managed as a temperate wetland habitat to retain the biological diversity of the place for waterbirds with specific reference to migratory species, which are the subject of international agreements.
- ◆ Jerrabomberra Wetlands has been included in the *Directory of Important Wetlands in Australia* since 1996, as a wetland that provides important habitat for animals at a vulnerable stage in their life cycles, or provides a refuge when adverse conditions such as drought prevail, and which is of outstanding historical or cultural significance.
- ◆ The National Capital Plan recognises the natural values of the area, and sets a key objective 'to define and maintain Jerrabomberra Wetlands as a protected wildlife refuge in a National Capital and urban context, with facilities designed to realise the area's potential as a significant conservation and education resource for Canberra residents, tourists and international visitors.'
- ◆ Related objectives include: 'To protect the ecological resources, geomorphological features and aquatic conditions of Jerrabomberra Wetlands and maintain a diversity of wetland and other habitats for wildlife conservation'; promotion of educational activities such as nature appreciation; fostering public awareness about wetland ecosystems; interpretation about birds and other aquatic wildlife; and availability for scientific research related to wetland environments.

The National Capital Plan also imposes conditions specifying that 'options for development of further aquatic habitats for conservation and/or recreation purposes would be subject to advice from the relevant Commonwealth Government Department of Authority that this would not increase the risk of bird strikes to aircraft', and would be subject to action under Commonwealth environment protection legislation.

Geomorphology

The setting of Jerrabomberra Wetlands is unusual in the context of the south-east Australian uplands, with a major river flowing across a wide, open valley, in a partly confined river style. The relatively wide valley enables preservation of ancient sediments and landforms, which record behaviour of the river system over time.

A number of writers have speculated about an ancient Molonglo Lake, dammed by scree from Black Mountain during a dry phase of the Pleistocene (between around 2 million and 10,000 years ago), and similar in position and size to Lake Burley Griffin. The lake left behind sandy river flats after the barriers were breached by erosion. Some writers consider that this theory is supported by the unconsolidated sands, clays and gravels of the Molonglo floodplain and remnant sand dunes at Russell and Pialligo. Other writers believe these can be explained by changing river channels and terraces.

Previous geomorphological work over the Reserve area includes studies of alluvial sediments in the Molonglo floodplains (1950s to 1970s), producing maps of the Dairy Flat floodplain, and analysis of sand transport from the Molonglo and Jerrabomberra Creek (1960s to 1990s).

From the latter studies, it has been concluded that most of the sediment entering Lake Burley Griffin is sourced from gully incision, much of which happened in the latter part of the 1800s. High rates of sediment transport during the early 1900s were a result of landscape instability arising from European agriculture, with reduced rates evident after the 1950s.

Further relevant work has included environmental impact assessments for landfills at Jerrabomberra Creek, geotechnical assessment for the East Lake precinct, and recent cultural heritage assessments and hydrological studies in the Reserve.

The Jerrabomberra Wetlands Geomorphic Assessment undertaken in 2013 built on previous work to describe the principal geomorphic features and zones within the Reserve, current condition, possible changes into the future, and implications for management. This included a detailed literature survey, compilation of geomorphic maps and a sequence of events, with field testing of uncertainties arising from maps and histories. This study was a significant update on geomorphology, sediments, and fluvial activity in the Reserve.

Geomorphic Units

The primary geomorphic units within the Reserve are the Dairy Flat (Molonglo) floodplain, Quaternary Dunes, Lower Terrace, Jerrabomberra Creek and Fyshwick Terrace, and a number of anthropogenic (human-made) forms.

Dairy Flat (Molonglo) Floodplain

The northern portion of the Reserve comprises fluvial sediments and geomorphic units from the present Molonglo River and previous river forms.

The mantle is 4-5m thick, a sequence of organic rich fine silt and clay derived from slow-flowing floodwaters, likely to be of Holocene age (c.10,000 to 200 years ago).

Below the mantle is at least 15m of coarse-grained alluvial sediment, mostly rounded to sub-rounded coarse sands and gravels, derived from a high energy (ancient) phase of the Molonglo River, which may have been either a braided system or a laterally migrating channel system. This is likely to be of Late Pleistocene age (c.50,000-10,000 years ago).

A variety of channel forms is preserved:

- (the oldest) a large, wide palaeochannel or very large flood channel of the Molonglo on the southern border of the floodplain; distinguished by absence of underlying silt and clay, in places lying directly on basal sandy gravels; of a very Late Pleistocene to Early Holocene age;
- scroll bars, gently curving linear deposits separated by a low swale, which when flooded look like channels; representing an earlier phase of deposition when the Molonglo was a meandering system actively migrating across the floodplain; likely to postdate the large palaeochannel; and
- a younger set of channels, formed by high flow events in the Molonglo in the modern flow regime (e.g. 1-in-10 to 1-in-25 year events); cross-cutting, and thus postdating, the scroll bars; more sinuous and deeper than the scroll bars; composed of floodplain silts and clays with occasional lenses of fine-medium sand from floods; likely to have been formed by the same flood events which deposited the upper alluvial silts.

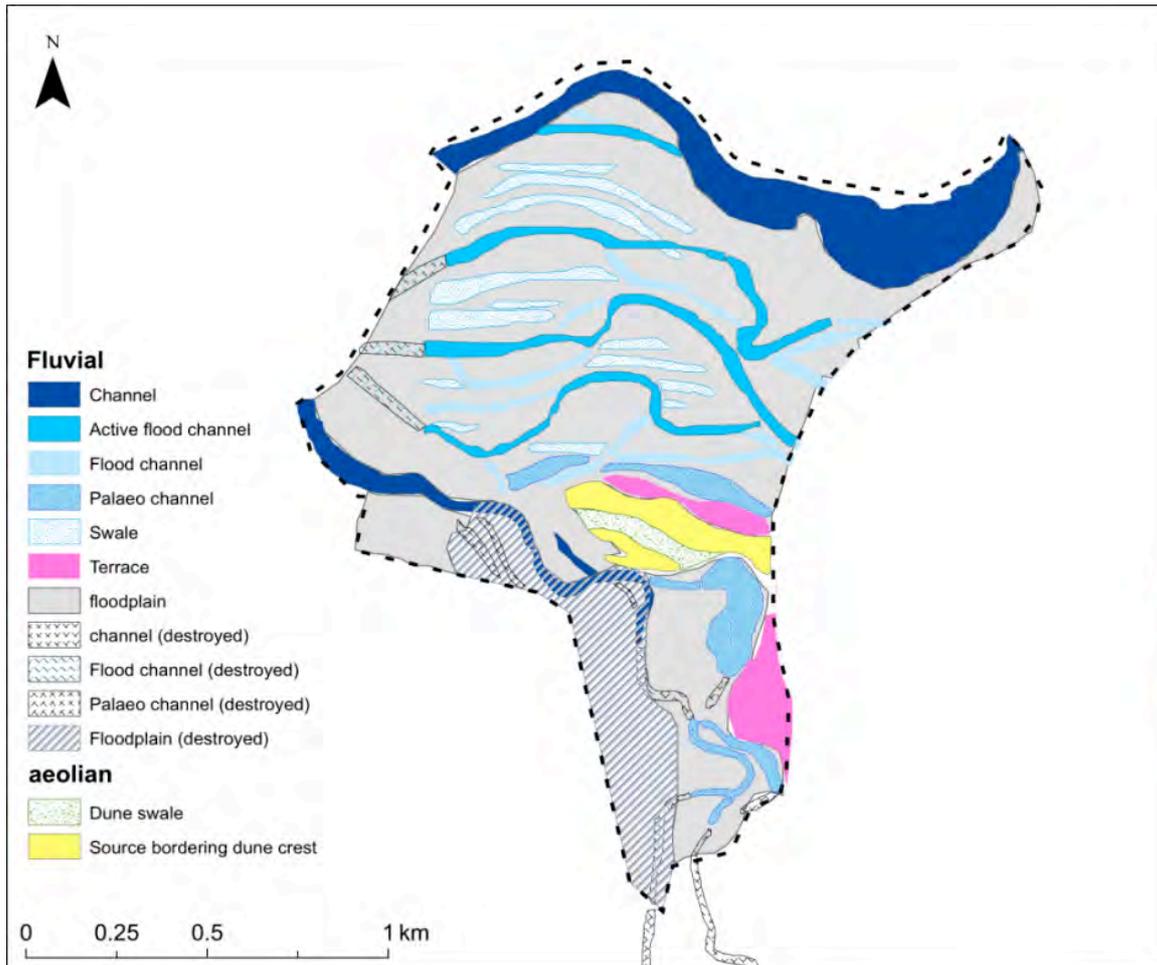


Figure 4: Geomorphic Features Prior to Anthropogenic Disturbance

(Source: White et al. 2013)

Quaternary Dunes

Two small east-west oriented dunes are found on the southern side of the Dairy Flat floodplain:

- The northernmost is approximately 80m wide, lying directly on top of basal gravels, about 3m thick and rising about 2m above the surrounding floodplain. The northern dune is dominated by red-brown medium quartz sand, with a silt/clay matrix.
- The smaller southern dune is only a few tens of centimetres higher than the Dairy Flat floodplain, and appears to be a mix of medium aeolian sand and clay-rich overbank flood deposit

The low area (swale) between the two dunes rises from each end to form a saddle. This is inconsistent with an alluvial formation, and it is likely to be a relic from when the dunes were active. The swale has started to accumulate fine alluvium about 30cm thick.

These are source-bordering dunes which are highly unlikely to be a product of the present climatic and vegetation regime, requiring greater availability of mobile sand and silt, either from decreased vegetation cover on the floodplain, or a river with highly seasonal flow exposing bedload sands to the wind during a dry season. The dunes almost certainly pre-date deposition of the organic rich silts and clays that presently cover the floodplain, and may have their source in the coarse sands and gravels underlying the floodplain. They are likely to be of Late Pleistocene age.

Lower Terrace

Directly north of the large dune is a terrace which sits a few tens of centimetres above the floodplain ridges. It appears to be composed largely of the same sandy channel material that underlies the dune, and the fine alluvial sediments on the floodplain.

Jerrabomberra Creek and Fyshwick Terrace

South of the Dairy Flat dune systems, alluvial features produced by Jerrabomberra Creek are bounded to the east by coarse grained gravels and sands that underlie most of Fyshwick, and by outcrops of Silurian metasediments and metavolcanics. The terrace gravels comprise highly weathered material, mostly quartz pebbles. These are thought to have been reworked by both the Molonglo River and Jerrabomberra Creek, but not significantly during the last 200 years.

Sediments and landforms on the floodplain of Jerrabomberra Creek preserve evidence of at least four different flow regimes:

- *Basal Gravels and sands* - coarse sand and gravels low in organic content; >2 m thick, and underlying most of the area currently occupied by the Jerrabomberra Creek floodplain; laterally extensive, coarsening to the south where the creek has been more confined. The surface appears to be relatively flat near Kellys Swamp, rising to the south, consistent with deposition by Jerrabomberra Creek. They are likely to have formed at the same time as those underlying the Molonglo floodplain, and represent a pre-Holocene period of increased erosion and reworking.
- *Swampy meadow deposits and palaeochannels of Jerrabomberra Creek* - overlying the basal sands and gravels, a 1-2m thick layer of black clay-rich alluvium.
Poorly developed channels, wide (>50 m) and very shallow (<0.5 m), form low points which accumulate water. They are mostly preserved on the eastern floodplain boundary, adjacent to the terrace and including Kellys Swamp, which likely exists because of the presence of a channel.
Another palaeochannel of Jerrabomberra Creek is preserved on the southern portion of the Molonglo floodplain, as a small channel cutting across the ridge and swale topography. Its location and north-west direction of flow are consistent with a Jerrabomberra Creek outflow. It has a small pond similar to the low energy form of that creek prior to European settlement.
- *Deep, sandy and gravelly channels* - maps and air photos show an active, sinuous and sandy channel until the 1960s consistent with large gullies that had developed by the 1900s higher in the catchment. Some recovery of form has occurred since the 1970s, as a result of in-channel bar construction and vegetation accumulation, reducing sediment transport. Upstream of the Reserve, the channel has no engineered structures and remains active and sandy.
A distinct meander in Jerrabomberra Creek was alienated by construction of the silt trap and levee in the 1970s. It no longer receives flow from the creek, and has begun to fill with silt and clay. It is now known as the Jerrabomberra Billabong.
- *Modern channel* - on entering the Reserve the channel is constrained along a concrete culvert. Directly downstream from the silt trap the channel appears to have a similar character to that present prior to the lake filling. Channel banks are largely clay-rich, but deposition of coarse sand and gravel has occurred in two bends downstream of the bike path bridge, in a zone of significant channel widening. The main channel below the silt trap is typically >3m deep, and approaches at least 5m in some sections. The modern channel is inundated by the lake at low flows, but flood flows broadly follow the channel shown on the 1912 topographic survey map.

Anthropogenic Landforms

Constructions and modifications which have had a lasting impact on geomorphology include:

- *Civic rail embankment & eastern shore of Lake Burley Griffin* – By 1921 an embankment had been built for the Civic Railway, with Jerrabomberra Creek diverted northward in a channel cut across the floodplain. While the embankment is no longer clearly evident, the Causeway channel remains and connects Lake Burley Griffin with lower ends of swales and flood channels on the Molonglo floodplain. These works have largely obscured the flood channels and swales that were present prior to European settlement and crossing the area now called the Peninsula.
Concrete and rock structures to prevent wave erosion have altered the lake shoreline.
- *Flood levee bordering Jerrabomberra Creek silt trap* – This has isolated the creek floodplain and Billabong since the 1970s.
- *Disturbed ground along the Molonglo River* – The floodplain has been disturbed by several periods of construction, including the sewage pipeline across the Reserve, with a small amount of fill added from an unknown source. This reshaped Shoveler Pool, raised the floodplain slightly and produced minor changes to hydrology that divert flow from Shoveler Pool away from swales to the west and towards the Molonglo to the north.

- *Landscaping beds* – raised beds of sandy material 1-2m thick constructed on dune crests on the northern margin of Kellys Swamp and to the south of Jerrabomberra Creek in the late 1990s. These have been planted with native vegetation and are thoroughly established.
- *Landfills along Jerrabomberra Creek* – substantial landfill along the floodplain of Jerrabomberra Creek in the 1970s and 1980s, during construction of new Parliament House, averaging about 3m thickness and more than 5m in places. All landfills are now largely vegetated and are stable.

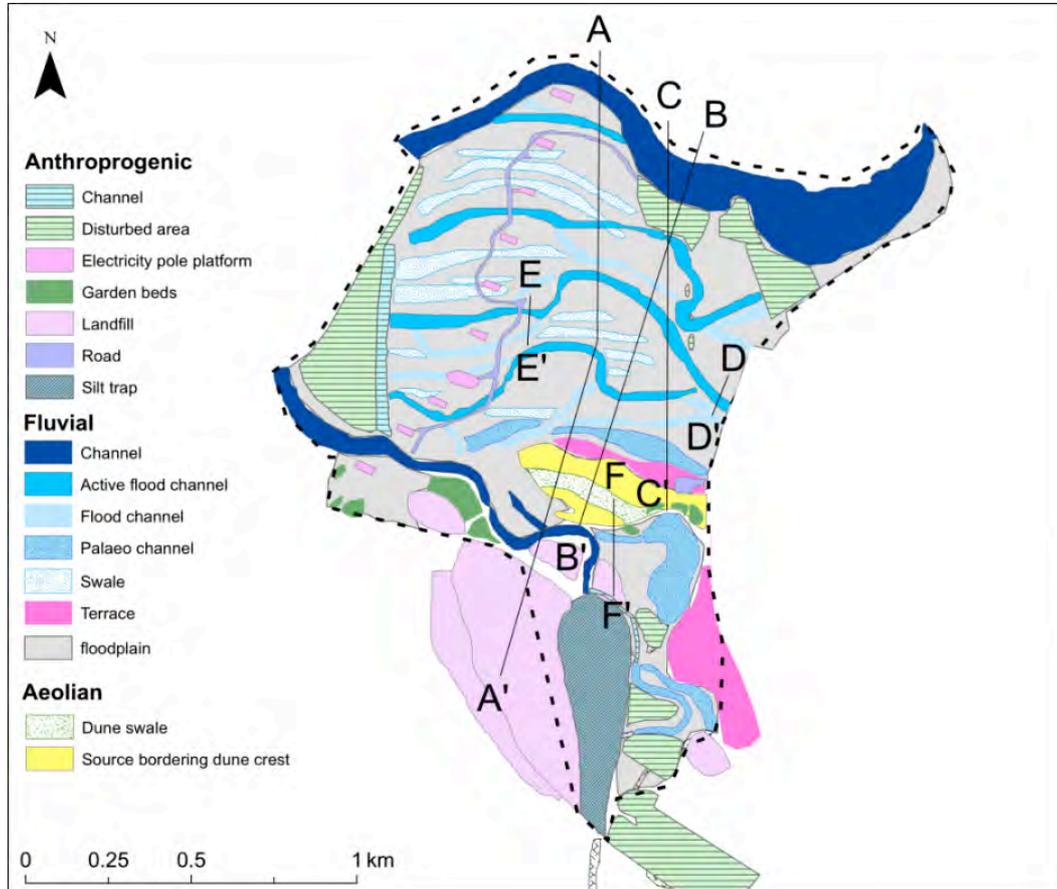


Figure 5: Geomorphic Features Present in 2013

(Source: White et al. 2013).

Letters refer to transects detailed in the Jerrabomberra Wetlands Geomorphic Assessment (White et al. 2013)

- *Roads, drainages and electrical infrastructure on the Molonglo floodplain* – the powerline service road has had a direct affect on drainage, with some road embankments cutting across the swales and flood channels. Many of the culverts have since clogged with sediment and effectively impound water flow along the channels.

Earthen embankments constructed to protect the 132 kV powerlines from flooding have had little impact on drainage. Some of the material to construct these was excavated from the floodplain in the area of the Shoveler Pool. This was a pre-existing in-stream pond, however the low point has become considerably broader and forms a more substantial wetland than prior to excavation activities.

More subtle influences include roads and channels constructed during early farming activities on the floodplain. Linear channels may be up to 0.5m deep, cutting across the floodplain along the course of former roadways. Their effect on present day water flow is unclear.

- *Constructed channel on Jerrabomberra creek cut-off* – construction of the silt trap disrupted drainage in the area immediately east of the new course of Jerrabomberra Creek. A relatively narrow channel was constructed from the cut-off of Jerrabomberra Creek, and now joins the modern course of the creek just north of the silt trap outlet. The channel is completely filled with cumbungi (*Typha* sp.) and is approximately 1m deep and 3m wide.

Table 4: Summary History of Geomorphic Events
(Source: White et al. 2013)

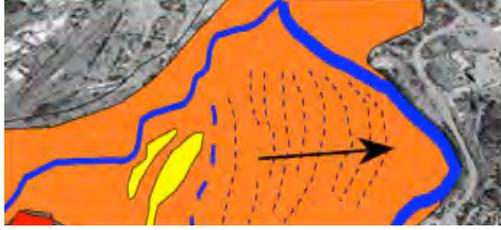
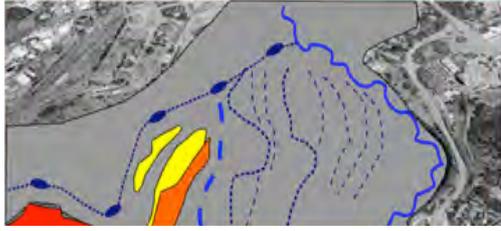
<p>Miocene or Pliocene c.10 million to 2.5 million years ago</p>		<p>High level gravels and terraces deposited Likely an energetic river system in a humid environment</p>
<p>Early-mid Pleistocene c.2.5 million to 100,000 years ago</p>		<p>High level terraces incised, gravels reworked and eroded</p>
<p>Late Pleistocene c.50,000 to 10,000 years ago</p>		<p>Source bordering aeolian dunes formed, channel migration, and scroll bars formed on Molonglo floodplain Aboriginal camps in (abandoned?) sandy channels</p>
<p>Holocene c.10,000 to 200 years ago</p>		<p>Silty sediments deposited on Molonglo floodplain Flood channels formed Swampy meadow sediment deposited in Jerrabomberra Creek chain of ponds</p>
<p>1870s -1960 Agricultural</p>		<p>Floodplain grazed, with extensive cultivation Molonglo channel expanded and straightened, point bars formed on inside of bends Jerrabomberra Creek incised, abandoning former channel, transporting substantial sand and gravel Civic railway constructed across floodplain, with diversion of Jerrabomberra Creek</p>
<p>Post 1960 Urban</p>		<p>Further development of suburbs and industry Flooding of Lake Burley Griffin inundating lower reaches of Jerrabomberra Creek, Molonglo, diversion and flood channels Landfill along Jerrabomberra Creek floodplain Jerrabomberra Creek channelled, and silt trap and levee constructed, alienating creek from floodplain Landscaping beds above Jerrabomberra Creek and around Kellys Swamp</p>

Table 5: Assessment of Geomorphic Units
(Source: White et al. 2013)

Geomorphic unit	Condition	Relative abundance
Wide floodplain (Molonglo)	Good	Rare in upland environments in ACT, also relatively rare in upland SE Australia
Flood channels	Moderate, some trampling by cattle	Rare in upland environments in ACT, also relatively rare in upland SE Australia
Scroll bars	Good	Rare in upland environments in ACT, also relatively rare in upland SE Australia
Source bordering dunes	Good	Previously relatively common along the Molonglo, largely mined for sand. Rare in upland environments in ACT, also relatively rare in upland SE Australia
Swampy meadow	Fragmented and incised	Previously very common, now rare as a result of hydrological changes associated with post-European agricultural practices
Chain of ponds	Fragmented, but those that remain are in good condition	Previously common, now rare as a result of hydrological changes associated with post-European pastoral or agricultural practices
Stony terrace	Fragmented	Previously common in ACT, becoming progressively modified by urbanisation

Trajectories of Geomorphic Change

Many of the sediment bodies and geomorphic features in the Reserve are the product of former hydrological or climatic regimes and are effectively ‘relict’ features. The majority have proved to be resilient features, despite subsequent modification through direct or indirect influences of agriculture, lake filling or late Quaternary climatic changes.

However, some have altered since European settlement, or are potentially sensitive to future disturbance. These include:

Stock trampling in wetlands – Grazing of cattle on the Molonglo floodplain has resulted in substantial trampling in wetland areas. Likely impacts include: reduced growth of wetland vegetation and increased suspended sediment, which may reduce ecological condition of wetlands and Lake Burley Griffin; increased erosion at the edges, resulting in expansion and shallowing of depressions (little direct evidence of this).

Silt deposition in submerged reaches of the Molonglo scroll bars & flood channels – The portions of channels and swales submerged by the lake are being modified by lacustrine processes, with up to 1.5m of soft silt deposited in the backwater environments. These channels serve as pathways for flow during floods, so it is feasible that some of this silt will be remobilised in future (as occurred in other areas of the lake during large floods in the 1970s). Well established vegetation on channel banks is likely to prevent significant erosion at the margins or in shallower reaches. The channel form is likely to continue to become narrow and shallow, and ultimately fill with lake sediment.

Bank erosion along Jerrabomberra Creek – Jerrabomberra Creek continues to evolve in response to hydrological changes in the catchment, arising from changes in land use and urban infill.

The unconfined reach downstream from the cycle path has widened and shallowed in response to filling of the lake.

Despite the effect of riparian vegetation, the creek banks may become unstable if urban infill changes hydrological connectivity without being offset by use of water sensitive urban design.

Similarly, changes in sediment supply, such as sand mobilised by recent willow clearance near Canberra Ave, may disrupt flow and produce bank scour.

Values

Geomorphic records provide a unique history of the character and dynamics of fluvial systems during the past few tens of thousands of years in the south-east Australian uplands. These records are a valuable resource for further scientific study, and for informing students and the broader community about past environmental change, and possible trajectories for future change in the area.

Table 6: Geomorphological Values

- Jerrabomberra Wetlands provides an unusually detailed record of landscape responses to changes in climate and land use, and is uniquely placed as a scientific and educational resource.
- Scientifically, the significant extent of geological and geomorphic study and investigation on Dairy Flat means that this area is well placed to provide further insight into processes and timing of geomorphic events in this area.
- Educationally, the location within central Canberra provides a readily available resource for public, school and university education that would be otherwise difficult to access.
- Other areas that might provide similar function are unprotected from disturbance, so their longevity cannot be guaranteed (e.g. blanketing of floodplains downstream of Captains Flat by mine waste).
- The inundated flood channels on Dairy Flat and the modern course of Jerrabomberra Creek, although highly modified, are important for waterbirds, while remnant native vegetation on undeveloped terraces of high-level alluvial gravels may become more important as these areas are actively targeted for industrial and residential developments.

Water

The Reserve is situated at the junction of the Molonglo River and Jerrabomberra Creek, both of which flow into the East Basin of Lake Burley Griffin, within the upper Murrumbidgee River catchment.

The Molonglo River rises below the Gourock Range in NSW and travels approximately 80km before entering the ACT, with a catchment of about 78,000ha above the lake. The Molonglo is joined by the Queanbeyan River that rises near Jerangle and has a length of about 104km and a catchment of 96,000ha. The Googong Dam was completed across the Queanbeyan River in 1979.

Jerrabomberra Creek rises near Royalla, with a total length of about 30km and a catchment of about 12,800ha.

In the Reserve the two sub-catchments of the Molonglo River and Jerrabomberra Creek are separated by a palaeodune which extends west from Dairy Road.

There have been significant modifications to both surface water and groundwater sources, pathways and movement patterns across the area, through excavation of drainage channels, and the impoundment of water in Lake Burley Griffin.

Studies undertaken in 2012-2013 described three broad landscape/hydrogeological systems (Fig.6):

- The Molonglo River floodplain north of the Reserve car park and Kellys Swamp, comprising 2.5-4m of silty loam soil overlying a shallow loamy sand aquifer.
- The Jerrabomberra Creek floodplain comprising a thin (0.1-1 m) layer of loamy soil overlying a loamy sand & gravel aquifer, associated with a deep medium sand dune.
- The southern Jerrabomberra Creek floodplain, cutoff meander & terraces, comprising a thin (0.1 m) layer of loamy soil overlying a sand & gravel aquifer.



Figure 6: Surface Water Hydrology: Internal and External Catchments

(Source: Lawrence 2013b)

Water Sources and Pathways

Four sources of water can be identified across Jerrabomberra Wetlands (Figure 7):

- surface stormwater discharges from Fyshwick and the Turf Farm area, and in the future from the East Lake development;
- groundwater inflows from the Lake backwater channels on the southern, western and northern boundaries;
- direct rainfall across the Reserve area; and
- during extreme wet conditions, flooding of the Molonglo River and Jerrabomberra Creek across their floodplains.



Figure 7: Sources of Surface Water
(Source: Lawrence 2013b)

An analysis of contour maps and stormwater infrastructure for Jerrabomberra Wetlands and adjacent areas identified eight *external sub-catchment discharges* onto the Reserve (Table 7):

- Floodplain palaeochannels, which are fully contained within the silty loam mantle (A), discharge into the Causeway channel, or spill over the floodplain surface during floods.
- From sub-catchment (B) the rapid discharge that would be expected from a large impervious area of Fyshwick industrial land appears to be attenuated by a 1500m long grassed channel linking this sub-catchment to the Reserve discharge point.
- Stormwater from the Fyshwick Sewage Treatment Plant and Dairy Road corridor discharge in the north (C1) to a flood channel/wetland, and in the south (C2) to Kellys Swamp. Both the large palaeochannel and Kellys Swamp are connected to the floodplain groundwater system.
- Three stormwater sub-catchments discharge to the wetlands and groundwater system in the southern Billabong groundwater zone. Two of these (D & E) include significant impervious areas, while the southernmost sub-catchment (F) comprises a large area of contaminated fill.

Table 7: Summary of Sub-Catchments and Recharge Zones in Relation to Wetlands
(Source: Lawrence 2013b)

Resources & Values of Jerrabomberra Wetlands

Sub-catchments		Catchment Upstream (ha)		Catchment within Reserve (ha)	
No.	Description	Impervious + Pervious = Total Area	Wetland No.	Wetland +Pervious = Total Area	Notes re Recharge Zones
A1	Molonglo River to Nth Turf Farm, Northern Bebo Arch, Dairy Road culvert, 80m to Molonglo River	1.5+22.5 =24			
A2	Northern Molonglo River floodplain west of Monaro Hwy	5+0 =5			
B	Fyshwick (N of Newcastle Street, W of Wollongong Street), Sthn Turf Farm area, Southern Bebo Arch to palaeochannel 14	13+104.5 =117.5	14 13 8 9	1.05+2.45=3.5 1.5+3.5=5.0	Flow along swale infiltration or groundwater recharge?
C1	Nthn ACTEW Sewage Treatment Works (excluding pond), culvert to broad flood channel north of the dune	1+7 =8		1.95+4.55=6.5	
C2	Sthn ACTEW Sewage Treatment Works (excluding pond), Dairy Road culvert to groundwater recharge, Wetland 19	1+7 =8	19	2.5+11.2=13.7	Groundwater recharge sand dune & area west of Kellys Swamp
D	Sthn side Newcastle Street west of Lyell Street, Nthn half of Wetlands Foreshore Estate, to groundwater recharge (Wetlands 21 & 22)	5+10 =15	21 22	1+4.5=5.5	Groundwater recharge billabong area
E	Sthn half of Wetlands Foreshore Estate, Nth of railway/W of Monaro Hwy, to groundwater recharge (Wetland 24)	4+0 =4	24	0.3+2=2.3	Groundwater recharge area sth of billabong
F	Area between Foreshore Estate & Railway, east to Pirie St/channel discharge to groundwater recharge (Wetland 24)	5+9 =14	24	0.2+1=1.2	Groundwater recharge area sth of Wetland 24

Groundwater Hydrology

Recent studies have assessed shallow groundwater resources within the floodplain alluvium and their interaction with wetlands environments (Fig.8).

The surface mantle of silty clay does not form an impermeable layer which confines the underlying aquifers from surface water infiltration or atmospheric pressure. In some areas the mantle may form a semi-permeable layer (aquitard). However, the shallow aquifer is considered to be an *unconfined system*, because of potential connection with surface water and channels that intersect the aquifer.

Groundwater levels indicate a *downward* gradient or 'losing' system that is typical of an unconfined alluvial aquifer system. In general, the standing water level is relatively shallow, between 1.07m and 3.7m below ground level.

Groundwater contours indicate very low hydraulic gradients, similar to the topographic relief. This, coupled with the relatively low permeability of the aquifer, leads to low flow rates for the Molonglo floodplain aquifer, calculated as 30-50 cubic metres/day for the Feb to May 2013 period. Flow is generally northwest towards the northern centre of the Reserve.

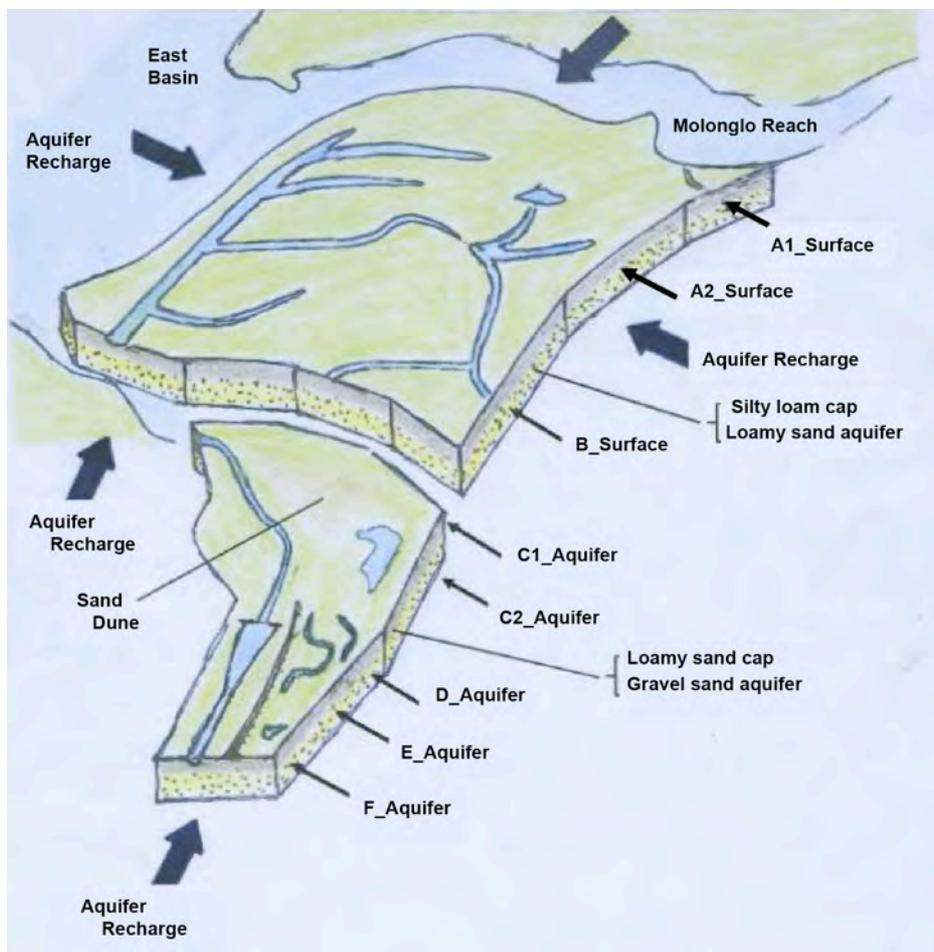


Figure 8: Summary Diagram of Groundwater Pathways

(Source: I Lawrence 2013b)

The *Molonglo floodplain aquifer* extends well to the east of Dairy Road, underlying much of the turf farm area. This aquifer appears to be connected with the lake backwater via the Molonglo River channel along the Reserve's northern boundary and the channel now within East Basin.

It is unlikely that there is a connection between the Causeway channel and the aquifer, or a connection between the lower reaches of the palaeochannels and the aquifer, because the Causeway channel bed lies 2 to 3m above the top of the groundwater aquifer and is lined with fine sediments.

The *Jerrabomberra floodplain aquifers* include the Kellys Swamp–sand dune & flood channel zone, and the southern Billabong groundwater zone.

Studies indicate that Jerrabomberra Creek intersects with the *Molonglo floodplain aquifer* and the *Jerrabomberra floodplain aquifer* along the southern boundary of the Reserve.

There is no certain division between the *Molonglo floodplain aquifer* and the *Jerrabomberra floodplain aquifer* (Kellys Swamp–dune groundwater zone) along the interface of the two zones.

Surface water levels in the lake and river are higher than the groundwater within the central north area, resulting in potential for significant recharge from the north and west. Aquifer boundaries adjacent to the lake and river are expected to be influenced by water levels in the lake, coupled with the degree of storage and through-flow within the aquifer. Under low groundwater flows, lake water may infiltrate further into the wetland areas and affect water levels and quality in the Reserve. There is likely to be significant mixing of groundwater with lake water at the boundaries, similar to mixing of coastal streams with tidal influences.

Rainfall infiltration and evapotranspiration rates are the major determinants of groundwater levels across the centre of the Molonglo floodplain.

Elevated groundwater levels in the Kellys Swamp–sand dune area and the Billabong area are a result of the sand dune and coarse sandy gravels close to the surface across these zones. This results in direct recharge of groundwater by rainfall across these areas, and a reduction in transpiration losses in the case of the dune area.

There is significant aquifer inflow from Jerrabomberra Creek into both the Kellys Swamp–dune groundwater zone and the Billabong groundwater zone during periods of low rainfall and low stormwater discharge, and significant drainage from those zones back to Jerrabomberra Creek during periods of high rainfall and stormwater discharges.

Recent studies recorded periods of no water in Kellys Swamp, exacerbated by drawdown of lake water for the repair of Scrivener Dam flood gates. This condition may become more common with extended dry periods and associated increased diversion of Molonglo and Queanbeyan River flows.

Ecosystem Perspectives

The diversity of habitats available for vegetation and animal (biotic) elements is determined by the landscape setting, geological and geomorphic history, and hydrology. These physical (abiotic) elements have been shaped by changes over time, including changes in climate and human use (Fig.9). Understanding interaction of these elements is essential to understanding:

- what is happening now in ecosystem processes, and the trajectory of those processes;
- which elements are capable of manipulation to change trajectories and bring about a desired condition or state in a resource; and
- what natural or anthropogenic factors constrain actions we may wish to undertake.

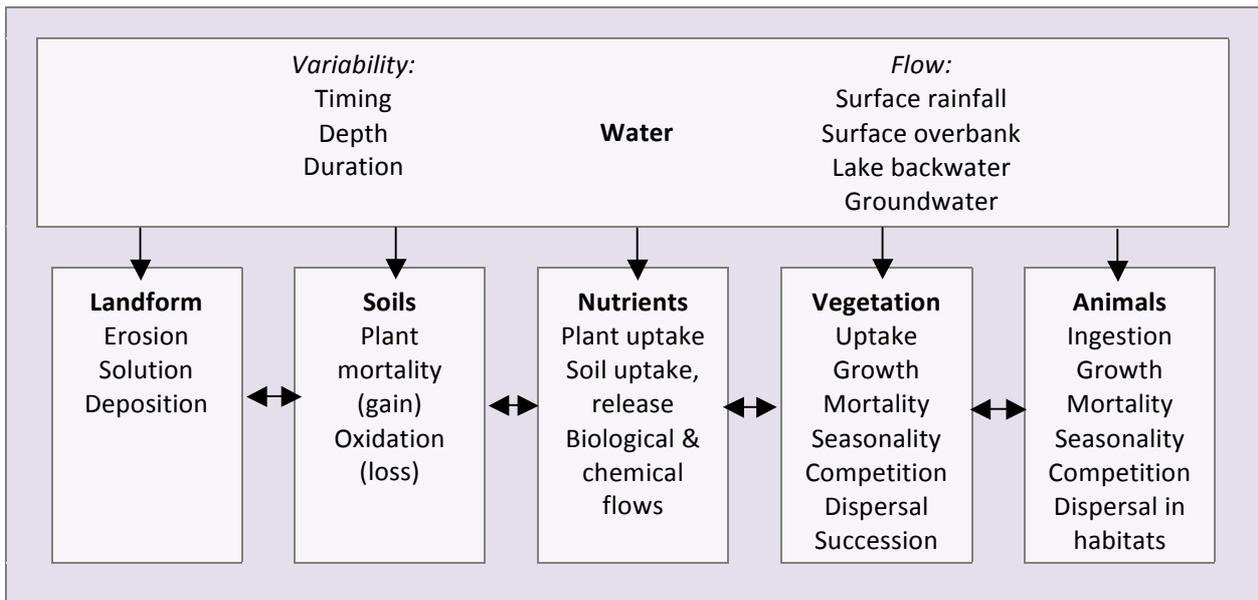


Figure 9: Simplified Model of Ecosystem Processes

A Novel Ecosystem

Jerrabomberra Wetlands has a documented history of sand and gravel extraction, soil dumping and landfill, loss of native vegetation, cultivation for production, changes to the catchment of its two streams, impounding of the Molonglo River to form Lake Burley Griffin, and spread of non-native plant species.

Ecosystems with this kind of history are usually referred to as degraded, or highly modified, or derived, or disturbed, or even abandoned (if previously used for agriculture), depending on which perspective of their history is being emphasised. Although such descriptions are valid, they serve as a constant reminder of what has been lost, emphasise a negative point of view, and are not encouraging.

A different view of the Jerrabomberra Wetlands is to see this as a *novel ecosystem*.

Novel (or emerging) ecosystems have been affected by anthropogenic activities and, as a result, when compared with their unchanged state, now have different ecological communities (in combinations or abundances of species), and different habitats (in combinations of characteristics). They function in a different way, or with different emphasis, driven by altered soils, hydrology and non-native species.

In the case of Jerrabomberra Wetlands, this understanding reinforces that 'restoration' (in the sense of returning an ecosystem to an historic state) is no longer possible, partly due to the influence of the Lake as a relatively stable and persistent waterbody, and partly due to increasing ecological isolation.

Framing Jerrabomberra Wetlands as a *novel wetland ecosystem* is a more positive view, which emphasises the ecological attributes that persist. Wetlands are the outcome of their current hydrology and their underlying geomorphic characteristics. The current hydrology of the Jerrabomberra Wetlands

is modified, but not wholly changed. Similarly, the geomorphic character is still dominated by floodplain forms and features. The history of environmental change is now known, and will prove valuable in understanding the contemporary ecosystem.

The frame of novel ecosystems also shows how the Reserve ‘fits’ in a wider context, within the South-Eastern Highlands bioregion or Canberra Nature Park. Within the city, the Reserve offers uncommon opportunities for urban residents to enjoy and experience nature, especially wetland nature (Fig.10).

Novel ecosystems are a growing field of study in conservation biology and ecology. In the past, a key focus for conservation effort was maintaining defined suites of species in defined places. However, the scale and rate of changes affecting ecosystems and species assemblages is such that customary conservation goals (e.g. ecosystem restoration) may be unrealistic in the future, or in the present.

A more pragmatic focus may be to focus on ecological diversity (functional, species and genetic), and on maintaining habitat structural complexity or ecosystem functioning and services.

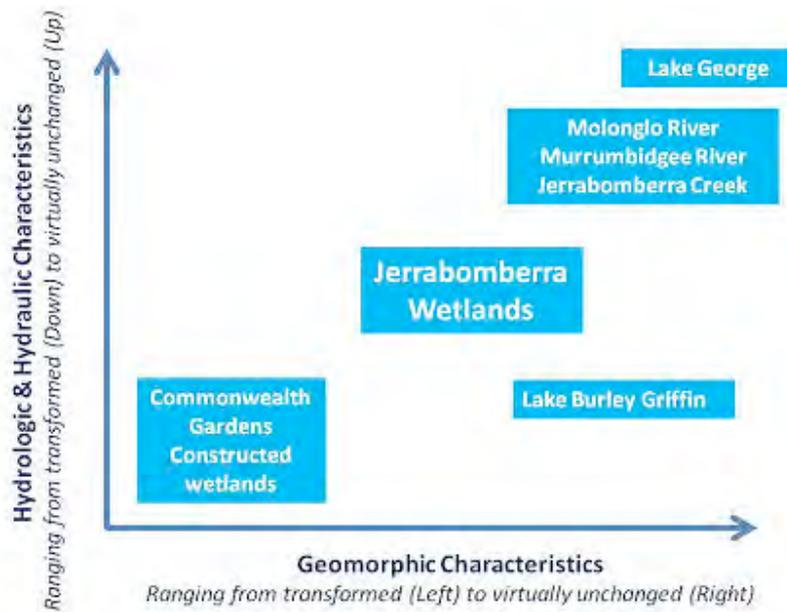


Figure 10: Jerrabomberra Wetlands in a Wetland Spectrum for Canberra and Region
(Source: Roberts 2013b)

Ecological Resilience and Resistance

The notion of dynamic stability underlies the idea of resilience in ecology. Over the long-term an ecosystem is not static. In wetlands, floodplains and rivers, fluctuations drive ecosystem processes and create diversity in a temporal sense.

Resilience is the capacity of an ecosystem to:

- tolerate disturbance without collapse or irreversible change (through properties which confer that tolerance, or resistance); and
- recover from a disturbance after incurring losses (through properties which promote recovery).

When the management goal is *sustainability*, then the intent is a resilient ecosystem which should:

- be self-perpetuating;
- not require constant or repeated management interventions to keep it in the desired state;
- not change as a result of a disturbance; and
- return to how it was prior to the disturbance.

Sustainability as a high-level goal might be supported by an objective about recovery capacity, and sub-objectives about fostering resilient characteristics (e.g. particular types of refuges; focusing on particular groups of species), and fostering resistant characteristics (targeting resistant species groups rather than sensitive species groups)

When the management goal is *restoration* or *rehabilitation*, then the intent is to shift the ecosystem to a desired (often new) state. This may not be achievable, or not easily achievable, if the ecosystem has developed resistant and resilient characteristics that help it to maintain, or return to, its current state.

Disturbance is very much a part of thinking about resilience and resistance. Forces strong enough to have potential to damage the ecosystem by killing or displacing organisms, degrading or destroying habitat structure, or depleting or removing sources of food or shelter, can change ecosystem character by moving it to a new state.

Ecosystems are repeatedly subjected to disturbances, which differ in size and intensity and duration and may result in a new state:

- *pulse disturbances* - short and well-defined e.g. flood, fire, storm events;
- *press disturbances* - rise sharply and then persist without really increasing or decreasing e.g. river regulation, pollution, invasion of non-native species; and
- *ramp disturbances* - increase steadily and intensify through time, eventually ceasing but with timing of the ending being uncertain e.g. drought.

Prior to European settlement, the most likely disturbances to the Reserve area would have been pulse disturbances such as flood and fire, and press disturbances such as drought or extreme winters.

Floods would have affected the Molonglo floodplain through sedimentation, by modifying the vegetation (with some deaths, patchiness, depending on duration and time of year) and would have swept away or drowned most of the terrestrial fauna, other than those who found refuge on higher terraces.

It is now appreciated that floods, although perceived as devastating by humans, are important disturbances which re-set floodplain ecology and create a dynamic environment. The physical changes caused by floods create new habitat patches, provide a pulse of resources that result in a growth surge in perennial plants, and provide brief competition-free opportunities for ephemeral plants.

Following this, populations of terrestrial fauna gradually re-establish from those which survived, whether on high ground, caught in trees, or by staying afloat long enough. The recovery process for floodplain fauna is dependent on having refuges from disturbance in landscape contiguous to the floodplain, and being able to move back to the floodplain after the pulse event.

Fauna have to re-establish after other types of disturbances, such as fire or drought, although refuges would be different. Fauna move back onto the floodplain gradually, and in response to needs for resources. Floodplains are generally a place of high productivity, of considerable habitat diversity (spatial and temporal), and they provide a combination of food resources, shelter and water access in warmer months.

This process of re-dispersing back onto the floodplain following flood, fire or drought is a normal part of dynamic conditions in floodplain landscapes.

Ecological Isolation

The position of Jerrabomberra Wetlands at the eastern end of Lake Burley Griffin is portrayed positively in strategic plans for Canberra such as Griffin Legacy 2004 and the National Capital Plan.

It is possibly the only Reserve located within the Central National Area. It is a wetland of national importance only a few kilometres from the heart of Canberra. It is part of the National Capital Open Space System, described in the Plan of Management 2010 as '*linking habitat between the woodland and open forest of Mt Pleasant and Mt Ainslie to the north, and Jerrabomberra Creek to the south*'.



Figure 11: Landscape Setting for Canberra

(Source: detail from Mackenzie and Sumartojo 2012) Dairy Flat floodplain is circled

This visualisation of the Reserve as part of a large inter-connected ecological system is shown in Fig.11. However, for Jerrabomberra Wetlands these habitat links are largely aesthetic. They are mostly dysfunctional for movement and dispersal of fauna, except those who can fly, that is birds and some invertebrates. In practice, the 'corridors' are not links, but instead are hazardous and/or discontinuous features that present formidable barriers to dispersing terrestrial fauna.

For most terrestrial fauna (reptiles, mammals, many invertebrates) and some aquatic fauna (fish), the Reserve is disconnected from its 'ecological catchment' and is effectively isolated:

- To the *north*, the Reserve is separated by the Molonglo River from the hilltops of Mount Pleasant and Mount Ainslie-Majura, and from the low slopes of the Majura valley.
Molonglo Reach is a perennial backwater of Lake Burley Griffin, which is maintained at a level equivalent to minor floods. Being quite wide (40-200m), it is not easily crossed except by flying or swimming. The elevated water level means the river is constantly wider in summer-autumn than it would have been prior to the construction of Scrivener Dam. Before that, the river shrank in summer-autumn, and became narrow, even to a chain of ponds in very dry years. There would certainly have been times when terrestrial fauna could have crossed quite easily.
- To the *west* is Lake Burley Griffin, a large permanent waterbody which is a major barrier for terrestrial fauna.
- To the *east* are the Monaro Highway, Fyshwick Sewage Treatment Works and the turf farm. None of these terrestrial environments provides safe and secure 'stepping-stone' habitat patches for dispersal of terrestrial fauna, and instead may be quite hazardous.
- To the *south* and *south-east* lie the industrial area of Fyshwick and residential developments. Increasing urban development and infill have been gradually eliminating even small parcels of waste land which served as relict or weedy habitat and contributed to diversity or could be used by dispersing fauna.

It is difficult to envisage how fauna that move over land (such as reptiles, macropods and non-flying invertebrates), might safely disperse into the Reserve, or why they might undertake a movement that is hazardous (swimming over Molonglo Reach, negotiating the turf-farm and the Monaro Highway). Individuals who do arrive in the Reserve are likely to be vagrants which have arrived by accident. Their options for moving out to new habitats are equally hazardous.

Isolation and disconnection applies also to some aquatic fauna, notably fish. Although the Reserve abuts two stream-river systems, it is partly disconnected from the regional drainage network.

The Molonglo River is impounded by Scrivener Dam to form a wide and permanent backwater. Absence of a fish ladder at the dam makes this a barrier for those native fish that would otherwise migrate through the river system, or move into floodplain wetlands to spawn.

The only fish moving into the Jerrabomberra Wetlands are those already present in Lake Burley Griffin, and these are a highly modified assemblage of native, introduced, and stocked species.

The only aquatic fauna likely to use the Molonglo River or Jerrabomberra Creek as a movement corridor are those which can clamber ashore and travel overland in addition to swimming, such as platypus, water rat, eastern long-necked turtle, and snakes. These are able to move fairly readily in and out of the Reserve. Denser littoral and riparian vegetation suggests that the Molonglo River is likely to be a more effective 'corridor' than Jerrabomberra Creek.

Ecological isolation of the aquatic environments is a disturbance which began with chronic zinc pollution from Captains Flat, pushed by major floods of 1939 and 1942 and effectively sterilising the river for fish.

Ecological isolation of the terrestrial habitats began more recently, and has been gradually intensifying. The wide permanent water barrier to the north, west and south-west began with the filling of the Lake in 1963-64. Urbanisation of nearby lands, such as Kingston Foreshore and rejuvenation of residential Kingston in the south, and establishment of industrial Fyshwick to the south-east, altered rough open habitat to areas with little or no habitat value and an impassable (or at best hazardous) barrier. Construction of the Monaro Highway and conversion of rough floodplain into intensively managed agricultural or horticultural enterprise completed the isolating circle around the Reserve.

This *ramp disturbance* is likely to intensify at least into the near future, with ongoing development of East Lake and Kingston Foreshores.

Vulnerability

The initial enduring disturbance to affect fauna and habitat on the floodplain was active development of Mill Flat (later Dairy Flat) for agricultural production, over 80-100 years. Lucerne cultivation, dairying and vegetable-growing eliminated native ground cover and residual native shrubs and trees, replacing it with *Phalaris* pasture. This was a wholesale change in habitat and food resources, affecting ground and seed-eating birds, invertebrates, and small ground fauna. The effects persist today, making this a *press disturbance*.

This explains much about the contemporary faunal assemblages in the Reserve:

- The general abundance and richness of the avifauna arises not only because of diverse habitats but also because bird movements are not much affected by the barriers described above.
- The general richness of aquatic and aquatic-dependent fauna with capacity for overland movement such as platypus, turtles, frogs, and water rat, arises because this is one of the few faunal groups which can readily re-colonise from connected refuges and habitats elsewhere.
- The general lack of 'bush' animals such as possums, echidna and wombat, can be attributed to the floodplain habitat, which would not be core habitat for these species; although they would have sometimes moved onto the floodplain, this is now difficult as the Reserve is virtually inaccessible.
- The presence of medium to large marsupials (kangaroos and swamp wallabies) may be what remains of a family group stranded in the Reserve by increasing isolation; however, it is more likely that these are an ad hoc group of casual arrivals, some voluntary (swimming over the river) and some involuntary (release of urban captures); this group may not remain viable.
- The general lack of small ground fauna such as skinks and dragons can be attributed to the change from native vegetation to pasture, a near monoculture with little structural or floristic diversity and trampling effects from cattle; this has presumably also affected native invertebrates.
- The lack of knowledge about bats can be attributed to a lack of bat sampling; however, it is probably an appropriate representation of a lack of suitable hollows and roosts for microbats.

Overall, despite offering habitats to some faunal groups, the Reserve is ecologically vulnerable. In the event of a population crash, for whatever reason, it is likely that certain faunal groups would not be able to re-establish within the Reserve.

Ecosystem Valuing

Focus on understanding of ecological interactions and processes enables a broader appreciation of the potential values of Jerrabomberra Wetlands than has been evident in previous documentation e.g. community benefits that arise from *ecosystem goods and services* (Fig.12).

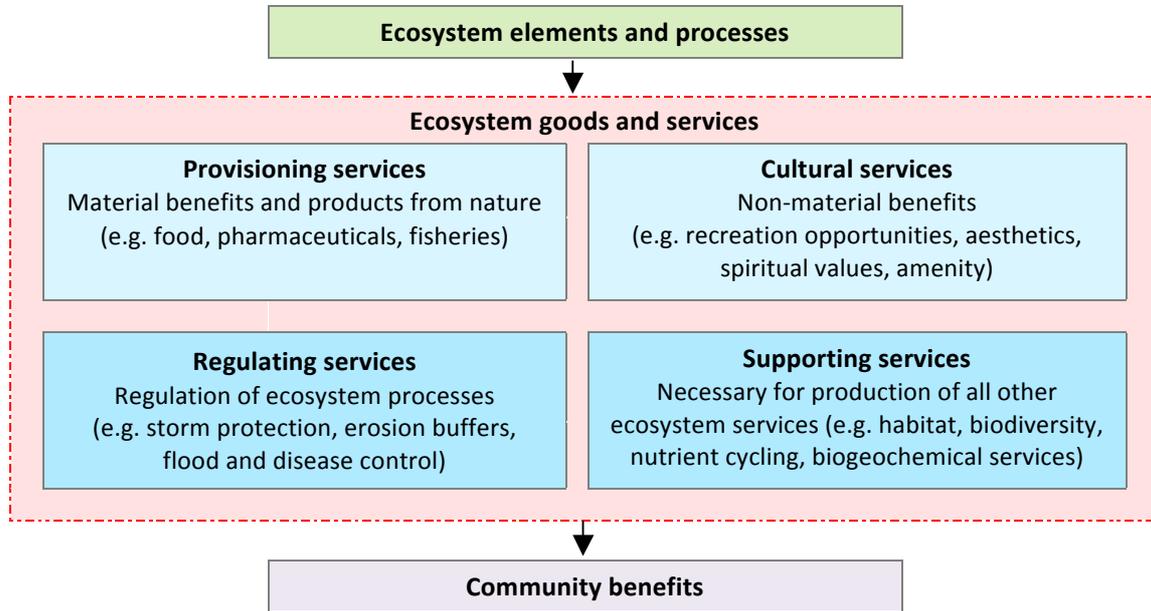


Figure 12: Ecosystem Goods and Services

(Source: after Millennium Ecosystem Assessment 2005)

Note: Provisioning and cultural services are dependent on regulating and supporting services

Because the Reserve was set aside primarily as a floodplain and due to the presence of wetlands, it has customarily been considered as a wetland ecosystem. It is now recognised as an interdependent complex of both wetland and non-wetland (terrestrial) elements, functioning together as part of the overall ecosystem.

The kinds of ecosystem goods and services which might be provided by a functional wetland ecosystem are summarised in Table 8.

The potential for Jerrabomberra Wetlands to provide community benefits of this sort depends on maintenance of numerous ecological interactions and processes, in turn influenced or controlled by a wide range of factors in land use and management, at local and regional scales, as well as larger forces such as climate change.

There has been little or no assessment of the value provided by the Reserve for services such as regulation of storm and flood flows, water quality, and carbon sequestration.

This suggests that valuing of the Reserve is incomplete, and is unavailable for decision-making about land use changes and urban development, which may compromise the functioning of the Jerrabomberra Wetlands ecosystem. Without this kind of valuing, trade-offs are not explicit and cannot be communicated.

Consideration of ecosystem processes at Jerrabomberra Wetlands points to a number of paradoxes:

- The ecosystem services provided by the wetland system may become even more significant and important as nearby urban development intensifies, and yet decisions made in design of that development are not able to take into account wetland ecosystem services and the development has the potential to impact adversely on these services.
- The attributes which make the Jerrabomberra Wetlands special in landscape and ecological terms – open space at the end of the Lake, a wetland of national significance, a refuge for waterbirds, a patch of wildness in the heart of Canberra – are those that challenge its future, through ecological isolation (discussed below).

Additionally, proximity to Canberra International Airport brings with it a duty of care to avoid increasing risk of aircraft bird strike. This is a major constraint on enhancement, and perhaps even maintenance, of wetland systems and associated habitat values.

Table 8: Examples of Services Provided by a Healthy Functioning Wetland Ecosystem

Regulating services	<p>Providing protection from potential storm and flood damage which is heightened by impervious surfaces in urban areas</p> <p>Reducing erosion by holding soil in place, absorbing energy, and reducing the velocity of water flow</p>
Supporting services	<p>Maintaining and improving water quality by intercepting surface water runoff, removing or transforming nutrients, organics, suspended sediment, metals, toxins and pathogens through physical, chemical, and biological processes</p> <p>Carrying out biogeochemical cycling of nutrients such as nitrogen, sulphur, and phosphorus</p> <p>Enhancing atmospheric equilibrium by sequestering carbon in vegetation and sediments</p> <p>Acting as a reservoir for slow release of water from rainfall, surface water, and ground water</p> <p>Providing habitat for diverse species of plants, insects, amphibians, reptiles, birds, fish, and mammals, as sources of food, water, nesting material, or shelter in critical stages of life cycles e.g. staging areas, resting, feeding, breeding, or nesting grounds for migratory waterbirds</p>
Provisioning services	<p>Enabling primary production e.g. grazing, dairying, food and fibre, and nature-based or heritage-based tourism</p>
Cultural services	<p>Providing opportunities for spiritual and traditional connection, aesthetic appreciation and inspiration, recreation and education</p>

Values

Ecosystem values arise as a result of natural processes acting on sites, including those which are or have been subject to disturbance, and are not considered 'natural' (Table 9).

Table 9: Summary of Ecosystem Values

Previous listings and descriptions of the Reserve have focused on its ecological value:

- ◆ An important habitat node in a largely modified landscape, because of availability of permanent water from Lake Burley Griffin, variety of wetland habitats, and proximity to nearby woodland patches
- ◆ One of the most significant freshwater wetland habitats in the ACT and surrounding region of New South Wales
- ◆ One of only two lowland wetlands in the ACT that are listed in the *Directory of Important Wetlands in Australia* 2001, the other being Horse Park Wetlands in the increasingly urbanised area of Gungahlin
- ◆ Drought refuge in periods when nearby large water bodies such as Lake George and Lake Bathurst are dry
- ◆ More than 170 species of birds known to use the Reserve:
 - Overwintering habitat for a number of migratory bird species listed under international agreements with Japan, China and the Republic of Korea
 - 20% of the bird species in the Reserve are listed for protection under at least one State, Territory or Commonwealth Act and may be considered sensitive species (includes migratory species)
 - Used by the majority of the terrestrial bird species found in the ACT, of which some may be common, opportunistic or adaptable, while others may have distinct habitat and seasonal requirements for breeding, foraging, hunting or roosting
 - Within the woodlands, all the known species are recorded rarely or very rarely, reflecting a typical pattern across the ACT and the surrounding region
- ◆ Habitat for other terrestrial fauna and aquatic species, including several frog, reptile and mammal species, some of which may be dependent on the Reserve.

To these can be added:

- ◆ A wetland providing a degree of services such as regulation of storm and flood flows, improvement of water quality, and carbon sequestration
- ◆ A novel wetland ecosystem with a known history of environmental change, which will prove valuable in understanding the contemporary ecosystem

Ecological Elements

Vegetation

Vegetation of the Reserve has been highly modified and is predominantly comprised of introduced species (invasive species, weeds, sown agricultural species, ornamentals, plantings, garden escapees), largely as a result of its history as a grazing, dairying, sown pasture and farm enterprise.

The few terrestrial native species present have been mostly planted, and are not necessarily native to the area. Vegetation of the Reserve has not been mapped or described, other than at a very coarse level, or to show broad habitat types.

The Plan of Management has a list of common weed species (8 trees, 6 shrubs, 3 ground cover, 1 vine), while the Draft Master Plan recognises 19 habitat types, a mix of wetlands, waterbodies and vegetation types, but contains no map or vegetation descriptions.

The few patches of native vegetation are not mapped, wetland and littoral communities are almost completely unknown, and grassland surveys have penetrated only about 20m into the Reserve.

The condition of riparian vegetation along the left (southern) bank of the Molonglo River was mapped as part of an ACT-wide project on riparian condition, and found to be low.

A vegetation map for the Reserve will be completed in 2014. This will provide:

- *Fundamental knowledge base*: the first real attempt at mapping vegetation characteristics;
- *Planning tool*: an essential first step in developing a whole-of-Reserve vegetation strategy;
- *Benchmark*: against which the Board’s achievements will be assessed in the future; and
- *Sound information base*: facilitating communication and discussion of issues, such as extent of particular types of habitat.

Table 10: Particular Challenges in Preparing a Vegetation Map for the Reserve

<p>Typology, Classification, Mapping units:</p>	<p>The Reserve has few, possibly no, residual pre-European plant communities; instead, the vegetation is a mix of plantings (native, non-native including sown pastures and fruit trees) and self-established species (native and non-native). This makes it very different from most vegetation mapping exercises. Although it is desirable to apply existing and current vegetation typologies to the Reserve, this may not be feasible, because most vegetation typologies are based on native species. A new typology or classification may (probably will) need to be developed.</p>
<p>Riparian, wetland, littoral and in-channel:</p>	<p>These are significant habitats within the Reserve and part of the distinctive character of the Reserve. It is important that vegetation mapping captures (in some way) how these vary floristically and structurally around the Reserve, as well as their extent; a single mapping unit labelled ‘riparian vegetation’ is inadequate. Detailed mapping of these communities is rarely done, usually because they are too narrow to show on a vegetation map or because they are variable at an intricate and finer scale that is not consistent with the rest of the vegetation mapping. Some means of representing these and recording their characteristics will need to be developed.</p>
<p>Benchmarking:</p>	<p>The mapping is to serve as a Benchmark against which to understand how the vegetation in the Reserves changes through time. Some parts of the Reserve will change through active intervention (rehabilitation such as plantings, weed removal); some parts will change as a result of change in management (altered grazing, change in fire regime, altered water management); some will change for reasons unknown; and some may not change much at all. The mapping needs to be presented in enough detail that a future review can be confident that (and why/how) a change has or has not occurred (rather than being confused by mapping quality or ambiguity).</p>

Wetlands

Wetlands are areas where water is the primary factor controlling the environment and the associated plant and animal life. In the context of the Reserve, 'wetland' refers to discrete areas on the floodplains, which retain water for sufficient time to support an ecologically distinctive flora and fauna, and to develop certain physical characteristics in the soil and sediments.

Wetlands in the Reserve have made it a popular destination for bird study, and the waterbirds found there are well recorded. By contrast, the wetlands themselves are not well-known.

Only a few of the wetlands have been individually named (Kellys, Shoveler, Billabong); and none have been studied directly. For example, the Plan of Management 2010 summarises and describes types of waterbodies and habitat in the Reserve, but not types and variety of wetlands. Until recently, most attention was on Kellys Swamp, largely due to its avifauna, with other wetlands largely ignored.

Wetlands in the Reserve are now valued in their own right, for their aesthetic qualities, and as potential sites for education and research, as well as for their habitat values for birds and other wetland fauna.



Figure 13: Distribution of Wetlands Across the Reserve
(Source: Roberts 2013a)

Form and Character

A review undertaken in 2013 has provided the first available census and mapping of wetlands in the Reserve, recording and describing 25 wetlands in the Reserve. These are shown in Fig.13, and listed in Table 11, with brief notes on their form and hydrology. This enables a more complete appreciation of the diversity of wetlands present.

In the table, geomorphic form (3-dimensional shape) notes whether the wetland may be natural in origin (in a riverine landscape, a result of fluvial activity), or not natural in origin (a result of human activities, principally excavation). The latter group of younger wetlands may exhibit a slightly different function, resilience, or habitat value, because they do not have the same sediment characteristics or the same reservoir of propagules as older wetlands. This is somewhat speculative, and it is worth noting that in their present form practically all the wetlands except Jerrabomberra Billabong, Kellys and Wetland 15 are relatively young.

Geomorphic form also indicates whether or not the wetland has a direct surface water connection to Lake Burley Griffin, because this strongly influences water regime and much of the ecological character.

Four hydrological categories can be identified:

- 'perched' wetlands contained within the surface soil mantle, having no intersection with the aquifer e.g. Shoveler Pool, floodplain 'palaeochannels';
- 'window' wetlands, which intersect the aquifer e.g. Kellys Swamp, Jerrabomberra Billabong;
- deep channels connected to lake backwater e.g. Causeway channel and lower reaches of palaeochannels; these usually have stable water levels and a permanent water regime, which is a rather unnatural combination of characteristics for this region; and
- large stream pools within the Molonglo River and Jerrabomberra Creek e.g. Molonglo Reach, Jerrabomberra Silt Trap, Jerrabomberra Reach.

Descriptions will be expanded and improved as various projects at the Reserve are completed.

The level of water within the wetlands and the groundwater level across the Reserve reflect the daily balance between:

- inputs to surface water features and groundwater aquifers, including external stormwater discharges, internal surface water runoff, and rainfall infiltration; and
- losses from evapotranspiration from the soil mantle and open water, discharge into adjacent channels or streams, or spill over the floodplain during extended wet conditions.

The wetlands in the Reserve are fairly diverse, with the northern Reserve and southern Reserve (separated by the cycle track) exhibiting a different array of wetlands:

- *Northern Reserve*: Many of the wetlands are long and narrow, and elongate in shape (Wetlands 1-9, 12-14), having been formed by the same geomorphic (fluvial) processes. Most have a surface water connection to Lake Burley Griffin, so tend to be permanently wet and have relatively stable water levels; exceptions are the palaeochannels separated from Wetland 1 by the service trail, which are ephemeral or wet-dry wetlands. The few that are not long and narrow (Wetlands 10-11, 25) are irregular, and hold surface water for a short while only, usually over cooler months into spring. Those on the Peninsula (Wetland 10) support short-medium wetland grasses and sedges, including the locally unusual *Schoenoplectus mucronatus* (found mainly along the eastern seaboard) and some bare areas. Latham's Snipe forage here in spring-summer.
- *Southern Reserve*: Wetlands are more diverse. One group was formed by Jerrabomberra Creek (Wetlands 16, 17, 19 and 21), two of which are lake backwaters, and are notable for being the deepest wetlands in the Reserve, shaded by overhanging trees including willows, and at times with some lotic (flowing) characteristics. Platypus forage in this area. Three wetlands have been completely or partly constructed (Wetlands 18, 20, and part of 17): the Silt Trap and the narrow channel downstream of Jerrabomberra Billabong have little habitat value and contribute little to the ecological assets in the Reserve. Two wetlands unlike the others are Wetland 15, likely a small backwater of Jerrabomberra Creek but possibly a geomorphic relic, and Wetland 25, unusual in being fairly elevated.

Two additional areas warrant inclusion in a future update of this list:

- Molonglo Reach – a significant waterbody within the Reserve that has not featured much in planning and forward thinking; and
- moist grassland west of Kellys Swamp – could be considered a distinctive habitat element of Kellys Swamp.

Table 11: Summary List of Wetlands in the Reserve

(Source: Roberts 2013a)

No	Name	Geomorphic form
Northern Reserve		
1	palaeochannels	Excavated (Causeway) channel and natural forms (flooded scroll bars) Surface water connection to Lake Burley Griffin
2		Natural form. Artificially connected to Lake Burley Griffin by cut channel
3		Natural form. Artificially connected to Wetland 2 by cut channel
4		Natural form. Surface water connection to Molonglo River.
5		Natural form; Divided in two by constructed trail Surface water connection to Molonglo River
6	palaeochannel	Natural form. Separated from Wetland 1 by trail and culvert
7	palaeochannel	Natural form. Separated from Wetland 1 by trail and culvert
8	palaeochannel	Natural form. Separated from Wetland 1 by trail
9	palaeochannel	Natural form. Separated from Wetland 1 by trail
10		Probably not natural, may relate to the causeway railway embankment Cluster of several wetlands, very shallow <10cm. Usually wet over winter-spring, and dry in summer except after much rain
11		Probably not natural. Poorly defined, very shallow. Usually wet over winter-spring, dry in summer, except after much rain
12	Shoveler Pool	Natural form that has been excavated. Relatively shallow
13	palaeochannel	Natural form
14	palaeochannel	Natural form
15		Natural form. Surface water connection to Wetland 16
Southern Reserve		
16	Jerrabomberra Reach (a, b) Jerrabomberra Pool (c)	Natural form. Formerly Jerrabomberra Creek Surface water connection to Lake Burley Griffin
17		Excavated and natural form. Formerly Jerrabomberra Creek
18	Silt Trap	Excavated and designed form
19	Kellys Swamp	Natural form with minor excavations and island
20		Excavated channel
21	Jerrabomberra Billabong	Natural form. Former channel of Jerrabomberra Creek
22		Origins not certain
23		Origins not certain
24		Origins not certain
25		Natural form. Inter-dune swale

Wetland Types

Assigning wetlands to a type or class assists communication and understanding by reducing bulky information to something more manageable, as a summary statement.

There is no single universal way of classifying wetlands, and the ACT does not have its own system. The census trialled the typologies used for NSW and for the Directory of Important Wetlands in Australia (DIWA) to assess their relevance and usefulness for planning and management. These were applied to wetlands as discrete waterbodies (i.e. excluding wetland complexes and mosaics such as floodplains) were investigated.

Neither of these proved to be satisfactory when applied to wetlands in the Reserve, because:

- they did not accommodate all the wetlands within the Reserve;
- classes or types were ambiguous, and not rigorously developed;
- classes or types did not provide a useful or reliable discrimination between the wetlands; and
- they are intended to be applied at a wider scale and not within a floodplain wetland complex.

For these reasons, a site-specific and functional approach to wetland typology was developed for use at Jerrabomberra Wetlands (Fig.14). It is based on two hydrological drivers of wetland functioning, both being aspects of water regime - the dominant *water source* and the characteristic *water depth*,:

- *Water source* is a useful indication of water regime (persistence, variability), of pollution pathways, and (potentially) of movements for aquatic fauna; and
- *Water depth* is a useful indication of water regime (persistence), types and diversity of wetland vegetation, types and diversity of aquatic habitats for fauna.

Other drivers of wetland functioning were found to be less relevant:

- *Water freshness* is not useful because all wetlands in the Reserve are fresh; and
- *Geomorphology* is not workable because the extent of modifications in the Reserve means assumptions about size-shape-substrate are not reliable.

The typology plots wetlands against water source and depth, with resulting water regime shown schematically:

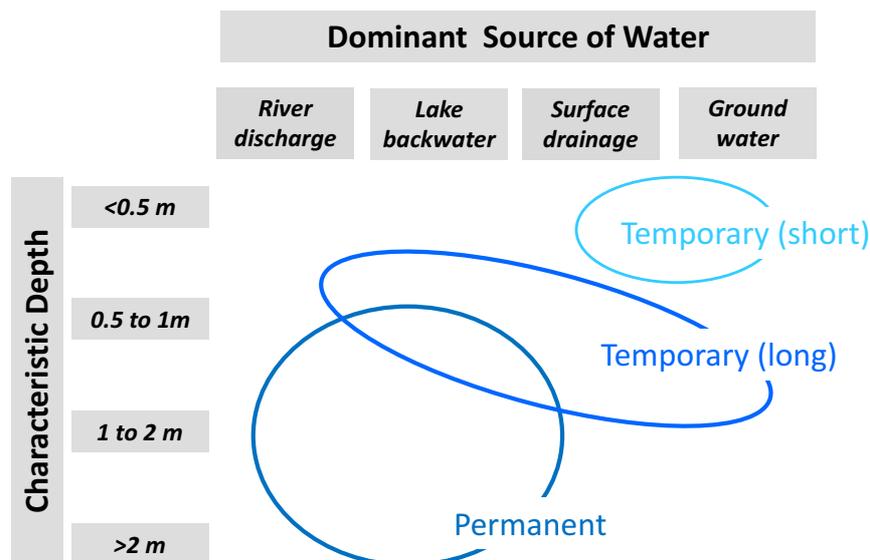


Figure 14: Wetland Typology Showing Drivers and Resulting Water Regime

(Source: Roberts et al 2013)

The basis for the typology is:

- *Water source*: River (or stream) discharge, Lake backwater, Surface drainage, Groundwater; and
- *Water depth*: Typical depths when full: shallow (<50cm), shallow to moderate (50cm to 1m), moderate (1 to 2m), and moderately deep (>2m).

Key:

- *Temporary (short)* (white): has a water surface present for relatively brief periods of time, from days to weeks, even a few months; is wet one or a few times in a year (roughly corresponds to *ephemeral* in other typologies; typically has surface water for less than 50% of year).
- *Temporary (long)* (light blue): has a water surface continuously for much of the year; may dry down for several weeks, even a few months, most likely in warmer months (roughly corresponds to *seasonal* and *near-permanent* in other typologies; typically has surface water for more than 50% of the year).
- *Permanent* (dark blue): retains surface water throughout the year and in all years (corresponds to permanent in other typologies; typically has surface water for 100% of year).

Fig.15 plots the 25 mapped wetlands, the large palaeochannel (PC), and Molonglo Reach (MR):

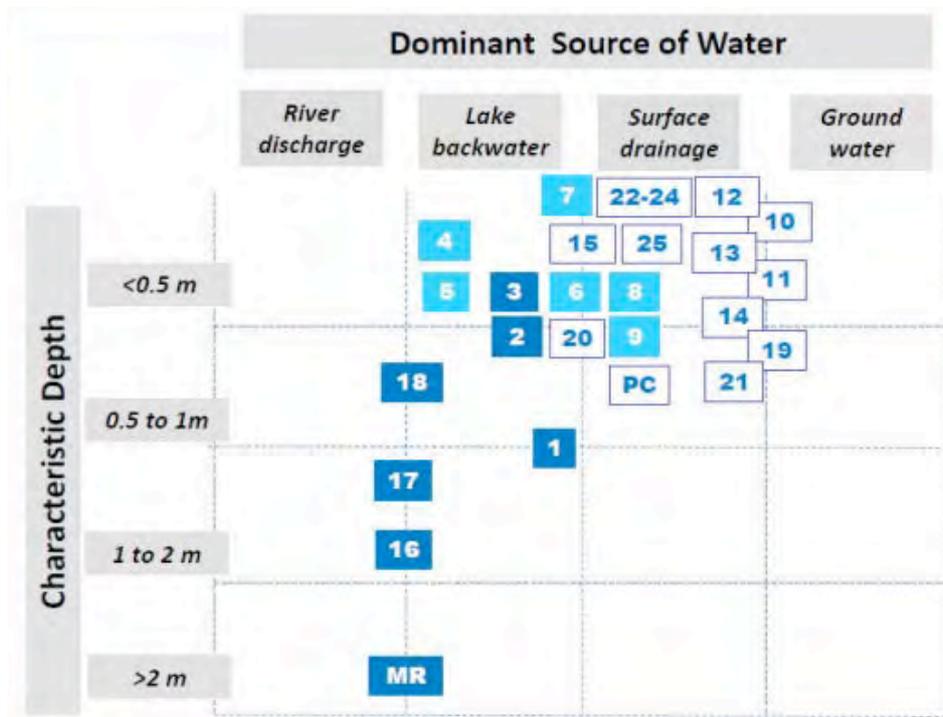


Figure 15: Distribution of Wetlands
(Source: Roberts et al 2013)

In numerical terms, the most abundant types are shallow and shortly temporary.

Based on surface area, however, most of the wetlands are moderate or moderately deep permanent wetlands.

Habitat

Table 12: Principal Habitat Types in the Reserve

Habitat types	Condition/Nature of habitat value	Examples
Permanent open water (areas with connection to Lake Burley Griffin)	Least disturbed (by people) High-quality waterbird habitat for species or individuals sensitive to disturbance Limited emergent macrophytes; submerged plants	Causeway channel, Jerrabomberra Backwaters
	Reliable deep water Habitat for waterbirds, landbirds, and non-avian species e.g. eastern water rat Sheltered habitat for birds preferring open deeper water e.g. cormorants, grebes, ducks, and pelicans Submerged & emergent plants	Molonglo Reach, Jerrabomberra Reach
Mudflats and rushlands	Fluctuating water levels, wetting and drying cycles Valuable feeding habitat for small waders	Molonglo floodplain palaeochannels Kellys Swamp, Shoveler Pool, parts of Jerrabomberra Billabong
Shallow wetlands	Ephemeral habitat for waterbirds, frogs and other non-avian species	Shoveler Pool Wetlands on the Peninsula
Riparian vegetation	Some highly modified by invasive exotic species and past grazing/trampling by cattle Habitat for waterbirds, landbirds and non-avian species Breeding and roosting sites for great cormorants, little pied cormorants and darters	Molonglo Reach, Jerrabomberra Reach
Floodplain grassland and marshland	Periodic flooding expands wetland areas Habitat for wading bird species and frogs Modified or artificial habitats suiting Latham’s Snipe Largely devoid of trees or shrubs	Molonglo floodplain palaeochannels Jerrabomberra Billabong
Grassland	Feeding grounds for some birds of prey, based on habitat for insects, small invertebrates and rodents Where cattle are excluded, a range of aquatic plant species, with <i>Typha</i> and <i>Phragmites</i> in littoral zones	Around Kellys Swamp and Jerrabomberra Silt Trap
Woodland and shrubland (terrestrial; planted native species)	Protected from uncontrolled grazing Understorey habitat for a diverse range of insects and small birds, shelter and roosting habitat for some birds and other fauna Cover and food sources for insectivorous and nectar-feeding birds Foraging for seed-eating birds in grassland interface Some connectivity with nearby habitat ('stepping-stones')	Landscape planting near Kellys Swamp and Jerrabomberra Creek

Waterbirds are important at Jerrabomberra and are one of the reasons that the area was listed in the Directory of Important Wetlands in Australia. It is therefore appropriate to consider habitats available for waterbirds, noting that these habitats are also the best understood.

Considering habitat from this perspective is a reasonable surrogate for considering habitat for other wetland animals (invertebrates and vertebrates). It is also related in part to diverse vegetation structure and composition, both aquatic and terrestrial.

This information is of value in considering potential impacts of modifying wetlands, including risk of aircraft bird strike.

Resource requirements for feeding, resting, shelter and breeding are summarised for waterbird guilds in Table 13. This indicates the range of wetland types needed to provide diverse habitat elements.

Water availability is the main driver for availability of food for waterbirds, in terms of timing, distribution and abundance.

Waterbirds respond in a variety of ways depending on: seasonality, flood extent and duration, water depth, water temperature, time since filling, length and time of drawdown, water quality, wetland type and size, and availability of breeding habitat.

These factors interact and help to determine the food resources in the wetlands. Many wetland types require a period of drying out, and the length of drawdown will determine nutrients, and plant and plankton response.

In this way, water availability will determine the sequence, type and abundance of food availability.

These attributes may be available either in individual, small wetlands or in large wetlands with the attributes available by varying water depth, or in different stages of a wetting and drying cycle.

Waterbirds require safe, predator-free areas to roost, either on islands, trees or bushes and logs in the water. Many waterbirds will feed in one area and roost in another. For example, pelicans, ibis and cormorants may roost in the Reserve yet depend on habitats outside the Reserve to obtain food.

Complementary waterbird habitats that are close to, or contiguous with, the Reserve include:

- Fyshwick Sewage Treatment Plant;
- Goldenholm Pond;
- the turf farm;
- reaches and shorelines of Lake Burley Griffin;
- watercourses and water-sensitive urban design features in neighbouring urban areas;
- cultivated and irrigated river flats on the Molonglo at Pialligo, including the Government gardens; and
- wetlands (natural and constructed) along upstream reaches of Jerrabomberra Creek.

Table 13: Waterbird Guilds and Habitat Requirements
(Source: C Davey 2013b)

Guild	Food requirements	Resting & shelter requirements	Breeding & nesting requirements
Dabblers (7 species recorded)	Temporary and established wetlands, quick response to flooding. Shallow wetland edges where they filter zooplankton by swimming or walking	Islands, peninsulas, logs in water	Sheltered vegetation along wetland margins and tree hollows in or very close to water
Grazing waterfowl (5 species recorded)	Temporary and established wetlands Some need well-established aquatic vegetation that responds to shallow, warm water; others, flooded short vegetation around wetland margins	Islands, peninsulas, logs in water	Tree hollows over or near water or predator-free tall vegetation around wetland margins
Shoreline foragers (5 species recorded)	Fluctuating water levels that expose mud flats Most feed on aquatic vegetation and nearby grasslands where insects, molluscs and small vertebrates are available e.g. Kellys Swamp, lower reaches of palaeochannels	Tall emergent aquatic vegetation	Nesting varies, from thick, tall emergent aquatic vegetation, to nesting over water in bushes or on the ground, sometimes far from water
Large waders (13 species recorded)	Established wetlands where food resources have time to respond to flooding conditions Use mud flats, shallow water and wet grasslands with water depth <0.4 m, seeking crustaceans, molluscs, gastropods and small fish	Trees, either dead or alive, to roost in	Nesting is either solitary or colonial, in open nests, usually over water
Small waders (23 species recorded; most are infrequent and in low numbers)	Temporary and permanent wetlands with mud flats where invertebrate communities have had time to respond to fluctuating water levels Well-established communities of aquatic & terrestrial invertebrates using habitats in mud and on mud surface	Generally undisturbed mud flats; some require dense emergent vegetation	Includes palaeartic migrants that do not breed in Australia Others require dense tall emergent vegetation for breeding
Deep water foragers (6 species recorded)	Large bodies of permanent, deep, open water with well-established invertebrate and vertebrate communities (including molluscs, crustaceans, gastropods)	All rest on the water and seek refuge by diving to obtain food up to 2 m deep	Vary from islands; bushes surrounded by water; to tall, dense emergent vegetation
Fish eaters (11 species recorded)	Permanent wetlands up to 2 m deep with fluctuating water levels. Some use fish, crustaceans, gastropods, molluscs that can be found in deep water Some feed by pursuit diving; others from shallow wetland margins by scooping or stalking		Some in shallow water on floating nests of aquatic vegetation, with little or no fluctuations in water levels around fringes; others in open nests in bushes or trees above or close to water

Cultural Resources

The Plan of Management 2010 and the Draft Master Plan 2012 contain very limited descriptions of cultural heritage and values.

A number of more recent reviews and studies have broadened knowledge and understanding of the Reserve's cultural heritage, associations and values, and these are reflected below.

The story of human use of the area dates back tens of thousands of years and moves through early European settlement nearly two centuries ago, to establishment and construction of the National Capital in the last century and, in the last few decades, Reserve management activities related to wetland habitats and associated recreation.

All of these human activities were focused in this landscape because of its biophysical elements, including the open floodplain below timbered hills and ridges, available water, soil and stone, plants and animals.

These elements became resources, i.e. humans placed value on them, and that has shaped the way we have used the area. Even though the nature of use and development has changed greatly, the same resource elements are valued today. They require careful stewardship if they are to continue to provide a suite of benefits to future generations.

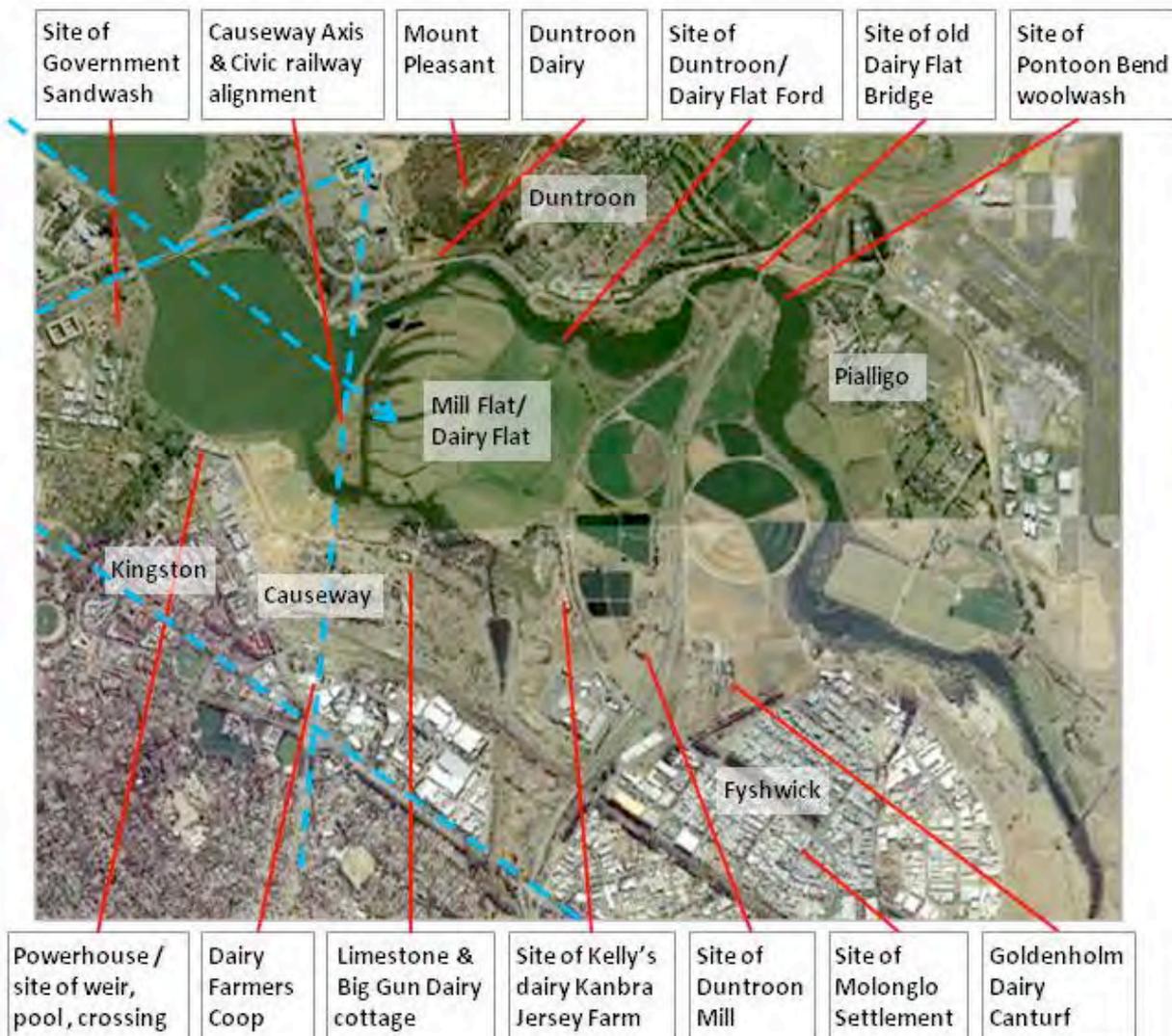


Figure 16: European Cultural Heritage Places and Context Mentioned in Text

Aboriginal places not shown
(Source: Butz 2013a; image c.2009)

Aboriginal Use and Connection

In this Report 'cultural resources' includes not only the archaeological and historic record, but also the continuing cultural and spiritual connection of Aboriginal people with Country. This includes inter-related values, places, stories, pathways, cultural practices and obligations for spiritual renewal, connection with ancestors, and managing natural resources.

The ACT Government acknowledges Ngunnawal people as Traditional Custodians of the Canberra region. The region is documented as an important meeting place with neighbouring clans, including Ngarigo from tablelands to the south, Wolgalu from the high country to the south-west, Wiradjuri from the north-west inland, Gundungurra from the north, and Yuin from the coast.

Aboriginal Use of Landscape

Aboriginal people have lived in and used the landscapes of what is now the Canberra region for upwards of 25,000 years. Oral traditions, stories, pathways and connections go beyond what has been documented by Europeans in the historical record.

Early accounts of Aboriginal lifestyles in the vicinity of the Reserve describe aspects of a successful hunting and gathering economy and eventful social life and inter-group contacts.

People occupied the floodplain landscape through a long period of significant environmental change, adapting also to seasonal availability of food, water and other resources and weather effects such as wind, storms and cold air drainage. Aboriginal people engaged in a complex system of active land management using fire and ecological knowledge to sustain a supply of plant and animal resources throughout the year.

Their material culture included stone and wooden artefacts, fishing lines and snares made from animal tendons, rugs and cloaks made from skins, bark canoes and dwelling shelters made from bark and boughs. In the archaeological record, extensive and varied stone assemblages collected from the Pialligo area indicate that it was a large lowland campsite, with the Molonglo River and its floodplain acting as a focus for human use.

The European historic record attempts to interpret oral gathering of names for places and landscapes, and is prone to discrepancies. The name Molonglo appears to be derived from Moolinggoolah, a name applied to the headwaters of the river near Captains Flat. Charles Throsby recorded the name for this river as Yeal-am-bidgee, which may have been applied to its length up to the junction with the Jullergung or Queanbeyan River at Oaks Estate. From that junction until it terminates at the Murrumbidgee it appears to have been called the Ngambri, rendered by John Lhotsky as Kembery.

Pialligo is likely to be a rendition of the name Biyaligee, recorded by Stewart Mowle of Yarralumla. This probably applied to the area of the Reserve, and much of the landscape upstream from modern Mount Ainslie through Fyshwick to the outskirts of Queanbeyan.

The river valley provided diverse habitats to yield a variety of resources. The open grassy plains and surrounding timbered hills supported animals such as kangaroos, wallabies, wombats, echidnas, birds, snakes and lizards, and many smaller creatures such as grubs and insects.

In periods of high flow, the river carried plenty of fish. An early account describes a large group of Aboriginal people fishing in a 'long waterhole' in the Molonglo near the Duntroon Dairy (now Molonglo Reach). In 1834 Lhotsky caught two cod in the Molonglo, each of which weighed about 13lbs (6kg). In periods of low flow, it is likely that the supply of larger fish ran out, but the remaining ponds would have supported smaller fish, tortoises and yabbies.

Aboriginal people also made use of a wide variety of plant materials for food, fibre and medicine, drawn from forest, woodland, grassland and aquatic or wetland environments. Sources of materials for tools and weapons were well known, and material such as stone was traded between groups.

Periods of relatively abundant resources, such as the summer migration of Bogong moths to the high country, enabled large gatherings and corroborees for the purposes of ceremony and trade. These involved both inland groups and coastal groups. Campsites associated with corroborees included an area in the shelter of Mount Pleasant, later known as Duntroon.

Ngunnawal people recognise Jerrabomberra Creek (or Girimbomberry or Giridomberra) as a ceremonial pathway, which guided visitors from the south to the central corroboree ground on the floodplain (now partly under Lake Burley Griffin). Stories relate that visitors would sit below Mount Jerrabomberra until they were formally welcomed to Country. They would then be accompanied to the junction of the creek and the river near what is now Kingston Foreshores, where they would wait until invited to join the corroboree. The last recorded corroboree on the Molonglo floodplain was in 1862.

Archaeological Record

Past archaeological work conducted in the areas adjacent to the Reserve includes surveys of Fairbairn Avenue, Morshead Drive and Pialligo Avenue, Duntroon, Dairy Flat, Fyshwick and Pialligo.

A cultural heritage assessment was undertaken in 2009 of areas within the Reserve potentially affected by the proposed East Lake Electrical Infrastructure Implementation. The assessment included literature review and database searches, field inspections and Aboriginal consultation. This updated knowledge of historical Aboriginal use of the area.

Although ancient sand dunes to the north of Kellys Swamp have been identified as areas of archaeological sensitivity, test pits yielded no archaeological material. This suggests that the dunes were remote from a permanent water source.

An area with higher archaeological potential is located in slightly elevated ground near Jerrabomberra Creek and immediately northwest of the Reserve office, where Aboriginal people may have used material from the Tertiary gravels for stone tool manufacture. This area would also have been associated with the shoreline of a hypothetical Pleistocene lake.

Continuing Connection

In recent years significant change has occurred in the extent and nature of recognition and acceptance of continuing Aboriginal cultural and spiritual connection to Country. Acceptance of this living culture offers much richer stories of the first people in the landscape than can be conveyed in the archaeological record.

By the end of the 19th century, the local historic record is stocked with accounts of the 'extinction' of the Aboriginal inhabitants, from the combined effects of European diseases, removal from customary places and resources, restricted movement due to fencing, competition for food sources, acts of violence, inter-marriage with European settlers, and dispersal due to government policy.

Far from being 'extinct', Ngunnawal people are recognised as the Traditional Custodians of the area. Theirs is a living culture of interconnected relationship between nature, people, and the spirit of the land through their ancestors.

As I walk this beautiful Country of mine I stop, look and listen and remember the spirits from my ancestors surrounding me. That makes me stand tall and proud of who I am – a Ngunnawal warrior of today.

(Carl Brown Ngunnawal Elder, Wollabaloola Marriage)

When Aboriginal people care for the land they also care for their culture. Working on land management projects not only gives Aboriginal...people a sense of personal pride, it also affirms their identity through a cultural belonging and connection to the land, and has direct benefits on the health and financial wellbeing of their community.

(ACT Government 2013)

European Use

1820-1860s

An area on the north bank of the Molonglo adjacent to the Reserve appears to be the first camp site used by Europeans within the present ACT border. In 1820 a party led by Joseph Wild and including Charles Throsby Smith and James Vaughan wrote the first account of the district, which became known as Limestone Plains, named for the outcrops of that stone which that they found. Smith's journal described the open landscape and recorded the sighting of Aboriginal campfire smoke.

Wild referred to the Molonglo as the Fish River during the 'excursion' of Capt Mark Currie to the Monaro in 1823, while visiting Polish naturalist John Lhotsky recorded it in 1834 as the Limestone.

The area near the confluence of the Molonglo River and Jerrabomberra Creek was first settled in 1825 when James Ainslie occupied the area with 700 sheep, on behalf of his employer Robert Campbell. Ainslie is said to have been guided by Aboriginal people to the well watered grasslands of this location (Pialligo/ Biyaligee). In 1830 Campbell arranged construction of a homestead Limestone Cottage on his property, using local stone, which was completed in 1833. The area of the Reserve was within a 5,000 acre block purchased by Campbell as part of his estate of Pialligo (later known as Duntroon). This block extended southwards from the Molonglo to the higher ground of Mugga Mugga.

Written descriptions from the 1820s suggest that the valley floor area was primarily natural temperate grassland below woodlands and forests on hills and ridges. It is likely that the combined action of cold air drainage, flood events, and soils would have favoured grassland over trees on the valley floor.

European settlers in the 1820s and 1830s recorded significant corroborees on the Molonglo, which place the floodplain in the context of regional-scale seasonal migrations and pathways from the coast, high country and inland areas.

From its initial settlement, the Duntroon estate used parts of the alluvial flats on the Molonglo River to grow vegetables, and in 1834 Lhotsky commented favourably on the quality and variety of garden produce grown there. Lhotsky stayed for six days at Limestone Cottage, by which time there were 20,000 sheep on the Campbell property. He described the view over the plains from the top of Cottage Hill (now Mount Pleasant), and cooled off in the dairy.

Many willows were planted along the Molonglo River from the mid 19th century, with one early account noting that in 1856 there were less than a dozen willows on the river, and a few years later they lined the bank from Duntroon to Yarralumla.

1860s-1912

The Molonglo was highly variable and unpredictable, ranging from a chain of ponds to a flowing stream, well stocked with fish (hence the name Fish River).

It was traversed by fords that became impassable (and deadly to some) in periods of severe flooding, such as those in 1852, 1853 and the early 1860s, 1870, 1891 and into the next century. By contrast, in 1865 the river froze in winter with ice 4 inches thick, and the local population was able to skate.

During intervening dry periods, the Molonglo dried up to a disconnected, rather muddy chain of ponds. The same was true of Jerrabomberra Creek, which was in average times a chain of ponds and swampy flats, prone to low flow or intense flooding. In 1838 even the Murrumbidgee River was completely dry for more than half a mile above its junction with the Molonglo.

A series of severe droughts is recorded: from 1838-1842, when Campbell's wheat crop was lost and the price of wool fell by 50%; in 1865 when the Duntroon estate lost half its sheep flock; another prolonged drought from 1875 to 1879; and again in 1885.

Landholders began ringbarking trees in around 1880. This is credited with causing springs to arise and dry creeks to flow, and the drought years of 1881 and 1885 were considered to be less severe.

From 1861 NSW legislation (the Robertson Acts) allowed people to purchase smaller holdings within leased Crown land. This enabled some closer settlement in the region, but did not affect the large portions on major watercourses that were allocated to the early settlers such as the Campbells.

Regional patterns of pastoral land use and localised cropping on river flats and floodplains would have remained fairly consistent for some decades, expanding in scale as local population grew. Production stepped up from the 1890s also as a result of mechanised agricultural technology, with steam-operated

farm machines taking over from horsepower. Access to and from markets also improved when the railway came to Queanbeyan in 1887.

However, there were setbacks, with serious bush fires in 1888 and the prolonged 'Federation Drought' from 1895 to 1903, with grasshopper plagues in 1893, 1898 and 1902, bringing economic depression.

The year 1897 saw the passing of Nellie Hamilton, commonly described as the last full-blood Aboriginal person in the Limestone Plains district. She was a Ngarigo woman who had been married to Bobby Hamilton, a Ngannawal (Ngambri) man.

There were no major changes to the ownership or use of the Reserve area until the land was acquired by the Commonwealth Government in 1912 for the establishment of the National Capital.

1913-1924

The Molonglo River was a crucial part of the decision about where to site the capital. One potential site (termed Mugga Mugga) was based on Campbell's 5,000 acre block, with the low-lying floodplain inundated to form a lake. This site was passed over for the site at Canberra, immediately to the west.

The choice of site responded to requirements for a picturesque site as well as water supply to enable creation of artificial lakes and public gardens. Surveyor Charles Scrivener suggested that artificial 'ornamental waters' be created by damming the Molonglo River west of the proposed city site. This led to the establishment of gauging weirs on the Molonglo and Queanbeyan Rivers, to assess flows.

Walter Burley Griffin's design for the city included numerous park-lined water features, including three formal central basins with circular and curved edges, and two informal lakes (West Lake and East Lake), which would cover the entire Molonglo flood plain. East Lake would have been some metres higher than the present Lake Burley Griffin, and would have inundated all of the area of the present Reserve as well as areas north of Fyshwick to Pialligo, up to the edge of the current airport runway.

The Territory Feature Map (c.1915) shows a track crossing the Molonglo River via a ford near Duntroon (Duntroon Crossing). The map also shows smaller fenced enclosures labelled Thistle Paddock, Crow and Magpie Paddock, Plantation Paddock, two Lucerne Paddocks, Pontoon Bend Paddock, and Mill House Paddock. To the south was the much larger Mugga Mugga Yard Paddock.

The name Mill House Paddock refers to George Campbell's mill on the Duntroon estate, operated by John Gregory from the 1850s to 1876. This comprised a timber post windmill with a small stone mill house. This site is on high ground adjacent to the Fyshwick Sewerage Treatment Plant. The mill fell into disuse and was destroyed by a strong wind in 1874, although the cottage persisted for some decades after that. The area between the mill and the Molonglo was long referred to as Mill Flat.

This name was also applied to Mill Creek, now Jerrabomberra Creek, traversed by the Queanbeyan-Uriarra Road. The name endures in the Mill Creek Oval, which adjoins the creek at Narrabundah.

In 1914 a low level concrete causeway weir was constructed across the Molonglo just downstream of its junction with Jerrabomberra Creek, forming a pond for the steam cooling system of the power house at Kingston. A timber bridge with rope handrail was built on the weir to provide a pedestrian route across the Molonglo between Eastlake (Kingston) and Duntroon, later replaced with a concrete roadway. The cooling pond was a swimming hole well used by residents until the opening of Manuka Pool in 1931.

During the First World War, Mill Flat was used by the Royal Military College (RMC) Duntroon for encampment of personnel, for practising manoeuvres and for field engineering instruction such as erecting suspension and pontoon bridges.

In 1920 the Pontoon Bend Paddock was retained by RMC Duntroon when the rest of the floodplain was divided into 'lucerne leases' as Mill Flats Soldier Settlement Area. The area now within the Reserve was surveyed into nearly 20 parcels of land (around 20 to 40 acres), available for 25 to 35 years.

Soldier Settlement schemes aimed to repatriate soldiers returning after World War I and to boost population and infrastructure in regional areas. The scheme operated in Canberra from 1920 to 1927, available to returned soldiers with a good record who were residents of the Territory and had volunteered for active service abroad. They required evidence of previous farming experience and were issued leases for terms of one, five, twelve or twenty-five years.

The scheme worked well for some, while others relinquished their blocks due to falling farm commodity prices between 1920 and 1924, poor seasons in the late 1920s, and the Great Depression from 1929, coupled with small non-viable blocks, and over-capitalisation in expensive stock and equipment.

When the first train arrived at Canberra in 1914, it seemed to represent the beginning of Griffin's ideal

that the capital would have rail connection not only with the Goulburn-Cooma line through Queanbeyan or Bungendore, but also through to the 'Great Southern Railway' (the Sydney-Melbourne line) at Yass.

The Griffin plan for the City of Canberra included the Civic Railway line, from the Canberra Railway Yard to the north across the Molonglo River, to terminate (initially) in Civic. A timber trestle bridge across the Molonglo River was completed in 1918, and the railway was completed and opened in 1921, initially as a light construction railway, with plans to upgrade the line later.

To carry the line to the bridge across the Molonglo River, an elevated embankment or 'causeway' was constructed. Just north of the river crossing a long siding was built, most likely for transport of workers from the camp at Russell Hill (Mount Pleasant)-Duntroon.

The Civic Railway embankment was aligned on a spatial axis in the Griffin plan for the National Capital. The Causeway Axis formed the eastern limit of the central city area, linking Hume Circle with Russell, and intersecting with the Water Axis. This lent its name to the workers settlement at The Causeway.

Ultimately, Griffin's plan was for a permanent weir to separate the central ornamental lake from the extensive East Lake. To enable construction of the temporary embankment, Jerrabomberra Creek was diverted into a newly cut channel, and the old creekline was filled in. The Civic railway bridge was severely damaged by floodwaters in 1922, lowering the rails into the river. The same flood forced Jerrabomberra Creek back to its original course, washing away much of the embankment and infill.

1925-1932

Another of the bridges destroyed in the 1922 flood was a 45m long suspension footbridge erected by RMC cadets across the Molonglo in 1916. Their engineering skills were put to good use in the record 1925 flood, when the cadets were able to restore access quickly to South Canberra with a pontoon bridge, in a flood often credited with providing a preview of the future Lake Burley Griffin.

The 1925 flood removed the last of the Civic railway bridge, and subsequent fire left 'a twisted and somewhat disjointed line of sleepers across the Causeway flat and on the flats of the northern side of the river'. In 1927 a new railway alignment across the Molonglo floodplain was proposed, about 50 feet to the east. However, the line was never rebuilt.

The Mill Flats Soldier Settlement blocks would have been flooded in both 1922 and 1925. Perhaps prompted by the latter flood, they were replaced by larger commercial dairy leases (between 200 and 300 acres), offered by the Federal Government to commence early in 1926 for a period of ten years. Each of the dairy blocks bordered the Molonglo, and was provided with a residence, outbuildings and milking yard, built above the floodline. This change of land use lent an alternative name to the area as Dairy Flat, and the Duntroon Crossing became Dairy Flat Ford.

The better known dairy lessees included: No.1 David Cargill (Big Gun Dairy); No.2 E G Kelly (later Kelly Bros.) (Jersey Farm, Kanbra Jersey Stud); No. 3 Donald Murray (Murray's Model Dairy) (later Sofus Frederiksen); and No. 4 Niels Nielson (Goldenholm Dairy) (later Alexander Stuart).

A 1949 cadastral map shows the area of the modern Reserve held by David Cargill (210 ac) and T J Kelly (278 ac), plus a riverside area east of the ford held by Frederiksen. Significant areas of Dairy Flat were cultivated over time, and much of the area was irrigated.

One of the old lucerne leases, an area of 17 acres on the Molonglo, was initially excluded from the dairy area. This was leased by Reuben Hill for growing vegetables, possibly to supply RMC Duntroon. The Hill family later became notable market gardeners at Pialligo.

1933-1962

The dairies had fluctuating fortunes, through large floods in 1934 and 1945, shortages of fodder, wartime labour shortages, an outbreak of brucellosis, and withdrawal of land for sand and gravel extraction, residential development, and construction of road, bridge, railway, garbage disposal and other urban infrastructure.

At least some of the dairy farmers also grew commercial vegetable crops, particularly potatoes, in the years immediately following World War II. The alluvial flats along the Molonglo were rich and deep, and production of potatoes at times exceeded 15 tons per acre (compared with an average yield throughout NSW of 3.5 tons per acre). The Kelly Bros. succeeded in growing a crop of carrots that produced 30 tons per acre.

By the time of the 1933-1949 edition of the Feature Map, modern Pialligo had been divided into 5 to 10 acre blocks for 'home-garden sites', with two large market garden leases on the alluvial flats of the Molonglo, held by Reuben Hill and William Lloyd.

A formalised road on Dairy Flat led to the first Dairy Flat Bridge (or Duntroon Crossing Bridge), completed in 1937. This allowed cattle to be delivered to the Queanbeyan abattoirs without having to use Scotts Crossing (near Blundells Cottage), from which point cattle would frequently stray into Civic.

Near the bridge, Canberra Sand and Gravel began extraction operations 'from Dairy Flat Road right opposite Duntroon' in 1960. It is likely that these extraction operations disturbed areas on the left (southern) bank, leaving a series of depressions.

This was not the first sand and gravel extraction in the general vicinity. The power house was built from unreinforced concrete made with gravel from the Molonglo. Mill Creek (Jerrabomberra Creek) was also a major source of 'good and clean' sand for construction of early Canberra. This was processed through the Government Sandwash which that began about 1925 on the rise above modern Bowen Drive.

A sequence of major heavy metal pollution events affected the Molonglo in 1939, 1942 and 1945, when mine tailings and dams collapsed at Captains Flat, about 70 km upstream from Canberra. These events had serious impacts on aquatic fauna.

In 1950 decision-makers deleted East Lake (and the Civic Railway) from the Canberra plan, on the grounds that the Molonglo would yield insufficient water to keep the lake filled, and to avoid flooding around 1,700 acres of farmland which was considered suitable for 'market-gardening or intensive fodder-crop growing to support hand-feeding of dairy cattle'.

1963-2013

Construction of what became Lake Burley Griffin commenced in 1960, finally filled in 1964. This led to a back-up of water into the Molonglo River, Jerrabomberra Creek, and former flood channels on Dairy Flat. The Dairy Flat Bridge was raised just above lake level, and was periodically inundated.

The filling of the lake led to rationalisation of minor sewerage systems in its catchment, and the Fyshwick Sewage Treatment Works was completed in 1967, with the capability to re-use treated effluent, unusual at that time.

Dairy Flat Road was officially gazetted as Dairy Road in 1968, despite opposition to changing the name. A new Dairy Flat Bridge was completed in 1984, as part of the planned Eastern Parkway, now the Monaro Highway extension. This reached Canberra Ave in 1989 and Newcastle St in 1991, and a new carriageway was completed in 2003 to replace access along Dairy Road. This removed the residence from dairy lease No.3.

From the 1980s until 2002 the ACT Department of Education & Training operated the Dairy Flat Farm (formerly Kellys Farm) as an experimental education centre. This was first used for off-campus curriculum options and later as the site of an Adolescent Development Program for students with significant behavioural, emotional, educational or social difficulties. During this period, the residence from dairy lease No.2 was removed.

After severe bushfires in January 2003 burned most of the buildings used by the Birrigai Outdoor School at Tidbinbilla, the ACT Government enabled it to move to the education centre at Jerrabomberra Wetlands as an alternative campus. This remained in use until the Tidbinbilla buildings were replaced, and the facilities passed to ACT Territory & Municipal Services.

Goldenholm was the last of the four Mill Flat dairy leases to cease operation. Having diversified into cool climate turf cultivation in the 1980's, the farm was sold to Canturf in 2002. By this time, it also incorporated the remaining area of dairy lease No.3 on the eastern side of Dairy Road.

From around 2003, extensive redevelopment took place in the Wetlands Foreshore Business Park and the Kingston Foreshores area, intensifying residential and commercial densities in close proximity to the Reserve. This was associated with construction of foreshore wetlands in Norgrove Park in 2004 and reshaping of the Kingston Boat Harbour in 2008.

The abandoned 'East Lake' is commemorated in the proposed urban development north-east and east of Kingston, which was identified in the Canberra Spatial Plan 2004 and detailed in the East Lake Urban Renewal Draft Planning Report 2007. In planning for this area the National Capital Authority document The Griffin Legacy, released in 2004, foreshadowed the retention and reinforcement of the spatial axes (including the Causeway Axis) as a key part of the geometry and symbolism of the Griffin plan, emphasising the city's landscape setting and approaches.

Values

Under the Australian Natural Heritage Charter 2002, cultural significance includes aesthetic, historic, scientific, social or spiritual value for past, present or future generations.

Apart from the cultural landscape itself, historical traces remaining within the Reserve include:

- fencelines that mark the boundaries of some of the dairy leases;
- access track to the site of the Duntroon Crossing/Dairy Flat Ford across the Molonglo;
- landform features (and possibly other traces) resulting from the Causeway railway embankment and associated redirection of Jerrabomberra Creek into the Causeway channel;
- traces from Kellys Farm and the later Dairy Flat Farm (Education Centre);
- traces of roads and drainages constructed during early farming activities on the floodplain; and
- old Causeway Oval, Eyre Street (formerly Newcastle Street).

Additional places nearby are connected to historical stories relevant to the Reserve. These include:

- Limestone exposure in grounds of the ACT Government weigh station, Eyre Street, Kingston, immediately adjacent to the Reserve – one of only two remaining outcrops for interpreting Limestone Plains historic landscape descriptions and naming (the other located at Acton);
- Traces of the Causeway railway adjacent to the Reserve on the left (southern) bank of Jerrabomberra Creek; also previously reported on the right (northern) bank of the Molonglo River, although now not likely following construction of the hospice and adjacent landscaping;
- Big Gun Dairy – residence (generally referred to as Cargill’s cottage) immediately adjacent to the Reserve; now used for artists-in-residence under Megalo Print Studio & Gallery, Kingston;
- Goldenholm Dairy – landscape, buildings and equipment from Canberra’s last dairy lease to be in operation (until 2002, since then a turf farm); located off Cessnock St, Fyshwick;
- Duntroon traces: Dairy (original parts built c.1832) – one of Canberra’s oldest extant buildings, serving Duntroon property and other local settlers, overlooking Dairy Flat across the Molonglo; Mugga Mugga outstation (established 1838); Woolshed on Woolshed Creek (original parts built c.1840); woolwash site on Pontoon Bend of the Molonglo; Blundells Cottage (c.1860);
- Dairy Farmers Cooperative, Mildura St, Griffith - original milk treatment depot, built in 1938 by the Canberra Dairy Society, which included the dairies on Mill Flat;
- Causeway Hall (built 1926) - the last substantial building remaining from the 1920s construction workers village of about 120 cottages, named for the causeway carrying the Civic Railway (in 1925 the lower northern half of the village was flooded, some houses up to the eaves; the hall is on higher ground); timber houses were replaced by 40 brick houses above the floodline in 1977;
- Site close to The Causeway of two camps for single construction workmen, known as Causeway (1925) and Eastlake. Causeway began in 1925 as a tent camp, with small single room huts erected in 1927; still in use at the end of World War II;
- Site of Eastlake hostel, built during the World War II as accommodation for RAAF personnel; used from 1946 as workers accommodation; sited close to the railway (location imprecise);
- Canberra Railway Museum, Cunningham St, Kingston - rail heritage precinct; display site for the rail-mounted Big Gun (the Amiens Gun) after World War I (barrel and canopy at Australian War Memorial); significant early Canberra landmark on Interlake (Wentworth) Avenue; and
- Site of World War I Molonglo Internment Camp (Concentration Camp), c.80 acres, now Fyshwick: 40 blocks of wooden huts, latrine/ ablution blocks, stores, military buildings (lookout tower, guard houses, barracks, stable and commandant’s residence), water reservoir (concrete walls extant) on Radio Hill (2CA transmitter) near Whyalla St; camp closed 1919 and most buildings sold.

In 1920 became the Molonglo Settlement of construction workers with families (population 750 in 1925); hospital and dispensary later became Molonglo Public School; this closed in World War II (1942) and became a naval wireless telegraph station; some buildings relocated, one cottage to Goldenholm Dairy, 1941-46; remaining buildings demolished 1981.

The Australian Historic Themes Framework 2001 was developed by the Australian Heritage Commission as a tool to assist in:

- emphasising historical processes and connections in assessing places;
- emphasising historical values of places rather than a fabric based assessment;
- structuring research and preparing interpretive texts; and
- explaining how particular elements of a place are significant because of their ability to illustrate important aspects of its history.

In particular, themes assist building of storylines on layers of history, some of which may no longer be evident in the places themselves.

This is particularly applicable to the Reserve, where most of the European cultural heritage values are those of association or connection with historical stories.

Although a comprehensive heritage evaluation has not been undertaken, some relevant Australian Historic Themes for the Reserve and environs can be readily identified, summarised in Table 14.

Table 14: Preliminary Historic Themes for Jerrabomberra Wetlands

Tracing the evolution of the Australian environment	
<i>Tracing climatic and topographical change</i>	Examining the geomorphic record in the floodplain Examining changes in hydrology and stream form
<i>Assessing scientifically diverse environments</i>	History of research, study and monitoring activities Study/ appreciation as a novel ecosystem
<i>Appreciating the natural wonders of Australia</i>	History of environment interpretation and education from community and government sectors Temporary relocation of Birrigai environment education facilities post 2003 fires
Peopling Australia	
<i>Living as Australia's earliest inhabitants</i>	Evidence of extensive Aboriginal use of floodplain resources over a long period Association with: <ul style="list-style-type: none"> • regional connectivity of stories and traditions • regional-scale migrations for ceremony, marriage, lore and trade • documented corroboree grounds and pathways • survival and resilience of Ngunnawal people
Building settlements, towns and cities	
<i>Planning urban settlements</i> Selecting township sites Making suburbs Creating capital cities Developing city centres	Association with National Capital planning/ development: <ul style="list-style-type: none"> • Griffin Plan and Legacy (East Lake, Causeway Axis) • use by RMC Duntroon cadets, WW1 training • Civic Railway line and causeway/embankment; loss of line in flood event (physical evidence/form)
<i>Supplying urban services (power, transport, fire prevention, roads, water, light, sewerage)</i>	<ul style="list-style-type: none"> • nearby Causeway construction workers village • nearby Kingston powerhouse, railway station, utilities
<i>Remembering significant phases in the development of settlements, towns and cities</i>	<ul style="list-style-type: none"> • nearby powerhouse weir swimming hole, river crossing • landfill from (new) Parliament House construction • inclusion in East Lake Urban Renewal area

Continued →

Table 14 (continued): Preliminary Historic Themes for Jerrabomberra Wetlands

Developing local, regional and national economies	
<p><i>Surveying the continent</i> Looking for inland seas & waterways Looking for overland stock routes Looking for land with agricultural potential Laying out boundaries</p>	<p>Association with:</p> <ul style="list-style-type: none"> • early explorer and surveyor activity, early descriptions of landscape and natural history (e.g. Lhotsky) • early settlement/ allocation of land at Limestone Plains • notable landholders - Campbell of Pialligo/ Duntroon
<p><i>Utilising natural resources</i> Mining</p>	<p>Physical evidence/form, and association with sand and gravel extraction: from Molonglo (RMC Duntroon; Canberra Sand & Gravel; nearby powerhouse construction, cooling pool); and from Mill/Jerrabomberra Creek</p> <p>Association with nearby Government Sandwash</p>
<p><i>Developing primary production</i> Grazing stock Breeding animals Developing agricultural industries</p>	<p>Association with:</p> <ul style="list-style-type: none"> • early grazing at Limestone Plains (Ainslie for Campbell) • Duntroon - windmill, woolwash, woolshed, dairy, Mugga Mugga outstation, Blundells Cottage
<p><i>Farming for commercial profit</i></p>	<ul style="list-style-type: none"> • soldier settlement leases post WW1
<p><i>Altering the environment</i> Regulating waterways Irrigating land</p>	<ul style="list-style-type: none"> • dairying (Dairy Flat leases, nearby Duntroon Dairy, Dairy Farmers Cooperative) • Jersey stud development (Kellys 'Kanbra' Jersey Farm) • vegetable growing on the floodplain
<p><i>Feeding people</i> Developing sources of fresh local produce</p>	<ul style="list-style-type: none"> • cultivation, cropping trials, irrigation • adjacent cool climate turf culture; use of pivot irrigators
<p><i>Moving goods and people</i> Moving goods and people on land Building and maintaining railways Building and maintaining roads</p>	<p>Association with generations of fords and crossings for people and goods/materials across the Molonglo River and Mill/Jerrabomberra Creek, including military engineering</p> <p>Physical evidence/form marking Civic Railway line and causeway/embankment</p> <p>Association with nearby Kingston rail heritage precinct (and Big Gun/Amiens Gun)</p>
<p><i>Struggling with remoteness, hardship and failure</i> Dealing with hazards and disasters</p>	<p>Physical evidence/form, and association with flooding history of Molonglo River and Mill/Jerrabomberra Creek; loss of life/ property damage/ landscape change</p>
Developing Australia's cultural life	
<p><i>Organising recreation</i> Developing public parks and gardens Enjoying the natural environment</p>	<p>History of provision of access and facilities for nature-based recreation and tourism</p> <p>Interaction with East Lake Urban Renewal and lake foreshores parks e.g. Norgrove Park constructed wetlands</p>
<p><i>Living in cities and suburbs</i></p>	<p>Association with transition from rural settlement to rural / nearby suburban use in capital city setting</p>
<p><i>Living in the country and rural settlements</i></p>	

Management Implications

Geomorphology

Jerrabomberra Wetlands preserve a diverse record of landscape events, including responses of a substantial river system to changes in climate and land use. This is relatively rare in the local and regional context, and is important to preserve for purposes of scientific study and public awareness of how upland rivers behave.

The geomorphic features in the Reserve appear to be relatively stable and resilient to change. Present management is not contributing substantially to degradation of the landforms preserved in the area.

Exceptions include minor instability of wetland features from cattle grazing, and silt deposition in the scroll bars and palaeochannels inundated by the eastern end of Lake Burley Griffin. Neither of these issues requires urgent management, but should be monitored for evidence of the rate of change.

While the geomorphology of the reserve is largely intact, human activity during the past two centuries has damaged or destroyed a number of the geomorphic units present in the reserve prior to European arrival. Most of the damage has occurred in the southern portion of the reserve, along Jerrabomberra Creek. While most of the sediments deposited when the creek behaved as a swampy meadow remain in the Reserve, the incision of the channel and its later concreting means this unit now behaves as a floodplain. Similarly, palaeochannels on the left bank of Jerrabomberra Creek, which are now covered by landfill, no longer perform their prior hydrological or ecological function.

Future management decisions need to consider likely impacts of construction or earthworks and alterations to hydrology on preservation and character of the geomorphic units that remain. Most units would be relatively resilient to minor land use changes, such as de-stocking or enhanced public interaction and passive recreational activities. The most sensitive units are likely to be the Late Pleistocene dunes, which would be sensitive to wind and rain erosion if de-vegetated, and the former channels of Jerrabomberra Creek (e.g. Kellys Swamp), which would be sensitive to enhanced flood flows.

Water

It appears at this stage that there is a limited role for surface water diverters in enhancing the operation and management of the wetlands.

Recent extended drawdown of water levels in Lake Burley Griffin for remedial work on Scrivener Dam has pointed to an issue which has not previously been anticipated. Lowering lake levels directly lowers water depths in all wetlands that rely on backwaters, and may also lower groundwater levels.

A potential reduction in water supply might also arise from pressure on water levels in the Molonglo or in groundwater aquifers, as industry and government activities which have legal entitlements exercise their rights to extract water.

Appropriate responses include:

- recognition that drying out is part of a seasonal water availability regime, and that this process increases productivity following re-inundation of a wetland;
- incorporation of the importance of drying cycles into interpretation and education programs and materials;
- determining priorities as to which wetlands (if any) should be watered during prolonged dry periods, based on evidence of tolerance to drying;
- investigation of potential avenues to gain a legal entitlement (environmental allocation) which would permit extraction of water from the lake, river or groundwater aquifer for specified volumes and at specified times and specified use/deployment; and
- increased use of some 'backwater'-based wetlands for interpretation and education, to address concerns about visitor experience during drying periods, when water surfaces and waterbirds are less visible.

Water Quality

Studies of water quality were undertaken to assess potential risks to health and biodiversity of aquatic fauna associated with the wetlands and Lake Burley Griffin. Implications include:

- Risks arise from potential sources of discharge, including the Fyshwick industrial area, Monaro Highway crossing, Fyshwick Sewage Treatment Plant, turf production farm, contaminated fill, and residential urban areas.
- Risk factors include heavy metal toxicants, nutrients, oxygen depleting substances, pH modification, salinity, and gross pollutants.
- The groundwater meets all water quality criteria, with the exception of one elevated nitrate reading adjacent to Kellys Swamp. Noting that both nitrite and phosphorus values were low, there is no indication of wastewater seepage from the Fyshwick Sewage Treatment Plant into Kellys Swamp.

External Discharges onto the Reserve

Potential sources of pollutant discharge onto the Reserve include:

- stormwater or industrial spills from adjacent catchments; and
- illegal dumping adjacent to the boundary, resulting in leachate discharge onto the Reserve.

Concern centres on the existing scale of pollution discharge onto the Reserve, which has an impact on water quality, pattern of flows and ecology within the southern part of the Reserve, particularly Jerrabomberra Billabong, a significant natural resource feature. There is a risk that a significant component of these pollutants may be washed into Jerrabomberra Creek and discharged into the Lake.

Appropriate responses include:

- developing stormwater pollution interception and spill detention devices appropriate to covering a high risk industrial area. This is a matter of urgency; and
- siting interception and treatment devices outside the Reserve, particularly Gross Pollutant Traps that bring high maintenance costs.

Where there are spatial constraints e.g. leases close to the Reserve boundary and/or groundwater recharge areas, the response required includes:

- re-assessing potential impacts/risks for the Reserve's natural resource values and for Lake Burley Griffin, based on discharge which is untreated, partially treated, and fully treated;
- investigating alternative pollutant interception devices with reduced scale and visual impact on local natural values;
- exploring opportunities to reduce the scale of treatment devices through adoption of an integrated risk management approach, including upstream and at-source management measures (not leaving it to near 'end-of-pipe'); and
- initiating a monitoring program to capture data necessary to determine more rigorously the impacts and risks.

Where uncontrolled dumping of wastes may generate leachates to discharge onto the Reserve, it is appropriate to initiate either 'containment' or 'in-situ chemical and biological remediation' measures to reduce this risk into the future.

Discharge Impacts from the Reserve to Lake Burley Griffin

Potential sources for discharge of pollutants from the Reserve to Lake Burley Griffin include:

- external discharges onto the Reserve, which then drain to the Lake;
- internal spills from services crossing the Reserve e.g. secondary treated sewage effluent rising main to the Canberra Trunk Sewer, secondary treated sewage effluent rising main to Duntroon playing fields, Googong water supply main;
- internal discharge overflow from Reserve wetlands high in nutrients or nuisance algae; and
- wash-off of organic material, nutrients or sediment as a result of inappropriate land use activities e.g. vegetation denudation, erosion from access tracks or construction activities, cattle grazing, spills of chemicals or herbicides.

Discharge to the Lake may occur via the Molonglo River or Jerrabomberra Creek, or via the groundwater system, or as a direct discharge.

The potential for pollutant discharge to Lake Burley Griffin via either the Molonglo River or Jerrabomberra Creek is an issue for the wider catchment. This requires a collaborative integrated catchment-based pollution control strategy, involving agencies with responsibilities for land management and pollution control.

The risk of impacts from wetlands across the Reserve is generally low, because of shallow water depths (promoting diatoms rather than nuisance blue green algae, and biological uptake of nutrients). The connection of a number of wetlands to the groundwater aquifer means that there is unlikely to be a surface water discharge, with groundwater recharge filtered through wetland sediments.

Management responses include:

- *chemicals or herbicide spills* – reducing likelihood by applying risk management strategies for the storage and use of chemicals or herbicides;
- *spills from services crossing the Reserve* – the responsibility of the respective service infrastructure agencies and their managers;
- *pollutant wash-off from inappropriate land use or management* – undertaking Erosion & Sediment Control Plans for all construction works, and walkway trails, parking areas and vehicle access tracks; constructing fencing around waterways and riparian zones to protect vegetation and isolate faecal matter from waterways; and
- *monitoring and review* – establishing a program of monitoring of potential discharge sources, to provide data necessary to periodically review the risk management performance.

Ecological Elements

Overall, habitats are in fair to poor condition, indicating a lack of scientifically and technically based development and management programs and investment in the Reserve in the past. Despite this, there do not appear to be any threatened species requiring management intervention at this time.

Any management interventions need to recognise the duty of care to avoid risk of aircraft bird strike.

Thinking about disturbance effects and recovery pathways helps to understand the character of the Reserve, and is one way of identifying where best to focus effort.

If aiming to be resilient and sustainable, then a sound approach might follow these steps:

- considering effects of likely disturbances and possible recovery mechanisms, to focus on habitats and faunal groups that are self-maintaining, with high recovery potential and effective inward and outward movements;
- using knowledge of recovery mechanisms to identify risks for different groups;
- setting objectives which are tailored to each group's needs for movement pathways, availability of safe and secure refuges and movement pathways to and from habitats beyond the Reserve, as well as providing resources within the Reserve;
- defining the ecological groups, broadly, in terms of their home range, dependence on the Reserve, and vulnerability to a destructive disturbance on the Reserve;
- evaluating what linkages are effective, where species and individuals might come from or move to, and what can be done to maintain these links; and
- focusing on what types of groups are likely to persist, and their habitat needs, to clarify the ecological limitations to the future Reserve, and the scope and range of its ecological character.

The implications for managing the Reserve in the 21st century are that birds, winged invertebrates and some aquatic fauna are the faunal groups most likely to be self-sustaining and to maintain genetic diversity, as they can move between the Reserve and other habitats.

Past planning and management has focused primarily on the birds of the Reserve, and particularly on waterbirds. As a result, most of the value statements and management attention have been focused on the faunal group who is most likely to carry potential for aircraft bird strike risk. As a result, it is likely

that very few management interventions will be undertaken with a specific objective to enhance conditions for waterbirds.

It is likely that management will need to broaden the range of approaches used to enhance biodiversity, and place greater emphasis on providing habitat for other faunal groups. This recognises that:

- A focus on developing increased *wetland diversity* across the Reserve would enable more balanced attention to non-waterbird elements of wetland biodiversity, including aquatic and riparian vegetation, mammals, frogs, reptiles, and invertebrates, and broader food chains/ecological webs.
- *Frogs* would benefit in abundance and diversity from wetlands which: are not connected to the lake (i.e. no *Gambusia* and able to dry out for a short period e.g. a few months); are not grazed (no trampling from cattle); and have perches for males to call from (depending on species) and tussocks and cracks for aestivation (diverse fringing vegetation).
- The number and diversity of *terrestrial mammals* across the Reserve appears to be limited. This can be partly addressed by an expansion of *woodland habitat* available for food and shelter.
- *Aquatic mammals* have received limited attention in the past. This can be partly addressed in management of *riparian vegetation*, and in interpretive and educational programs and resources.
- *Fish* species present in the Reserve reflect both the manipulation of fish in response to fishing recreational demand and the adverse impact of introduced Common Carp and Eastern *Gambusia* on habitat and fish population dynamics. There is a need to manage Common Carp numbers across the water features of the Reserve, and to investigate reintroduction or enhancement of small native fish species (e.g Mountain Galaxias; Western Carp Gudgeon) in selected wetlands.

Table 15: Summary of Opportunities for Habitat Management

Habitat types/ Current Significance	Management opportunities	Examples
<p><i>Permanent open water</i> (areas with connection to Lake Burley Griffin)</p> <p>Habitat threatened by sedimentation and Common Carp infestation</p>	<p>Introducing some variation in inundation levels to promote edge emergent plants</p> <p>Control of Common Carp and managing fish species with ecological links to the Reserve</p> <p>Including aquatic mammals in interpretation/education</p> <p>Enhancement of biomass and woody vegetation for bird roosting and diving</p>	<p>Causeway channel, Jerrabomberra Backwaters</p> <p>Molonglo Reach, Jerrabomberra Reach</p>
<p><i>Mudflats</i> <i>Shallow wetlands</i></p> <p>Potentially significant conservation value</p>	<p>Maintenance of periodic inundation zones and protection e.g. from cattle grazing; enhancement where viable</p> <p>Re-establishment of previously disrupted hydrological connection, where viable</p> <p>Encouraging self-establishing species or planting with sedges, grasses, rushes</p>	<p>Floodplain palaeochannels</p> <p>Kellys Swamp, Shoveler Pool, Billabong (parts)</p> <p>Wetlands on the Peninsula</p>
<p><i>Riparian vegetation</i></p> <p>Important visual and functional habitat along stream channels</p>	<p>Containing or reducing invasive introduced species, with priority given to those adversely affecting aquatic ecosystems</p> <p>Re-planting with native species</p>	<p>Molonglo Reach, Jerrabomberra Reach</p> <p>Causeway channel</p>
<p><i>Floodplain grassland and marshland</i></p> <p>Important habitat component</p> <p>Important cover for smaller birds</p>	<p>Control of cattle grazing and weed incursions</p> <p>Recovery of riparian zones along palaeochannels and swales</p>	<p>Molonglo floodplain scroll bars/ palaeochannels</p> <p>Jerrabomberra Billabong</p>
<p><i>Grassland</i></p> <p>Limited ecological value; exotic pasture species</p>	<p>Varied grassland management regimes to promote a mosaic of different habitats and associated fauna</p> <p>Long-term replacement strategy to increase the value of grassland for a range of fauna, as habitat, foraging area</p> <p>Incorporation in interpretation/education</p>	<p>Around Kellys Swamp and Jerrabomberra Silt Trap</p> <p>Peninsula</p>
<p><i>Woodland and shrubland</i></p> <p>Limited ecological value; a 'planted' woodland</p>	<p>Re-establishment on selected areas to form a mosaic and offer 'stepping-stones' across an otherwise open landscape for both terrestrial and avian fauna</p> <p>Can play an important ecological role in a novel ecosystem</p>	<p>Landscape planting near Kellys Swamp and Jerrabomberra Creek</p>

Duty of Care: Potential Aircraft Bird Strike Risk

The Canberra International Airport safety regulatory regime requires that the airport identify and manage all the risks within the vicinity of the airport and up to 30km from the airport.

With the setting aside of Jerrabomberra Wetlands 3 to 5km from the airport, and the emphasis on its waterbird populations, there has been understandable concern about potential risk of aircraft bird strike, dating back some decades.

The National Airports Safeguarding Framework - Guideline C is part of a broader framework designed to protect airports from incompatible planning, development and land use.

That Guideline states: Land use planning decisions and the way in which existing land use is managed in the vicinity of airports can significantly influence the risk of wildlife hazards. Many existing airports are surrounded by areas that are attractive to wildlife, especially birds. As examples, land uses such as agriculture, wildlife sanctuaries, wetlands and landfill sites can attract a high number of birds which increase the risk of interference with aviation activity.

Appendix 1 to that Guideline considers that a 'Wildlife sanctuary/ conservation area - wetland' poses a High wildlife attraction risk. A new or revised development of that nature within 3km from the airport is deemed 'Incompatible'. From 3 to 8km, the focus for existing developments is to 'Mitigate'. From, 8 to 13km, the focus for existing developments is to 'Monitor'.

The Framework directs State/Territory and local government decision makers to manage the wildlife risk.

This represents a significant constraint on aspirations to enhance habitat values and associated interpretation / education in the Reserve.

This situation is acknowledged in Appendix I of the National Capital Plan, which includes within Specific Area Policies for Jerrabomberra Wetlands:

Overall, emphasis will be placed on habitat diversity rather than significant increases in general waterbird populations in order to minimise the risk of birdstrike to aircraft using Canberra Airport...

...The option to be retained for the development of further aquatic habitats for conservation and/or recreation purposes. This would be subject to advice from the relevant Commonwealth Government Department of Authority that this would not increase the risk of birdstrikes to aircraft. Major changes of this type to be subject to action under [Commonwealth environment protection legislation].

The Board of Management accepts a duty of care to avoid increasing aircraft bird strike risk at Canberra International Airport (the Airport) in its decisions relating to management of Jerrabomberra Wetlands.

At the same time, the National Capital Plan requires that the Reserve is defined and maintained as a protected wildlife refuge. It sets out a number objectives regarding protection of the ecological resources, geomorphological features and aquatic conditions of Jerrabomberra Wetlands and maintenance of a diversity of wetland and other habitats for wildlife conservation. It also notes international obligations with regard to listed migratory species.

These objectives are reflected in the statutory Plan of Management 2010, which also explicitly addressed bird strike risk.

Broadly, areas of concern with regard to bird strike risk include:

- enhancement of habitats which attract and foster waterbird populations;
- bird movement during periods of drought; and
- creation of 'flyways' which may increase bird passage across or around the Airport.

These concerns are generic to all airports. And in the case of Canberra, they do not arise solely from Jerrabomberra Wetlands, but also from a range of areas such as Lake Burley Griffin, Fyshwick Sewage Treatment Plant, the turf farm, cultivated Molonglo River flats, and urban wetlands.

In relation to Jerrabomberra Wetlands specifically, the Draft Master Plan 2012 contained numerous wetland enhancement and facility development proposals which caused the Airport to become concerned, and did not address bird strike risk directly or in any detail.

This had followed other planning concept documents which aroused concerns with regard to bird strike risk from wetland enhancement.

For example, the Griffin Legacy (NCA 2004) contained a vision of substantial increases in water bodies and within a Jerrabomberra Wetlands Park, adjacent to intensive urban development, to parallel Centennial or Millennium Parks in Sydney as a wetlands recreation park and eco-tourism destination (Fig.17).

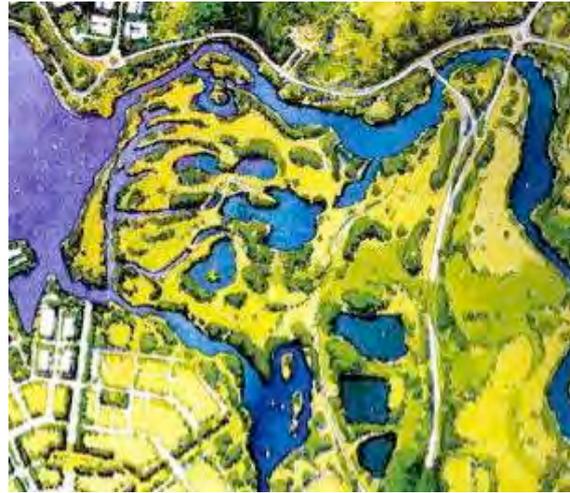


Figure 17: Jerrabomberra Wetlands Park Concept
(Source: NCA 2004)

The need to avoid increasing aircraft bird strike risk makes such propositions untenable, and points to the need for a substantial reframing of the values of the Reserve and a reorientation of management and facility development activities.

A responsible pathway forward will require:

- an agreed principle;
- a shift in management focus;
- a risk management approach; and
- regional communication, education and partnership approaches.

The *fundamental principle* to be applied is that our activities should result in no net increase in risk of bird strike.

This precludes a wide range of potential waterbird habitat enhancement interventions, and also some types of facilities provision (such as for picnics and barbecues), unless robust risk assessment indicates otherwise.

Initially, this would rule out increase in water surface area of wetlands which attract 'high damage risk' categories of birds, such as Pelican, Swan, Black Duck, Spoonbills, and Ibis.

Risk assessment may suggest a need to reduce attractiveness of the Reserve to waterbirds and some other species in the future, and our duty of care requires us to respond accordingly.

To avoid a pessimistic outlook, the focus needs to be on what can be done, and on opportunities to work with a novel ecosystem and in new partnerships.

This requires a *shift in management focus* away from enhancing waterbird values, to include a range of priorities and activities outlined earlier in this Report, including:

- enhancing native grasslands and woodlands, and habitat for terrestrial fauna;
- managing for, and interpreting, non-avian wetland fauna e.g. frogs, mammals;
- enhancing riparian vegetation (structural diversity);
- managing water inundation depths and duration in some of the wetlands;
- interpreting floodplain geomorphology; and
- shifting place identity by interpreting cultural heritage e.g. emphasis on Aboriginal use and continuing connection, Limestone Plains and Mill Flat/Dairy Flat.

Some proposed interventions, which result in changed on-ground or habitat conditions are likely to improve conservation values in the Reserve without increasing risk, but will need to be subject to robust risk assessment. For example:

- closure of the Causeway channel connection to Jerrabomberra Reach will reduce permanent water surface area and allow fluctuation in that channel and palaeochannels (and also allow control of Carp);
- potential creation of one additional wetland in the south western corner of the Reserve (for improved wetland diversity and interpretation) may be traded-off against removal of the Jerrabomberra Silt Trap (by reconnection of the Billabong), because water surface area increase would be neutral; and
- development of stormwater treatment wetlands on southern side of Jerrabomberra Ck, associated with East Lake residential development and the Learning Centre may allow expanded interpretation opportunities in an area more removed from the Airport.

Robust assessment necessitates a continuing scientifically-supported *risk management approach* that is rigorous and transparent, and is agreed with the Airport.

Guideline C paragraph 13 states: 'where the elimination of existing sites [any source which attracts wildlife to the aerodrome, or its vicinity] is not possible, the appropriate authority shall ensure that any risk to aircraft posed by these sites is assessed and reduced to as low as reasonably practicable'.

Paragraph 22 of Guideline C states that 'action plans for monitoring and, where necessary, reducing wildlife attraction' which are agreed with airport operators could include:

- regular monitoring;
- wildlife hazard assessment;
- wildlife awareness and training;
- bird population triggers;
- activities to reduce hazardous bird populations; and
- availability of wildlife deterrent technologies.

This will require methodologies for assessment and monitoring of factors which may increase aircraft bird strike risk, to include bird population triggers and wildlife hazard assessment, and to enable an effective response where increased risks are observed.

Recognition of multiple sources of risk necessitates *regional communication/education and partnerships* to share information, knowledge and expertise and to coordinate effort.

An initial step that recognises the diverse interests pertaining to this issue, may be establishment of a steering group on bird strike risk management, comprising TAMS, the Board of Management, the Airport and National Capital Authority, to liaise about assessment and management response development over the next 12 to 18 months, and to begin to build partnership in responding to this issue.

This should also aim to develop regional all-party planning, perhaps by seeking ACT, Commonwealth and NSW Government commitment to development of a *Canberra and Region Aircraft Bird Strike Hazard Management Strategy*. This would seek to engage (additionally) Department of Civil Aviation, Civil Aviation Safety Authority, ACTEW, ActewAGL, and Queanbeyan City Council as bodies having responsibilities for addressing this concern.

Habitat

Management Using Cattle Grazing

Cattle grazing has been used as a management tool in the Reserve for some decades. There has been some experimentation with grazing exclosures and trials:

Table 16: Benefits Sought by Cattle Grazing, and Experience to Date

Benefit	Summary
<p>Management of fuel load (fire control)</p>	<p>Reduction in fire fuel load (terrestrial grassland/pasture habitats) Cattle can reduce fuel load in areas where tractors/slashers would cause considerable damage (boggy, wet areas, islands) Removal of grazing can quickly result in chest-high grass (tall fescue), with consequent concern for fire risk. Prior to the gazettal of the Nature Reserve, stock grazing (sheep and cattle) occurred over the majority of the Reserve area; also pre-European settlement grazing by native herbivores</p>
<p>Access control</p>	<p>The presence of large bulls has previously provided a deterrent that minimised public access to the Refuge Zone</p>
<p>Maintenance of mudflats (for small wading birds)</p>	<p>Removal of grazing led to rapid loss of mudflats around Kellys Swamp (quickly covered by water couch), with consequent loss of small waders (dotterels, sandpipers etc), lessening interpretive values. Tall reeds and bulrushes expanded considerably, restricting viewing opportunities from the constructed bird hides. Manual maintenance/creation of suitable habitat for small wading birds was attempted (use of heavy machinery to scrape invading vegetation off mudflats; creation of gravel islands to promote visibility of small dotterels) but required ongoing maintenance. Manual containment of reeds and bulrushes by excavation, hand pulling, or cutting and herbicide application was intensive and not entirely successful.</p>
<p>Maintenance of habitat for Latham’s Snipe</p>	<p>Removal of grazing in the Peninsula led to long rank vegetation that caused snipe to abandon their preferred habitat, from which they were slow to return once grazing resumed. Grazing is a vital tool for lowering vegetation height for snipe.</p>
<p>Preservation of rural historical landscape</p>	<p>Grazing cattle allow continued appreciation of rural land use as a heritage theme (links to dairying)</p>
<p>Minor contribution to bird diversity</p>	<p>It is unlikely that the cattle egret would be present in the Reserve if it was not grazed</p>

Potential Risks/Detrimental Effects of Cattle Grazing

- grazing changes plant composition and diversity, such that only unpalatable or grazing-resistant plants remain;
- cattle encourage weed establishment by selective grazing and spreading seeds;
- grazing maintains grassland as a very simple vegetation structure and mostly as a monoculture, which may have relatively little value as a habitat to small fauna and insects;
- potential physical damage to infrastructure (hides, pathways, plantings, plumbing);
- pugging of edges of shallow wetland habitats/ geomorphic features e.g. palaeochannels/scroll bars;
- trampling affecting mud flats associated with wetlands;
- increased turbidity in shallow waterbodies;
- increased nutrient load in shallow waterbodies (faeces, urine);
- damage to riparian zone vegetation, erosion of banks;

- requirement for management infrastructure (fencing, off-stream watering);
- there may be a critical threshold for grazing activities below where a rural lessee may no longer be interested in maintaining a herd at the wetlands; and
- boundaries of Refuge and Buffer zones are substantially influenced by grazing, rather than ecological considerations.

Implications for Broader Wetland Management

- Because the low lake levels of the last few years have desiccated previously important snipe habitat, the value of the Peninsula for snipe needs to be re-examined.

Management Responses to These Risks

- Capability is required to exclude cattle from shallow wetland areas (including palaeochannels) during spring and summer months when shorebirds and migratory species are most common, and to reintroduce in autumn and winter, as the need arises to control vegetation.
- Exclusion fences and off-stream watering points have been established in riparian zones and more can be considered.
- Monitoring of mudflat area and grass height to determine appropriate stocking rates and duration of access.
- A plan for revegetation and on-going vegetation management is required for areas where grazing is to be removed.
- Continuing constructive liaison with the grazier supplying stock.

Alternative Means of Achieving Outcomes

Application of a range of techniques across the Reserve to enhance structural and species diversity, including:

- a variety of grazing practices e.g. crash grazing, longer-term grazing at lower intensity, rotational paddocks, controlling areas grazed by using geo-fencing technology;
- consideration of additional off-stream watering points and shade areas;
- mechanical control of terrestrial vegetation (slashing);
- mechanical/chemical control of wetland vegetation (cutting, spraying, pulling seedlings) to preserve waterbird viewing opportunities around Kellys Swamp;
- mechanical control of wetland edges (scraping to provide mudflats);
- manipulation of water levels to maintain mudflats;
- investigation of the use of fire to replace grazing as a supplementary means of biomass management. Fire in conjunction with herbicide spraying of regrowth and seeding may also be a means to encourage the re-establishment of native grasses; and
- encouragement of research to help determine most appropriate means to reduce the biomass of introduced pasture species, including replacement of some areas with native grasses, shrublands and woodlands as part of a landscape mosaic for terrestrial fauna.

Pest Species Management

The Plan of Management lists introduced species which occur in the Reserve, and indicates which of these are declared pest species in the ACT.

There is potential for pest plants or animals damage habitat or to spread from the Reserve to neighbouring land areas and water bodies.

Pest Plants

This risk is weighed against the value of some stands of exotic plants in providing habitat. As a result, the emphasis in management is on control of declared pest plant species and maintenance of habitat continuity after control and removal. The removal of willows along Molonglo Reach is an example of this approach, and additional removal of woody species from riparian areas is planned.

Terrestrial Vertebrate Pests

Vertebrate pests are controlled as necessary, e.g. removal of introduced hollow-nesting species such as the Common Starling and the Common Myna.

Control of feral cats, rabbits and foxes considers potential impacts of control operations on non-target species such as raptors.

Fish Pests

The diversity of introduced fish in the Reserve is effectively determined by connections to the Molonglo River, Lake Burley Griffin and Jerrabomberra Creek.

Two fish pest species of most concern are: Eastern Gambusia (for its impacts on frogs/tadpoles) and Common Carp (for its impacts on aquatic plants, turbidity, and general public concern).

- Eastern Gambusia: elimination would require an ability to totally dry (or construct) a wetland with no regular/episodic connectivity to lake backwaters or the aquifer.

Because of their small size, mesh screening of dispersal pathways is impractical with this species. Control in isolated wetlands may be possible by repeated trapping.

It may be possible to publicly demonstrate the benefits of Gambusia control by constructing some outside ponds at the Learning Centre, with and without Gambusia, stocked with small fish and tadpoles native to the area. Such ponds could be used to provide interpretation/education about increased tadpole abundance, fish abundance, and improved native fish condition.

- Common Carp: periodic drying out and mesh screening of the piped inlet to Kellys Swamp will remove Carp and lessen reinvasion, with potentially obvious results such as reduced turbidity, which can form the basis for interpretive/educational materials.

Creation of an earth barrier across the Causeway channel is likely to reduce significantly Common Carp abundance in this area. Eradication may be possible, and would require: repeated removal of Carp over a number of years; and screening of the inlet from the lake into wetlands 2 and 3 (at the confluence of the Molonglo and Lake) to prevent reinvasion.

Another broader ecological/educational program may be to harvest Common Carp moving from the lake into the Reserve to spawn. This would likely involve a temporary trap (e.g. from September to December) set in Jerrabomberra Reach, with Carp manually removed from the trap. This may be a partnership program with the ACT Government and other adjacent stakeholders (e.g. National Capital Authority), to assess the impact of control in the Reserve on Carp numbers in the lake.

A related partnership option is to establish and interpret a 'Carp digester' near the Learning Centre, converting trapped Carp into a fertiliser.

Cultural Resources

Cultural heritage in the Reserve has received scant attention in past planning. Reserve management can go much further than meeting legislative requirements for heritage protection.

Table 17: 'Good practice' for Integration of Aboriginal Cultural and Spiritual Values

- ◆ Due respect for Aboriginal lore, custom and traditional knowledge.
- ◆ Early identification and engagement of the most appropriate Aboriginal stakeholders/representatives.
- ◆ Information sharing using a range of accessible formats e.g. illustrated models, booklets and stories.
- ◆ Proactive efforts to build cultural awareness and positive relationships between stakeholders.
- ◆ Integration of science and traditional knowledge.
- ◆ Continual collaboration with Aboriginal stakeholders.

Consultation and Archaeological evidence

ACT Government agencies consult the United Ngunnawal Elders Council (UNEC) on Aboriginal cultural issues.

The ACT Heritage Council requires that Registered Aboriginal Organisations (RAOs) be consulted with regard to management of, and potential impacts to, Aboriginal cultural values and places in the ACT.

Four local Aboriginal organisations are recognised as RAOs under the ACT *Heritage Act 2004*:

- Buru Ngunnawal Aboriginal Corporation (Buru Ngunnawal);
- Consultative Body Aboriginal Corporation (CBAC) (now King Brown Tribal Group);
- Little Gudgenby River Tribal Council (LGRTC); and
- Ngarigu Currawong Clan (Ngarigu).

The group descriptor 'Ngunnawal' applies to only two of the four RAOs. This indicates that in development of the Concept Plan and other significant management matters, additional Aboriginal stakeholder groups will wish to be consulted.

All archaeological evidence of occupation by Aboriginal people is considered significant. It is likely that stone tools and other artefacts remain buried near the surface or at depths up to 2m in the Reserve. These could be exposed by disturbance such as earthworks or scouring by floodwaters, requiring assessment prior to and during earthworks, and following significant flooding.

Cultural and Spiritual Connection and Renewal

Ngunnawal people continue to experience cultural and spiritual connection with the landscape, and maintain traditional knowledge and practices handed down through many generations. This is a living culture which finds expression as Aboriginal people engage with the landscape and exercise responsibility to Country and people.

Aspirations for cultural and spiritual renewal through connection with Country go beyond inclusion of Aboriginal information or themes in educational/interpretive materials and programs, and may include:

- encouraging Aboriginal community members to maintain or build a connection with landscape pathways and stories through oral history, writing and creative arts, and gathering and use of natural materials in tool manufacture and craft;
- working on Country to apply traditional knowledge and methods (cultural science) in land management in association with Aboriginal ranger programs and cultural tours e.g. Murumbung Yurung Murra ('good strong pathways'); and
- enriched visitor experience through interpretation/education to build appreciation, understanding and respect for the cultural landscape and for continuity of Aboriginal culture through past, present and future (shared journeys, shared stories).

Part 2: Vision, Objectives & Principles

Part 1 described ‘*what is*’ – the current state of natural and cultural resources and some implications. This Part sets out ‘*how we want it to be*’ – the Vision and Objectives for the state of those resources in the future, and Guiding Principles for making responsible choices

Our Vision

A diverse and dynamic floodplain landscape and wetland resource, inspiring the community to enjoy and appreciate its natural and cultural values, and to participate actively in its care and management

This supersedes previous versions, including the Vision in the Plan of Management 2010.

Scenario: Journey into a Working Wetland - 2030

The Canberra community treasures the Jerrabomberra Wetlands as ‘a little bit of wildness’ in the city – both a distinctive component of the Bush Capital and an important element in the spectrum of landscape and wetland types across the ACT and region.

We can readily access the perimeter of the area from several directions and using a range of transport, via, road access, cycle paths, and easy walks from nearby urban areas. We enter through developed intensive-use areas near the eastern and southern edges and can make our way to some of the more remote, ‘wilder’ areas, in a broad spectrum of safe public access.

The area is a drawcard for nature-based and cultural heritage-based recreation and tourism, with significant numbers of local, national and international visitors of all ages and abilities appreciating its values through diverse activities such as bird study, photography, walking, and cultural tours.

The exciting Bialigee Learning Centre is the hub of professional interpretation and education programs and facilities presenting layers of stories offered by the area. These assist visitors to learn about the dynamics, processes and values of a floodplain landscape, and about cultural heritage of the Ngunnawal and neighbouring nations, early European settlement of the Limestone Plains, key phases in development of the National Capital, and some of the significant environmental events that have affected the area and people around it.

The area is a focus for local Aboriginal re-connection and re-invigoration of culture through sharing stories of the floodplain landscape. All visitors benefit from cultural interpretation/education displays and tours, learning from use of natural materials in traditional tool manufacture and crafts, and from Ngunnawal people working on Country to apply traditional land management knowledge and methods (cultural science).

Connections with the local arts community celebrate the layers of history and continuing Ngunnawal connection with landscape pathways and stories, through programs of oral history and writing, and displays/exhibitions of creative arts in diverse media, within and around the area.

We can appreciate the mosaic of landscapes across the area, from open water to reed beds and fringing aquatic plants, mudflats and marshlands in old stream channels, pools, billabongs and swales, through woodland and shelter belts of trees and shrubs, to open grassy areas - with fine views to National Capital landmarks.

Judicious design for access and use minimises potential visitor disruption to the wildlife which the diverse aquatic and terrestrial habitats support. Waterbirds are a notable element, including migratory species protected by international agreements. Other aquatic fauna, such as frogs, platypus and water rats are popular with visitors. And as early landscape enhancements have matured, the diversity of terrestrial wildlife has increased, greatly adding to its appeal for nature-based recreation and tourism.

Careful management of habitats, along with effective exclusion of introduced pests from some areas, has enabled the return and recovery of some native species not seen in the city for many years. The area plays an important ecological role as a seasonal habitat, and as a refuge for species affected by longer-term changes in climate.

Adaptive management has re-established a dynamic wetland landscape, through more variable linkages with the Molonglo River, Jerrabomberra Creek and Lake Burley Griffin, and additional areas can now reflect seasonal wetting and drying patterns.

The entire wetland system plays a key role in regulation of water quality, as a set of natural filters. It earns its title as a 'working wetland'.

Researchers value the numerous opportunities offered by the area, including its status as a 'novel ecosystem'.

The modified nature of the area in no way diminishes its significant value for conservation, education, and nature-based and heritage-based recreation and tourism in the eyes of the Canberra community. During any visit, we can find people engaging in 'hands-on' landscape enhancement and in citizen science, research and monitoring, inspired by its natural and cultural values and the important roles played by the area.

A strong sense of community pride and ownership is evident among local communities in the Kingston-East Lake area and the Wetlands Foreshore Business Park. We find many residents and workers playing active roles in continuing care of landscapes which complement the more formal urban parklands and recreational facilities within those developments.

Volunteers comment that one of the strong attractors for active participation in the area is its distinctive model of community-driven partnership, enabling collaborative management between communities and government management agencies. That model continues to build creative partnerships with peak community and industry groups, educational and research institutions, and financial supporters and investors.

These collaborations allow the area to be a showpiece or 'centre of excellence' for natural and cultural values. It provides a hub for information, interpretation and education for sustainability and Ngunnawal connection to Country, with impact on local, regional, national and international scales.

The achievements here have drawn national and international acclaim. Numerous awards are displayed at the site, and it has become a much sought after destination for study tours from overseas delegations.

These forms of recognition acknowledge Jerrabomberra Wetlands as a working demonstration of what is possible when communities are enabled to participate creatively in ecosystem management, conservation, education, and nature-based/ heritage-based tourism.

Objectives

Management objectives are an expression of the values identified in Part 1 and must be consistent with the Goals and Objectives in the Plan of Management 2010 and the National Capital Plan (Table 18).

Table 18: Goals and Objectives in the Plan of Management and the National Capital Plan

Nature Reserve	To conserve the natural environment	To provide for public use of the area for recreation, education and research
Plan of Management	Wetland habitats, waterbird populations and the landscape character of the Jerrabomberra Wetlands are conserved and maintained in perpetuity	Canberra residents and visitors value the Jerrabomberra Wetlands for the recreational, educational and research opportunities that derive from the natural and cultural values of the area
National Capital Plan Appendix I	To define and maintain the Jerrabomberra Wetlands as a protected wildlife refuge, in a national capital and urban context...	...with facilities designed to realise the area's potential as a significant conservation and education resource for Canberra residents, tourists and international visitors
	The challenge of the Jerrabomberra Wetlands is to ensure that a significant ecological resource in the centre of Canberra is protected and maintained...	...while being used sensitively for residents and tourists in ways which enrich their experience of the National Capital and develop greater community awareness and appreciation of the natural environment

The Plan of Management and the National Capital Plan provide more detailed objectives for specific areas and/or for specific themes and values (Tables 19 & 20).

Table 19: Thematic/Value Objectives in the Plan of Management

Biodiversity	<p>The diversity of wetland and other habitats is conserved</p> <p>Habitats suitable for migratory bird species protected under international agreements are conserved</p> <p>The Reserve supports diverse waterbird populations, including migratory species</p>
Landscape	<p>Distinctive features of the landscape are conserved, in particular, the rural and floodplain character and geomorphological features</p> <p>Management of the Reserve takes account of the national capital significance of the area and its role as a significant part of the Lake Burley Griffin foreshore</p>
Recreation	<p>The Reserve is used for recreation activities that are compatible with the conservation values and objectives of the area, and facilities are provided for this purpose</p>
Education & Research	<p>The Reserve is used for education about wetland ecosystems, their management and enhancement, and facilities are provided for this purpose</p> <p>Wetland research is facilitated and supported</p>
Cultural Heritage	<p>Cultural heritage values of the Reserve are identified and conserved</p>

Table 20: Specific Objectives (General Conditions) in the National Capital Plan

Conservation	To protect the ecological resources, geomorphological features and aquatic conditions of Jerrabomberra Wetlands and maintain a diversity of wetland and other habitats for wildlife conservation
Education & Research	To provide for the use of Jerrabomberra Wetlands as a significant educational resource that promotes educational activities appropriate to the area such as nature appreciation, fosters public awareness about wetland ecosystems, and facilitates interpretation about birds and other aquatic wildlife The area is also to be available for scientific research related to wetland environments
Landscape	To maintain and enhance the rural and floodplain landscape character and strengthen the perception and appreciation of the Jerrabomberra Wetlands and its surroundings as an integral part of the landscape of Lake Burley Griffin and the setting for the National Capital
Recreation	To facilitate recreational use for education and interpretation programmes coupled with informal and quiet enjoyment of the area's natural qualities consistent with the protection of Jerrabomberra Wetlands as a significant conservation resource in an urban setting A range of facilities to be provided from Visitor Information Centres and bird-hides to information signs and paths
Services	To provide for the continuation of current essential urban service infrastructure (electricity, water supply, sewerage) Any future proposal for new or upgraded services to be required to protect the nature conservation core areas and to be subject to a full environmental assessment
Planning, Development & Management	To facilitate planning, development and management of the Jerrabomberra Wetlands as a part of the National Capital Open Space System and in a manner which sustains specific uses consistent with conservation of its wetlands habitats, protects it from the impacts of external land uses, and ensures the wetlands are maintained and used in the broader context of planning for the whole of the Molonglo River and Jerrabomberra Creek floodplain and the Lake Burley Griffin Technical and Management Guidelines

Terminology

Terms used in the objectives, such as ‘conserve’, ‘protect’, ‘maintain’ and ‘enhance’, may be used in a variety of ways and with differing intent.

This Report recognises these as *actions* across a spectrum of *intent* and *possibilities* for the resource/system, including:

Conserve	Use it wisely so as to prevent loss, damage or degradation	May include <i>avoidance</i> of damaging impacts and influences
Protect	Maintain/Retain it as is, in a desired state/condition/function	
Rehabilitate	Move it to a desired state/function	May include <i>cessation</i> and <i>mitigation</i> of damaging impacts and influences
Restore	Move it towards an earlier (historical) state/condition/function	
Remediate	Fix an undesired impact or state	
Enhance	Add to its values and/or improve condition/function May include new elements For clarity, needs to be expressed using the active voice e.g. increase x, decrease y	

Guiding Principles

The Board of Management has developed a set of Guiding Principles to inform and influence decision-making:

Being a 'good citizen' and 'good neighbour'	<p>We accept a duty of care to minimise adverse impacts on our neighbours and the broader Canberra-Queanbeyan community from management of the Reserve</p> <p>Specifically, we accept a duty of care to not increase the risk of aircraft bird strike at Canberra International Airport</p>
Striking an appropriate balance between conflicting uses and values	<p>We acknowledge and promote multi-purpose use and values in the Reserve e.g. aesthetic, appropriate recreation, education/ interpretation</p> <p>We work to manage potential tensions and conflicts between different uses and values, recognising that these may offer opportunities and benefits</p> <p>In managing potential tensions and conflicts, priority is given:</p> <ul style="list-style-type: none"> • firstly, to the long-term integrity of natural/ecological resource values (both condition and function) • secondly, to education/interpretation values; and • then, all other considerations with regard to access and use, or external/ imposed impacts

Access and use	<p>We enable access and uses, which are appropriate to the place and its values</p> <p>Access and uses must not compromise resource qualities and values of the place</p> <p>Multiple mechanisms are available to respond to access and uses (e.g. physical, temporal, programmatic)</p>
External/ imposed impacts on Reserve values	<p>We encourage location of urban infrastructure, including stormwater pollution control devices and associated wetlands, outside the Reserve wherever feasible</p> <p>Where no feasible alternative exists, we seek to:</p> <ul style="list-style-type: none"> • maximise the potential to enhance natural/ecological resource values (in condition and function) while minimising risk of aircraft bird strike • develop arrangements that address costs and maximise benefits, and with shared responsibilities • ensure that trade-offs are transparent and communicated
Sustainability	<p>We emphasise community engagement/ ownership / partnership (including sponsorship opportunities) to achieve the vision and uphold the primary values</p>
Adaptability	<p>We recognise that knowledge / understanding of resources and values is dynamic, and requires research, survey, monitoring and review to enable adaptation to changing conditions and opportunities</p>

These Guiding Principles are to be implemented through a structured decision-making process (Table 21).

Table 21: Steps in Structured Decision-Making

<p>1 Scope and context for decision-making</p> <p>Defining what decision is being made and why, establishing roles and responsibilities (including stakeholders and experts) and identifying time scales, spatial scales, risks and constraints May take into account bio-physical limitations, statutory constraints and duty of care</p> <p>2 Objectives and performance indicators</p> <p>Defining how the decision relates directly to objectives for both outcome and process Defining indicators of the consequences of a decision, in relation to achieving the objectives</p> <p>3 Alternative possibilities</p> <p>Defining a range of options for management which will address the objectives</p> <p>4 Implications and consequences</p> <p>Defining likely consequences of options in relation to the objectives, using available knowledge, expert opinion, and conceptual or predictive models May take into account bio-physical and social benefits, possible costs and resourcing implications</p> <p>5 Trade offs</p> <p>Intersecting consequences of options and the values attributed to multiple or competing objectives</p> <p>6 Decision and action</p> <p>Determining the most favoured (priority) option and ensuring it is implemented and reviewed</p>

High levels of uncertainty favour use of these steps in an adaptive management approach, in which monitoring and review support learning about the most effective action.

Figure 18: An Adaptive Management Cycle

(Source: Jones 2005)



Management objectives can be developed in collaboration with stakeholders. Multiple options for management may be specified, including 'do nothing'. Monitoring assists interpretation of how the system responds to management actions

Additional information on Monitoring, Review and Reporting is included in Part 4.

Part 3: Possibilities

Part 1 described *‘what is’* – the current state of natural and cultural resources and some implications.

Part 2 set out *‘what we want’* - the Vision and Objectives for the state of those resources 30 years into the future, and Guiding Principles for making responsible choices

This Part outlines *‘what is possible’* - a range of pathways to achieve the Vision and Objectives and give effect to the Guiding Principles.

The sections explore options, explain management considerations, establish some specific propositions, and provide guidance on future management activities.

Access & Use

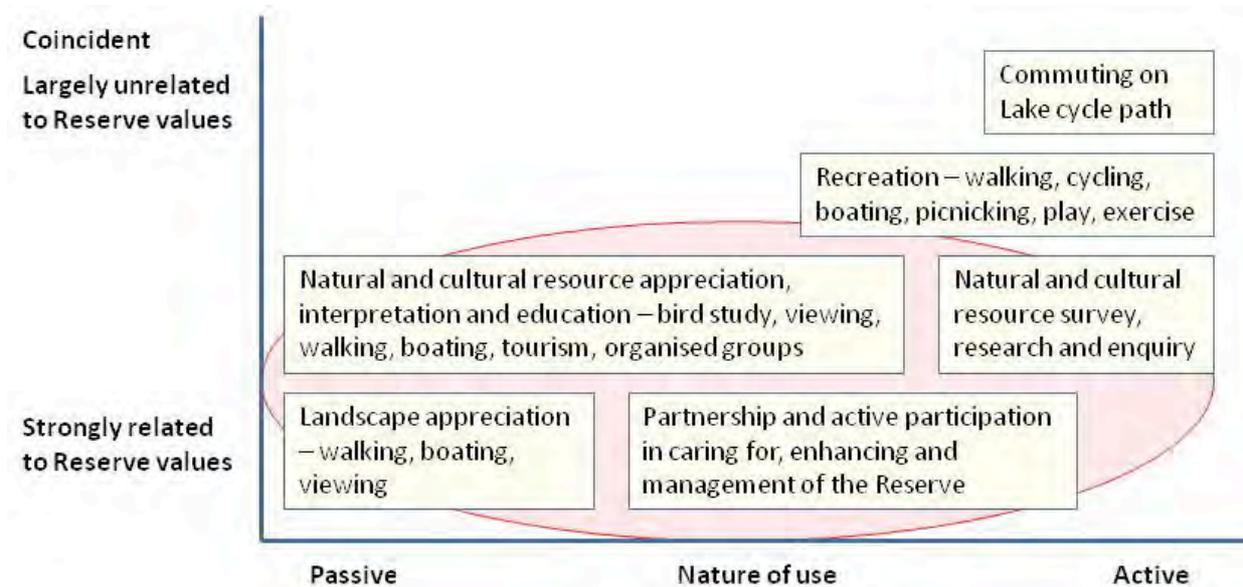
Uses of the Reserve, by individuals or by organised groups, may be passive or active in nature. They may have varying degrees of consistency with Reserve values, objectives, and guiding principles. Some will be consistent only if they are undertaken in specified areas or at specified times.

Priority will be given to those uses and programs which support or depend on Reserve values, and that relate directly to the objectives for Reserve management.

Little or no development will be undertaken for those uses which are largely unrelated to Reserve values, and which can be readily provided for in settings outside the Reserve.

Where coincident uses are located in the Reserve, measures may be taken to relocate these uses in areas outside the Reserve, or at the periphery.

Figure 19: Spectrum of Use Opportunities



Provision and Management of Access

Table 22: Access Arrangements to Support Consistent Uses and Opportunities

<p>Access points</p>	<p>East: Existing eastern access points at the Reserve ‘operations, maintenance & training facility’ and at the Dairy Road car park will be retained</p> <p>South: The southern boundary of the Reserve near Jerrabomberra Creek is likely to become the major access and movement corridor. This anticipates major residential development at Kingston Foreshores, redevelopment across Kingston, East Lake urban renewal, and use of Eyre Street (formerly Newcastle Street) as an entry corridor into East Lake</p> <p>The existing cycleway entry point at the eastern end of Eyre Street, and the preferred site for a Learning Centre (details below), reinforce this as a major entry point and corridor</p> <p>Consideration may be given to adding a further access point on the south eastern corner of the Reserve. This anticipates development of a Jerrabomberra Creek park corridor and cycleway south to Canberra Ave, in association with the East Lake development</p> <p>North: Consideration will be given to adding a northern access point at the north eastern corner of the Reserve. This reflects the existing cycleway entry point at the northern end of Dairy Road, and significant interpretive values in this northern part of the Reserve. Public vehicle access will not be permitted. Consideration will be given to placing cycle racks on the path along Dairy Road</p> <p>West: Access into the Reserve from Lake Burley Griffin will not be permitted, with landing on the Peninsula area prohibited</p>
<p>Access and facilities for visitors</p>	<p>High Value Areas: Access to areas of high natural, ecological and cultural value will be carefully managed to ensure the protection of these values</p> <p>Walkways and bridges will be used to present selected high value sites, with screening used in areas sensitive to visual disturbance</p> <p>Educational and interpretive signage in high value areas will provide information on the values and the need for certain understandings and behaviour by visitors, which will vary with the seasons</p> <p>Southern Border/transitional Area: Local residents will be particularly encouraged to use the Reserve and be involved in its evolving development and management</p> <p>Providing recreational facilities encourages access and use, and the type of facilities shapes the type of access and use. Recreational facilities for use of the local population and visitors from further afield will be located in the southern border/ transitional area adjacent to residential areas and the Learning Centre</p> <p>In this area, the emphasis will be on providing largely informal recreational facilities related to passive uses which support Reserve values, and (secondly) to the least active types of recreational uses e.g. picnics not barbecues, open play spaces not playgrounds, walking tracks not exercise equipment.</p> <p>More active recreational uses are largely unrelated to, or may conflict with, Reserve values. Facilities for these are most appropriately provided within the residential development areas, in intensively managed urban parks</p>

Continued →

Table 22 (continued): Access Arrangements to Support Consistent Uses and Opportunities

<p>Edge fencing</p>	<p>Parts of the Reserve boundary or interface with urban areas may be fenced to:</p> <ul style="list-style-type: none"> • exclude domestic pets and introduced pests • mark/define the boundary of an area having special values and/or conditions of use • provide security for an area • provide legal identification of the Reserve and conditions of entry and use <p>The nature of fencing will be appropriate to its purpose e.g. defining/markings or excluding</p> <p>Edge fencing is preferred over fencing of individual areas within the Reserve, and may be combined with landscaping to reduce visual impact without compromising effectiveness of purpose</p> <p>The Board recognises constraints in erection of fencing, including:</p> <ul style="list-style-type: none"> • restriction (under the Territory Plan) on construction of fencing across the Molonglo River or Jerrabomberra Creek floodways • the current open cycleway through the Reserve, which complicates physical exclusion of pets and pests <p>Potential conflicts between objectives include:</p> <ul style="list-style-type: none"> • Not having a fence to prevent incursion of domestic pets and introduced pest species may pose risks to protection/conservation of fauna and flora • A fence may be unsightly, and may be perceived by neighbours as a barrier to their use of the area, which may inhibit efforts to build partnership with local communities <p>Options that may be used where objectives are seen to conflict include:</p> <ul style="list-style-type: none"> • legislative requirement for digital tagging, containment and/or curfew to manage domestic pets within a set distance of the boundary • inclusion of ‘incidence of domestic pets and introduced pest species within the Reserve’ in monitoring, research and educational programs
<p>Control of domestic pets</p>	<p>Control of domestic pets is the responsibility of owners</p> <p>The Plan of Management prohibits domestic pets in the Reserve. The placement of the cycleway through the Reserve complicates enforcement of this prohibition</p> <p>High Value Areas: Because of the risk of pets chasing, disturbing, or preying on, wildlife, management will focus on ensuring exclusion of domestic pets from areas with significant natural, ecological and cultural values</p> <p>Fencing and gating may be used adjacent to areas of high potential risk, including the adjacent residential area, to reduce likelihood of ingress by domestic pets</p> <p>Some areas will be made safer from predation by provision of refuge islands and use of dead trees and logs in open water to create perching sites</p> <p>Information and Education: Entry points to the Reserve will be used to present educational and interpretive messages on the values of the wetlands and to reinforce that domestic pets are excluded from the Reserve</p> <p>In residential areas adjacent to the Reserve it is intended that there be a legislative requirement for cat identity chips and containment of cats</p>

Continued →

Table 22 (continued): Access Arrangements to Support Consistent Uses and Opportunities

<p>Major cycleway access</p>	<p>Continued efforts will be made to reduce conflicts between cyclists and pedestrians/ other users on the main through-cycleway, with a focus on the shared use bridge over Jerrabomberra Creek</p> <p>Alternative pedestrian paths and crossings will be developed</p> <p>Additional paths may be included in the border/transitional area adjacent to residential areas to the south-west of Jerrabomberra Creek. These will be shared paths for slower-paced cycling and for pedestrians, and (subject to investigation/trial) may include those with dogs on leashes</p> <p>The effectiveness of different approaches to managing joint use of paths by cyclists and pedestrians will be monitored</p> <p>Consideration will be given to diverting the through-cycleway around the south-eastern corner of the Reserve or across the northern end of the Silt Trap. This would expand options for both commuting and recreational cyclists, for walkers, and for exclusion of pets and pest species from the current cycleway route</p>
<p>Boating access (including canoes)</p>	<p>Access by boat will be permitted only into areas where pre-existing approvals or recent approved use applies i.e. Molonglo Reach, and on Lake Burley Griffin adjacent to the Reserve.</p> <p>Boating access will not be permitted on Jerrabomberra Reach within the Reserve, except for direct access between Lake Burley Griffin and the Boat Harbour</p> <p>Access to land parts of the Reserve from these waterways will not be permitted. Signs with educational material will be used to advise of these restrictions and the reasons for them</p> <p>High Value Areas: All boating will be excluded from high value areas and from refuge areas of target species (at least seasonally).</p> <p>A barrier across the Causeway channel will be investigated to protect wildlife, exclude Common Carp from the backwaters, and enable management of water levels – this would prevent boat access to that channel</p> <p>Additional restrictions will be considered in lower parts of Molonglo Reach. This may include prohibition of boat landing, and restrictions on use of motor boats and fishing in this part of the Reach</p> <p>Access will only be by permit issued by the Parks and Conservation Service for conduct of research or study relating to species using these areas</p> <p>Boating groups will be provided with educational material on these provisions, and their cooperation in monitoring use and access will be sought as part of a wider monitoring program to gauge effectiveness</p>

Table 23: Issues for Visitor Safety that Require Management

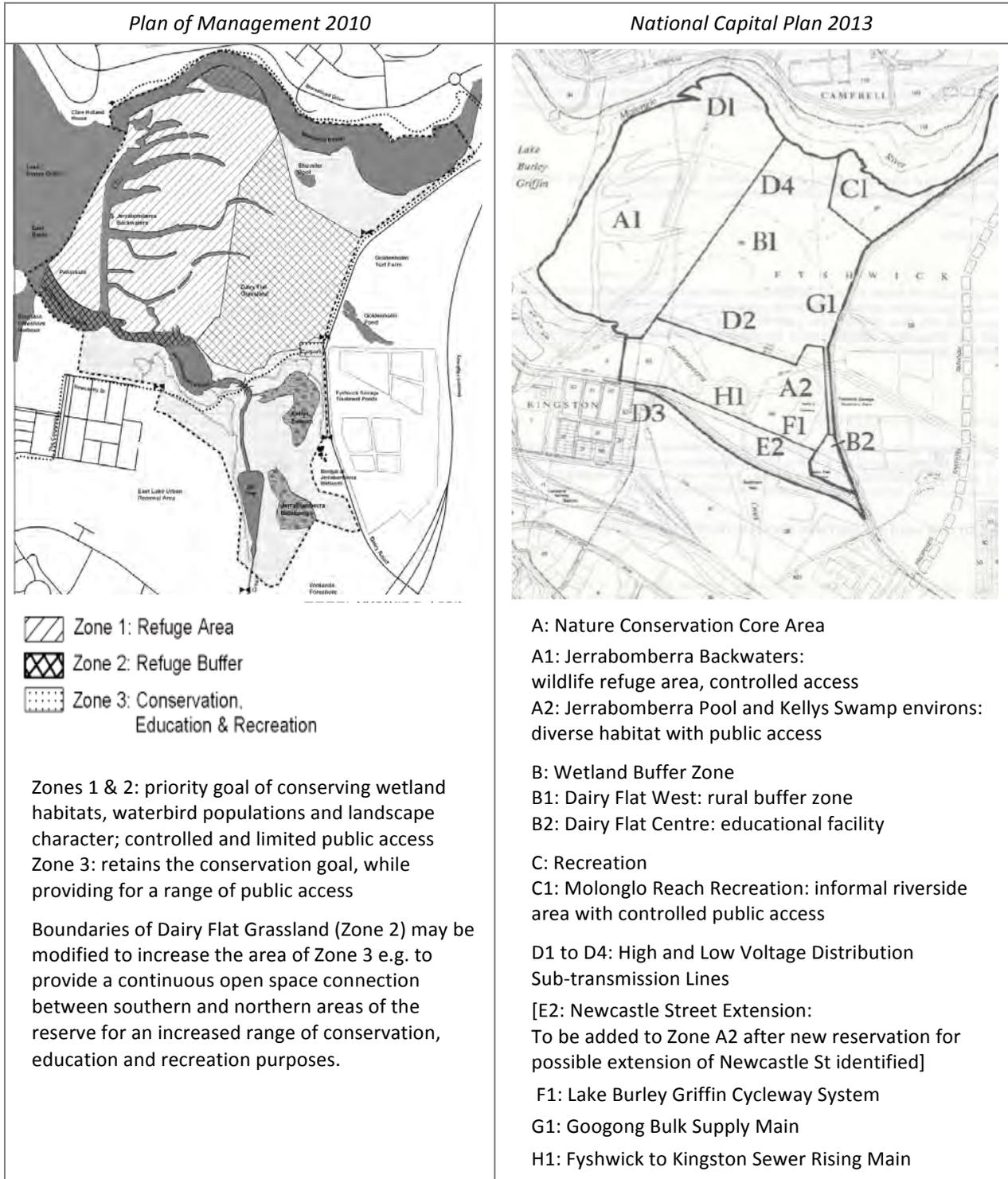
Issue	Management Response
<p>Casual visitors: may arrive at odd times, undertake unusual activities and have variable education, skills and awareness of safety issues.</p> <p>The outdoor environment can be inherently a more hazardous and unpredictable one, and legal precedents have been established around the need for park visitors to be more aware of their surroundings.</p>	<p>All developments will comply with current Australian and ACT legislation, policies and standards relating to public safety</p> <p>Signage and other public information will remind visitors of the changeable nature of the environment and will be used to warn visitors of safety hazards where appropriate.</p>
<p>Formal visitors such as organised groups, contractors and volunteers</p>	<p>Often subject to a permit or approval process which might include a briefing, and other conditions such as a requirement for the wearing of personal protective equipment (PPE) and compliance with Safe Work Method Statements</p> <p>Where possible, groups are required to carry their own public liability insurance; the ACT Government carries this for recognised volunteer groups.</p>
<p>Asbestos present around the former Kellys Farm precinct</p>	<p>Efforts are underway to assess the risk and determine appropriate mitigation measures</p> <p>The public are generally excluded from this area</p> <p>A site management plan will be developed following remediation</p>
<p>Chemical contamination in some earth fill and stormwater, which may affect volunteers who are active in the area</p>	<p>Standard operating procedures and use of personal protective equipment will protect these volunteers</p>
<p>Some issues of walker safety along the cycle path</p>	<p>Current planning is focused on separating these user groups</p>

Management Zoning

Zoning is one of the principal management tools for balancing use of an area with protection of its natural and cultural values. A system of zoned uses/values enables managers to accommodate a diverse range of user expectations while minimising conflict with values.

Two versions of current zoning are provided in the Plan of Management 2010 and the National Capital Plan (Fig.20):

Figure 20: Management Zones and Specific Policy Areas



Although zones are primarily spatial (applied to a defined area), they may also be temporal (applied for a defined time period).

Zoning addresses a range of purposes and needs, including:

- protection and conservation of key species, including meeting international obligations;
- most appropriate use of each area, respecting and communicating its natural and cultural values and constraints in providing opportunities for interpretation, education and recreation;
- provision of safety for visitors; and
- communication about values/priorities and expectations of access, use and visitor behaviour.

Zoning requires a specific focus, clear intent; and sound understanding of 'sensitivity' of an area in terms of resources and values.

Understanding 'sensitivity' requires articulation of: which *specific* aspect of the resource is affected by or sensitive to which *specific* uses / activities / events; and at what scale (temporal and spatial).

It needs to take into account: habituation / modified behaviour, lag time for impacts to be evident, cumulative impacts; and resilience thresholds.

The most likely concerns about sensitivity will relate to waterbird species. This will depend on factors such as the level of disturbance, type of disturbance, timing of disturbance (e.g. breeding seasons), food abundance, habitat, residential status and individual species characteristics such as flight distance.

In this context, disturbance is likely to refer to people-related behaviour and activities that affect behaviour or safety of wildlife due to (for example) noise, movement, proximity, pets, odours or litter.

Some resident species may tolerate a higher level of disturbance than temporary visitors, and many species will soon become habituated to constant background noise and movement, provided there is plenty of food or cover available. Sudden, unexpected changes in noise or movement patterns may cause a level of disturbance unacceptable to many species.

For many of the bird species to remain at wetlands where high levels of disturbance are likely (e.g. Kellys Swamp), it is critical to provide nearby habitat to which birds can move once disturbed.

A refuge zone needs to be an area of low disturbance, especially during the spring and summer months when species of concern such as Latham's Snipe and shorebirds are visiting, when breeding of most species occurs, and when the level of disturbance is likely to be high.

Refinements of Management Focus

Proposed refinements of management focus within Plan of Management Zoning and National Capital Plan Specific Policy Areas are summarised in Table 24.

Temporal (seasonal or episodic) Zoning:

Where a refuge area may generally be open to visitors, it may be necessary to close that area if a particularly sensitive species is present.

The size of a restricted area will depend on specific circumstances.

It may be necessary to close off access to certain watching hides if breeding is occurring, especially for those species which breed in colonies or are tree nesters e.g. a recent Royal Spoonbill breeding event at Kellys Swamp.

A restricted area of approximately 100m radius may be sufficient, applied when the species arrives. In a recent arrival of three Australian Painted Snipe on Kellys Swamp, the level of disturbance became excessive, particularly from photographers, necessitating a temporary restriction of access.

The current Plan of Management treatment of the Wildlife Refuge Zone may be overly cautious in constraining access. Temporal (seasonal or episodic) zoning is suggested in this area to enable:

- careful management of potential disturbances during periods of breeding or nesting of endangered species or visitation by migratory species (for Latham's Snipe this is likely to be August to March, subject to monitoring and review); and

- some easing of access restrictions at other times of year to make better use of its interpretive potential.

Additional Restrictions in Molonglo Reach

Re-establishment of the small island in Molonglo Reach may be coupled with prohibition of boat landing, and restrictions on use of motor boats, active boating, and fishing in this part of the Reach.

This is the section downstream from the site of the old Dairy Flat Ford (north-east of Shoveler Pool). This coincides with the point where the boundary between National Capital Plan Specific Policy Areas B1 and C1 meet the Molonglo.

Some of these options may necessitate future revision of the Plan of Management.

Table 24: Refinement of Management Focus Within Current Zoning and Specific Policy Areas

Zone / Policy Area	Associated management
<p>Zone 1 / A1 Peninsula Causeway channel Grassland west of service track Lower (flooded) palaeochannels Associated riparian corridors</p>	<p>International obligations to protect migratory species Conservation of geomorphology Enhancement of selected natural values including riparian areas Interpretive & educational use Temporal (seasonal or episodic) zoning to protect breeding or nesting species or visiting migratory species Screening & walkway infrastructure design Use of remote camera/video display of sensitive fauna in the Learning Centre Regulatory signage to restrict access by land or water</p>
<p>Parts 1 & 2 / A1 & B1 Grassland east of service track Upper palaeochannels Associated riparian corridors</p>	<p>Enhancement of selected natural values Interpretive & educational use Walkway and cycleway access in this zone Fencing to exclude cattle from riparian areas</p>
<p>Zone 3 / A2 Kellys Swamp Zone 3 / B1 Shoveler Pool</p>	<p>Modified & constructed wetland areas Enhancement of selected natural values Visitor facilities and infrastructure Interpretive and educational use</p>
<p>Zone 1, (2) & 3 / A1, B1, C1 Molonglo Reach Associated riparian corridors</p>	<p>Conservation & rehabilitation to protect breeding or nesting species Interpretive & educational use East (upstream) of the Dairy Flat Ford site: <ul style="list-style-type: none"> • Screening & walkway infrastructure design • Active, motorised and team/organised boating use and fishing permitted, consistent with protection of natural values West (downstream) of the ford site: <ul style="list-style-type: none"> • Passive, non-motorised boating permitted, consistent with protection of natural values, no fishing permitted </p>
<p>Zone 3 Jerrabomberra (Billabong) floodplain</p>	<p>Geomorphological and hydraulic conservation / rehabilitation zone Interpretive & educational use Screening & walkway infrastructure design</p>
<p>Zone 3 / A2, (E2) Left (southern) bank of Jerrabomberra Creek</p>	<p>Enhancement of selected natural values Interpretive & educational use Wider recreational use (passive and some active) Learning Centre, car parking, urban interface</p>

Habitat Development

This section addresses measures to develop habitat values, including managing water levels and flows, and landscaping/planting (Table 25).

These measures require: a clear objective; established likelihood of success; consistency with overall objectives; and minimal risk.

Any proposed habitat development will be assessed to avoid increasing aircraft bird strike risk

Table 25: Specific Requirements and Options for Habitat Development

Area	Requirements and Options
<p>Wetlands Kellys Swamp Billabong Silt trap and others</p>	<p>All wetlands in which water level is manipulated will have an operational plan prepared to specify management and maintenance of water levels, vegetation, mud flats, water quality, fish fauna and other elements</p> <p>Design of any new or reshaped wetland areas will incorporate latest knowledge on hydrology, geomorphology and ecology of the area</p> <p>Options (additional detail below) will be investigated and assessed to:</p> <ul style="list-style-type: none"> • develop some palaeochannels as managed wetlands upstream of the service track • modify physical (and perhaps seasonal) vehicle access to enable re-establishment of the small island in Molonglo Reach • consider construction of a new wetland with a ‘chain-of-ponds’ structure near Kellys Swamp and towards the Learning Centre site • develop Shoveler Pool to lengthen duration of wetting, with supplementary scrapes nearby • redesign the Jerrabomberra silt trap and channel to deliver additional ecological services • construct new wetlands and recreational facilities in the interface with the East Lake development and southern (left) bank of Jerrabomberra Creek, with: <ul style="list-style-type: none"> o stormwater treatment wetlands and ponds o bio-filter systems o swales intercepting peak stormwater flows o integration of walkways and entrance to the Learning Centre with constructed wetlands systems • enhance natural values of the Jerrabomberra Billabong
<p>Water flow controls Weirs Valves Levees Drains Bores Pumps</p>	<p>Flow control devices will include provision for control of Common Carp movement where feasible</p> <p>Options (additional detail below) will be investigated and assessed to:</p> <ul style="list-style-type: none"> • use control devices to capture and control flows around Shoveler Pool • construct control devices under the palaeochannel crossings on the service track to allow control of flows in the palaeochannels • exclude Carp with a structure across the mouth of the Causeway channel • divert some flow from Jerrabomberra Creek to the Billabong, using bores, pumps or levee modifications

Continued →

Table 25 (continued): Specific Requirements and Options for Habitat Development

Area	Requirements and Options
<p>Vegetation</p> <p>Woodland</p> <p>Screening</p> <p>Riparian</p> <p>Corridors</p> <p>Grassland</p>	<p>Species planted will generally be native replacing exotic (using endemic and local provenances where possible)</p> <p>Landscape screening will be critical in many areas to minimise disturbance to birds</p> <p>Riparian rehabilitation (including willow removal) should be staged to ensure adequate replacement for habitat purposes</p> <p>Any areas of native grassland will be nurtured and monitored, and extended where feasible</p> <p>Options will be explored for increasing floristic and structural diversity of areas of pasture species by gradual re-planting or seeding</p> <p>The woodland area will be extended to enhance landscape connectivity ('stepping-stones') for birds and other terrestrial species</p> <p>Landscape connectivity will:</p> <ul style="list-style-type: none"> • encompass riparian, grassland, shrubland and woodland vegetation • be considered on a sub-regional scale, with connectivity to: <ul style="list-style-type: none"> ○ waterway 'corridors' of Molonglo River, Jerrabomberra Creek and Woolshed Creek ○ constructed wetlands and water sensitive urban design ○ forested ridges of Canberra Nature Park
<p>Habitat enhancements</p> <p>Roosts</p> <p>Nest boxes</p> <p>Predator proof fence</p> <p>Islands</p>	<p>Logs and branches may be judiciously placed into the main wetlands during dry periods for roosting perches</p> <p>Nest boxes may be placed for ducks and other wildlife</p> <p>A fence across the Peninsula to exclude mammalian predators will be investigated</p> <p>Several island refuges may be constructed within the silt trap, Shoveler Pool and possibly other (deeper, more reliably watered) wetlands</p> <p>The small island refuge in Molonglo Reach will be re-established by reconnecting the secondary channel</p> <p>Opportunities for Carp control in specified locations (removal, barriers to invasion) will be investigated</p>
<p>Grazing management</p> <p>Fences</p> <p>Yards</p> <p>Gates</p> <p>Troughs</p>	<p>Fences will be maintained to confine stock to the floodplain area and away from selected riparian zones, Shoveler Pool and palaeochannels</p> <p>New fences will be erected to help establish an ecological grazing regime</p> <p>The existing stock yards will be removed from Shoveler Pool and relocated, to enable continuation of grazing as a management tool, in a manner consistent with protecting rural landscape and heritage</p> <p>The two existing watering troughs are temporary and relocatable as needed</p> <p>Additional troughs may be required once riparian zones are fenced</p>

Wetland Diversity

This section considers options for increasing landscape, ecological, interpretive and educational values of wetlands in the Reserve, informed by new understandings of geomorphology and hydrology.

Wetland Values and Visitor Experience

The morphology of water features, and patterns of water inundation, depth and duration are key determinants of the flora and fauna associated with wetlands and their productivity (vegetation abundance, terrestrial and avian fauna numbers).

A number of Jerrabomberra wetlands are located within the surface mantle of fine silts and clays, independent of (perched above) the underlying shallow groundwater aquifer systems. Water levels in these wetlands depend on winter and spring runoff from sub-catchments to the east and south-east of the Reserve. Over the summer period, reduced rainfall and high evapotranspiration rates result in substantial loss of water from the wetlands, frequently resulting in complete drying of the wetlands and decline in aquatic fauna and avifauna. Wetlands connected to the aquifer may also lose water as a result of groundwater drawdown and reduced recharge.

Issues in management or presentation of wetland biodiversity include:

- paramount duty of care to avoid risk of aircraft bird strike at Canberra Airport;
- permanently inundated water level wetlands exhibiting low fauna diversity and populations;
- limited extent and diversity of riparian zones adjacent to water features, as a result of clearing and cattle grazing;
- limited options to manage wetland inundation levels and duration (both increased and decreased);
- past hydrological disconnection of the floodplain in the Silt Trap-Billabong area;
- public access to wetlands largely confined to the Kellys Swamp (Dairy Road) area;
- periods of dry wetlands conflicting with some visitor expectations of a wetland and wildlife viewing experience; and
- walking trails not linked to the Causeway channel wetlands zone.

There are options to:

- re-establish hydrological connectivity and natural dynamics by modifying barriers;
- disconnect some backwaters from permanent inundation to enable seasonal variation;
- manage inundation periods and levels to promote enhanced biodiversity and productivity ;
- manipulate the distribution of surface discharges to the Reserve across the wetlands;
- construct wetlands to provide biochemical processing of 'imposed' discharges to the Reserve e.g. from urban development; and
- expand the diversity of wetlands available for viewing, education and interpretation.

Parts of these approaches provide opportunities for community partnership in their development and implementation.

Table 26: Broad Options and Constraints for Increasing Wetland Diversity

Broad Options	
Manage existing wetland types in a more appropriate way	<p>This may include:</p> <ul style="list-style-type: none"> • management of water levels to enable wet and dry cycles • re-establishing hydrological connectivity • improved management of aquatic vegetation biomass • application of an appropriate regime of cattle grazing <p>It may be useful to sub-divide Zone 1 (Wildlife Refuge) and Zone 2 (Refuge Buffer) to apply different management strategies to different sub-zones</p> <p>Any option must include a temporal element e.g. cattle grazing and public access allowed at a specified certain time of the year</p>
Enhance existing wetland types with the addition of new elements	<p>This may include:</p> <ul style="list-style-type: none"> • supplementing water supply • reshaping existing wetlands, building islands, or altering profiles to include both deep and shallow water areas • restructuring to allow for growth and control of certain aquatic vegetation such as <i>Typha</i> and <i>Phragmites</i> • adding nesting boxes and perching/roosting sites • adding sluice gates or water diverters to manage water levels and flows.
Develop a new wetland area	<p>A new wetland can be designed as a perched or window wetland, determined by the constructed profile</p> <p>A perched wetland can be supplied with water from runoff, supplemented by using solar-powered pumps connected to surface water bodies or the aquifer</p> <p>Water levels may also need to be drawn down, to allow periods of drying out</p>
Constraints	
Neighbouring activities	<p>There is a duty of care to not increase risk of aircraft bird strike at Canberra International Airport, that leads to proper concerns about presence, abundance and activities of certain bird species.</p> <p>Any management options must take into account these concerns.</p>
	<p>It is unclear what effect the Fyshwick Sewage Treatment Plant has on diversity of avifauna in the Reserve. Similar species have been recorded in both areas, suggesting that the ponds influence abundance, and perhaps also diversity.</p> <p>This influence is likely to be increased when water is scarce in the Reserve, when the ponds act as a buffer against drought</p>
Conflicts of Objectives	<p>Tensions between protection, rehabilitation, remediation or enhancement</p> <p>Perception that a ‘natural’ system is being modified by imposed changes in discharges to the wetlands e.g. in urban interface areas</p> <p>Conflicts between enhancing values of wetlands (e.g. by adding water at times) and conserving water across the catchment (hydrologic ‘loss’ of water).</p> <p>This may serve to discount or blur the value of seasonal drying as an inherent feature of ecology across the region</p>

Table 27: Specific Options for Increasing Wetland Diversity

Note: any modifications are subject to assessment with regard to aircraft bird strike risk

Wetlands	Water sources	Options
Multiple areas		<p>Explore passive management to allow a range of water zones to self-establish, with monitoring of vegetation dynamics</p> <p>Where required, plant riparian vegetation to highlight the range of water zones within all wetlands except those connected to lake backwaters</p>
Northern area of the Reserve		
Palaeochannels area	Periodic inundation by stormwater discharges	<p>‘Topping up’ of some palaeochannels by drawing from surface water bodies or the aquifer, to enhance water distribution across floodplain wetlands</p> <p>Expansion of shallow water habitats next to Molonglo Reach by watering palaeochannels and wetlands 2 & 3 near the Molonglo / Lake confluence, at times when these are largely dry</p> <p>Management of inflow to wetlands fed by surface water, via a series of low (e.g. 0.3m height) timber bulwarks or weirs</p> <p>Potential benefits: providing and interpreting an example of a different sort of wetland for visitors, leaving others naturally dry</p>
Causeway channel Wetland 1	Lake backwater Does not appear to be connected to aquifer	<p>Closure of this channel by constructing an earth embankment across its opening into Jerrabomberra Creek, with management of water levels in the channel and lower palaeochannel reaches</p> <p>Potential benefits: eliminating Common Carp infestation; more natural variation in water levels to promote riparian vegetation and biodiversity; barrier to incursion of boats into the channel; access enabled over the barrier to restricted areas of the Peninsula (only at times when risk of impacts on bird nesting or refuge is minimal); establishing a new ephemeral zone</p>
Molonglo Reach Wetland 5	Lake backwater	<p>Removal of the small causeway to connect two parts of secondary flood channel (Wetland 5) to re-establish the small island, excluding predators while enabling (seasonal?) access for powerline maintenance</p>
Shoveler Pool Wetland 12	Periodic inundation by stormwater discharges and surface water inflow	<p>Extension of inundation by working clay into the bed of the Pool (to limit infiltration losses); may be ‘topped up’ by drawing from surface water bodies or the aquifer</p> <p>Potential benefits: providing and interpreting an example of a different sort of wetland for visitors, while leaving others naturally dry</p>

Continued →

Table 27 (continued): Specific Options for Increasing Wetland Diversity

Note: any modifications are subject to assessment with regard to aircraft bird strike risk

Wetlands	Water sources	Options
Southern area of Reserve		
Kellys Swamp Wetland 19	Both groundwater aquifer inflows and surface water inflow	Not feasible to 'top-up'(by pipe) because of aquifer connection Consideration of increasing depth of a section of the bed a further 300mm into the underlying aquifer to extend inundation, if desired in the future Potential benefits: maintaining at least a small pool of water over the mid- to late summer period
Palaeochannel west of Kellys Swamp	Periodic inundation by stormwater discharges	Consideration of creating a new wetland with a 'chain-of-ponds' structure in the broad palaeochannel to the west of Kellys Swamp, if desired in the future Potential benefits: variation in water levels; an 'ephemeral zone' around the edges; enhanced productivity; sustained visitor wetlands experience; improved vista from the Learning Centre
Billabong Wetlands 21, 20	Both groundwater aquifer inflows and surface water inflow	Not likely to be feasible to 'top-up'(by pipe) because of aquifer connection Potential diversion of some base flow from Jerrabomberra Creek to provide a more natural flow pattern through the Billabong floodplain and cutoff channel system e.g. by a side-pit on the channel and a pipe through the levee or by upstream and downstream breaches in the levee Remedial work on the original creek channel outlet from the Billabong, to its intersection with the modified creek alignment Potential benefits: hydrological reconnection of creek to floodplain, providing base inflow and partial flood flows with fresh fine sediment accumulation; removal of fine sediment from the cut-off, potential reconnection of Kellys Swamp with Jerrabomberra Creek; benefits for instream fauna
Jerrabomberra silt trap Wetland 18	Surface water inflow	Modification with a series of gabion walls to promote sedimentation, returning form to a more natural curvilinear channel Installation of roosts and perches Potential benefits: expected to be high; currently this is an 'unnatural' feature in the landscape, with severely depleted ecology, and ineffective as a silt trap
Jerrabomberra Creek Interface area		Use of stormwater discharges from the East Lake development to construct wetlands in this zone Potential benefits: could be used for interpretive/ educational purposes

Woodland and Grassland Diversity

Although the focus in expansion of native woodland, shrubland and grassland vegetation as a mosaic in the landscape is on all terrestrial animals, birds serve as a useful focal group for assessing changes in the ecological value of planted or enhanced environments.

The importance of these two vegetation types as habitats for reptiles, in particular skinks, and insects will be considered in the future.

Some 114 woodland and grassland bird species have been recorded in the Reserve. Of these, many use both habitat types. In south-eastern Australia, species which are restricted to grassland habitats are poorly represented, and even more so where grasslands comprise mainly introduced grasses. In the Reserve, woodland species generally dominate, with many also using the grasslands.

Table 28: Woodland and Grassland Bird Guilds and Habitat Requirements

Habitat	Guild / Requirements
<p>Woodlands</p>	<p><i>Invertebrate feeders</i></p> <p>Diverse structure and floristic elements provide for a wide range of species, although in general the abundance is low</p> <p>Require trees and understorey that allows for a constant source of invertebrates, best provided by a variety of seasonal flowering plants</p> <p>A diverse guild of species. Many are partial or complete migrants moving away from the area in the autumn and returning to breed in the spring.</p> <p>Includes honeyeaters that require both a diverse range of invertebrates and also the pollen and nectar of many flowering plants</p>
	<p><i>Seed eaters</i></p> <p>The bird community that feeds on the ground, whether on invertebrates or seeds, is low, as it is in much of the local region</p> <p>Lack of grassy understorey in the woodland restricts the abundance of this guild</p> <p>The guild may be further divided into 7 that feed on grass and weed seeds and 7 that feed on hard eucalypt and casuarina seeds</p> <p>For the small amount of woodland, this group of is well represented but in low numbers</p>
<p>Grasslands</p>	<p><i>Invertebrate feeders</i></p> <p>About 8 species are unlikely to be present in the Reserve if this habitat was not present. Presence of cattle provides an opportunity for the Cattle Egret to be present. This species is unusual elsewhere in the ACT.</p> <p>A greater abundance and diversity of grassland species may use the area if the grasslands were not so dense or tall. Many of the species that utilize the grasslands for feeding and breeding are insectivore woodland species.</p>
	<p><i>Seed eaters</i></p> <p>11 species that use both grass and weed species in the grasslands are low in abundance. This group is well represented within the Reserve compared with the local region.</p> <p>Lack of grass diversity and height and density of grassland vegetation is a limiting factor in the abundance of this guild</p> <p>This guild would benefit from a system of crash grazing and/or fire, and the introduction of native grass species, to provide a sparse ground vegetation matrix</p>

The small patch of planted woodland in the south-west of the Reserve is an island for many bird species, with grassland forming a major barrier to connectivity for small woodland birds. Additional areas of woodland are required to provide landscape connections or 'stepping stones', especially between the two river systems. This would not only increase the abundance of woodland birds in the Reserve but also improve connectivity across the Reserve for a range of other terrestrial species. The appropriateness of tree and shrub planting in the floodplain grassland area would need to be investigated.

In summary, grassland and woodland animals would benefit from:

- increased area of woodland with a diverse floristic understorey;
- increased connectivity of both woodlands and grasslands;
- expanded areas of native grasslands;
- a reduction in height and density of existing exotic grasslands; and
- careful management of cattle grazing in grasslands and around wetlands to improve habitat quality.

Priority for Establishment

Southern Reserve: Initial (and high priority) focus for expansion of woodland planting is adjacent to Fyshwick, to provide visual screening from the Wetlands Foreshores Business Park.

Northern Reserve: Establishment of new woodland plantings needs to consider retention of the rural floodplain landscape character, and is to be focused on areas adjacent to Dairy Road and the closed section of that road north of the Kellys Swamp carpark.

Raptor Requirements

The raptor guild is very well represented within the Wetlands (18 species recorded)

A few appear to be residents; others appear to be present for a short while; many may be passing through using the river corridors of the Molonglo River and the Jerrabomberra Creek

Nearby habitats such as Fyshwick and Queanbeyan Sewage Treatment Plant ponds, urban lakes, water sensitive urban design treatments, and grasslands of the Jerrabomberra Valley, may all contribute to diversity of raptors in the Reserve

It is likely that the Reserve provides important supplementary food resources for many species, utilising invertebrates, reptiles, small mammals and birds. Despite this, only the Black-shouldered Kite and possibly the Collared Sparrowhawk breed in the Reserve. It is unclear whether this low breeding diversity is a result of lack of food or nesting resources. The availability of resources needs to be maintained and enhanced by appropriate adaptive management practices.

Potential Additions to the Reserve

Inclusion of additional areas in the Reserve may offer opportunities for increased habitat diversity or ecological connectivity, or for education/interpretation.

Potential adjacent areas may include:

- Goldenholm Pond;
- upstream sections of the Molonglo River;
- Jerrabomberra Creek corridor ;
- limestone outcrops (weights and measures station, Eyre [formerly Newcastle] Street, Kingston); and
- Cargill's cottage (adjacent to south of weigh station) from Big Gun Dairy.

Table 29: Factors in Considering Inclusion of Additional Areas

<p>Contribution to Reserve values and objectives e.g.:</p> <ul style="list-style-type: none"> ◆ habitat diversity or connectivity ◆ improved water quality management ◆ educational/interpretive opportunities ◆ limiting encroachment or impacts of urban development ◆ operational assets ◆ increased resource availability 	<p>↑ ↓ balanced against</p>	<p>Increased management burden and/or complexity e.g.:</p> <ul style="list-style-type: none"> ◆ active recreation patterns ◆ weeds ◆ landfill/contamination ◆ pollution sources ◆ structures ◆ operational liabilities ◆ increased resource demands
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Infrastructure Development

This section addresses ‘things built or significantly modified’ – measures to enhance visitor experience and Reserve management, such as signs, fencing, access, carparks, gates, tracks, bridges, hides, lookouts, seats, built screening, lighting, Learning Centre, management and maintenance facilities.

Table 30: Overall Requirements for Infrastructure Development

Design	<p>Objective to be clearly articulated - intended purpose and assumptions made</p> <p>Must comply with ACT accessibility guidelines and legislation</p> <p>Must comply with the reserve vision and guiding principles for decision-making</p> <p>Must consider potential aircraft bird strike risk</p> <p>Should provide for safe and efficient operation and maintenance</p> <p>Should be in accordance with the Reserve Style Manual</p>
Construction	<p>Must be timed and undertaken to minimise ecological impacts</p> <p>Must be staged to minimise risk and disruption to visitors and other users</p>
Maintenance	<p>Will focus on maintaining functionality (to deliver the intended objective), minimising public risk and minimising adverse ecological impacts</p> <p>Will have a maintenance plan and schedule prepared for all significant infrastructure to ensure timely and appropriate allocation of resources for maintenance</p>

Table 31: Specific Options for Infrastructure

Infrastructure	Options and Proposals
<p>Cultural</p> <p>Ngunnawal culture</p>	<p>Biyaligee Learning Centre shaped by Ngunnawal landscape knowledge, with displays and programs on stories, pathways and traditional knowledge</p> <p>Adjacent workshop and area at the old Causeway oval (Eyre Street) for cultural learning, as a community centre, arts and crafts hub, and place of healing</p> <p>Options may include dance, creative art, tool making, weaving, grinding, men’s and women’s craft, and other demonstrations and activities</p> <p>Cultural walking trail for interpretation of bush-tucker and landscape knowledge including natural/ cultural elements such as sources of wild food and medicine, fibre, materials for tools, transport etc</p> <p>Entry and interpretive signage including Ngunnawal language and incorporating Ngunnawal knowledge, naming of places, natural features, plants, animals and other resources</p> <p>Signs and maps showing dual European/Aboriginal naming and descriptions, as negotiated</p>
<p>European heritage</p>	<p>Relics of European heritage preserved and interpreted</p> <p>Limestone outcrops in the grounds of the ACT Government weigh station in Eyre Street and Cargill’s cottage (Big Gun Dairy) considered for addition to the Reserve and/or inclusion in interpretation resources and programs</p>

Continued →

Table 31 (continued): Specific Options for Infrastructure

Infrastructure	Options and Proposals
<p>Educational</p> <p>Pond dipping steps</p> <p>Soil profile trench</p> <p>Remote cameras</p> <p>Water bores, staves</p>	<p>A number of small ponds constructed on the old Causeway oval to be used for education and interpretation</p> <p>Boardwalks constructed in several locations to permit pond dipping, water testing and similar outdoor educational activities</p> <p>A soil profile trench providing access for students of soil, hydrology, geomorphology etc.</p> <p>Remote cameras relaying images of sensitive fauna species to the Learning Centre</p> <p>Water bores and staves providing data on ground and surface water</p>
<p>Amenities</p> <p>Picnic tables</p> <p>Open spaces</p> <p>Toilets</p> <p>Rubbish bins</p>	<p>A small low key family recreation area with tables and open spaces established adjacent to the Learning Centre (Eyre Street)</p> <p>Barbecue facilities not provided, to discourage feeding of birds by visitors</p> <p>Controlled access points established along Jerrabomberra Creek to manage use of the broader Reserve from the East Lake area</p> <p>Tables and viewing points in the East Lake interface for residents and visitors</p> <p>Public toilets provided at the Learning Centre and at the Birrigai office</p> <p>Rubbish bins not provided in outdoor areas, and visitors will be encouraged to take their rubbish away with them</p>
<p>Buildings</p> <p>Learning Centre</p> <p>Birrigai office</p> <p>Old Birrigai sheds</p> <p>Bird hides</p> <p>Lookout tower</p>	<p>A multi-use Learning Centre, off Eyre Street (detail below)</p> <p>The Birrigai office retained, pending development of additional operational infrastructure, and consistent with interpretation of the educational use of the site</p> <p>Surplus Birrigai sheds removed, consistent with interpretation of the Kellys Farm/ Dairy Flat Farm site</p> <p>Existing bird hides (recently renovated) to remain, unless the western hide is displaced by the Learning Centre and moved elsewhere on Jerrabomberra Reach</p> <p>Two additional bird hides at Shoveler Pool and the palaeochannel area</p> <p>A 10m high lookout considered south of the existing cycle path footbridge</p>
<p>Grounds</p> <p>Lawn</p>	<p>Some mown/slashed areas maintained for protection of assets from fire, some for aesthetic reasons, and some to facilitate movement of people</p> <p>A small mown family space established adjacent to the Learning Centre</p> <p>Mowing continuously reviewed to minimise ecological impacts, maintain pleasing aesthetics, and minimise costs</p>
<p>Access management</p> <p>Carpark</p> <p>Entry gates</p>	<p>The Kellys Swamp (Dairy Road) carpark redesigned to reduce its size and to minimise issues related to security and aesthetics</p> <p>A new carpark developed adjacent to the Learning Centre</p> <p>Existing office carpark expanded to cater for overflow bus parking and organised groups</p>
<p>Signage</p>	<p>Regulatory, directional, interpretive and warning signage generally minimal, sympathetic to the environment, and graffiti-resistant</p> <p>A detailed signage strategy and style guide developed</p>

Continued →

Table 31 (continued): Specific Options for Infrastructure

Infrastructure	Options and Proposals
<p>Paths</p> <p>Cycle shared path</p> <p>Walking trails</p> <p>Boardwalks</p> <p>Seats</p>	<p>No further cycle paths constructed within the Reserve unless this serves to remove the existing through-cycleway route</p> <p>Low-speed cycle access provided to the Learning Centre</p> <p>Some infrastructure (fountain, bike rack, signage) provided along the cycle path to encourage visitors into the Reserve</p> <p>A cycle route permitted along the interface with East Lake provided it is mostly located within the residential area</p> <p>Consideration given to diverting the through-cycleway around the south-eastern corner of the Reserve or across the northern end of the Silt Trap</p> <p>A hierarchy of walking trail options developed, focused on visitor nodes</p> <p>Where possible, pedestrians and cyclists separated on trails</p> <p>Some walking trails accessible to people with impaired mobility</p> <p>Walking trails elevated where required to minimise environmental impact</p> <p>Seats provided, particularly at key vista and interpretive points</p> <p>A new walking trail considered along the existing powerline maintenance track, with branches into screened hides and walkways at selected points along the southern (left) bank of the Molonglo River, and into Shoveler Pool. This may also include side tracks into selected locations along the Causeway channel, subject to detailed assessment (additional detail below)</p>
<p>Bridges</p> <p>Footbridge</p>	<p>A footbridge (pedestrian only) proposed across Jerrabomberra Creek, downstream from the silt trap</p> <p>An additional footbridge across Jerrabomberra Reach next to the Learning Centre</p>
<p>Roads</p> <p>Gravel/earth trails</p>	<p>Existing vehicular tracks (including the powerline service track) maintained</p> <p>No new formed roads constructed</p>
<p>Lighting</p> <p>Paths</p> <p>Security</p>	<p>Lighting minimised and designed to minimise adverse ecological impacts</p> <p>Overhead, downward facing lights on paths through the East Lake interface and to the Learning Centre</p> <p>Security lights provided around the Learning Centre (Eyre Street)</p>

Biyaligee Learning Centre

The proposed Biyaligee Learning Centre is to serve as a vital hub for interpretation and education at the Reserve.

The name Biyaligee has been selected to reflect both the earliest name for the area and its original inhabitants, and the earliest European use for the Campbell property of Pialligo (later Duntroon).

The design of the building and grounds is to reflect floodplain landscape character, and to draw from iconic and totemic species which are important to Ngunnawal culture, such as the wedge-tailed eagle, snake (echoing the serpentine course of the Molonglo), and platypus.

A potential Ngunnawal phrase to capture the spirit of the Centre is: *Yerrabi Ngadyung Biyaligee* ('walk along the waters of our ancestors').

Planning has assumed development of a facility of a similar size and function to the Namadgi Visitor Centre. Facilities required include:

- Entry/Reception area;
- Display and exhibition space (some permanent, some transient);
- Conference room;
- Café/Restaurant (potential);
- Classrooms with teaching aids including Internet access for up to 30 students;
- Library for educational and research needs;
- Facilities for a shop and specific area for 'Friends of Jerrabomberra Wetlands';
- Management offices;
- Toilet and washrooms (showers);
- Viewing deck;
- Car parking for 75 car spaces and dedicated bus parking;
- Outdoor classroom area;
- Interpretive ponds/theme activity area ('water in the landscape'); and
- Close links to the Ngunnawal workshop/ community centre/ place of healing.

Siting

The Draft Master Plan 2012 recommended a site off Dairy Road, overlooking Kellys Swamp. In 2013 the Board opted for facilities and amenities to be located across two sites: in the east near Dairy Road, and in the west on the left (southern) side of Jerrabomberra Creek.

Evaluation of potential sites near Kingston was undertaken in 2013 and Option 4, the 'Jerrabomberra Reach' site, was selected (Fig.21).

The Option 4 site offers:

- reasonable access from Eyre Street and main cycleway route;
- proximity to proposed East Lake development;
- reasonable space for buildings;
- a site for a car park already present, which would need to be enlarged;
- elevated site with a good vista over Jerrabomberra Creek, offering an immediate sense of being associated with wetlands;
- views over the Reserve with the slopes of Mount Pleasant as a backdrop;
- close to the old Causeway oval, in which wetland interpretation areas can be developed;
- potential for a deep water wetland to be constructed nearby, using the present creek system or stormwater discharges from the East Lake development; and
- proximity to limestone outcrops in Eyre Street (Limestone Plains theme) and to Cargill's cottage (Big Gun Dairy/dairying history theme, used for artist-in-residence programs).

This site is underlain by past landfill, which will need to be taken into account in design and construction.

Further and more detailed planning will be undertaken as part of planning for the interface area in the Design Report.



Option 4: Jerrabomberra Reach

Figure 21: Location for Learning Centre
(Source GHD 2013)

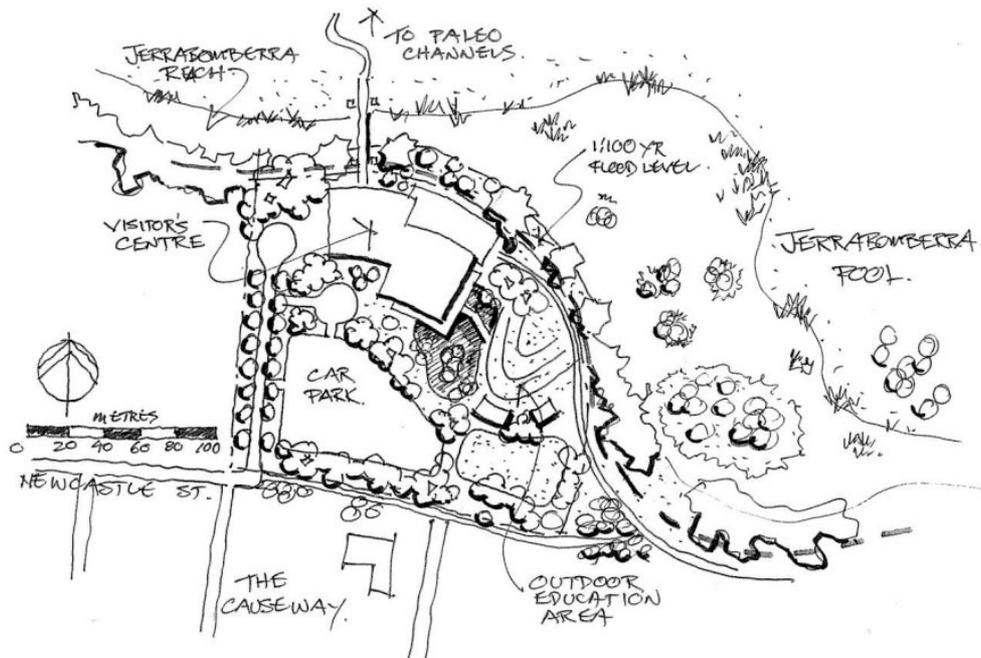


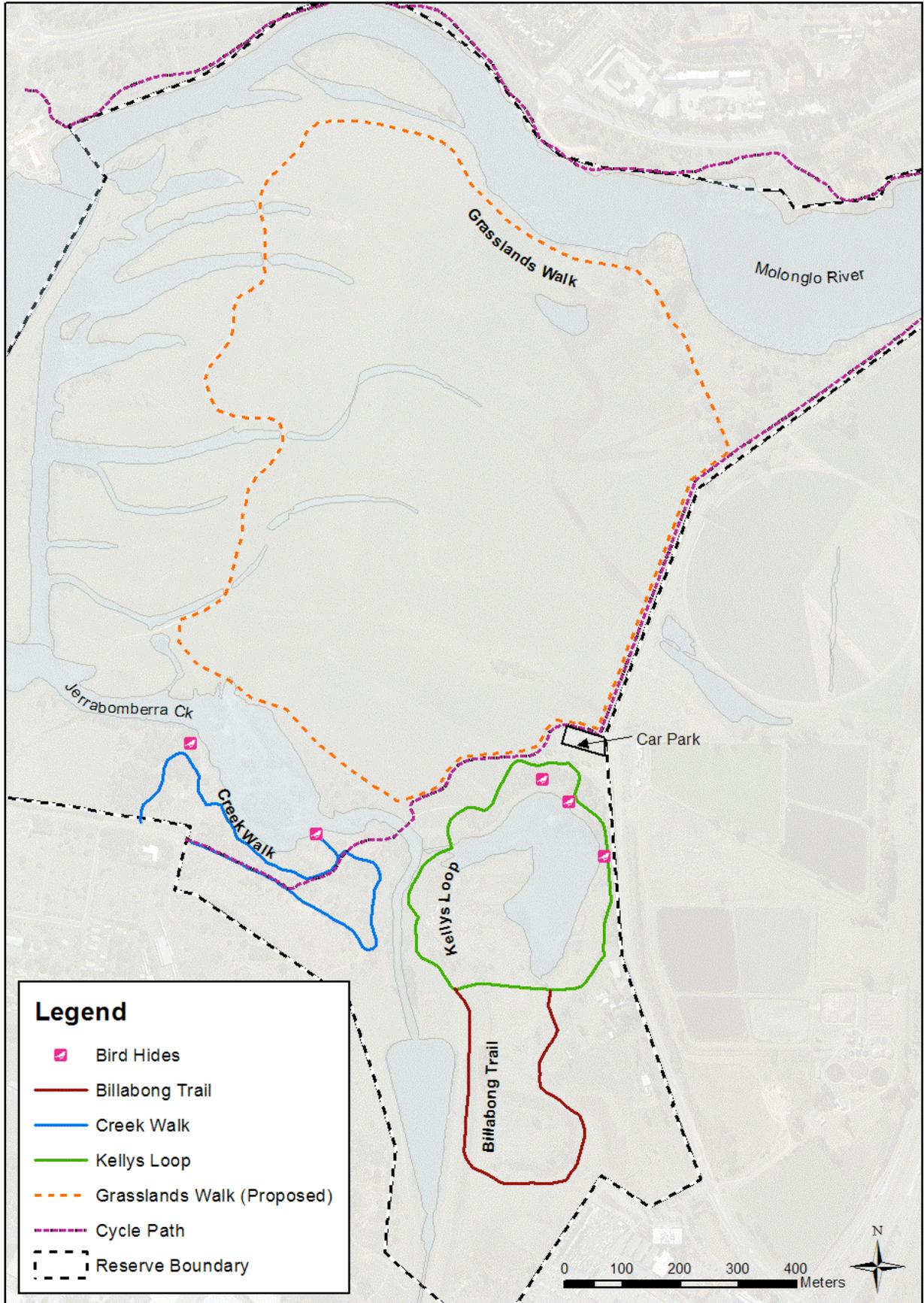
Figure 22: Notional layout for Learning Centre
(Source: GHD 2013)

Walking Trails

Table 32: Existing and Proposed Walking Trails

Existing / in process of development	
<p>Kellys Loop About 40 mins</p>	<p>A gravel path and trail presently allow walking around most of Kellys Swamp Construction will commence shortly on a connecting boardwalk to form a loop around the entire Swamp The grade of Kellys Loop trail will be easy, much of it accessible by wheelchair Parking is at the Kellys carpark</p>
<p>Billabong Trail About 45 mins</p>	<p>A temporary mown trail heading south from Kellys Swamp, passing around the original Jerrabomberra Creek watercourse (now Jerrabomberra Billabong) and returning via the levee, with views across the Reserve Parking is at the Kellys carpark</p>
<p>The Creek Walk About 30 mins</p>	<p>A gravel path along the left (southern) bank of Jerrabomberra Creek, linking two bird hides and extending around to the trestle bridge before returning via the shared bitumen path Parking is along and/or from Eyre Street, Kingston</p>
Proposed	
<p>Molonglo River Walk About 30 mins</p>	<p>A River Walk proceeding westward from Dairy Road along the existing management trail on the left (southern) bank of the Molonglo River A diversion loop through a planted riparian woodland area, with the trail returning at the current boundary of the Plan of Management refuge zone boundary This would provide interpretive opportunities around riparian habitats, planted woodland, past agricultural use and bird study at Shoveler Pool</p>
<p>Grassland Walk About 1 hour</p>	<p>A longer Grassland Walk commencing from Dairy Road carpark, northward along the eastern boundary, westward along the existing service trail and continuing along that trail southward toward Jerrabomberra Creek, at which point it would follow the northern bank back to the bitumen shared path and carpark This would provide interpretive opportunities similar to the River Walk, and also refuge management, geomorphology and habitats along Jerrabomberra Creek It could branch into screened hides and walkways at selected points along the (left) bank of the Molonglo River, and into Shoveler Pool Access may need to be restricted seasonally</p>
<p>Other</p>	<p>A footbridge across Jerrabomberra Creek and a linking trail between Creek Walk and Kellys Loop This could possibly be sited downstream of the silt trap, and has been developed as a proposal for fund-raising by the Capital Woodland and Wetlands Conservation Trust It would allow pedestrians and cyclists to be almost totally separated within the Reserve, and open up options to exclude domestic pets and animal pests</p> <p>A crossing, possibly a causeway for machinery and stepping stones for pedestrians, at the upstream end of the silt trap</p> <p>Walks as required around proposed interpretive wetlands on the Causeway oval area (Eyre Street)</p>

Figure 23: Walking Trail Network
(Grassland Walk indicative only)



Interpretation and Education Resources and Programs

Interpretation and education are both processes for communication and learning
 Education is related largely to schools and formal institutions, and may emphasise facts and figures
 Interpretation is for all visitors, and emphasises ideas and relationships.
 Interpretation is: *'Any communication process designed to reveal meanings and relationships of cultural and natural heritage to the public, through first-hand involvement with an object, artifact, landscape or site'* (Freeman Tilden).

The facilitation of environmental education (education for sustainability) is a core objective for Reserve management identified in the Plan of Management 2010 and the National Capital Plan. This requires a stimulating and innovative strategy and program, supported by a range of infrastructure and resources.

Partnerships will be developed with learning institutions, corporate sponsors and community groups to support and deliver the interpretation and education program.

Table 33: High-level Themes for Interpretation Stories

Note: More detailed themes are to be developed for each of these e.g. Historic Themes listed in Part 1

Biophysical	Hydrology	Water in the landscape – regional and local connections Inland freshwater systems Water as habitat Flows – variability, floods, dry-wet cycles Groundwater, surface water systems Water quality Landscape and catchment context
	Geomorphology	Parent material and soils Features (flood channels, palaeochannels, scroll bars, aeolian dunes, groundwater aquifer) Past changes in landscape form
	Ecology	Habitats (wetland, grassland, woodland, shrubland, riparian) Novel ecosystems Ecological connectivity Flora and fauna (species, habitat use/needs, populations, migrations) Floodplain ecology Wetting and drying cycles Rehabilitation and restoration Past changes in vegetation Climate change and adaptation Pests and weeds
Socio-economic	Cultural	Past use Aboriginal and European cultural heritage Ecosystem and landscape valuing (e.g. aesthetics, wild places)
	Economic	Agriculture Conservation financing Urban planning and development
	Organisational	Reserve governance, planning, management and maintenance Volunteering

Resources and Programs

The Reserve offers varied opportunities for learning through visitation (e.g. observation and signage), participation (e.g. volunteering, ranger-guided activities, cultural tours), reading (e.g. publications, website), analysing (e.g. researching, data analysis), and listening to teaching and presentations.

The Reserve in itself constitutes a valuable resource for interpretation and education, offering a range of geomorphological and hydrological elements in a floodplain landscape with wetlands, grasslands and woodlands.

Infrastructure directly relevant to interpretation and education includes:

- learning centre – displays and resources;
- trails, boardwalks, hides, lookouts;
- constructed or modified ponds, wetlands;
- soil profile trench;
- signs; and
- supporting infrastructure for experiential activities.

A wide range of interpretive material will be developed, together with professionally developed resources.

Table 34: User Groups and Interpretation / Education Resources and Programs

User Group	Options and Proposals
All visitors	Interpretive signage for visitor nodes and paths Volunteering opportunities Website resources (e.g. podcasts, virtual tour, study notes, activity sheets etc.) Publications with both interpretive and educational content Ongoing monitoring and evaluation of the education program
Primary school children Secondary school children	Teacher notes and lesson plans professionally developed Ranger guided activities / cultural tours A range of experiential learning opportunities e.g. pond dipping, sensory walking trail, bush tucker trail etc. Outdoor classroom e.g. soil profile trench, water testing Video feeds of sensitive species to Learning Centre
Tertiary students / researchers	Ranger supervised activities Reserve management presentations as required Access to hydrological/geomorphological resources (data, GIS) and ecological resources (vegetation and fauna, remote media) Areas available for research experiments e.g. grazing, contaminated land

Partnership

Partnership approaches in natural and cultural resource management offer potential for a renewed and adaptive response to a world of growing pressures on natural and cultural resources, including those arising from climate change.

The location of the Reserve in the heart of the city, coupled with existing and proposed urban renewal in areas adjoining its boundaries, offers both challenges and opportunities:

The interface of a protected area with a sizeable population can have significant implications for resourcing and planning, and can compromise achievement of conservation objectives

Conversely, it offers potential for significant mutual benefits if partnership approaches are adopted as formal relationships with local stakeholders to achieve shared goals and objectives.

The care and development of the Reserve in partnership with government, community, industry and research organisations enables exploration of new kinds of resource management and conservation arrangements, which are more appropriate to changing times.

This view of partnership emphasises:

- *precursors* – development of dialogue before relationship before partnership;
- *mutual benefit* – understanding and accommodation of the needs and interests of partners;
- *equal worth* – respect for different strengths that different partners bring to the relationship; and
- *co-design* – focus on interaction that is creative rather than reactive.

Table 35: Objectives of a Partnership Approach in Natural & Cultural Resource Management

- ◆ Harness energies, knowledge and capacity to benefit both community stakeholders and managers
- ◆ Improve dialogue, mutual learning and trust between managers and community stakeholders
- ◆ Increase awareness and knowledge of the resources and values of the Reserve, and support for goals, policies and programs
- ◆ Increase community stakeholder skills and confidence to participate in projects and programs to uphold those values
- ◆ Engender a sense of pride in, shared ownership of, and responsibility for, the Reserve
- ◆ Develop management policies and activities that reflect community stakeholder aspirations and offer some measure of accountability
- ◆ Develop case studies and models of participatory practice and positive impact to share with others

In developing partnership arrangements, the Board of Management will have attention to:

- effective means of initiating, promoting and developing partnership arrangements;
- appropriate partnership models;
- scope of partner organisations/individuals;
- scope of projects or programs attractive to partners;
- scope of information, communication channels and project/program reporting, which will encourage partnership agreements; and
- consolidation, reporting and publication on partnership building capacity and performance.

Community Stakeholders

Stakeholders in the Reserve are not restricted to neighbours in adjoining communities.

The Reserve has importance for the whole of the Canberra and Queanbeyan communities, as well as for visitors to the National Capital and Capital Region.



Figure 24: Indicative Groupings of Community Stakeholders

Potential community stakeholder partners include:

- adjoining residents and communities (neighbours);
- groups representing neighbour communities, both residential and commercial;
- Friends of Jerrabomberra Wetlands and other Reserve user groups;
- Traditional Custodians and other Aboriginal community groups;
- descendants of European settler families with local knowledge;
- community naturalist and environment groups;
- research and educational institutions and organisations;
- business/industry organisations;
- tourism promotion organisations;
- utility and infrastructure managers;
- ACT and Australian Government agencies; and
- funders, both philanthropic (through Capital Woodlands & Wetlands Trust) and grant programs.

Potential Program Model

The Capital Woodland and Wetlands Conservation Trust was established to help generate community funding for Board initiatives in both Jerrabomberra Wetlands and Mulligans Flat Nature Reserves.

As an important protected area that is directly adjoined by residential and commercial development, Mulligans Flat has also been the focus for a significant partnership program under the banner of 'Bush on the Boundary' (BoB). Partnerships have been developed by the Ginninderra Catchment Group aimed at 'managing biodiversity at the urban interface'. This approach brings together and coordinates a range of government, research, education, community and business/industry organisations. These organisations undertake projects or contribute resources to better ensure the long term protection and management of the reserves.

The Molonglo Catchment Group has commenced an additional BoB program associated with the Molonglo urban development, with additional programs under consideration.

The kinds of projects being undertaken by BoB participants include long-term research and community environmental monitoring e.g. Waterwatch, Frogwatch, noxious weeds, bird species and numbers.

Business/industry participants have sponsored printing and distribution of interpretive brochures and display materials, highlighted the importance of reserves in neighbourhood newsletters, distributed promotional material.

The focus for these participants has been on helping to ensure that development is sensitive to long-term conservation objectives of the adjoining protected area. This includes actively encouraging new residents to get involved in conservation activities being offered, but also to think of their residential area as being an extension of the protected area.

The BoB program may provide a workable model for the Reserve, although the intensity of urban residential and commercial development next to Jerrabomberra Wetlands may differ from that associated with the Mulligans Flat and Molonglo developments.

Table 36: Likely Requirements for Effective Stakeholder Partnerships

- ◆ Unequivocal commitment from the managing organisation
- ◆ A shared understanding and commitment to the program among employees
- ◆ A partnership strategy developed in consultation with management, employees and stakeholders
- ◆ Market research to determine respective needs and priorities of different stakeholder groups
- ◆ Training for staff aimed at responding to stakeholder issues
- ◆ Ongoing feedback mechanisms for stakeholders, and an annual review process
- ◆ Encouragement of innovation in stakeholder partnerships
- ◆ Appropriate technology and record-keeping
- ◆ A spectrum of communication methods and approaches
- ◆ Strategies, initiatives and resources targeted at high priority issues
- ◆ Resolution of stakeholder relations issues by collaborative methods
- ◆ A holistic approach to resolving stakeholder issues, integrated with other agencies
- ◆ Pilot programs for a small target population before implementing the programs more broadly

Part 4: Survey, Monitoring, Review & Reporting

An adaptive management approach employs survey, monitoring, review/evaluation and reporting as enabling activities and learning processes, at the heart of improvement in the way the Reserve and its values are managed and presented.

Survey and Research

Both Survey and Research are aimed at learning, and enhanced understanding:

- Survey is primarily about compiling an inventory
- Monitoring is repeated sampling using the same techniques
- Adaptive Monitoring is sampling through time to answer specific questions and to feed back the learning into management
- Research is primarily about interpretation and understanding of processes, past or present or future

Research and investigation related to environmental management of the Reserve are actively encouraged for professionals, community groups and managers, by:

- maintaining a Research Portfolio: a short-list of projects requiring external skills and funding;
- forging and maintaining links with relevant tertiary institutions;
- endeavouring to support student projects;
- encouraging researchers to deliver a public seminar on their project; and
- encouraging special-interest community groups.

The potential for use of the Reserve for research is shaped by:

- proximity to tertiary institutions (short travel time);
- regional significance (unusual in region);
- history of disturbance (a highly modified ecology); and
- size (relatively small, few opportunities for replicate sites, if needed).

Despite its singular value at the confluence of two floodplains, the Reserve is too modified and floods too infrequently to be attractive as a site for researching floodplain ecology, native or natural floodplain vegetation, or natural behaviours of floodplain and wetland species.

However, the Reserve could be attractive as a research site for questions about ecology in a disturbed and modified environment (a novel ecosystem). The disturbances it provides include: anthropogenic effects, river regulation, geomorphic changes, catchment influences, and biogeochemical processes.

The Reserve is also a useful site to test ideas about 'novel ecosystems' - genesis, attributes, and trajectory. Modelling can be particularly useful for understanding the trajectory of a novel ecosystem, and the development of simulation models could be of mutual interest.

Survey and Research Themes

It is likely that survey and research will be needed in areas/themes such as:

- Monitoring and management systems to mitigate aircraft birdstrike risk;
- Habitat enhancement or remediation, including wetlands, grassland, and shrubland/woodland;
- Dynamics and improved management of cattle with respect to specific flora, fauna or ecosystems;
- Use of fire as a management tool, and other applications of traditional Aboriginal knowledge;
- Bird and other fauna movement patterns within and external to the Reserve;
- Introduction of flora and fauna elements e.g. frogs, reptiles, fish, native grasses;
- Enhanced management techniques to manage aquatic and terrestrial fauna within the Reserve;
- Investigation of management practices to improve water quality within the Reserve; and
- Structural analysis and dating of fluvial sediments in the Reserve.

Monitoring

Monitoring is the collection of data or information over time. For Reserve management, this may go beyond ‘data’ in the sense of quantitative measurements, to include other forms of information and data (categorical, qualitative such as visual records, structured observations, or photopoints). These can be valid and useful if the data are appropriately matched to the question.

Commonly associated with biological resources, monitoring may also be used to track a range of factors e.g. people numbers/movements; disturbances and effects; undesirable biota such as pets, feral predators, introduced birds; or undesirable use such as rubbish, campfires, vandalism, or trespassing.

Monitoring in the Reserve is needed to inform and improve management, over short-term and long-term time scales (Table 37).

Table 37: Types of Monitoring to Support Management

Type	Description	Relevance / Examples
Compliance	Monitoring because it is a statutory or legal requirement to monitor, or because monitoring is the chosen means of discharging a statutory obligation	<i>Example: A Waterways License includes a requirement to monitor turbidity, in case removing willows on Jerrabomberra Creek results in a sediment ‘event’</i>
Condition or Surveillance:	Monitoring to detect changes in ecological or physical condition that occur over the long term (i.e. trend data) Requires both a specific question and a defined endpoint Probably the hardest to do well, and the easiest to do badly	Particularly important in systems undergoing change and/or being exposed to change in their ecological drivers, as in the Reserve Helps to set priorities and points to likely areas of change Requires a conceptual understanding of how the ecosystem functions, and an ability/capacity to project through time and incorporate the effects of disturbances
Temporal Pattern	Monitoring to determine physical/ecological characteristics or responses through time Independent of activities and decisions Core information, exploratory, a platform for understanding resources	<i>Example: Groundwater and wetland water level monitoring installed in the Reserve in 2012-2013, and reported on</i>
Alert or Trigger	Monitoring to detect a specific occurrence or value which, if it is detected or if it meets or exceeds criteria, triggers a pre-determined response e.g. a management action, or a policy change	Can be valuable in dealing with threats and risks <i>Example: Under fire management plans, there is a requirement to ensure fuel accumulation does not exceed a specified level</i>
Feedback	Monitoring to find out whether a particular action does or does not result in an expected response, and then using the findings to choose future actions A key to adaptive management	Addresses nature of a response rather than linking a response to a specific alert threshold or criterion Shape future management actions, where these are not sufficiently well understood to prescribe a particular management response in advance

Reasons for Monitoring

Monitoring is intended to:

- assist the Board of Management and Reserve managers to discharge their duties and responsibilities;
- build knowledge and place management on a sound footing and evidence base;
- provide the knowledge feedback needed to keep planning and management on track;

- be relevant input to the review of plans;
- involve partners, according to their needs, skills, expertise and interests; and
- be efficient and effective in use of resources, and proportionate to the intended use of information gained.

In pursuit of efficiency and effectiveness, the following are important considerations:

- Monitoring and measurement requires a purpose to be stated up front; this may be simple or complex, stand-alone or part of a larger question;
- Monitoring needs to be a finite activity, with an end point or review date stated at the outset;
- Measurement requires analysis and interpretation; these are to be planned from the outset; data collection without interpretation is not monitoring;
- Measurement form and frequency needs to be appropriate to the purpose and expected use; and
- Protocols for processing and storing measurements, data ownership, and access need to be established in advance of data collection.

Table 38: Framework for Monitoring

Reason	Application	Types
Discharging responsibilities	Statutory or legal requirements e.g. threatened species and communities, or as part of a License, or as Duty of Care e.g. neighbours	<i>Compliance Condition Alert</i>
Managing threats	Addressing potential threats by prompting an action or decision or policy change, or to validate the need for a particular course of action or decision or policy change	<i>Alert Feedback</i>
Gaining feedback on management	Determining whether actions and changes e.g. policy, access, management zones, assets, are or are not having an expected positive effect, or are having an unwanted or negative effect	<i>Feedback</i>
Improving knowledge and understanding	All new information and monitoring improves knowledge Addressing gaps in conceptual understanding through specific monitoring projects	<i>Temporal Pattern</i>

Monitoring and Adaptive Management/Learning

Adaptive management capability requires integration of monitoring with project/program design and management. This enables:

- *Testing of assumptions* - using knowledge to choose a strategy, making explicit the assumptions behind the choice, and collecting monitoring data to determine if the assumptions can be sustained;
- *Adaptation* - changing assumptions and approaches in response to new or different information obtained through monitoring and experience; and
- *Learning* - documenting the planning and implementation processes, successes and failures for internal learning and to share with others.

Table 39: Potential Monitoring Projects Identified in Studies and Reviews Undertaken in 2013

Biophysical factors

- ◆ Avifauna in the Reserve by species presence and abundance, once each season, plus any unusual species to the area or an unusual increase in abundance of a particular species, such as large bodied birds that flock
- ◆ Detailed timing of breeding, nesting or visitation of endangered or migratory bird species in the Reserve, as input to temporal (seasonal or episodic) zoning for access management
- ◆ New weed infestations and assessment of success of treatment and revegetation activities
- ◆ Incidence of domestic pets and introduced pest species within the Reserve
- ◆ Accumulation of lake sediment in the Causeway channel and lower reaches of palaeochannels
- ◆ Mudflat area and grass height to determine appropriate cattle stocking rates and duration of access
- ◆ Water levels in the network of nine shallow monitoring bores and seven surface water staves (plus recording of lake backwater levels), in early spring, mid-summer and late autumn (plus installation of additional monitoring bores over time)
- ◆ Water quality analysis for heavy metals in sensitive zones (annually) plus seasonal physico–chemical analysis
- ◆ Levels and nature of external discharges into the Reserve, impacts, and risk management performance

Management Consequences

- ◆ Consequences of zoning and associated conditions of use
- ◆ Consequences of pest management programs (rabbits, fish, weeds, etc)
- ◆ Consequences of different approaches to managing joint use of paths by cyclists and pedestrians
- ◆ Consequences of different applications of traditional Aboriginal knowledge in land management

Social factors

- ◆ Patterns of use and access by boating groups
- ◆ Patterns of use of the Reserve by owners of domestic pets
- ◆ Attitudes of local residents and visitors to the evolving program of pest management and restrictions placed on access with domestic pets

Projects Suited to Community or Specialist Interest Groups

Some projects are suitable/ amenable to being undertaken by community or specialist-interest groups.

These can make a significant contribution to knowledge about the Reserve.

In addition, they encourage and foster interest in, and commitment to, the Reserve.

A strategy for maintaining quality and ensuring long-term value of community projects should include:

- use of or access to professional skills in sampling design and on information storage, retrieval and interpretation; and
- expectation of reporting regularly to the Board and/or to public seminars.

Potential community groups include: a special interest group (e.g. Canberra Ornithologists Group, herpetologists, Waterwatch, Frogwatch) or other types e.g. volunteers, school groups.

Participation in such a project may provide: experience in animal handling, in ecological survey; opportunity to learn about target biota (longevity, social systems); opportunity to learn the basics of data storage, data bases, and information handling.

The following monitoring projects are conducted at present within the Reserve:

- seasonal bird surveys to determine species distribution and abundance;
- annual frog surveys to determine species distribution and abundance;
- water quality at various sites;
- rainfall and water table levels; and
- photo monitoring of vegetation and landscape.

Candidate community projects include:

- Annual Banding & Mark Recapture Programs (selected species);
- inventory in the Reserve (annual or seasonal);
- water quality;
- invertebrates;
- platypus;
- water rats;
- frogs; and
- native fish.

Table 40: Types of Investigative Projects that Might be Undertaken in the Reserve
(H) = Hypothetical example

Type	Description	Examples
Commissioned or encouraged projects	<p>Survey or Research or synthesis addressing previously identified questions and knowledge gaps</p> <p>Findings which will boost knowledge of resources or processes in the Reserve, and/or contribute directly to their management</p> <p>May be funded wholly or in part, or as in-kind support</p>	<p>Geomorphology assessment</p> <p>(H) Quantification of ecosystem goods and services provided by Jerrabomberra Wetlands and potential impacts on that provision</p>
Hosted projects	<p>Research seeking to use the Reserve as a field site</p> <p>Research questions may be identified by a third party such as a tertiary institution, and may be about natural assets and processes</p> <p>Hosted projects about the Reserve, or using the Reserve, to enrich knowledge and contribute to management, at least in the long-run</p> <p>The project may be hosted not only in the sense of having permission to use the Reserve, but also may be facilitated by providing background information and participating in a voluntary capacity</p>	<p>(H) Studying effects of climate warming on distribution, movements and dispersal of small-bodied versus large-bodied frogs, requiring field work in the Reserve</p> <p>(H) Developing a dynamic simulation model of micro-climate patterns through Canberra, requiring a weather station in the Reserve</p> <p>Existing CSIRO Dung Beetle study</p>
Community projects	<p>Projects run and maintained by community groups seeking to build information about an aspect of the Reserve e.g. individual species or species groups or usage patterns</p> <p>To encourage acquisition of long-term data and information, projects are required to have a well-designed robust sampling and site selection protocol, and procedures for data handling and analysis</p>	<p>(H) Quarterly surveys of terrestrial insects from twelve sites across the Reserve</p> <p>(H) Seasonal patterns in number and type of users visiting selected features in the Reserve</p>

Research

Ideas on possible research topics are given in Table 41.

Table 41: Potential Research Projects Requiring External Skills and Funding

Topic	Possible content
<i>Structure and chronology of sediments on the Molonglo floodplain</i>	<p>Determination of 3-D structure of floodplain sediments underneath Dairy Flat. This would allow better analysis of types of channels that produced scroll bars and underlying sands and gravels, refining palaeoclimatic interpretation of these features. Could involve direct observation in trenches, or non-invasive Ground Penetrating Radar</p> <p>Dating of fluvial sediments using optically stimulated luminescence and radiocarbon for late Quaternary sediments (dunes, and presumed Holocene/Late Pleistocene sediments underlying Dairy Flat), and cosmogenic burial dating for likely Pliocene/Miocene Fyshwick gravels</p>
<i>Sediment dynamics in a narrow backwater on an intermittently-flooded floodplain</i>	<p>Modelling and /or field determinations of deposition history, accumulation rates, and potential entrainment to improve understanding of in-filling of the Causeway channel; also insights into time-scale and trajectory for change (episodic and event-based or continuous), potential role of wetland vegetation in consolidation, and potential for scour</p>
<i>Development of wetland conceptual models</i>	<p>Conceptual modelling to enable visual display of important elements of ecological functioning of the wetlands, and manipulation of links/relationships between these to show changed conditions (consequences) under different situations/ scenarios</p> <p>Understanding these relationships and changes will help to communicate wetland science to decision-makers, managers, scientists and the broader community</p> <p>Understanding of these systems will also support development of appropriate indicators of wetland extent, distribution and condition, consistent with the National Wetland Indicators Review</p>
<i>Carbon forms and accumulation in relation to wetland productivity: projections through time</i>	<p>Improved understanding of wetland productivity through time. ‘Young’ created wetlands are not equivalent to natural mature wetlands in terms of biogeochemical characteristics or functioning, and take time to accumulate these characteristics</p> <p>Understanding this trajectory and what controls it for the wetlands in the Reserve will help shape ideas about future productivity and species richness (e.g. two to three decades)</p>
<i>Dispersal mechanisms and wetland age: characteristics of seedbanks/ propagule banks</i>	<p>Wetland seedbanks are a biological reservoir, both of seeds and other plant propagules and of microfauna such as zooplankton which drive the aquatic foodweb. Differences in dispersal mechanisms, propagule longevity, water regime and wetland age make it highly likely that wetlands in the Reserve vary widely in this biological potential</p> <p>Understanding this will provide a basis for understanding future management actions (e.g. changing wetland water regime; plantings)</p>

Continued →

Table 41 (continued): Potential Research Projects Requiring External Skills and Funding

Topic	Possible content
<i>Resistance characteristics of a pasture (Phalaris, Fescue) grassland and manipulating these to rehabilitate a floodplain</i>	<p>A literature review to identify ecological processes that make a pasture grassland resistant to change (competitiveness, propagule persistence, grazing pressure, soil characteristics, species characteristics of Phalaris) and then to test and evaluate strategies for breaking down this resistance (e.g. change in grazing regime, shading effects, fire)</p> <p>This would clarify options for rehabilitating parts of the northern Reserve to native vegetation</p>
<i>Pathways and flyways of waterbirds and waders using Jerrabomberra Wetlands Nature Reserve</i>	<p>Making explicit the movements of a selected number (individuals, guilds or species) of waterbirds and waders arriving at, using, and leaving, the Reserve, using tracking technology. This will show how the Reserve fits in to movement patterns in eastern Australia, what habitats are being used by different travellers, and indicate resident-sedentary groups of birds.</p> <p>This could be of public interest, and potentially valuable in considering bird-strike issues. Cost of satellite tracking is expensive but likely to decrease</p>
<i>Impact of cattle grazing on wetland habitat attributes</i>	<p>Examination of grazing impacts on particular wetland locations or types e.g. ephemeral pools on the Peninsula, and target species e.g. small waders, using small grazing exclosures to assess habitat response</p> <p>There are two large fenced areas that could be used as exclosures</p> <p>This would clarify options for using grazing for grassland management without risk to wetland values</p>
<i>Attributes, trajectory and controlling factors of a floodplain novel ecosystem: a systems perspective at different points in time</i>	<p>Developing a whole-of-system understanding of the Reserve as a novel ecosystem, via a history and an emphasis on controlling factors</p>

Review

The adaptive management cycle includes evaluation of management effectiveness and review of the overall management program.

The Plan of Management is due for revision in 2020, and management actions arising from this Report will be reviewed in tandem with that process.

Additionally, review of this Report will address the functioning of the Board of Management, community partnerships, and other matters that are not currently included in the Plan of Management.

Table 42: Review Schedule and Processes

<p>Major Review 15-20 years</p>	<p>Undertaken by the Board of Management (or equivalent body at that time) to review progress in realising the Vision, Goals and Targets since baseline Builds logically on a series of performance reviews, with larger more strategic scope Requires external independent input, either as a facilitator, or contractor <i>Provisional timing:</i> completed 2028 (input to 2030 Plan of Management revision)</p>
<p>Performance Reviews 5-yearly intervals</p>	<p>Undertaken by the Board of Management to review progress towards achieving the Vision, Goals and Targets since baseline Requires external independent input, either as a facilitator, or contractor <i>Provisional timing for the initial Performance Review:</i> first six months of 2019; completed by end June 2019 (input to 2020 Plan of Management revision) Takes an <i>analytical approach</i> to understand both progress and non-progress, and reports on reasons for achievements and non-achievements Takes a <i>positive and creative attitude</i>, so that insights gained can inform a review of the Targets, Goals and Vision, and the processes and instruments set in place to deliver them e.g. the Board, partnership model, funding processes, the Plan of Management, agreements, communication Needs to consider: appropriateness, practicality, and relevance into the future Findings and outcomes of the Performance Review are an input into (re-)setting Targets for the ensuing five years (a new/ separate planning process) Finalised review <i>publicly available</i> on the web Any foreshadowed changes to Goals, Plan of Management etc placed on the web, and announced through the media</p>
<p>Interim Review After 2 years</p>	<p>Undertaken by the Board of Management <i>Provisional timing:</i> early in 2016 and completed by end April This ‘safety valve’ recognises that:</p> <ul style="list-style-type: none"> • Five years to an initial Performance Review is a reasonably long time for a ‘new’ concept and operating model to run • Pressures from urbanisation and development, particularly along the boundaries of the Reserve, are likely to intensify <p>Has limited and quite specific terms of reference to review:</p> <ul style="list-style-type: none"> • whether or not the partnership model and funding arrangements are working as effectively as expected or needed, in delivering the Vision, Goals and Targets, and implementing the Plan of Management • targets or steps that if not progressed rapidly will become obstacles to progress and achievement <p>Where weaknesses/defects can be identified, acts as an alert and suggests how these might be remedied, in both short-term and long-term</p>

Principles for guiding and informing the review process are shown in Table 43, with Indicative Goals and Targets for the review process suggested in Table 44. These will be refined by the Board in the first year of operation.

Table 43: Principles for Review Process

Baseline	<p>All reviews will be undertaken against a baseline reference point, which is both a point in time and a set of prevailing conditions</p> <p>Provisional starting point for purposes of review: Jan-Feb 2014</p>
Inputs	<p>Will include (not limited to):</p> <ul style="list-style-type: none"> ◆ this report and associated documents defining Vision, Goals and Targets ◆ business documents and agreements of the Board ◆ invited input from community stakeholders, partners and neighbours ◆ results of monitoring, survey and research <p>Board documents will comprise meeting papers, verified financial statements and accounts, and incidental and routine reports</p>
Goals and Targets	<p>Goals need to:</p> <ul style="list-style-type: none"> ◆ be distinct from Targets, in being qualitative, generalised, high-level statements of intent (outcomes) ◆ last as long as the plan cycle ◆ be few in number ◆ mirror agreed priorities ◆ cover the spectrum of processes and activities required to deliver on the priorities ◆ shape review by informing interpretation of achievement of Targets <p>Targets need to:</p> <ul style="list-style-type: none"> ◆ be derived from Goals ◆ be specific and measurable, preferably quantitative, steps (milestones) to achieving broader Goals ◆ form the basis for review, informed by Goals

Reporting

Reporting will happen at various time scales:

- *Monthly*: Minutes of monthly meetings are a record of decisions and Board deliberations, and are an essential input to the Review process.
- *Annual*: Annual reports summarising the years' activities and achievements will be prepared, including the annual Stakeholder Evening Forum.

Annual reporting will be a necessity if the Board becomes incorporated in the future.

These annual reports will be the most significant input to the Review process.

Table 44: Indicative Goals and Targets

Area / Theme	Long-term Goal	Interim Target	1 st Review Target
Partnership model	On-going dialogue is maintained with neighbours and other stakeholders	Establish/ host an annual informal 'listening' forum about the Reserve, for parties to present/ discuss achievements and aspirations, and to canvas issues and up-coming changes	
Facilities and Infrastructure	<p>The Learning Centre is established, and:</p> <ul style="list-style-type: none"> • services 'behind-the-scenes' needs of those responsible for managing/ supporting the Reserve; and • provides an attractive and welcoming facility for users and visitors to the Reserve 	<p>Identify the likely range of users and uses, and for each develop an understanding of likely building specifications</p> <p>Scope user and visitor numbers, and likely pattern of use; provide data to designer</p> <p>Identify a financial target (external funds)</p>	<p>A strategy for attracting funds is established and operational</p> <p>The first 25% is secured, another 50% is probable</p> <p>The date for officially 'turning the first sod' is agreed on</p>
Education and Public Support	Canberra citizens have an improved understanding and an active appreciation of the floodplains at Jerrabomberra as a natural archive of two stream catchments, long history of Aboriginal use, and effects of rural history, settlement and urbanisation	<p>Develop and implement a mini-media campaign, to promote natural, historical and 'archive' values of the Reserve</p> <p>Prepare information kits, leaflets, signage and/or information web pages for:</p> <ul style="list-style-type: none"> • natural archive of two river catchments - geomorphology/ecology • Aboriginal use, traditional knowledge, and cultural connection to Country • rural history pre- and post-establishing the ACT/ building Canberra 	Jerrabomberra Wetlands is part of regional school curricula

References

[JW] = Internal unpublished document Jerrabomberra Wetlands Board of Management

Preamble

National Capital Authority (NCA) 2013. *Consolidated National Capital Plan incorporating amendments*. September 2013. Commonwealth of Australia, Canberra

National Capital Planning Authority (NCPA) 1995; 2011. *Lake Burley Griffin Management Plan*. Commonwealth of Australia, Canberra

Territory and Municipal Services (TAMS) 2010. *Jerrabomberra Wetlands Nature Reserve Plan of Management*. ACT Government, Canberra

EcoLogical 2012. *Jerrabomberra Wetland Nature Reserve. Draft Master Plan*.

Part 1: Resources and Values

ACT Government 2013. Traditional Custodians – a time to reflect in *Explore: your free guide to Canberra's urban parks, nature reserves, national parks and recreational areas*. ACT Government, Canberra

Australian Heritage Commission 2002. *Australian Natural Heritage Charter for the conservation of places of natural heritage significance*. 2nd edition. Australian Heritage Commission/Australian Committee for IUCN, Canberra

Butz, Mark 2013a. [JW] *Jerrabomberra Wetlands: synthesis of cultural heritage information and preliminary historic theme identification*

EcoLogical 2012 *op.cit.*

Environment ACT 2006. *Draft ACT Wetlands Policy. A strategy for the management and conservation of ACT wetlands*. March 2006. ACT Government

Environment Australia 2001. *A Directory of Important Wetlands in Australia*. Third Edition. Environment Australia, Canberra

Hydroilex P/L 2013. *Hydrogeological Investigation. Jerrabomberra Wetland Environs*. [HG13.5.2.CA.R2] May 2013

Lawrence, Ian 2013a. [JW] *Jerrabomberra Wetlands Master Plan Material: Recreational values & uses*. Jun 2013

Lawrence, Ian 2013b. [JW] *Draft Report. Assessment of water sources, pathways & inundation patterns across the Jerrabomberra Reserve*. Jul 2013

Lawrence, Ian 2013c. [JW] *Jerrabomberra Wetlands Master Plan Material: Management instruments*. Jul 2013

Lawrence, Ian 2013d. [JW] *Jerrabomberra Wetlands Ecological Values Assessment*. Sep 2013

Lennon, Jane & Centre for Western Australian History 2001. *Australian historic themes: a framework for use in heritage assessment and management*. Australian Heritage Commission, Canberra

Lennon, Jane & Matthews, Steve 1996. *Cultural landscape management: Guidelines for identifying, assessing and managing cultural landscapes in the Australian Alps national parks*. Australian Alps Liaison Committee

MacKenzie A and Sumartojo S 2012. *Narratives of sustainability in the urban landscape: Canberra's National Capital Open Space System (NCOSS)*

Millennium Ecosystem Assessment 2005. *Ecosystems and human well-being: a framework for assessment*. World Resources Institute, Washington DC

National Airports Safeguarding Framework 2013. Department of Infrastructure and Regional Development, Canberra.

http://www.infrastructure.gov.au/aviation/environmental/airport_safeguarding/nasf/

National Capital Authority (NCA) 2004. *The Griffin legacy: Canberra, the nation's capital in the 21st century*. Commonwealth of Australia, Canberra

National Capital Authority (NCA) 2013 *op.cit.*

Navin Officer Heritage Consultants 2009. *East Lake Electrical Infrastructure Implementation Project - Cultural Heritage Assessment 61*, July 2009

Nicholls, Warren 2013a. [JW] *Cultural values*. Jul 2013

Opik, A A 1958. *The geology of the Canberra City district*, Bur. Min. Res. Aust. Bulletin 32 with map
Department of National Development, Canberra

Roberts, Jane 2013a. [JW] *Wetland Mapping, Types and Inventory for Jerrabomberra Wetlands Nature Reserve*. Apr 2013

Roberts, Jane 2013b. [JW] *Novel ecosystems*. Sep 2013

Roberts, Jane 2013c. [JW] *Regional context*. Sep 2013

Roberts, Jane 2013d. [JW] *Glossary aka working definitions*. Sep 2013

Roberts, Jane 2013e. [JW] *Resilience, Disturbance and contemporary Fauna*. Sep 2013

Roberts, Jane et al. 2013. [JW] *Wetland typology*. Sept 2013 (with M Lintermans, I Lawrence)

Taylor, Ken 1989. 'Conservation and interpretation study of the rural heritage landscape, Lanyon-Lambrigg ACT' *Historic Environment* vol.7 no.2 : 16-23

Taylor, Ken 1992. 'Cultural values in natural areas' in Scougall, Babette (ed.) 1992. *Cultural heritage of the Australian Alps: Proceedings of the symposium held at Jindabyne, New South Wales, 16-18 October 1991*. Australian Alps Liaison Committee, Canberra

Territory and Municipal Services (TaMS) 2010 *op.cit.*

White, Duanne et al. 2013. *Jerrabomberra Wetlands geomorphic assessment. Report for ACT Parks and Conservation*. Institute for Applied Ecology, University of Canberra

Part 2: Vision, Objectives and Principles

Butz, Mark 2013b [JW] *Jerrabomberra Wetlands Vision and Critical Issues Workshop – 19 December 2012 - Outputs*

Butz, Mark 2013c. [JW] *Jerrabomberra Wetlands Vision and Critical Issues Workshop - 13 March 2013 - Outputs*

Butz, Mark 2013d. [JW] *Jerrabomberra Wetlands Vision and Critical Issues Workshop - 11 April 2013 - Report and Outputs*

Butz, Mark 2013e. [JW.] *Jerrabomberra Wetlands Vision and Critical Issues Workshop 4 - 19 June 2013 - Report and Outputs*

Jones, Glenys 2005. 'Is the management plan achieving its objectives?' in Worboys, G, Lockwood, M & De Lacy, T 2005. *Protected Area Management. Principles and Practice*. Second edition, Oxford University Press

Part 3: Possibilities

Jerrabomberra Wetlands Draft Master Plan. *Public Consultation Report*

Jerrabomberra Wetlands Nature Reserve *Draft Concept Plan (Track changes)* May 2013

Davey, Chris 2013a. [JW] *Jerrabomberra Wetlands Visitors Centre: Discussion paper*. May 2013

Davey, Chris 2013b. [JW] *A description of and issues concerning birds of the Jerrabomberra Wetlands*. May 2013

Davey, Chris 2013c. [JW] *Discussion paper on issues concerning the Jerrabomberra Wetlands and the Canberra Airport Authority - a possible way forward*. Jun 2013

Davey, Chris 2013d. [JW] *Assessment matrix for the potential of attracting birds to create an aircraft bird-strike hazard*. Discussion paper. Jun 2013

Davey, Chris 2013e. [JW] *Scientific Survey and research needs and meetings, presentations and research facility requirements at the Jerrabomberra Wetlands Nature Reserve*. Jul 2013

Freeman, John 2013a. [JW] *Visitor Safety*. Jun 2013

Freeman, John 2013b. [JW] *Infrastructure Design, Construction and Maintenance*. Jun 2013

- Freeman, John 2013c. [JW] *Cultural Aspects for the Master Plan*. Jun 2013
- Freeman, John 2013d. [JW] *Bushfire Risk*. Jun 2013
- GHD 2013. *Visitor & Management Facilities Jerrabomberra Wetlands Nature Reserve*. Final Options Paper
- Ginninderra Catchment Group n.d. *Protecting our bush on the boundary*.
<http://www.ginninderralandcare.org.au/landcare/bush-boundary>
- Lawrence, Ian 2013e. [JW] *Critical issues assessment matrix*. Spreadsheet. Apr 2013
- Lawrence, Ian 2013f. [JW] *Policy of Fencing*. May 2013
- Lawrence, Ian 2013g. [JW] *Potential aircraft bird strikes risk issue* (with Comment). May 2013
- Lawrence, Ian 2013h. [JW] *Management of wetlands to enhance their values*. May 2013
- Lawrence, Ian 2013i. [JW] *Manipulation of wetland inundation*. May 2013
- Lawrence, Ian 2013j. [JW] *Development of a 'selection & application of management zones' policy*. May 2013
- Lawrence, Ian 2013k. [JW] *Development of a 'new wetland development' policy*. May 2013
- Lawrence, Ian 2013l. [JW] *Jerrabomberra Wetlands Master Plan Material: Access & walking trails*. Jun 2013
- Lawrence, Ian 2013m. [JW] *Jerrabomberra Wetlands Master Plan Material: Hydraulic enhancement of Wetlands*. Jun 2013
- Lawrence, Ian 2013n. [JW] *Jerrabomberra Wetlands Master Plan Material: Duty of care*. Jun 2013
- Lawrence, Ian 2013o. [JW] *Governance, partnership & sponsoring provisions*. Jun 2013
- Lawrence, Ian 2013p. [JW] *Jerrabomberra Wetlands Master Plan Material: Management objectives: Protection, Restoration, Enhancement*. Jun 2103
- Lawrence, Ian 2013q. [JW] *Jerrabomberra Wetlands Master Plan: Management of pollutant discharge risks*. Jun 2013
- Lawrence, Ian 2013r. [JW] *Development of an outline of Jerrabomberra Wetland Futures*. Aug 2013
- Lawrence, Ian 2013s. [JW] *Water Rights Issues*. Sep 2013
- Lawrence, Ian 2013t. [JW] *Partnership building capacity*. Sep 2013
- Lawrence, Ian 2013u. [JW] *Follow-up to Draft Master Plan Report Workshop*. Sep 2013
- Lintermans, Mark 2013. [JW] *Grazing at Jerrabomberra Wetlands (aka The Beef Position)*. Jul 2013
- Lintermans, Mark 2013. [JW] *Options and opportunities for alien fish management in the Jerrabomberra Wetlands*. Sep 2013
- Lintermans, Mark 2013. [JW] *Thoughts on the Non-avian fauna of the Jerrabomberra Wetlands*. Sep 2013
- Nicholls, Warren 2013b. [JW] *Governance and Regulatory Arrangements*. Jul 2013
- Nicholls, Warren 2013c. [JW] *Managing Introduced Pests and Domestic pets*. Jun 2013
- Nicholls, Warren 2013d. [JW] *Provision and Management of Access to the Reserve*. Jun 2013
- Roberts, Jane 2012. [JW] *The southern part of Jerrabomberra Wetlands Nature Reserve*. Revised Aug 2012
- Roberts, Jane 2013f. [JW] *Education & Interpretation*. Jun 2013

Part 4: Survey, Monitoring, Review & Reporting

- Roberts, Jane 2013g. [JW] *Chap 3: Scientific Survey & Research*. Jul 2013
- Roberts, Jane 2013h. [JW] *Chapter 6: Evaluation, Review, Reporting*. Jul 2013
- Roberts, Jane 2013i. [JW] *Chap 6: Measurement and Monitoring*. Jul 201

