PIG SWAMP

ENVIRONMENTAL WATERING PLAN

NORTH CENTRAL
Catchment Management Authority
Connecting Rivers, Landscapes, People

PREPARED FOR THE
GOULBURN-MURRAY WATER CONNECTIONS PROJECT

GOULBURN-MURRAY WATER

Version 9, July 2015

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Management agreement

Where consistent with the obligations and responsibilities of the respective agencies, I agree to the management actions and responsibilities as described in this EWP.

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EXECUTIVE SUMMARY

The Pig Swamp Environmental Watering Plan (EWP) documents the approach to mitigating the potential impacts of the Goulburn-Murray Water (GMW) Connections Project, previously named the Northern Victoria Irrigation Renewal Project (NVIRP). An EWP is required in response to the decommissioning of the eastern end of the Straight Cut Channel. The Straight Cut Channel divides the wetland into a northern and southern section.

In 2007, Goulburn-Murray Water (GMW) constructed an earthen embankment to block the Straight Cut Channel upstream of Pig Swamp as a drought/water savings measure; consequently, no water can now be delivered to Pig Swamp. This was done prior to the Connections Project; nonetheless in accordance with the Water Change Management Framework, the GMW Connections Project will manage any potential impacts to the wetland by preparing and implementing an EWP. The water savings generated by the project will contribute to the Connections Project overall water savings.

The following components are the primary means by which the commitment of no net environmental loss for Pig Swamp will be achieved for the GMW Connections Project. The main conclusions are summarised below.

Defining the environmental values of Pig Swamp

Pig Swamp is part of a wetland of international and national significance, the Gunbower Forest Ramsar site and listed on the Directory of Important Wetlands in Australia. Pig Swamp occupies approximately 50 ha and is situated towards the southern end of Gunbower Forest. It has been classified as a shallow freshwater marsh dominated by River Red Gum and dead timber both prior to and following European settlement.

Pig Swamp vegetation comprises Sedgy Riverine Forest, Tall Marsh, open water and River Red Gum and is surrounded by Riverine Chenopod Woodland. It provides a diversity of habitats for aquatic and amphibious plants as well as habitat and food sources for birds, frogs and reptiles.

Pig Swamp water management goal:
Support a diversity of flora and fauna typical of a shallow freshwater marsh, in particular providing habitat for frogs and waterbirds, while also maintaining the health and distribution of the current mosaic of plant communities. An intermittent watering regime is alternately wet and dry but less frequently or regularly than seasonal waters.

Defining the water regime required to protect the environmental values

A number of ecological objectives are identified and are based on historic and current wetland condition, and water dependent environmental values (habitat, species/communities and processes). The hydrological requirements for each of these objectives are identified, and a desired water regime required to achieve the water management goal is described.

Wetland water regime:
Inundate wetland two in five years to Full Supply Level (FSL) and allow to dry out completely one in five years. Ideally, fill in winter/spring with inundation to FSL lasting three to six months. Allow 'natural' floods to inundate Pig Swamp and if possible, enhance flood level or extend duration with environmental water.

The volume of water required to provide the desired water regime for Pig Swamp has been estimated using a simplified version of the 'Savings at Wetlands from Evapotranspiration daily Time-Series' (SWET) model.

The mean long-term annual controlled inflow requirement volume required to fill Pig Swamp, based on the two in five year watering regime is 170 ML/year. The maximum annual volume ever likely to be required (95th percentile) is 521 ML.

Assessment of mitigation water requirement

Mitigation water is defined as the volume of water required to ensure no net impacts on high environmental values of a waterway or wetland resulting from the GMW Connections Project. Mitigation Water may be required where both:

- the waterway or wetland has received incidental irrigation water beneficial and material to high environmental values before the modernisation associated with the Connections Project, and
- where a similar contribution is assessed as being a beneficial part of a water regime which is proposed to continue to support high environmental values following the modernisation

The assessment process for the requirement of mitigation water demonstrates that the **supply of irrigation water provided significant benefit to Pig Swamp and mitigation water is warranted.** In particular, if the volume of irrigation water was to be removed, additional water would need to be secured to maintain the wetland's environmental values (specifically waterbird and frog habitat).

The incidental water at the origin was 455 ML in the baseline year and the annualised baseline mitigation water volume was calculated as 455 ML. The Mitigation Water Commitment for Pig Swamp is 37%. However, the calculated water savings and mitigation water volumes must be fixed because the incidental water contributions were calculated based on fixed water losses.

Therefore, each year 170ML of water must be made available for mitigation water and 285ML made available as water savings.

Potential risks, limiting factors and adverse impacts associated with the desired water regime

A number of potential risks, limiting factors and adverse impacts have been identified that may result from the provision of mitigation water. For example, a supply point to Pig Swamp is required to ensure the recommended desired water regime is achieved. Pig Swamp has been added to the Environmental Infrastructure Register to confirm the requirements for infrastructure to enable the supply environmental water.

Infrastructure requirements

At present, the Straight Cut Channel is operated to deliver water to the two remaining service points upstream of Pig Swamp. The earthen block in the Straight Cut Channel prevents the delivery of water to the wetland. Therefore, Pig Swamp can only be filled via high Murray River flow events exceeding 50,000ML/day.

It is recommended that the Straight Cut Channel is retained and upgraded to ensure Pig Swamp is able to receive environmental water, otherwise alternative supply arrangements will need to be sought. The necessary works include a pipe and outlet structure at the wetland entry point in the Straight Cut Channel, a structure placed in the channel on the east side of Pig Swamp and the capacity of the Straight Cut Channel restored (removal of debris, vegetation and sediment build up).

Adaptive management framework

An adaptive management approach (assess, design, implement, monitor, review and adjust) is incorporated into the EWP to ensure to ensure an appropriate application of the scientific method to management.

The Pig Swamp EWP has been developed using the best available information. However, a number of information and knowledge gaps are identified which may impact recommendations and/or information presented. These knowledge gaps will be addressed as part of the adaptive management approach outlined within the EWP as additional information becomes available.

Governance arrangements

A summary of the roles and responsibilities (e.g. land manager, environmental water manager, and system operator) relating to the development and implementation of EWPs are defined. A framework for operational management has also been developed to describe the annual decision-making process required to coordinate the implementation of the desired water regime for Pig Swamp.

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ACKNOWLEDGEMENTS

The information contained in the Pig Swamp Environmental Watering Plan (EWP) of 26 March 2013 (Version 8) was sourced from a variety of reports and field inspections and from individual knowledge and expertise.

The North Central Catchment Management Authority (CMA) acknowledges the assistance of the following people in preparing this EWP.

- Ross Stanton, Anne Graesser, Geoff McIvor and Dan Radcliffe (GMW)
- Karen Weaver, Michael Dedini and Glenn Smith (Department of Sustainability and Environment)
- Mark Tscharke (Parks Victoria)
- Ross Plunkett, Chris Solum and Scott Morath (Goulburn-Murray Water Connections Project)
- Environmental Technical Advisory Committee (listed in Appendix A, Table A1)
- Wetland workshop attendees (listed in Appendix A, Table A2)
- Bazil Brereton, Roger Brereton, Kurt Brereton, Ray Harrower, George and Marion Mc Gilivray and Graham and Ursler Sutcliff (community) (listed in Appendix B)
- Jon Bartley (Bartley Consulting)
- Wes Pye (Northern Land Solutions)
- Chris Gippel (Fluvial Systems)
- Expert Review Panel: Jane Roberts and Terry Hillman
- Emer Campbell, Lyndall Rowley, Melanie Tranter and Rebecca Horsburgh (North Central CMA).

The EWP was updated in April 2015 (Version 9) in consultation with:

- Emer Campbell and Bree Bisset (North Central CMA)
- Andrea Keleher and Bruce Mathers (Department of Environment, Land, Water and Planning)
- Goulburn-Murray Water Connections Project Environmental Technical Advisory Committee
- Chris Solum, Ross Plunkett and Ed Thomas(Goulburn-Murray Water).

ABBREVIATIONS

AAV	Aboriginal Affairs Victoria
ANCA	Australian Nature Conservation Agency
AUSRIVAS	Australian River Assessment System
BE	Bulk Entitlement
Bonn	Convention on the Conservation of Migratory Species of Wild Animals
CAMBA	China–Australia Migratory Bird Agreement
CMA	Catchment Management Authority
DCFL	Department of Conservation Forests and Lands
DEDJTR	Department of Economic Development, Jobs, Transport and Resources
DELWP	Department of Environment, Land, Water and Planning
DEWHA	Department of the Environment, Water, Heritage and the Arts
DPCD	Department of Planning and Community Development
DPI	Department of Primary Industries
DSE	Department of Sustainability and Environment
EES	Environment Effects Statement
EPBC	*Environment Protection and Biodiversity Conservation Act 1999*
ERP	Expert Review Panel
ETAC	Environmental Technical Advisory Committee
EVC	Ecological Vegetation Class
EWH	Environmental Water Holder
EWP	Environmental Watering Plan
FFG	*Flora and Fauna Guarantee Act 1988*
FSL	Full Supply Level
GIS	Geographic Information Systems
GL	Gigalitre (one billion litres)
GMID	Goulburn Murray Irrigation District
GMW	Goulburn–Murray Water
JAMBA	Japan–Australia Migratory Bird Agreement
LTCE	Long-term Cap Equivalent
MDFRC	Murray-Darling Freshwater Research Centre
MNES	Matters of National Environmental Significance
North Central CMA	North Central Catchment Management Authority
NVIRP	Northern Victoria Irrigation Renewal Project
ROKAMBA	Republic of Korea–Australia Migratory Bird Agreement
SEMP	Site Environmental Management Plan
SEWPaC	Department of Sustainability, Environment, Water, Population and Communities

TAC	Technical Advisory Committee
TIS	Torrumbarry Irrigation System
VBA	Victorian Biodiversity Atlas
VEAC	Victorian Environmental Assessment Council
VROTS	Victorian Rare or Threatened Species
WCMF	Water Change Management Framework

1. Goulburn-Murray Water Connections Project

The Goulburn-Murray Water (GMW) Connections Project, previously named the Northern Victoria Irrigation Renewal Project (NVIRP), is a $2 billion works program to upgrade ageing irrigation infrastructure across the Goulburn Murray Irrigation District (GMID) and to save water lost through leakage, seepage, evaporation and system inefficiencies. Works include lining and automating channels, building pipelines and installing new, modern metering technology. These combined works will improve the irrigation system's delivery efficiency and recover a long term average[1] of 425 GL of water per year.

The GMID uses a number of natural carriers, rivers, lakes and wetlands for both storage and conveyance of water. While the water savings generated are from 'losses' within the irrigation system, in some cases the losses from the pre-GMW Connections Project operating regime provide incidental benefits to environmental assets (SKM 2008).

1.1. Decision under the Environment Effects Act 1978

On 14 April 2009, the Minister for Planning made a decision that an Environment Effects Statement (EES) was not required for the Connections Project, although this decision was subject to several conditions (DPCD 2009). The conditions that apply to the protection of wetlands and waterways include:

Condition 3: *"development of a framework for protection of aquatic and riparian ecological values through management of water allocations and flows within the modified GMID system to the satisfaction of the Minister of Water"*

The GMW Connections Project has developed a Water Change Management Framework (GMW 2013) in response to this condition. The framework outlines the processes and methods for preparing Environmental Watering Plans (EWPs) to mitigate potential impacts on wetlands and waterways at risk from the implementation of the Connections Project through adaptive water management (GMW 2013).

Condition 5: *"Environmental Watering Plans are required for 'at risk' waterways and wetlands before operation of the relevant NVIRP work commences"*

1.2. Decision under the Environment Protection and Biodiversity Conservation Act 1999

On the 10 May 2010, the Minister for Environment Protection, Heritage and the Arts approved the NVIRP, now GMW Connections Project, under the *Environment Protection and Biodiversity Conservation Act 1999*, subject to several conditions. The conditions that apply to the protection of wetlands and waterways include:

Condition 3: *This condition applies equally to sites identified through the Water Change Management Frameworks, or through Conditions 4 or 5 below, as requiring the preparation of an environmental watering plan (plan). This includes Johnson Swamp. All plans must be prepared in accordance with the Water Change Management Framework and provided to the Minister for approval. No modified operations potentially impacting on a site to which a plan relates may occur until the plan has been approved by the Minister. All approved plans must be implemented.*

GMW Connections Project has developed this Environmental Watering Plan in accordance with the EPBC Act decision and the Water Change Management Framework (GMW 2013).

[1] The volume of water that will be recovered by a water recovery measure is calculated as a 'long-term cap equivalent' volume. The long-term cap equivalent (LTCE) is a type of average. It takes into account the different characteristics of water entitlements in New South Wales, Victoria and South Australia, and their reliability.

1.3. Water Change Management Framework

The Water Change Management Framework (GMW 2013) sets out the overarching key principles with respect to environmental management for the operation of the modified GMID. These principles include:

- GMW Connections Project will strive for efficiency in both water supply and farm watering systems
- GMW Connections Project will design and construct the modernised GMID system to comply with environmental requirements as specified in the no-EES conditions
- GMW Connections Project will develop management and mitigation measures consistent with established environmental policies and programs in place in the GMID
- renewal or refurbishment of water infrastructure will be undertaken to the current best environmental practice, including any requirements to better provide environmental water. Best environmental practice will require irrigation infrastructure required to deliver environmental water to be retained (no rationalisation at these sites) or upgraded to allow for future use
- management and mitigation measures will be maintained into the future through establishment of or modification to operating protocols and operational arrangements (NVIRP 2010).

In October 2008, the Food Bowl Modernisation Project Environmental Referrals Report (SKM 2008) assessed Stage 1 (upgrade of the backbone and connections) of the GMW Connections Project in relation to operational impacts on waterways, wetlands and regional groundwater from increased system efficiencies such as changes in channel outfalls, delivery patterns and reductions in leakage and seepage.

SKM (2008) identified 23 wetlands and 17 waterways with significant environmental values which were potentially at risk from the GMW Connections Project, particularly by significant reductions in channel outfalls across the GMID. A wetland shortlisting report undertaken by Hydro Environmental (2009) reduced this number to nine wetlands, all of which required an EWP to be prepared. Feehan Consulting (2009) shortlisted the waterways, resulting in three waterways requiring EWPs.

EWPs have been required for two waterways and a wetland as a result of further information and scope changes.

While the GMW Connections Project has been established to implement the modernised works, the project will have no ongoing role in the operation of the modified GMID or environmental management in the region. Therefore the GMW Connections Project will need to establish effective management arrangements to ensure that any management or mitigation measures are implemented on an ongoing basis, particularly in the EWPs (GMW 2013).

In 2007, GMW constructed an earthen embankment to block Straight Cut Channel upstream of Pig Swamp as a drought/water savings measure. This was done prior to the Connections Project. In accordance with the Water Change Management Framework, the GMW Connections Project will manage any potential impacts to the wetland by preparing an EWP. The water savings generated by the project will contribute to the GMW Connections Project's overall water savings. Therefore to mitigate the risk, preparation and implementation of an EWP is required.

1.4. Purpose and scope of Environmental Watering Plans

The EWPs are the primary means by which the commitment of no net environmental loss will be achieved for water savings projects (GMW 2013). Each EWP will:

- identify environmental values of the wetland
- identify the water required to protect the environmental values
- define the environmental water regime and the sources of water

- identifying if there is a need to provide mitigation water and, if so, determine the quantity of mitigation water
- identify the infrastructure requirements
- identify mitigation measures to minimise the potential risks and impacts associated with the provision of mitigation water
- draft protocols for ongoing water supply
- outline governance arrangements.

This EWP is not a wetland management plan, therefore it is not intended to provide management guidance for wetlands; rather it is aimed at providing a water supply protocol that can be agreed upon by land, water and catchment managers.

The GMW Connections Project is responsible for managing and mitigating the significant environmental effects of its own activities. It is not responsible for managing and mitigating the effects of other activities or circumstances. The GMW Connections Project is not responsible for managing and mitigating the environmental effects of activities or circumstances beyond its control such as:

- reduced outfalls due to government policy initiatives
- water trade
- drought and climate change
- management and modernisation programs carried out by others (GMW 2013).

1.5. Development process

The Pig Swamp EWP was developed in collaboration with key stakeholders including GMW, GMW Connections Project, the Department of Sustainability and Environment (DSE; now Department of Environment, Land, Water and Planning [DELWP]), Parks Victoria and the Department of Primary Industries (DPI; now Department of Economic Development, Jobs, Transport and Resources [DEDJTR]) according to the process outlined in Figure 1. A number of tasks were undertaken to develop the EWP, as follows:

- scoping and collating information
- consulting and engaging stakeholders and adjacent landholders
- defining ecological objectives and associated water requirements
- identifying risks and threats
- identifying need to provide mitigation water and, if needed, determine the quantification of mitigation water
- assessing infrastructure requirements
- developing recommendations on governance arrangements and adaptive management.

Following development, EWPs were reviewed by the Expert Review Panel (ERP) prior to consideration by the Victorian Minister for Environment, Climate Change and Water and the Commonwealth Minister for the Environment.

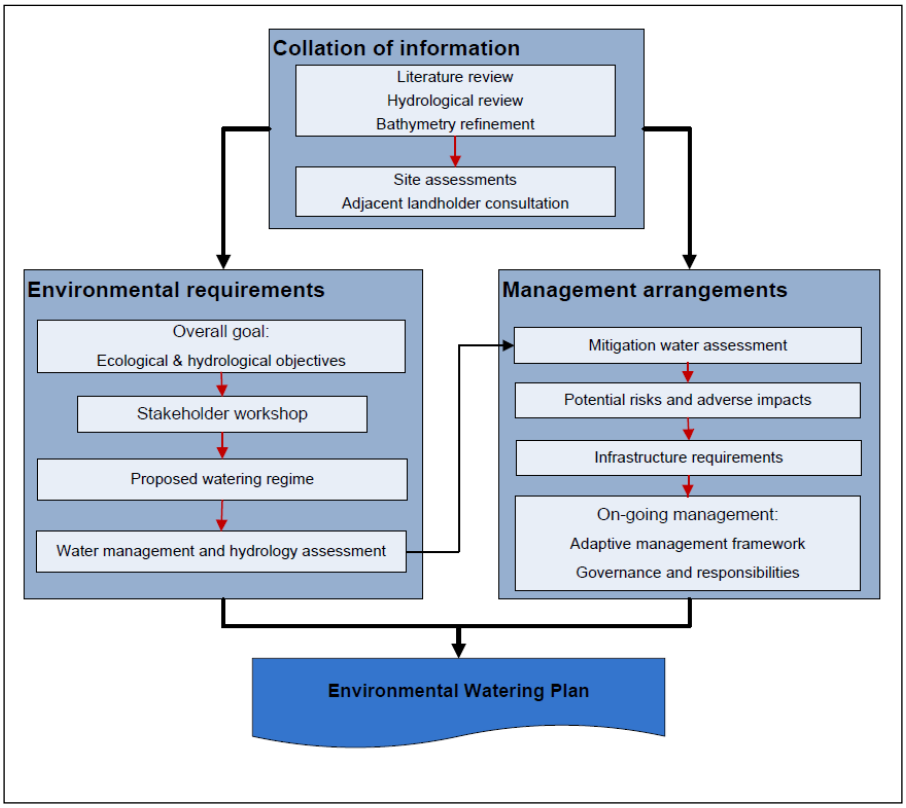


Figure 1: EWP development process

1.5.1. Consultation and engagement

To assist in collating information for the Pig Swamp EWP, a targeted community and agency engagement process was undertaken. Key groups consulted were the Environmental Technical Advisory Committee (TAC), agency stakeholders, interest groups and adjoining landholders. An outline of the various groups' involvement is provided below.

The TAC was convened by the GMW Connections Project to oversee the development of the EWPs to ensure quality, completeness and practicality. The committee includes representation from CMAs, GMW, DPI, GMW Connections Project and DSE (Appendix A). A content template for the EWPs was developed and approved by the TAC.

A workshop was held on 5 May 2011 with key agency stakeholders and technical experts (Appendix A) in order to discuss and refine the water management goal, ecological objectives, and water requirements for Pig Swamp.

Consultation was also undertaken with adjoining landholders (January and February 2011) who have had a long association with the wetland and proven interest in maintaining its environmental value. Other community and agency people were directly engaged to provide technical and historic information, including GMW staff and bird observers. A summary of the information sourced from this process is provided in Appendix B.

1.5.2. The 2015 Review

This review has been completed in consultation with the CMAs, GMW, DELWP and Parks Victoria. GMW Connections Project prepared a report (GMW 2015) to review the ecological data for each EWP site against the stated ecological objectives. The TAC has been replaced by the Environmental Technical Advisory Committee (ETAC), comprising departmental representatives (see Appendix A for membership). This report has been reviewed and approved by the GMW Connections Project ETAC and reviewed by the GMW Connections Project ERP. Outcomes from the ecological objectives review were used in the 2015 review of this EWP. The reviewed EWP has been approved by the GMW Connections Project ETAC

and the GMW Connections Project ERP. The GMW Connections Project ETAC now includes representation from CMAs, GMW, DEWLP, DEDJTR and Parks Victoria.

This document was reviewed in 2015, in accordance with the requirements of the WCMF (GMW 2013). The review addressed any new hydrological and ecological knowledge, changes impacting on the mitigation water assessment and changes to project and departmental names. Specific changes to this document are:

- Updating of site hydrological information (Section 4)
- Updating of roles and responsibilities of agencies (Sections 8, 9 and 10)
- Administrative changes such as project and departmental name changes (throughout document).

1.5.3. Cessation of GMW Connections Project

The GMW Connections Project is scheduled for completion in June 2018. At this time, as per Section 9.4.4 of the WCMF, the responsibility for delivery of mitigation water will transfer to the designated environmental water manager, operating under the Victorian Environmental Water Management Framework. The entitlement itself will be held by the Victorian Environmental Water Holder. Calculation and confirmation on the LTCE conversion factor will be required from DELWP to finalise mitigation water arrangements prior to handover. This will be decided at or near the end of the GMW Connections Project.

2. Pig Swamp

Pig Swamp is a small, shallow freshwater marsh situated towards the southern end of Gunbower Forest in northern Victoria, 4 km northeast of Gunbower and 1.5 km southwest of the Murray River (Figure 2). Gunbower Forest lies between the townships of Torrumbarry and Koondrook and is bordered by the Murray River to the northeast and the Gunbower Creek to the southwest. Gunbower Forest forms part of the larger Gunbower-Perricoota-Koondrook forest complex that receives flooding from the Murray River.

Pig Swamp occupies approximately 50 ha within the Gunbower Forest (Northern Land Solutions 2011). The wetland has a full supply level (FSL) of 84.05 m AHD at which height its storage capacity is 213 ML (Northern Land Solutions 2011). The wetland floor has a slightly undulating surface with its lowest points at 83.4m AHD north of the Straight Cut Channel, and approximately 83.60m AHD to 83.80m AHD south of the Straight Cut Channel. The maximum depth of surface water that could occur within Pig Swamp as a discrete wetland is therefore 0.65m, but is more commonly from 0.2m to 0.4m.

Refer to Appendix C for the contour plan prepared for Pig Swamp by Northern Land Solutions (2011).

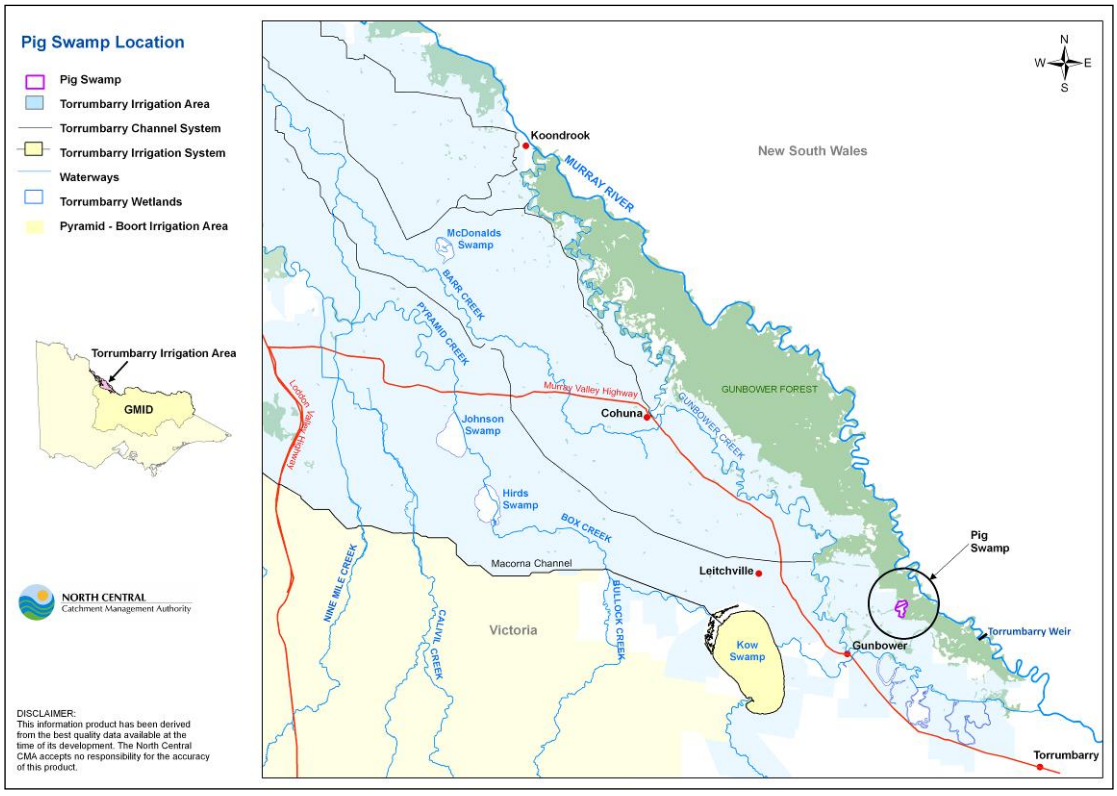


Figure 2: Location of Pig Swamp

2.1. Wetland context and current condition

Pig Swamp is a wetland depression that would have naturally been inundated during flood events on the Murray River floodplain (GHD 2007). It has been classified as a shallow freshwater marsh dominated by River Red Gum and dead timber both prior to and following European settlement (DSE 2009a and 2009b).

Prior to European settlement, the wetland contained mature, widely spaced River Red Gum (*Eucalyptus camaldulensis*) surrounded by Black Box (*E. largiflorens*). Pig Swamp naturally received floodwater from the south through a series of interconnecting creek lines and drainage depressions that flowed during moderate Murray River flood events. Larger flood events resulted in more general sheet flooding that would have inundated the higher surrounding Black Box areas.

The irrigation system provided a frequent and permanent watering regime which caused the death of older trees and establishment of younger River Red Gums (ECOS, 2005). A natural Murray River flood event partially filled the wetland in December 2010; and filled and overflowed the wetland in January 2011 (O'Brien 2011). Pig Swamp was grazed by domestic stock until 2007 in the southern section, with stock removed from the northern section approximately 30 years ago (O'Brien 2011).

The vegetation within Pig Swamp north of the Straight Cut Channel (Figure 6) is different and less diverse than the area south of the channel. The northern section contains a large thick stand of Cumbungi (*Typha* sp.) that dominates the central section of the wetland (Plate 1). This is surrounded by a narrow band of River Red Gum and sedges (Plate 2). The surrounding higher Black Box woodland supports drier understorey species, particularly saltbush, and is rarely flooded (Plate 3).

The vegetation contained in the southern section of the wetland is more diverse and influenced by the subtle variations in elevation (Plate 4). The wetland floor is dominated by River Red Gum, sedges and water couch. The native sedge *Carex tereticaulis* is prominent, particularly towards the southern end. The adjoining Black Box areas along the eastern boundary support similar species to the northern section; however, the natural drainage lines that enter the southeast section of the wetland support a wetter understorey species. Nardoo was very prevalent after 2010/11 flooding and only a small number of Tangled Lignum (*Muehlenbeckia florulenta*) plants were observed.

The western boundary of Pig Swamp abuts irrigated farmland. Irrigation practices are of a high standard with minimal drainage water entering the wetland or adjoining forest. There appears to be no salinity risk at Pig Swamp as groundwater levels beneath the farmland are low and drop further beneath forest (refer to Section 4.3).

Plate 1: Tall Marsh, Pig Swamp North (DPI, March 2011)

Plate 2: River Red Gum, Pig Swamp North (MDFRC, March 2011)

Plate 3: Black Box woodland, Pig Swamp South (MDFRC, March 2011)

Plate 4: Aquatic vegetation, Pig Swamp South, (MDFRC, March 2011)

2.2. Catchment setting

Pig Swamp is located on the southwest edge of Gunbower Forest, an island on the Murray River floodplain, bordered to the north by the Murray River and to the south by Gunbower Creek. Irrigated farmland is located to the southwest of the Forest and the floodplain and forest extend north of the Murray River into New South Wales.

Gunbower Forest is a highly significant floodplain ecosystem on the Murray River, covering 19,450 hectares. The forest is part of the Gunbower-Koondrook-Perricoota system. The extent of flooding within Gunbower Forest is determined by the height of the Murray River below Torrumbarry Weir. Torrumbarry Weir is adjacent to the upstream part of the forest. It creates a weir pool that maintains a high, stable water level to supply irrigation water to the Torrumbarry Irrigation Area. The Murray River at Torrumbarry Weir receives flows from downstream of Barmah-Millewa Forest, with discharges from both the Goulburn River upstream of Echuca and from the Campaspe River at Echuca (URS 2001 in North Central CMA 2010).

Gunbower Forest is situated within the semi-arid / grassland climatic zone of south-eastern Australia (Hale and Butcher 2011). The general climatic pattern is hot dry summers and cold winters. Maximum average temperatures range from 35.6°C in January to 16.5°C in July, with minimum average temperatures falling to 11.3°C in June. Rainfall, on average, occurs year round with highest monthly median rainfall in June (41 millimetres) and lowest in February (15 millimetres). Annual average rainfall at Echuca is in the order of 450 millimetres per year (Bureau of Meteorology 2011).

There are permanent and intermittent watercourses that serve as distributary systems and preferred flowpaths during floods. The floodplain also has a network of irrigation channels and drains. Vegetation includes River Red Gum and Black Box woodlands, with Black Box in areas subject to less frequent inundation. The floodplain is a flat to gently sloping plain comprising alluvial sands, silts and clays (Bartley Consulting 2011).

2.3. Land status and management

In 2009, the Victorian government endorsed (with amendments) the Victorian Environment Assessment Council (VEAC) recommendations for public land management. As of June 2010, Gunbower National Park (recommendation A4) comprises 8892 hectares of Gunbower Forest, with the remainder comprising Gunbower State Forest (recommendation C3) (VEAC 2009). The national park is dominated by Grey and Black Box woodlands, which are listed as endangered vegetation communities within Victoria.

Pig Swamp is part of the Gunbower National Park under the *National Park Act 1975* and is managed by Parks Victoria. National parks are managed for the preservation and protection of the natural environment including wilderness areas and remote and natural areas (Victorian Government 1975).

2.4. Cultural heritage

Evidence of Aboriginal occupation in Gunbower Forest includes scarred trees, earthen mounds, artefact scatters, shell middens and burial sites (SKM 2009). However, archaeological sites across the forest have become fragmented by destruction and damage caused by past land use including stock grazing and timber harvesting. The majority of remaining scarred trees are box trees which are outside the area of forest managed for timber harvesting (Rhodes 1996).

Pig Swamp sits within Yorta Yorta Registered Aboriginal Party (RAP) native title area. Two scarred trees have been recorded within a 5km grid intersecting with Pig Swamp and are registered with Aboriginal Affairs Victoria (AAV).

No surveys have been conducted regarding European heritage at the site.

2.5. Recreation

Pig Swamp is a relatively unknown wetland for recreation within the Gunbower Forest area. The wetland has been known to support primarily duck hunting. However since listing as a

national park in June 2010, hunting activities are prohibited under Section 17C of the National Parks Act 1975.

2.6. Legislative and policy framework

2.6.1. International agreements

Ramsar Convention on Wetlands
The Ramsar Convention, to which Australia is a signatory, provides a framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. Pig Swamp forms a component of the Gunbower Forest Ramsar site, listed as a wetland of international importance in 1982 (DSE, 2004). The site covers 19 931 hectares and consists of River Red Gum forest and wetlands between the Murray River and the anabranch Gunbower Creek.

The second Ecological Character Description for the Gunbower Forest Ramsar Site has been prepared. It provides an update of the description in line with the current national framework. Criteria for which the Gunbower Forest Ramsar site qualified are:

- Criterion 1: A wetland should be considered internationally important if it contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.
- Criterion 2: A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities.
- Criterion 4: A wetland should be considered internationally important if it supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions (Hale and Butcher 2011).
- Criterion 8: The site provides migratory routes between habitat in the Murray River, anabranches and floodplains and is considered important for recruitment of native fish (King et al. 2007).

Migratory bird bilateral agreements and conventions
Australia is a signatory to the following international migratory bird treaties:

- Japan–Australia Migratory Bird Agreement (JAMBA)
- China–Australia Migratory Bird Agreement (CAMBA)
- Republic of Korea–Australia Migratory Bird Agreement (ROKAMBA)
- Convention on the Conservation of Migratory Species of Wild Animals (also known as the Bonn Convention).

Pig Swamp is not known to support species protected by any of the above international migratory bird agreements (Table 1).

2.6.2. Federal legislation and policy

Environment Protection and Biodiversity Conservation (EPBC) Act 1999
The *(EPBC) Act 1999* is the key piece of legislation pertaining to biodiversity conservation within Australia. It aims to control potential impacts on matters of national environmental significance (MNES)[2]. Pig Swamp is not known to support protected migratory waterbirds, or species listed under the *EPBC Act*. Actions that may significantly impact any of these MNES are subject to assessment and approval by the Minister for the Environment. The GMW Connections Project works program is also subject to assessment and approval under the *EPBC Act*.

[2] There are seven MNES that are protected under the EPBC Act, these are: World Heritage properties, National Heritage places, wetlands of international importance, listed threatened species and ecological communities, migratory species protected under international agreements, Commonwealth marine areas, and nuclear actions (including uranium mines) (DEWHA 2009).

Other - *Directory of Important Wetlands in Australia*
The Directory of Important Wetlands in Australia describes 851 wetlands that have qualified as nationally important against the selection criteria. Of these wetlands, 56 are designated to the List of Wetlands of International Importance of the Ramsar Convention. Pig Swamp is listed in the Directory of Important Wetlands in Australia.

Other - *The Guide to the Murray Darling Basin Plan*
The Basin Plan is a strategic plan for the integrated and sustainable management of water resources in the Murray Darling Basin. It provides a framework for setting environmentally sustainable limits on the amount of surface water and groundwater that can be taken from the Murray Darling Basin. In addition it identifies, and seek to protect and restore, key environmental assets which are essential to the life of the rivers, their surrounding landscapes and the cultural values of the communities which depend on those water resources.

2.6.3. State legislation

Flora and Fauna Guarantee (FFG) Act 1988
The *Flora and Fauna Guarantee (FFG) Act 1988* aims to conserve and manage threatened species and communities within Victoria. Pig Swamp is known to support a number of species both protected[3] and listed under the *FFG Act* (Table 1 and Table 3). Proposed disturbance or collection of any of these threatened species will require a permit from the DELWP.

Environmental Effects Act 1978
Potential environmental impacts of a proposed development are subject to assessment and approval under the *Environmental Effects Act 1978*. As such, the GMW Connections Project works program and any associated environmental impacts are subject to assessment and approval under the Act (as discussed in Section 1.1).

Planning and Environment Act 1987
The removal of, or disturbance to, native vegetation within Victoria is controlled by Clause 52.17, Particular Provisions, in all planning schemes which are developed under the *Planning and Environment Act 1987*. The purpose of this clause is to protect and conserve native vegetation by .the implementation of a three-step process to: avoid removal; if this cannot be avoided, then minimise removal; and to offset the loss. Any proposed removal or disturbance to native vegetation associated with the GMW Connections Project works program will require the implementation of the three-step process, assessment and approval under the Act.

Water Act 1989
The Water Act 1989 is the key piece of legislation that governs the way water entitlements are issued and allocated in Victoria. The Act also identifies water that is to be kept for the environment as part of the Environmental Water Reserve. The Act provides a framework for defining and managing Victoria's water resources.

Aboriginal Heritage Act 2006
All Aboriginal places, objects and human remains in Victoria are protected under the *Aboriginal Heritage Act 2006* (DPCD 2007). Pig Swamp supports sites of Aboriginal cultural significance (Section 2.4).

Native Title Act 1993
This Act provides for the recognition and protection of native title. It establishes ways in which future dealing affecting native title may proceed and sets standards for such dealing. It establishes a mechanism for determining claims to native title. It provides for, or permits, the validation of past acts, and intermediate period acts, invalidated because of the existence of native title.

National Parks Act 1975
The *National Parks Act 1975* is a law which was passed by the Victorian Parliament in 1975. The decision to place an area of land under a schedule is based on its size, diversity of ecosystem and significance of their conservation values. In June 2010, 8,892 hectares of Gunbower Forest (which includes Pig Swamp) was declared a national park by the Victorian Government to protect and enhance the River Red Gum forests (Parks Victoria 2010). The

[3] Includes plant taxa belonging to families or genera protected by the Act (DEPI 2014).

Australian Constitution gives state and territory governments control over management of public land; for the State of Victoria the park management agency is Parks Victoria (Victorian Government 1975).

Other - *Threatened Species Advisory Lists*

Threatened species advisory lists for Victoria are maintained by DELWP and are based on technical information and advice obtained from a range of experts which are reviewed every one to two years. These advisory lists are not the same as the Threatened List established under the *FFG Act*. There are no legal requirements or consequences that flow from inclusion of a species in advisory lists. However, some of the species in these advisory lists are also listed as threatened under the *FFG Act*. Pig Swamp is known to support flora and fauna species that are included on the advisory lists (Table 1 and Table 3).

3. Pig Swamp environmental values

The primary purpose of this EWP is to assess and advise on mitigating potential impacts from the GMW Connections Project on high environmental values supported by Pig Swamp. While it is recognised that the wetland provides a number of broader ecological and landscape values (i.e. ecological processes, representativeness and distinctiveness in the landscape), high environmental values have previously been defined by the conservation significance of the wetland or species at an international, national or state level (SKM 2008; Hydro Environmental 2009; GMW 2013).

As such, in describing the values supported by the wetland in the sections below, an emphasis is placed on identifying listed flora and fauna species and vegetation communities, followed by the broader ecological and landscape values. All listed values have been presented in this section with full species lists provided in Appendix E.

Pig Swamp is considered a high value wetland because it sits within the Gunbower Forest Ramsar site. In addition, Pig Swamp is listed in the Directory of Important Wetlands in Australia, and the wetland has the potential to provide an important aquatic habitat in a mostly drier landscape.

3.1. Fauna

Pig Swamp supports Sedgy Riverine Forest, Tall Marsh, open water and River Red Gum and is surrounded by Riverine Chenopod Woodland. It provides a diversity of habitats for aquatic and amphibious plants as well as habitat and food sources for birds, frogs and reptiles.

Pig Swamp has a shallow nature and has mostly been dry in the past decade. It is unlikely to be utilised for colonial waterbird breeding (pers. comm. Melanie Tranter, [North Central CMA] 5 May 2011) nor by threatened fish species such as Murray Cod, Macquarie Perch and Murray Hardyhead as the habitats are unsuitable. However, Pig Swamp does provide suitable habitat for frog populations including the Barking Marsh Frog. Six threatened fauna species have been recorded within Pig Swamp (DSE 2010a) (Table 1 and Appendix E).

Table 1: Significant fauna species recorded in Pig Swamp

Common Name	Scientific Name	International treaty	EPBC status	FFG status	DELWP status
Australasian Bittern	*Botaurus poiciloptilus*		EN	L	EN
Azure Kingfisher	*Alcedo azurea*				NT
Brown Treecreeper (south-eastern ssp.)	*Climacteris picumnus victoriae*				NT
Grey-crowned Babbler	*Pomatostomus temporalis temporalis*			L	EN
Hooded Robin	*Melanodryas cucullata cucullata*			L	NT
Lace Goanna	*Varanus varius*				VU

Conservation Status:

- J/C/R/B: JAMBA/CAMBA/ROKAMBA/BONN International agreements listed in section 2.6.1
- FFG listing: L – Listed as threatened
- EPBC listing: EN- Endangered
- DELWP listing: EN – Endangered, VU – Vulnerable, NT – Near Threatened (DEPI 2013)

3.2. Flora

There are four Ecological Vegetation Classes (EVCs) mapped by DSE (2011a and 2011b) within and surrounding Pig Swamp (refer to Table 2): However, ground validation of EVCs found no Lignum Swampy Woodland (presumably areas have been cleared/modified, and/or hydrological conditions have changed). Most of the swamp is covered by Sedgy Riverine Forest (refer to Appendix F).

Table 2: Current (field validated) EVCs within Pig Swamp and their bioregional conservation status

EVC No.	EVC	Bioregional Conservation Status*
103	Riverine Chenopod Woodland	Endangered
817	Sedgy Riverine Forest/Riverine Swamp Forest Complex	Depleted
821	Tall Marsh	Least Concern

*Murray Fans Bioregion

The survey undertaken in March 2011 recorded 87 plant species, 24 of which are exotic and two of which are rare or threatened (Bogenhuber and Campbell 2011), refer to Table 3 below and Appendix E for the full species list (DSE 2010b).

Table 3: Significant flora species recorded at Pig Swamp

Common name	Scientific Name	EPBC status	FFG status	DELWP status
Einadia	*Einadia nutans* subsp. *linifolia*			k
Two-spined Copperburr	*Sclerolaena uniflora*			r

Conservation Status:

- EPBC listing: EN – endangered
- FFG listing: L – Listed as threatened, P – Protected
- DELWP listing: r – rare, v – vulnerable, k – poorly known and suspected, but not definitely known, to belong to one of the categories (x, e, v or r) within Victoria (DSE 2005a).

As outlined in section 2.1 the vegetation within Pig Swamp north of the Straight Cut Channel is less diverse with Cumbungi (*Typha* sp.) dominating the central section. The vegetation contained within the southern section of the wetland is dominated by River Red Gum, sedges and water couch.

Additional significant species including, Long Eryngium (*Eryngium paludosum*), Stiff Groundsel (*Senecio behrianus*), River Swamp Wallaby-grass (*Amphibromus fluitans*) and Winged Peppercress (*Lepidium monoplocoides*) have been recorded within five kilometres of Pig Swamp (GHD 2007, DSE 2010b and Bogenhuber and Campbell 2011) and considered to be wetland dependent / flow dependent (DNRE 2002 and VEAC 2008). These species were also considered when developing the desired watering regime (Section 5.3). There is currently no information to indicate the recommended water regime will be detrimental to these species.

3.3. Representativeness and distinctiveness

Shallow freshwater marshes are often degraded as a result of agricultural activities, including grazing or cropping, and consequently have decreased in extent across the landscape. The area of shallow freshwater marshes across Victoria is estimated to have decreased by approximately 60% since European settlement (DNRE 1997). Table 4 illustrates the area and proportion of shallow freshwater marshes across various defined landscapes. Pig Swamp is an example of the second most depleted wetland category within Victoria following the deep freshwater marsh.

Table 4: Current area of shallow freshwater marsh wetlands across the landscape

	North Central region	GMID	Murray Fans
Shallow freshwater marsh (ha)	4753	1085	8747
Pig Swamp	1%	6%	1%

Pig Swamp is a unique wetland type within Gunbower Forest, the wetland is shallow and supports a healthy mosaic of native emerged aquatics and is surrounded by a large area of Black Box woodland. The native sedge *Carex tereticaulis* is prominent particularly towards the southern end of the wetland. Pig Swamp is the only shallow freshwater marsh represented in the national park (pers. comm. Mark Tscharke, [Parks Victoria] 25 May 2011).

4. Hydrology

Wetland hydrology is the most important determinant in the establishment and maintenance of wetland types and processes. It affects the chemical and physical attributes of a wetland, which in turn affects the type of values the wetland supports (DSE 2005b). A wetland's hydrology is determined by surface and groundwater inflows and outflows, in addition to precipitation and evapotranspiration (Mitsch and Gosselink 2000 in DSE 2005b). Duration, frequency and seasonality (timing of inundation) are the main components of the hydrologic regime for wetlands.

4.1. Natural water regime

Pig Swamp is situated relatively high on the Gunbower Forest floodplain receiving water during moderate to high Murray River flood events. Murray River flows are highly variable and inundate different floodplain areas at different flood levels. A series of well defined creeks south of the swamp are well connected to the Murray River and would commence to flow as the Murray River water levels rise. Three of these, Cameron's, Dry Tree and Baggots creeks feed water across the southern end of Gunbower Forest into Pig Swamp and the Upper Gunbower Creek. High local rainfall events across the Patho Plains area generate local catchment runoff that could also occasionally enter the Upper Gunbower Creek.

Pig Swamp would have filled from flows of 50,000ML/day or more in the Murray River downstream of Torrumbarry Weir. This has recently been validated in the field where flows of 50,000 to 56,000ML/day during December 2010 to January 2011 resulted in Pig Swamp refilling. MSM-Bigmod data[4], shows that from 1895 to 2009, under modelled 'natural' flow conditions, Pig Swamp would have filled on average every 1.2 years (83 in 100 years) (Figures 3 and 4) (Bogenhuber and Campbell 2011).

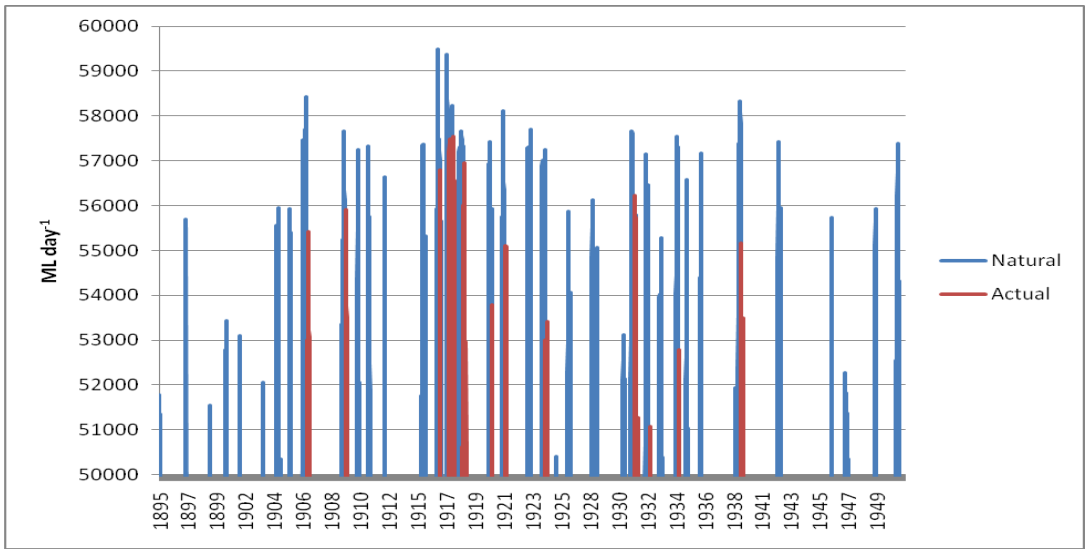


Figure 3: Murray River flows when Pig Swamp filled (1895 to 1951) (Source Andrew Keogh, MDBA)

[4] MSM-Bigmod is two computer based models of River Murray flows used by MDBA that work together – output from MSM (Monthly Simulation Model) feeds into Bigmod (a daily simulation model).

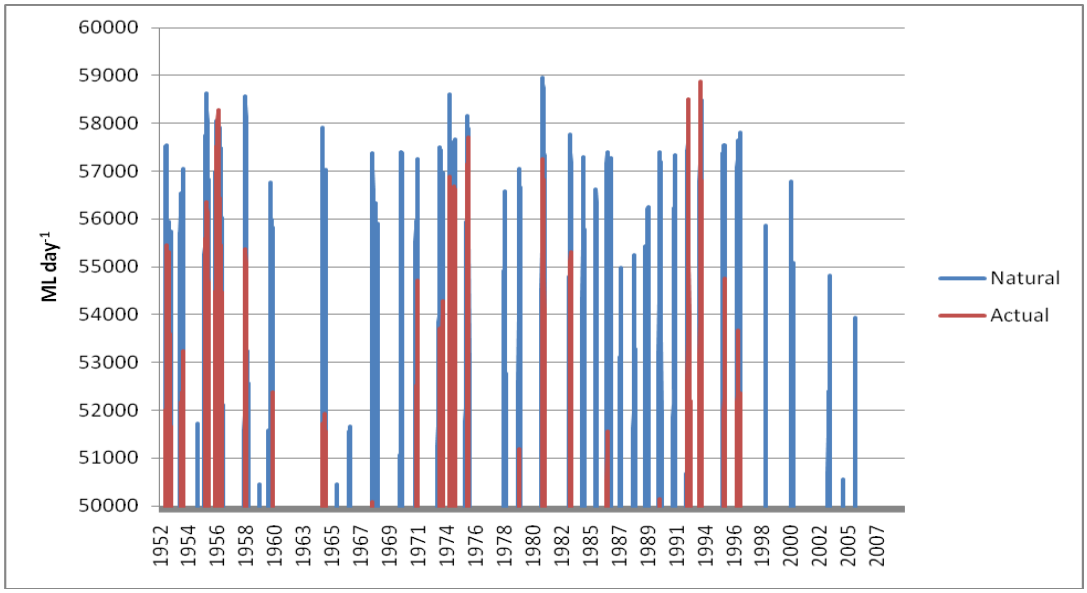


Figure 4: Murray River flows when Pig Swamp filled (1952 to 2009) (Source Andrew Keogh, MDBA)

The shallow depth of Pig Swamp (0.2 m to 0.4 m) results in water being retained for only a few months after a flood event. This water regime encouraged the establishment of large widely spaced River Red Gums that could survive dry periods on the heavy floodplain clay soils.

4.2. History of water management

Under modelled 'actual' flows, Pig Swamp received water every 2-3 years (2.71 years) on average from the Murray River (refer to Figures 3 and 4 above). Flow records from Torrumbarry Weir (1974 to 2011) shows that Pig Swamp has filled on average every 2.77 years (36 times in 100 years) (Figure 5) (Bogenhuber and Campbell 2011). The graph also illustrates that under regulated conditions, there were extended dry periods where Pig Swamp did not receive floodwater, such as from 1996 to 2010.

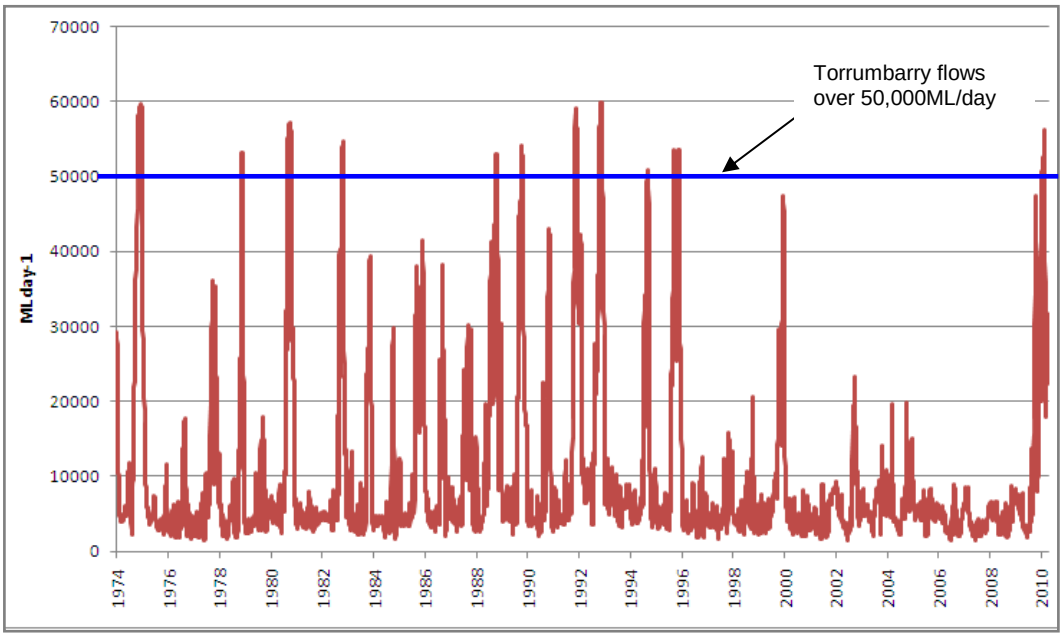


Figure 5: Torrumbarry Weir flow data (1974 to 2010)

The natural water regime of Pig Swamp was altered during early European settlement as part of river regulation and the establishment of irrigated agriculture. The most significant change occurred during the 1870s when the Straight Cut Channel was constructed through the northern section of Pig Swamp (Figure 6). The channel initially transferred water from the Murray River to the Upper Gunbower Creek (also called the No. 3 Lagoon). This channel prevented floodwater from moving northwards during flood events and became breached where it crossed Pig Swamp. Therefore, shortly after construction, a large earthen block was constructed at the entrance of the Straight Cut Channel, adjacent to the Murray River to prevent further uncontrolled flooding. This block has been in place for over 100 years.

The irrigation channel was an impediment to natural flooding and in the 1970s the channel was cut at three locations where it crossed Pig Swamp. These breaches resulted in water spilling out into Pig Swamp when the Straight Cut Channel was used to deliver irrigation water. Refer to Figure 6.

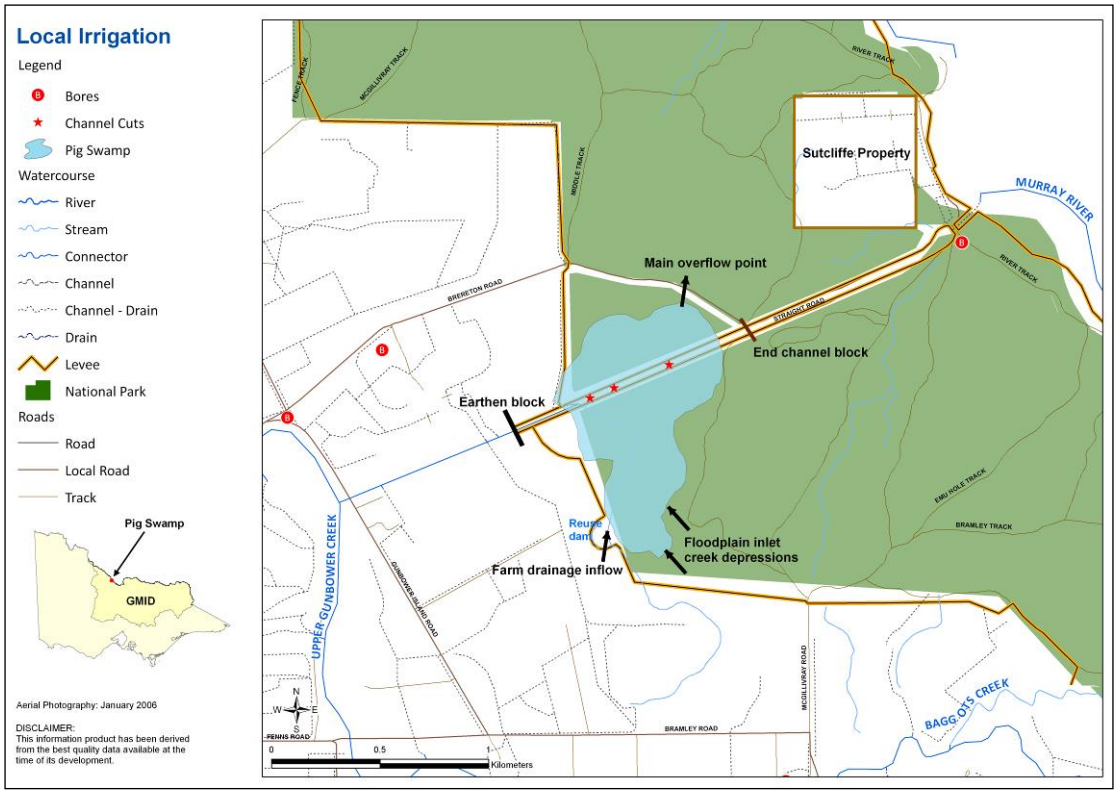


Figure 6: Pig Swamp local irrigation

Following modification to the banks of the Straight Cut Channel, water would spill into Pig Swamp. The volume of water that reached Pig Swamp was directly related to the volume of water in the Upper Gunbower Creek. During the irrigation season (August to May) high water levels were maintained for irrigation purposes, which resulted in Pig Swamp being permanently inundated. This permanent inundation drowned most of the original large River Red Gum and Black Box and encouraged the establishment of water dependant aquatics (e.g. Cumbungi) (O'Brien 2011). Outside of the irrigation season, water levels in the Upper Gunbower Creek were lowered, which also partially drained Pig Swamp.

The Straight Cut Channel is 3.3 km long and used to supply three service points (NVIRP 2010). The property that was supplied at the eastern end of the Straight Cut Channel (Sutcliffe property - refer to Figure 6) was purchased by Water for Rivers in 2010. In 2007 the channel was blocked 200m upstream of the Pig Swamp (Figure 6) with compensation provided to the landowner. This completely eliminated the losses into the wetland with the result that the eastern section of the Straight Cut Channel and Pig Swamp completely dried out in 2007, and remained dry until the recent December 2010 natural flood event. River Red Gums have regenerated into the base of Straight Cut Channel during the dry phase.

Pig Swamp's recent wetting/drying calendar (1995 onwards) is outlined in Table 5 below. The Pig Swamp EWP was only developed and approved in 2013, the Swamp has not received water since this time.

Table 5: Pig Swamp wetting/drying calendar

95/96	96/97	97/98	98/99	99/00	00/01	01/02	02/03	03/04	04/05	05/06	06/07	07/08
w	w	w	w	w	w	w	w	w	w	w	w	d

08/09	09/10	10/11	11/12	12/13	13/14
d	d	w	d	d	d

4.2.1. Influence of the Straight Cut Channel

As outlined in Section 4.2, from 1970s when the banks were cut until 2007, Pig Swamp was maintained permanently full during the irrigation season and drained down to a slightly lower level during the middle of winter (non irrigation season). As water was delivered through cuts in the banks of the channel, there is no ability to measure the volume of water delivered.

Important points to consider when estimating the water provided to Pig Swamp from the irrigation system are that:

- inundation was controlled by the water level in the Straight Cut Channel, which is fed by the Upper Gunbower Creek (the other GMW Connections Project wetlands were controlled by inflows quantified as volumes)
- prior to 2007 the level of water in the Straight Cut Channel was controlled to supply a number of irrigators, with the consequence that Pig Swamp had a tightly managed regime (the other GMW Connections Project wetlands were fed by irrigation outfalls) (Gippel 2011).

In the absence of historic data, modelling was done on the assumption that, between 1923 and 2007, the wetland was filled to 84.00mAHD (where it remained for 10-15% of the time) from 15 August fluctuating to the lower level of 83.90 mAHD over the irrigation season until 15 May. Over the winter period (16 May to 14 August) the wetland retreated to approximately 10ha (83.5mAHD) (pers. Comm. Ross Stanton [GMW] 7 June 2011).

The Savings at Wetlands from Evapotranspiration daily Time-Series (SWET) model has been used to quantify this hydrological regime from the Straight Cut Channel prior to 2007 (Gippel 2011). In this case the model was utilised to calculate how much water needed to leave the irrigation channel in order to maintain the water in the wetland at a particular level. Refer to Appendix G for the data used, model structure, parameter selection and assumptions made.

The pre-2007 scenario produced a regular water level regime over a fairly narrow range. The water level in Pig Swamp mirrored that in the Straight Cut Channel, but the degree of variation in water level was lower, due to the hydraulically constricted connection between the two water bodies. The water level duration curve demonstrated that the water level was between 83.8 and 83.9 m for most of the time (Figure 7). For about 80 percent of the time, 20 percent or less of the wetland bed area was exposed (Figure 7) (Gippel 2011).

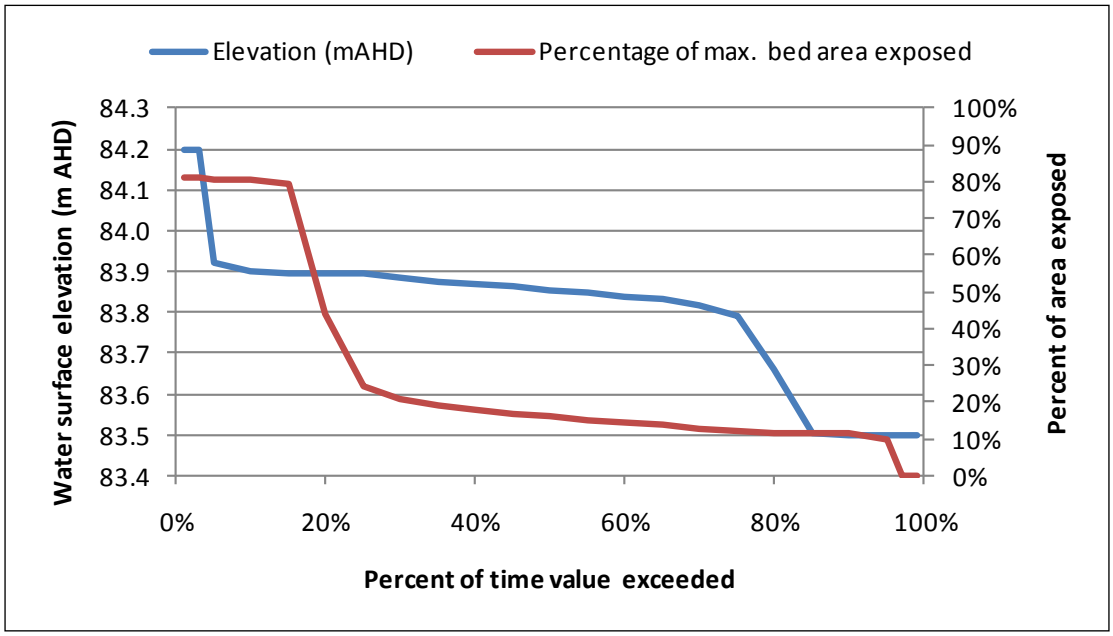


Figure 7: SWET model predicted duration of water level and percent of maximum bed exposed for pre-2007 Pig Swamp scenario

The incidental losses from the irrigation system used by Pig Swamp varied with climate, and averaged 437 ML per year (Figure 8). The 95th percentile annual loss was 545 ML and in the 2004-05 baseline year net incidental water losses from the irrigation system were 455 ML (Figure 8) (Gippel 2011).

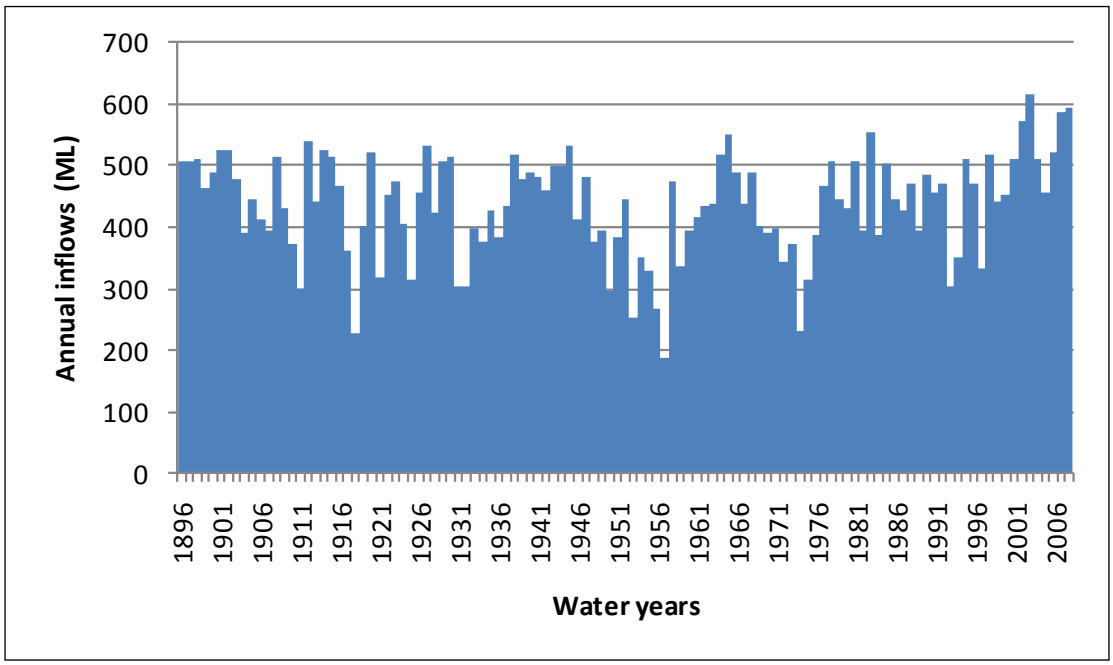


Figure 8: SWET model predicted annual net incidental water losses from the irrigation system for pre-2007 Pig Swamp scenario

4.3. Surface water/groundwater interactions

The Murray River floodplain is a complex area of former “prior stream” and “ancestral river” sediments (Pels, 1964), comprising channel, near floodplain and far floodplain deposits that overlay older riverine sediments. The present day Gunbower Creek and Murray River in the vicinity of Pig Swamp are within the area of these ancestral systems.

The floodplain is a flat to gently sloping plain comprising alluvial sands, silts and clays. The principal aquifers are the outcropping Coonambidgal Formation and Shepparton Formation, and the underlying Calivil Formation and Renmark Group. The Coonambidgal and Shepparton Formation sediments are sandy clay and clay with variably connected layers of fine to coarse sand. They are approximately 100 m thick at the site[5] and overlie Calivil Formation and Renmark Group sediments.

Regional groundwater levels have been declining since the late 1990s, which corresponds with an extended period of below average rainfall (Figure 10). The drier period and lower irrigation amounts have meant less recharge to groundwater from either rainfall, flooding, surface water bodies, or from irrigation accessions. The (regulated) river water level is consistently higher than groundwater level. It is notable that historically, during periods of extremely low or no flow, the river base was around the groundwater level, hence making it possible for discharge at those times.

Figure 9 shows the approximate location of soil and groundwater investigation sites in the vicinity of Pig Swamp.

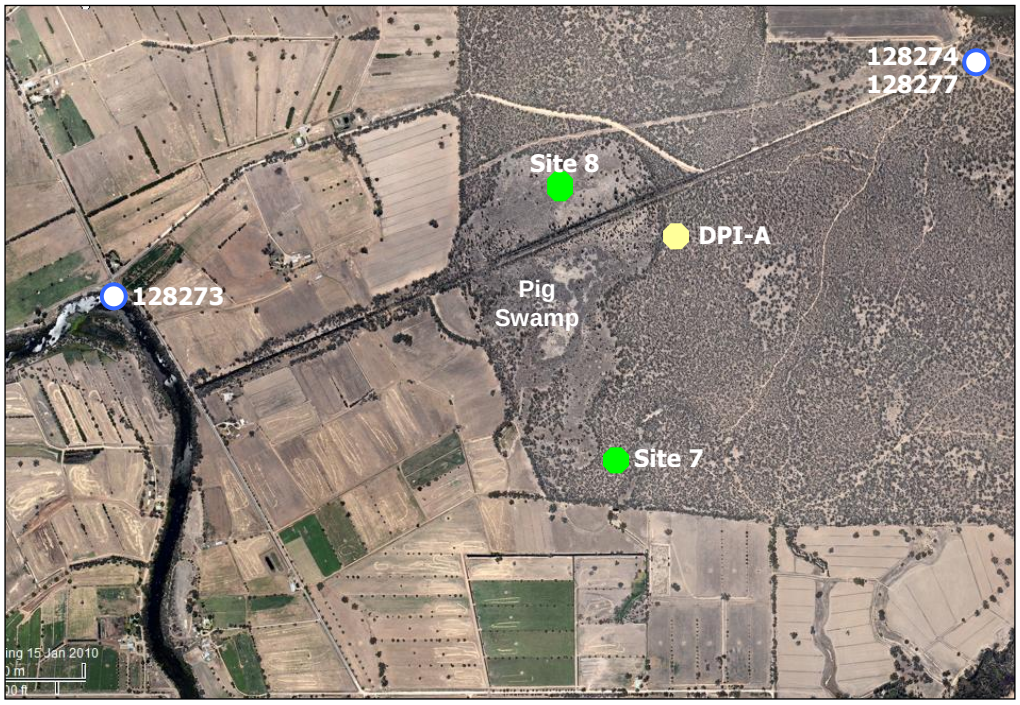


Figure 9: Soil and Groundwater Sites in vicinity of Pig Swamp

Two auger holes drilled at site DPI-A in February 2011 (Figure 9) found:

- Hole 1 (to 5.3 m depth) – 25 m from water edge. Thin organic layer over 4 m of medium to heavy clay, 1 m of clay loam and becoming silty clay and silt. Dry.
- Hole 2 (to 5.3 m depth) – 3 m from water edge. Thin organic layer over 4 m of medium to heavy clay, with clay loam to base. No silty material. Dry.

In both auger holes, the upper 1 – 2m of the profile was moist, the remainder of the profile dry, and there was no water standing in the base of the holes after 48 hours. These observations are consistent with the Wrigley Dillon (2007) findings at Site 7 and Site 8 (Figure 9):

- Site 7 (to 2.2 m depth) far floodplain heavy soil – 150 mm friable loam over medium to heavy clay and medium clay, with poor to moderate to poor drainage.
- Site 8 (to 1.3 m depth) in wetland – 300 mm friable clay loam over light clay with moderate to poor drainage.

[5]Bore 66514 – drilled in 1985 approximately 6 km west of the site.

The water table depth at 128274/128277 near the Murray River has ranged from 5 m to 10 m below ground surface, but near Gunbower Creek it has been shallower at 128273 (2 m to 6 m deep), Figure 10.

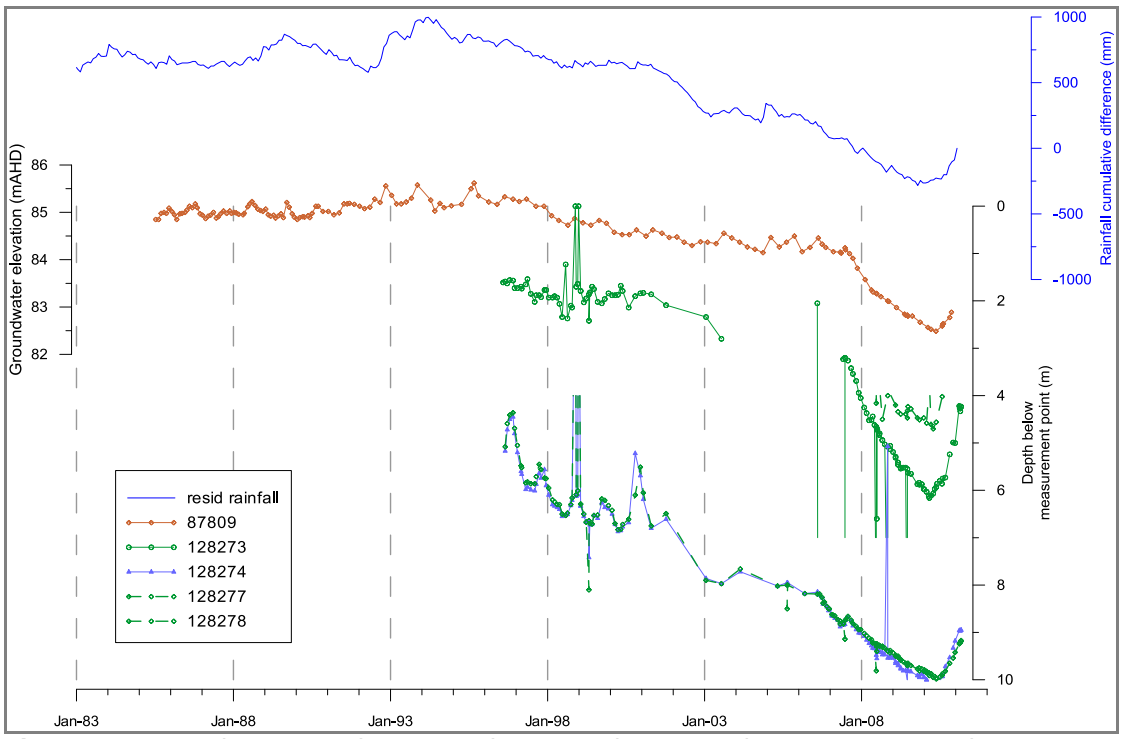


Figure 10: Groundwater Level – Bores Closest to Pig Swamp (1983 – 2012. No data was available for the period between 2013-2014) (Source: Victorian Water Measurement Information System)

Extrapolating between these bores, it appears that when it contained water, the Pig Swamp water level would have been at least three metres above the local groundwater level. The soil conditions suggest that only a small amount of surface water could actually reach the water table, and more likely to be held within the soil profile and available for evapotranspiration.

In summary, based on the above data and assessment (Bartley Consulting 2011), Pig Swamp is:

- Likely to have been a relatively minor source of groundwater recharge due to the shallow water depth (a limited driving head) and the underlying clay soils, with a recharge rate similar to other local areas that are underlain by mid and far floodplain soils that are intermittently flooded.
- If flooding occurs, the local groundwater would respond gradually beneath the floodplain, with no significant difference in groundwater level response beneath the site to elsewhere on the floodplain.
- The greatest likelihood of watertable rise to within the capillary fringe (in surrounding areas) is when there is inundation combined with high regional groundwater levels.
- The data indicates this is negligible risk from environmental watering, unless there is also significant change in land or water use practices that causes a significant rise in regional groundwater levels. If water is introduced intermittently, then this water is likely to slowly enter the subsurface; however, it is likely to be mostly used in evapotranspiration.
- The groundwater level is currently (greater than 5 m deep) below the soil capillary zone; therefore, there is no significant risk of adverse impact on the wetland or neighbouring land through watertable rise. This assumes inundation of the wetland is not permanent.

- Putting water into the wetland could increase the opportunity for salts to move down the soil profile; however, this movement would be limited by the medium to heavy clay soils (Bartley Consulting 2011).

4.4. Operational uses

GMW currently has no operational requirements that influence the water regime of Pig Swamp. An earthen block was positioned in the Straight Cut Channel, 200 metres upstream of Pig Swamp in 2007, which prevents any irrigation water entering the wetland.

The Straight Cut Channel is 3.3 km long and was used to supply three service points. As a result of the changed operation of the channel and sale of the Sutcliffe property to Water for Rivers, only two service points are currently supplied, upstream of the earthen block.

4.4.1. Flood mitigation

There is no active flood mitigation that influences the water flows into Pig Swamp. The southern end of Gunbower Forest, including Pig Swamp, floods naturally via a series of natural breakaway creeks off the Murray River during high flow events.

4.4.2. Drainage

Minimal drainage water enters Pig Swamp. A small area of agricultural land including 20 hectares of annual pasture and 20 hectares of perennial pasture drains towards Pig Swamp. This water is commonly reused across the farm and would rarely enter the wetland.

5. Management objectives

The following table is a summary of previous assessments undertaken at Pig Swamp. There are no specific recommendations for water regime in any of the available background documents (Ecos Environmental Consulting 2005, GHD 2007, SKM 2009).

Table 6: Previous management recommendations

Source	Ecological values	Objectives	Recommendation
GHD 2007	Aquatic plant communities. Platypus population	Increase the length of potential habitat for aquatic plant species and the Platypus.	Maintain a portion of the Straight Cut channel beyond the last supply pump.
	Aquatic plant seed bank	Maintain existing aquatic plant seed bank.	Provide an environmental water release to Pig Swamp from gates or other structures at the end of the shortened channel.
SKM 2009	Migratory water birds	Will only use Pig Swamp in wet years.	None
	Mature Black Box around margin of wetland	Recruitment of Black Box may be favoured (over River Red Gum) by reducing flow into Pig Swamp.	None
	River Red Gum		None
	Frog communities		None

5.1. Water management goal

The water management goal for Pig Swamp has been derived from a variety of sources including previous management goals, local expertise and knowledge, water availability and feasibility of delivery, and has been appraised by agency stakeholders and technical experts (wetland workshop, 5 May 2011, Appendix A, Table A2) and confirmed as part of the 2015 review. It takes into consideration the values the wetland supports, the current wetland condition and potential risks that need to be managed.

Pig Swamp water management goal:

Support a diversity of flora and fauna typical of a shallow freshwater marsh[6], in particular providing habitat for frogs and waterbirds, while also maintaining the health and distribution of the current mosaic of plant communities. An intermittent watering regime is alternately wet and dry but less frequently or regularly than seasonal waters.

5.2. Ecological objectives and hydrological requirements

Ecological objectives and hydrological requirements to meet these have been identified in determining a desired water regime to support key environmental values supported by Pig Swamp (Table 7). The ecological objectives outline the outcomes desired from delivery of the desired water regime.

Water dependent environmental values including habitat, species/communities and processes were identified from local anecdotal information, relevant reports, condition assessments, and records (such as the Victorian Biodiversity Atlas (VBA) database).

Ecological objectives were identified based on the environmental values in terms of the physical conditions (habitat objectives), species and/or biota (biodiversity objectives), and biological processes (process objectives) needed to achieve the water management goal.

Habitat objectives identify habitat components considered critical in achieving the water management goal. While it is recognised that each habitat component will attract an array of fauna species, examples of previously recorded listed species whose habitat requirements

[6] Shallow freshwater marshes are generally less than 0.5 m deep and are inundated for less than 8 months of the year (DCFL 1989b)

closely align with a specific component have been provided as potential indicator species. Those species and communities of international, national and state conservation significance were given highest priority as were those that are indicative of integrated ecosystem functioning.

The objectives are expressed as one of four types of target, which are related to the present condition/functionality of the value:

- Reinstate – no longer considered to occur
- Restore/Rehabilitate – severely impacted and only occur to a reduced extent
- Maintain – not severely impacted but are desirable as part of the ecosystem
- Reduce – have increased undesirably at the expense of other values.

Hydrological requirements describe the water regimes required for achieving ecological outcomes (ecological objectives) (DNRE 2002). All values identified have components of their life-cycle or process that are dependent on particular water regimes for success e.g. colonially breeding waterbirds require certain timing, duration and frequency of flooding to successfully breed and maintain their population. Requirements for the three components of a water regime[7] were identified and described for all of the ecological values (Campbell, Cooling & Hogan 2005).

The ecological objectives and hydrological requirements for Pig Swamp were developed in conjunction with agency stakeholders and technical experts at the wetland workshop held on 5th May 2011. The ecological objectives and hydrological requirements were reviewed in 2015 in consultation with GMW, the CMAs, DELWP and Parks Victoria. The review found that ecological objectives, hydrological requirements and water management goal were still appropriate (GMW 2015).

As outlined in Section 2.6.1, the Ecological Character Description for the Gunbower Forest Ramsar Site has developed limits of acceptable change in relation to the critical components, processes and services (Hale and Butcher 2011). The desired water regime recommended for Pig Swamp has ensured the wetland type, physical habitat, threatened species and hydrological connectivity is within the limits of acceptable change for the whole of the Gunbower Forest Ramsar Site.

Table 7: Pig Swamp proposed ecological objectives and hydrological requirements

Ecological objective	Justification	Hydrological requirement
1. Habitat objectives		
1.1 Maintain health and distribution of Sedgy Riverine Forest/Tall Marsh/open water mosaic.	The Sedgy Riverine Forest/Tall Marsh/open water mosaic provides a diversity of habitat for aquatic and amphibious plants as well as habitat and food sources for birds, frogs and invertebrates.	Inundate Pig Swamp two in every five years (on average), once to full supply level (FSL; 84.05 mAHD) and once to inundate 75% of FSL surface area (83.8 mAHD), and maintain at this level for a duration of three to six months, then allow to drawdown by evapotranspiration, seepage etc. Inundate no more than four in every five years.
1.2 Maintain health and distribution of River Red Gums.	River Red Gums are the dominant tree species across the wetland and provide nesting, feeding and breeding habitat and refuge for a range of fauna; shade; and a source of carbon and nutrient inputs to the floodplain and floodwaters.	Inundate Pig Swamp two in every five years (on average), once to full supply level (FSL; 84.05 mAHD) and once to inundate 75% of FSL surface area (83.8 mAHD), for a duration of three to six months. Allow the wetland to dry completely at least one in five years.

[7] Timing, frequency and duration

Ecological objective	Justification	Hydrological requirement
1.3 Maintain health of the fringing Riverine Chenopod Woodland.	Black Box trees provide hollows, fallen branches and shading for habitat (e.g. White-bellied Sea-eagle, Grey-crowned Babbler), and provide a source of seed for recruitment.	Watering regime will provide a valuable 'wetting' role to the surrounding Riverine Chenopod Woodland. It will also allow subsequent flows to penetrate further into surrounding areas.
2. Species/community objectives		
2.1 Establish a diverse and resilient native-dominated plant community that prevents the spread of exotic plant species and prevents the dominance of any one native species, e.g. *Typha* sp.	Exotic and some native plant species have the potential to spread rapidly and (consequently) reduce diversity. Establishing and/or maintaining a diverse native plant community to out-compete unwanted species.	Limit the spread of exotic aquatic species through regular dry cycles. Limit the extent of *Typha* sp. through a variable water regime. Limit the spread and reproductive opportunities of exotic terrestrial plant species through inundation of Pig Swamp at least two in every five years.
2.2 Maintain habitat for waterbirds, including threatened species.	Linked to habitat objectives. Providing a mosaic of habitat types will increase the likelihood of maintaining waterbird populations such as the threatened Azure Kingfisher and the Australasian Bittern.	Allow the wetland to fill during times of natural floods and high flows.
2.3 Provide periodic habitat for frog populations.	Linked to habitat objectives. Providing a mosaic of habitat types will increase the likelihood of maintaining frog communities, including populations of Barking Marsh Frog (*Limnodynastes fletcheri*). The Barking Marsh Frog utilises wetlands with abundant emergent vegetation (e.g. Cumbungi), and breeds mainly in Spring/Summer. The preferred duration of flooding for breeding sites is three to six months (Rogers and Ralph 2011).	Allow the wetland to fill during times of natural floods and high flows. Inundate Pig Swamp two in every five years (on average), for a duration of three to six months, during Spring to Autumn. Allow the wetland to dry completely at least one in five years.
2.4 Maintain habitat for invertebrates.	Linked to habitat objectives. Providing a mosaic of habitat types will increase the likelihood of maintaining invertebrate communities, which are an important food source for other fauna.	Inundate Pig Swamp two in every five years to full supply level for a duration of three to six months. Allow the wetland to dry completely at least one in five years.
2.5 Ensure a viable seed and egg bank is maintained.	Seed banks provide a means of persistence for macrophytes in intermittent wetlands during dry periods. Egg banks provide a means of persistence for invertebrates in intermittent wetlands during dry periods.	Ensure suitable habitat for aquatic and amphibious plant and invertebrate communities is maintained long enough to complete life cycles i.e. maintain inundation for three to six months two in five years.
3. Process objectives		

Ecological objective	Justification	Hydrological requirement
3.1 Restore connectivity between the northern and southern sections of Pig Swamp.	Connectivity facilitates dispersal and movement of plant propagules, micro and macroinvertebrates, fish, frogs and turtles, as well as nutrient and carbon cycling.	Modify Straight Cut Channel (investigate partial removal of the channel within the wetland bed) to increase connectivity between the northern and southern sections of the wetland.
3.2 Restore connectivity between river, floodplain and wetland.	Connectivity facilitates dispersal and movement of plant propagules, micro and macroinvertebrates, fish, frogs and turtles, as well as nutrient and carbon cycling.	During times of 'natural' flood/ localised rainfall, provide additional environmental water if necessary and where possible to reach full supply level or extent flooding duration and ensure all wetland components are inundated.
3.3 Return Pig Swamp to a wet/dry cycle.	Pig Swamp was naturally an intermittent wetland. Regular wetting and drying cycles consolidate soils and allow sedimentation process to occur, allow for the germination of seeds and eggs, will help to limit the distribution and spread of *Typha* sp. and exotic species, and will generally increase productivity and increase overall biodiversity over the long-term.	Allow regular complete drying cycles. Allow the wetland to naturally fill during times of flood. Inundate Pig Swamp two in every five years for duration of three to six months. Allow the wetland to dry completely at least 1 in 5 years to maintain the health and distribution of habitats.

5.3. Desired water regime

A desired water regime has been defined for Pig Swamp and is presented below. This regime is based on the ecological objectives and hydrological requirements outlined in Section 5.2.

Figure 11 illustrates the various components of the wetland (e.g. open water, Sedgy Riverine Forest and Tall Marsh) that are being targeted by the water regime.

Timing: Winter/Spring

Frequency of wetting: Minimum: one in five years

Optimum: two in five years

Maximum: four in five years

Please note: a frequency of drying one in five years has also been recommended. The wetland is shallow and unlikely to retain water for a full 12 months, therefore drying is likely (and desirable) within six months.

Duration: Variable, three to six months at FSL.

Extent and depth: Fill to FSL (84.05 m AHD) in winter/spring and allow natural draw-down. To achieve this during times of 'natural' flood / localised rainfall, provide environmental water if necessary and where possible to inundate Pig Swamp to full supply level or above and ensure all wetland components are inundated.

Variability: High. Variability is desirable in all components of the watering regime e.g. timing, frequency, duration, extent and depth. Variability in flood extent and depth will assist in maintaining a mosaic of open water, Tall Marsh and Sedgy Riverine Forest and avoid a 'fringe' effect, particularly of River Red Gums. Seasonal variability (e.g. variability in timing of flows) is also desirable as it will allow for the germination and recruitment of seasonal plant species, thus maintaining and increasing overall biodiversity.

Wetland water regime:
Inundate wetland two in five years to FSL and allow to dry out completely one in five years. Ideally, fill in winter/spring and maintain full for three to six months. Allow 'natural' floods to inundate Pig Swamp and if possible, maintain flood level or extend duration with environmental water.

Please refer to the figures in Appendix G for the modelled desired water regime.

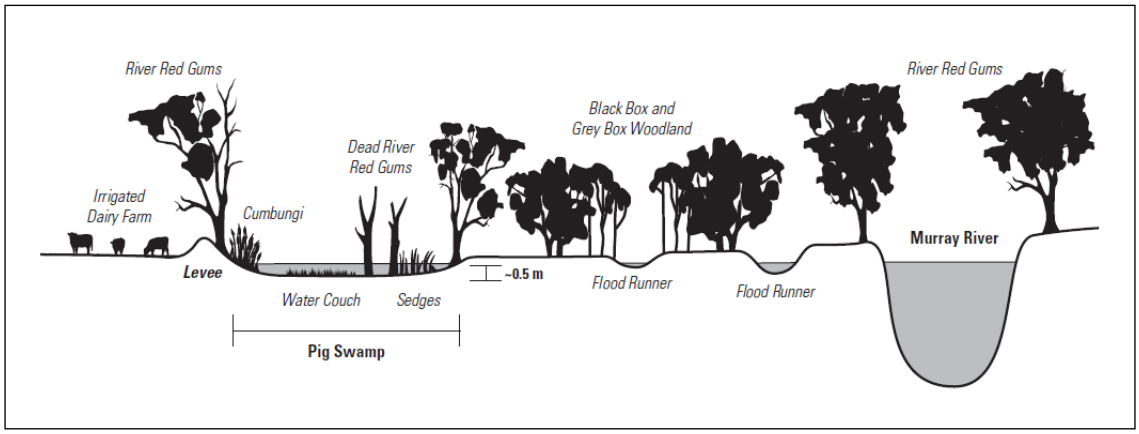


Figure 11: Schematic of wetland areas and surrounding floodplain (not to scale)

The volumes of water required to provide the desired water regime for Pig Swamp are presented in Table 8 and Figure 12. These volumes reflect the results from the SWET modelling of the desired water regime (model described in Section 4.1 and results presented in Appendix G) and were based on filling Pig Swamp to 84.05 m AHD. Refer to Section 4.1 for the data used, model structure, parameter selection and assumptions made.

Table 8: Volumes required in providing the desired water regime for Pig Swamp (SWET modelling output)

Result	
Mean long-term (LT) annual controlled inflow requirement	170 ML/year
95th percentile of mean LT annual controlled inflow requirement	512 ML/year
Average LT controlled inflow requirement for filling periods	421 ML
Record length	114
No. of periods	46 (last one incomplete)
Years with no inflow	68 in 114 years
No. of draw downs over record	43
No. of draw downs not fully drawn down	2
% of draw downs not fully drawn down	4%
95th percentile duration of full period (months)	5.8
50th percentile duration of full period (months)	4.5

A brief description of each the main results is provided below:

- **Mean long term annual controlled inflow requirement**: the total amount of water required to be delivered into the wetland annually in a controlled fashion to achieve the specified level and the desired regime (excluding natural inflows from rainfall and local catchment runoff). This is the average over the modelled period. A mean long term annual volume of 170 ML is required to fill Pig Swamp to 84.05 m AHD.
- **95th percentile of mean long-term annual controlled inflow requirement**: an estimate of the maximum volume ever likely to be required over any 12 month period (512 ML).
- **Average long term controlled inflow requirement for filling period:** the total amount of water to be put into the wetland in a controlled fashion to achieve the desired water level regime for the recommended period (five year filling period). This does not account for natural inflows from floods, rainfall and local catchment runoff. Therefore, the volume required to fill Pig Swamp to 84.05 m AHD would be approximately 421 ML (Gippel 2011).

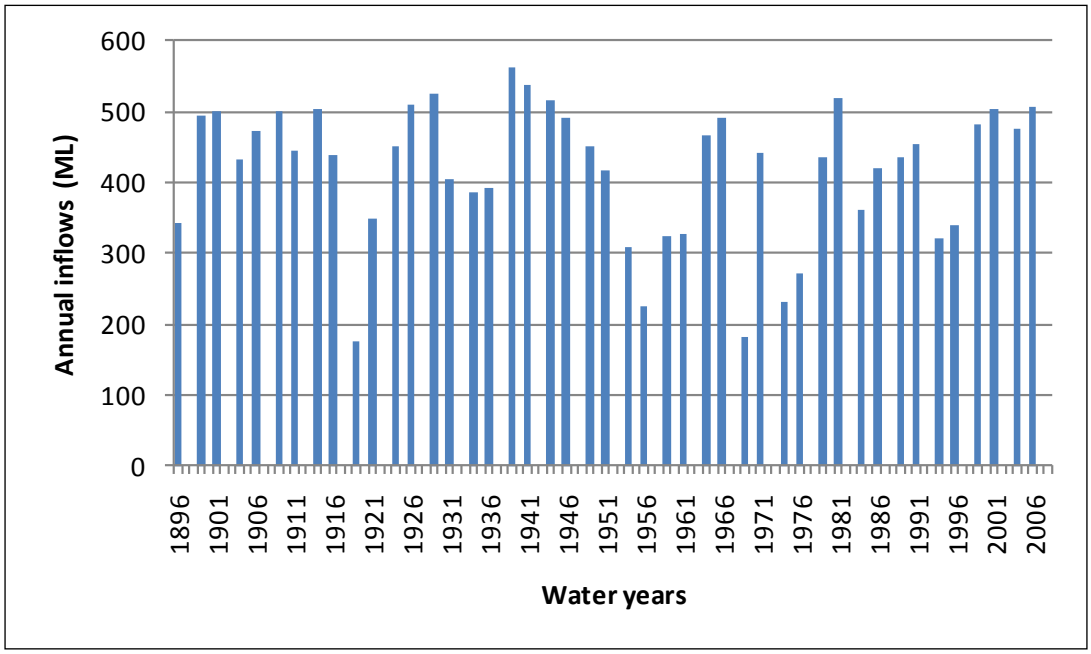


Figure 12: SWET model predicted annual environmental water use for the desired water regime

Refer to Appendix G for SWET modelling Results.

Please note: due to the variability of inflows to the wetland, particularly in response to current climate conditions, determination of inflows from local rainfall and runoff in any one year will need to be undertaken by the environmental water manager when watering is planned. Surface water inflows to Pig Swamp and rainfall will vary considerably from year to year, depending on seasonal conditions.

5.4. Mitigation water

The volume of water that is required to offset the impact of the GMW Connections Project on wetlands that have become reliant on this water to support high environmental values is termed 'mitigation' water. The potential impact of the GMW Connections Project considered in the Pig Swamp EWP is related to the decommissioning of the Straight Cut Channel in 2007. Other potential impacts to the wetland will be managed in accordance with the Water Change Management Framework and Site Environmental Management Plans.

Guiding principles for mitigation water based on government policy have been defined in the Water Change Management Framework and are:

1. Water savings are the total (gross) volumes saved less the volume of water required to ensure no net impacts due to the project on high environmental values.
2. Using the same baseline year (2004–05) as that used to quantify savings, taking into account the long-term average annual patterns of availability.
3. The mitigation water will be deployed according to the EWP.
4. Sources of mitigation water will be selected to ensure water can be delivered in accordance with the delivery requirements as specified in the EWPs. Water quality will need to be considered for all sources of water to ensure it is appropriate.

In the majority of cases, actual outfall volumes will be less than what is required to support all water-dependent environmental values of a particular wetland. Therefore, the outfall water only forms part of the overall volume required to provide the water regime of the wetland. The water regime supports processes and systems which in turn provide suitable conditions for defined ecological values (e.g. breeding of waterbirds).

A process for calculating mitigation water based on the best available information has been developed and involves the application of a series of steps that includes:

Step 1: Describe the desired water or flow regime

Step 2: Determine the baseline year incidental water contribution

Step 3: Assess dependency on baseline incidental water contributions

Step 4: Calculate the annualised baseline mitigation water volume

Step 5: Calculate the mitigation water commitment

Step 6: Calculate the LTCE mitigation water volume

5.4.1. Pig Swamp mitigation water

Step 1: Describe the desired water or flow regime

The desired water regime for Pig Swamp is filling to FSL two in five years. Further detail is provided in Section 5.3.

The mean long-term annual controlled inflow requirement to fill Pig Swamp is 170 ML/year. The 95% percentile mean annual volume required equates to 512 ML/year.

Step 2: Determine the baseline year incidental water contribution[8]

The SWET model for pre-2007 is used to quantify incidental water contribution from the Straight Cut Channel. Water losses to Pig Swamp were not recorded, therefore the scenario of *"the wetland was filled to 84.0 mAHD from 15 August, fluctuating over the irrigation season until 15 May. Over the winter period the wetland retreated to 83.5 mAHD"* was modelled.

The incidental losses from the irrigation system averaged 437 ML per year and the 95th percentile annual loss was 545 ML. The 2004-05 baseline year net incidental water losses from the irrigation system was 455 ML (Table 9), refer to Appendix G.

Table 9: Determination of the baseline year incidental water contribution

Hydrological connection or incidental water source (e.g. Outfall #)	Baseline year incidental water at origin (Gross) (ML)	Estimated losses between origin (irrigation system) and wetland (for baseline year) (ML)	Baseline year incidental water contribution at the wetland (Net) (ML)
Straight Cut Channel	455 ML	0 ML	455 ML

Step 3: Assess dependency on baseline incidental water contributions

The Water Change Management Framework (GMW 2013) specifies criteria to be applied in assessing whether mitigation water is required for a wetland or waterway with high environmental values. These criteria have been applied to Pig Swamp with the results presented in Table 10.

[8] Incidental water contributed in the baseline year for each hydrological connection i.e. outfall water, seepage and leakage of a supply channel within 200m of the wetland.

Table 10: Mitigation water dependency assessment

Criteria by which mitigation water may be assessed as not required	Link between incidental water (losses) and environmental values
1. Mitigation water may be assessed as not required where:	
1.1 There is no hydraulic connection (direct or indirect) between the irrigation system and the wetland or waterway	There is a direct hydraulic connection. The Straight Cut Channel delivers water to the swamp via a series of cuts in the channel
1.2 The water does not reach the wetland or waterway with environmental values (e.g. the outfall is distant from the site and water is lost through seepage and evaporation before reaching the area with environmental values)	Water does reach the wetland. Prior to 2007, irrigation water entered Pig Swamp through a series of cuts in the Straight Cut Channel (losses calculated in SWET model).
2. Mitigation water may be assessed as not required where the wetland or waterway receives water from the irrigation system:	
2.1 That is surplus to the water required to support the environmental values (e.g. changing from a permanently wet to an intermittently wet or ephemeral regime is beneficial or has no impact)	Pig Swamp does not have more water than is required to support the desired state of the environmental values. While the desired watering regime is drier than what the irrigation system has provided, the wetland requires mitigation water to maintain its wetland dependent values.
2.2 That occurs at a time that is detrimental to the environmental values	Water provided to the wetland from the irrigation system has provided a seasonal pattern that is inverted relative to the natural watering regime. This is believed to have had detrimental effects on tree survival by in preventing summer-autumn drawdown and periodic drying out..
2.3 That is of poor quality (or results in water of poor quality entering a site e.g. seepage resulting in saline groundwater intrusions to wetlands) and the removal of which would lead to an improvement in the environmental values	Irrigation water received via the Straight Cut Channel is of acceptable water quality.
3. Mitigation water may be assessed as not required where the environmental values:	
3.1 Do not directly benefit from the contribution from the irrigation system (e.g. River Red Gums around a lake may not directly benefit from an outfall and may be more dependent on rainfall or flooding)	The irrigation water from the Straight Cut Channel supports water dependent values within the wetland.
4. Mitigation water may be assessed as not required where the removal of the contribution from the irrigation system does not:	
4.1 Increase the risk of reducing the environmental values (e.g. outfalls form a very small proportion of the water required to support the environmental values and their removal will not increase the level of risk)	If the contribution from Straight Cut Channel was removed from the wetland, additional water would need to be secured for filling the wetland to FSL two in five years.
4.2 Diminish the benefits of deploying any environmental water allocations (over and above the contribution from the irrigation system)	The Straight Cut Channel has provided water to Pig Swamp from the irrigation system. An earthen embankment currently blocks the Straight Cut Channel upstream of Pig Swamp, no environmental water can be delivered to Pig Swamp. The wetland can only receive inflows from high Murray River flood events exceeding 50,000ML/day. .

The assessment of the requirement for mitigation water for Pig Swamp demonstrates that the **incidental irrigation supply from the Straight Cut Channel provided environmental benefits and that the provision of mitigation water is warranted**. If the contribution from the Straight Cut Channel was removed, additional water would need to be secured to provide the desired watering regime outlined in Section 5.3.

Step 4: Calculate the annualised baseline mitigation water volume (BMW)

The BMW volume is expressed as the baseline incidental water contributions divided by the number of years in the cycle of the desired water regime. As there are no losses associated with transmission (irrigation contribution and subsequent wetland use has been modelled) the annualised baseline mitigation water volume has been calculated from the baseline year incidental water at origin (Gross).

Gross BMW = Baseline year incidental water contribution at origin $_{(Gross)}$ (Step 2) / The inherent cycle (years) of the desired water regime (Step 1)

= 455 ML / 2.5 (two in five years)

= 182 ML/year

= **170 ML/year***

*Mitigation water cannot be more than what is required to provide the desired watering regime, therefore the Gross BMW has been reduced to the mean annual volume required to provide the desired water regime (Step 1 and Section 5.3).

Step 5: Calculate the mitigation water commitment (MWC)

The MWC expresses the BMW (Step 4) as a percentage of the baseline incidental water contribution. It is used to calculate the share of annual water savings. These are calculated each year in accordance with the Water Savings Protocol and the associated Technical Manual (DSE 2009c) and will become available in any following year.

MWC (%) = Gross BMW $_{(Pig\ Swamp\ 2004/05)}$ (Step 4) / Baseline incidental water contributions at origin $_{(Gross)}$ (Step 2)

= (170/455) x 100

= 37%

Although the MWC (%) has been calculated over the course of the filling/drying cycle to be 37%, the incidental water contributions were calculated based on fixed water losses (essentially unchanging operation of the irrigation system). The losses are not dependent on irrigation deliveries, the contribution of water from the irrigation system to Pig Swamp would have occurred irrespective of system allocations.

Therefore the calculated water savings and mitigation water volumes must also be fixed. Hence, each year 170ML of water must be made available for mitigation water and 285ML made available as water savings.

The incidental water supplied to Pig Swamp is a component of the fixed water losses of the irrigation allocation to Torrumbarry Irrigation Area.

Step 6: Calculate the LTCE mitigation water volume

The LTCE mitigation water volume is used to account for mitigation water when reporting against the net savings target. This volume is calculated by multiplying the mitigation water commitment (Step 5) by the baseline mitigation water volume (Step 4) and the LTCE conversion factor.

Please note: calculation and confirmation on the LTCE conversion factor is required from DELWP. This will be decided at or near the end of the GMW Connections Project.

5.5. Other water sources

The calculated mitigation water represents 100% of the mean annual volume of water required to provide desired water regime (170 ML/year). The GMW Connections Project is only accountable for mitigating any potential impact from the project i.e. for provision of mitigation water as a proportion of the total outfall, seepage and leakage volumes received by the wetland if they are supporting high environmental values. As such, it is important that the environmental water holder secures additional sources of water to provide the desired water regime for Pig Swamp. The most likely additional sources of water will be existing and future environmental entitlements.

Discussion of potential sources of water to provide the desired water regime to Pig Swamp follows.

5.5.1. Murray flora and fauna bulk entitlement

In 1987, an annual allocation of 27,600 ML of high security water was committed to flora and fauna conservation in Victorian Murray wetlands. In 1999, this became a defined entitlement for the environment (DSE 2006). Each year, a prioritisation process is used to decide on the best use of the available water (based on River Murray allocations). An annual distribution program identifies wetlands that will receive a portion of the entitlement utilising a decision flowchart (DSE 2006). Pig Swamp is eligible to receive environmental water from this entitlement.

5.5.2. 75 GL environmental entitlement

Water savings generated by Stage 1 of the GMW Connections Project will provide up to 75 GL to be vested in the Minister for Environment, Climate Change and Water as an Environmental Water Entitlement. This environmental water is in addition to Government's commitments to provide water for the Living Murray process and will be used to help improve the health of stressed wetlands and waterways in Northern Victoria and the River Murray (NVIRP 2010).

In addition, Stage 2 of the GMW Connections Project will generate up to 204 GL of water savings, which will be allocated to the environment. This water will be vested in the Commonwealth Environmental Water Holder.

5.5.3. Commonwealth environmental water

Under Water for the Future the Australian Government has committed to purchase water in the Murray-Darling Basin over 10 years. The program will complement a range of other measures to address sustainable water management in the Basin. The Commonwealth Environmental Water Holder, in DoE, will manage the Commonwealth's environmental water.

The *Water Act 2007 (Aust)* provides that “the Commonwealth Environmental Water Holder must perform its functions for the purpose of protecting or restoring environmental assets so as to give effect to relevant international agreements”. Wetlands of International Importance (Ramsar wetlands) are considered priority environmental assets for use of the commonwealth environmental water (DEWHA 2008). Pig Swamp is part of the Gunbower Forest Ramsar site, which is of international importance. A case for the receipt of Commonwealth environmental water could be made.

6. Potential risks or adverse impacts

An important component of the EWPs is the identification of potential risks, limiting factors and adverse impacts associated with the delivery of the desired water regime of which mitigation water represents 100% of the mean annual volume required (170 ML). Awareness of the potential risks and impacts will influence future intervention and long-term condition monitoring undertaken at Pig Swamp, will inform the adaptive management of the water regime and the provision of mitigation water (Section 8).

Table 11 outlines the risks, limiting factors and potential impacts associated with the provision of mitigation water to provide the desired water regime that need to be considered by the GMW Connections Project and the environmental water manager.

Appendix H outlines a range of additional risks and limiting factors identified which may arise as a direct result of, or in association with, implementing the desired water regime at Pig Swamp. It is envisaged that these additional risks and limiting factors will be considered in the future management of the wetland (i.e. management plan).

Mitigating measures have been recommended to minimise the likelihood or the risk occurring and/or its potential impact.

Table 11: Potential risks, impacts and mitigatng measures associated with provision of mitigation water at Pig Swamp

Risks/limiting factors	Impacts	Mitigating measures
Additional sources of water are available in times other than preferred winter/spring (e.g. autumn)	Failure to achieve identified objectives and water management goal	Adaptively manage water regime and delivery of mitigation water to assist the achievement of desired goal i.e. fill a portion of the wetland to minimise the water required to fill the following winter/spring.
Ineffective delivery	Inefficient delivery not mimicking natural flooding and associated deterioration of water quality over extended fill time	Upgrade the Straight Cut Channel to ensure environmental water delivery is possible, refer to Section 7. Ensure that the delivery capacity is sufficient to facilitate delivery of required volumes at critical times (e.g. delivery share).
No supply point re-instated to the wetland	Desired water regime not achieved Provision of mitigation water not possible	Upgrade the Straight Cut Channel to ensure environmental and mitigation water delivery is possible, refer to Section 7.
Operating level in Gunbower Creek	Limits the volume of water that can be delivered as it is a gravity fed system from Gunbower Creek.	None required for current watering regime.

7. Water delivery arrangements

Pig Swamp has previously received water from the Straight Cut Channel via a series of cuts in the banks of the channel (Figure 13).. The Straight Cut Channel from the Gunbower Creek to the wetland is currently uncommitted Crown Land.

As of 2015, the Straight Cut Channel is operated to deliver water to the two remaining service points upstream of Pig Swamp. In 2007, GMW constructed an earthen embankment to block the Straight Cut Channel upstream of Pig Swamp as a drought/water savings measure (Figure 13). Therefore, no water can now be delivered to Pig Swamp.

The maximum reported capacity of the Straight Cut Channel is 30ML/day which is restricted by fallen trees, weeds and silt build up. Flow in the channel is also restricted by the pipe culvert under Gunbower Island Road to 50-60ML/day (pers. Comm. Ross Stanton [GMW] 7 June 2011).

7.1. GMW Connections Project works program – Straight Cut Channel

The Stage 1 GMW Connections Project works program includes delivering an automated backbone for the water distribution system, rationalising spur channels, connecting farm water supply to the backbone and upgrading metering on up to 50% of customer supply points in the GMID.

As part of the project, GMW Connections Project will be investigating options to move the current two service points on the Straight Cut Channel (upstream of the earthen block) to the backbone. It is viewed that downstream of the earthen bank would remain untouched (pers. comm. Mark Paganini [GMW Connections Project] 8 June 2011).

The GMW Connections Project is responsible for “retain(ing) infrastructure and improving where practicable, where it will be required for delivering environmental water….” (NVIRP 2010). A review of the infrastructure requirements and supply arrangements will need to be undertaken to enable the delivery of environmental water to Pig Swamp.

The GMW Connections Project have developed an Environmental Infrastructure Register for irrigation infrastructure that is/could be used to deliver environmental water to waterways and wetlands (NVIRP 2011). Pig Swamp has now been added to this register.

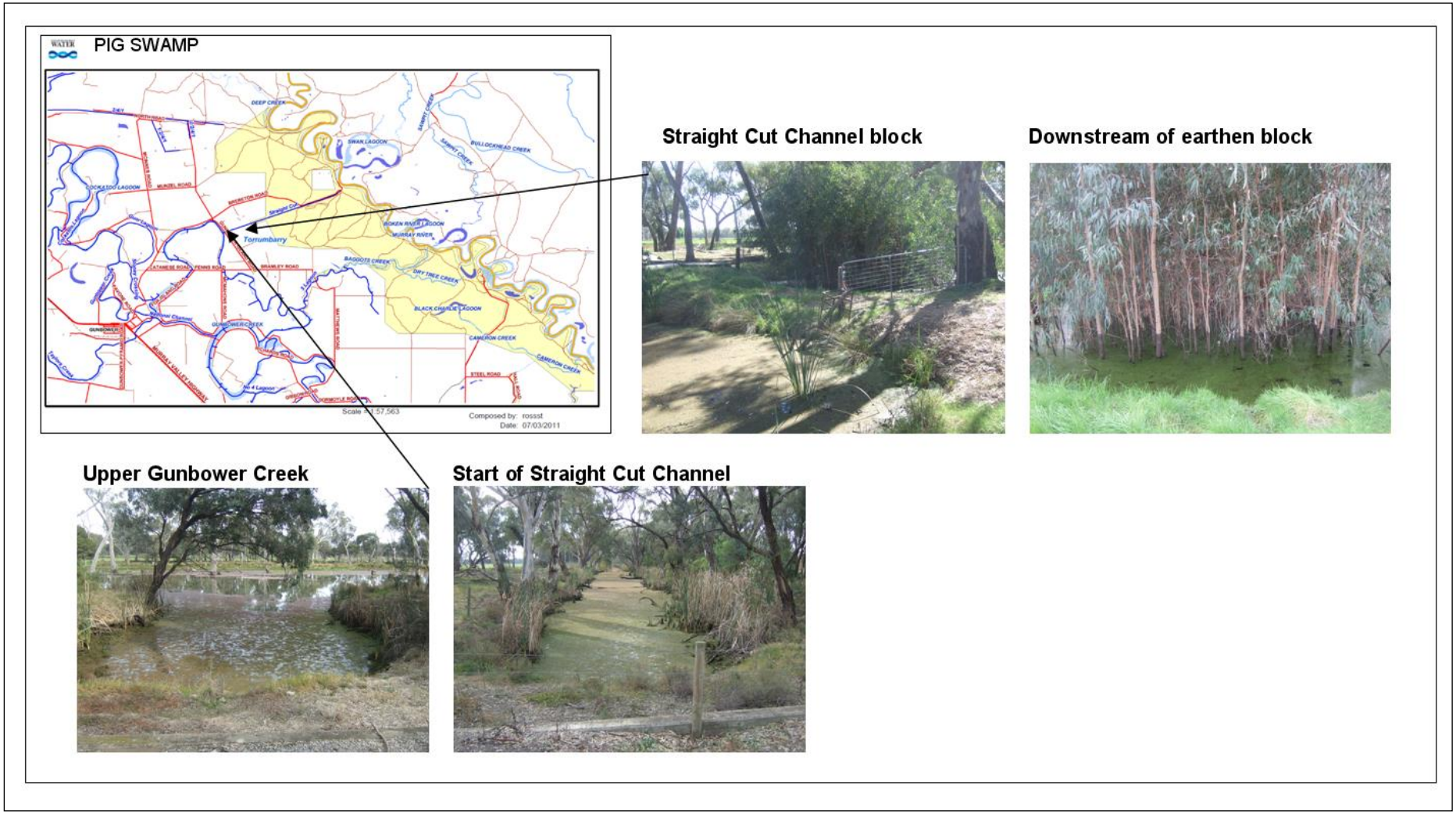


Figure 13: Pig Swamp Infrastructure

7.2. Infrastructure requirements

As noted previously, the earthen block in the Straight Cut Channel prevents the delivery of water to the wetland.

The Straight Cut Channel will be retained to ensure Pig Swamp is able to receive environmental water.

A small regulator structure in the form of a gated pipe outlet from the Straight Cut Channel into Pig Swamp is required, including:

1. The current earthen block (200m upstream of the wetland) is removed
2. A pipe and outlet structure could be placed at the wetland entry point in the Straight Cut Channel to allow water to be intentionally delivered into the wetland.
3. A structure should be placed in the channel on the east side of Pig Swamp to prevent water from filling the full length of the channel.

The supply of water from the Straight Cut Channel to Pig Swamp is restricted by the operating level in the Upper Gunbower Lagoon. The Upper Gunbower Lagoon FSL ranges between 83.90-84.00 m AHD. GMW has indicated that delivery to Pig Swamp from the Straight Cut Channel is restricted to 84.00 m AHD (pers. Comm. Ross Stanton [GMW] 1 July 2011).

It is recommended that the supply point outlined above is provided to Pig Swamp and that a delivery rate of 20 ML/day is provided. This has been calculated based on capacity and depth at FSL (National Heritage Trust 2001).

Optimal delivery rate	= (Capacity at FSL / target depth) x maximum rate of fill
	= (213 / 50) x 5
	= 21.3 ML day

7.2.1. Further system modifications and improvements

The following recommendations are outside the responsibility of the GMW Connections Project, however they require investigation to improve water management in the Upper Gunbower Forest. These modification and improvements include:

- The Straight Cut Channel is an impediment to flood flows, preventing overbank flows from moving through the Gunbower Forest and the channel itself acts as a barrier between the northern and southern parts of Pig Swamp. The removal of this channel from the recommended delivery point to Pig Swamp needs to be investigated. Consideration could also be given to breaching the channel in such a way as to establish 'islands' of channel bank which would provide the desired habitat and some protection from predation (e.g. turtle eggs from foxes).
- Consideration should be given to placing a structure on the eastern end of the Straight Cut Channel, where it joins the Murray River. This structure could be operated to prevent water from draining out of Pig Swamp into the Murray River, maintaining water levels in the swamp.
- Concepts put forward in Ecological Associates (2004) involved the Straight Cut Channel being modified to provide a controlled flooding regime to Pig Swamp or the upper forest generally. A major channel constructed through the upper part of Gunbower Forest has been identified to deliver flows in excess of 4,000 ML/day to the vicinity of Broken Axle Creek. A regulator would be required at Straight Cut Channel where it leaves Upper Gunbower Lagoon and where Gunbower Island Road crosses this channel. Straight Cut Channel would require improvements to increase the bed to at least 10 m wide with 1 in 3 sides. This will provide 3 m depth of flow in this channel (Ecological Associates 2004).

8. Adaptive management framework

A key GMW Connections Project principle is that an adaptive management approach is adopted to ensure an appropriate application of the scientific method to management (Section 9.4, GMW 2013).

Adaptive management is a continuous management cycle of assessment and design, implementation, monitoring, review and adjustment. Table 12 shows how the adaptive management approach will be applied in the context of this EWP.

Table 12: Adaptive management framework

Adaptive management phase	Application to this EWP (Responsible agency)	When (Sections 15 and 19, GMW 2013)
Assessment and design	Assessment identifies environmental values, their water dependencies, and the potential role of incidental water. Design determines the desired water regime to support environmental values and determines any mitigation water commitment. Details of both these phases are documented in this EWP. (GMW Connections Project)	2013
Implementation	Implementation is the active management of environmental water, of which mitigation water may form a portion, consistent with this EWP. (North Central CMA)	Continuous
Monitoring (and reporting)	Monitoring is gathering relevant information to facilitate review and enable any reporting obligations to be met. Two types of monitoring are required. Compliance monitoring is checking that the intended water regime is applied. Performance monitoring is used to inform the review of the effectiveness of the mitigation water contribution to achieving the water management goal. (North Central CMA)	Annual
Review	Review is evaluating actual results against objectives and identifying any improvement opportunities which may be needed. (GMW Connections Project, until responsibilities transferred to other agencies)	2015, 2020, 2025, etc
Adjustment	Adjustment is determining whether changes are required following review or after considering any new information or scientific knowledge and making any design changes in an updated version of the EWP. (GMW Connections Project, until responsibilities transferred to other agencies, adjustment is limited to the extent that the new information relates to the impact of the GMW Connections Project at the time of the impact occurred, and only insofar as the new information could change the mitigation outcomes)	2015, 2020, 2025, etc

8.1. Monitoring and reporting

It is assumed that if mitigation water is supplied in accordance with the desired water regime proposed within the EWP then environmental values potentially impacted by the GMW Connections Project will be maintained. The GMW Connections Project will report, annually, on the contribution, or provision, of “Mitigation Water” towards achieving the water regime (Section 18, GMW 2013). This will be done through liaison with other agencies in relation to monitoring and then reporting whether:

- mitigation water was available for delivery to the wetland or waterway

- a decision was made that water was required for the wetland or waterway for that year
- mitigation water was delivered to the wetland or waterway in accordance with the desired water regime proposed within the EWP (i.e. quantity, timing, duration, frequency)
- the ecological objectives were achieved or are being achieved.

It is expected the CMA will monitor environmental water delivery (i.e. quantity, timing, duration and frequency). GMW Connections Project will not implement a detailed monitoring program. It is beyond the scope of this EWP to provide a detailed monitoring program to determine the effectiveness of the desired water regime in achieving ecological objectives and the water management goal.

However, Appendix I provides some suggested components identified during the preparation of this EWP to be considered in preparing a monitoring program for the wetland.

8.2. Review

Periodic reviews provide the opportunity to evaluate monitoring results in terms of compliance, ecological objectives and to learn from implementation.

As per the requirements of the WCMF, it is expected this EWP will be reviewed in, 2015, 2020 and every five years thereafter, or at any time, if requested by the Victorian Minister for Environment, Climate Change and Water or Commonwealth Minister for the Environment (Sections 15 and 19, GMW 2013). The GMW Connections Project is responsible for reviews until such time as responsibility is transferred.

8.3. Adjustment

Adjustments may be made to:

- operational management
- management hypotheses and, perhaps, to ecological objectives
- cope with unexpected issues.

These adjustments will be incorporated into the EWP.

9. Governance arrangements

A summary of the roles and responsibilities of the various bodies relating to the delivery and review of management and mitigation measures is provided in Table 13 (GMW 2013). The table outlines the roles and responsibilities before and during the implementation of the GMW Connections Project in the modified GMID.

Table 13: Roles and responsibilities

Agency	Assess and develop management and mitigation measures	Deliver and review management and mitigation measures during GMW Connections Project implementation
GMW Connections Project (until such time as responsibility is transferred)	• Identify and account for water savings, subject to audit by DELWP accredited auditor • Lead the assessment and development processes for management and mitigation measures including developing and gaining approval to the WCMF (which guides the development of EWPs and the assessment of mitigation water). • Maintain short-list of all wetlands, waterways and groundwater dependent ecosystems for mitigation. • Identify and source mitigation water required to implement management and mitigation measures including the adaptive development of EWPs. • Retain or provide infrastructure to deliver water to wetlands and waterways. • Convene and chair the Environmental Technical Advisory Committee. • Convene the Expert Review Panel	• Apply, review and, as necessary, develop amendments and gain approval to updated versions of the WCMF. • Provides resources to enable monitoring and review of management and mitigation measures • Establish protocols for transfer of responsibility to relevant agencies. • Coordinate with other agencies to deliver management and mitigation measures. • Arrange for the provision of delivery and measurement infrastructure including capacity and operational flexibility for mitigation water
Catchment Management Authority	• Identify and inform the GMW Connections Project of opportunities for best practice. • Inform the GMW Connections Project of its infrastructure requirements to deliver environmental water.	• Advise Environmental Water Holder and system operator on priorities for use of environmental entitlements (including mitigation water) in line with recommendations outlined in the EWPs • Implement the relevant components of Environmental Watering Plans.

Agency	Assess and develop management and mitigation measures	Deliver and review management and mitigation measures during GMW Connections Project implementation
	• Participate in Environmental Technical Advisory Committee. • Agree to implement relevant components of Environmental Watering Plans. • Agree to implement other relevant regional management and mitigation measures required due to the implementation of GMW Connections Project.	• Operate, maintain and replace, as agreed, the infrastructure required for delivery of mitigation water, where the infrastructure is not part of the GMW irrigation delivery system. • Report on environmental outcomes (e.g. wetland or waterway condition) from the delivery of the water, in the course of normal reporting on catchment condition. • Where agreed conduct the periodic review of EWPs and report results to GMW Connections Project. • Manage and report on other relevant catchment management and mitigation measures required due to the implementation of GMW Connections Project.
Land Manager (Public and private as relevant)	• Identify and inform GMW Connections Project of opportunities for best practice. • Participate in Environmental Technical Advisory Committee. • Agree to implement relevant components of Environmental Watering Plans. • Agree to implement other relevant regional management and mitigation measures required due to the implementation of GMW Connections Project.	• Implement the relevant components of Environmental Watering Plans. • Operate, maintain and replace, as agreed, the infrastructure required for delivery of mitigation water, where the infrastructure is not part of the GMW irrigation delivery system. • Where agreed, participate in the periodic review of relevant EWPs. • Manage and report on other relevant catchment management and mitigation measures required due to the implementation of GMW Connections Project.
System Operator	• Identify and inform the GMW Connections Project of opportunities for best practice. • Participate in Environmental Technical Advisory Committee. • Agree to implement relevant components of Environmental Watering Plans.	• Implement the relevant components of Environmental Watering Plans, namely delivery of mitigation water. • Operate, maintain and replace, as needed, the infrastructure required for delivery of mitigation, or other, water, where the infrastructure is part of the GMW irrigation delivery system. • May negotiate transfer of ownership of infrastructure to the environmental water/land manager for provision of mitigation water if it is no longer required for the public distribution system, in accordance with the principles set out in the WCMF. • Where the infrastructure assets are due for renewal or refurbishment,

Agency	Assess and develop management and mitigation measures	Deliver and review management and mitigation measures during GMW Connections Project implementation
		the water corporation will undertake the upgrade to the best environmental practice, including any requirements to better provide Environmental Water Reserve. • Report annually on the availability and delivery of water for mitigating environmental impacts as part of reporting upon meeting obligations under its bulk entitlement. In some instances, it will be appropriate to measure mitigation flows to ensure mitigation volumes of water are delivered.
DELWP	• Identify and inform the GMW Connections Project of opportunities for best practice. • Participate in Environmental Technical Advisory Committee. • Arrange funding to enable environmental water manager, catchment manager and land manager to deliver agreed measures.	• Participate in the periodic review of the Water Change Management Framework and relevant EWPs.
Victorian Environmental Water Holder		• Hold and manage environmental entitlements, including mitigation water that becomes a defined entitlement. • Consult with CMAs in identifying priority wetlands, waterways and groundwater systems for environmental watering. Plan and report on the use of environmental entitlements. • Negotiate with Commonwealth Environmental Water Holder to arrange delivery of Commonwealth environmental water.

9.1. Framework for operational management

The obligation to annually reserve and supply mitigation water will be established by amendment to the River Murray and Goulburn System Bulk Entitlements held by GMW. This arrangement is legally binding and reflects the commitments of the GMW Connections Project to provide water to mitigate potential impacts to high value environmental assets. The arrangements require GMW to set aside water in the Goulburn and Murray Systems to meet the mitigation water needs, calculated in accordance with the methods in the Water Change Management Framework, for future use at wetlands and waterways that have an approved EWP.

Mitigation water will be able to be carried over in line with other entitlements and will only be supplied to those wetlands where a mitigation water requirement has been identified. The specification of the volume and use of mitigation water will be the same regardless of whether it is established via bulk entitlement or contract.

Delivery of environmental water to Pig Swamp requires the coordination of information, planning and monitoring among a number of agencies.

A framework for operational management outlining the relevant roles and responsibilities is presented in Figure 14. This has been developed to describe the decision-making process required to coordinate implementation of the desired water regime for Pig Swamp. The various government bodies and their roles will change over time. Therefore, this framework should be taken as a guide only.

The main components are:

- assessment of current conditions i.e. wetland phase, climatic conditions, etc.
- identification of potential water sources and preparation of relevant information for submission of water bid
- coordination of the environmental water delivery and adaptive management process.

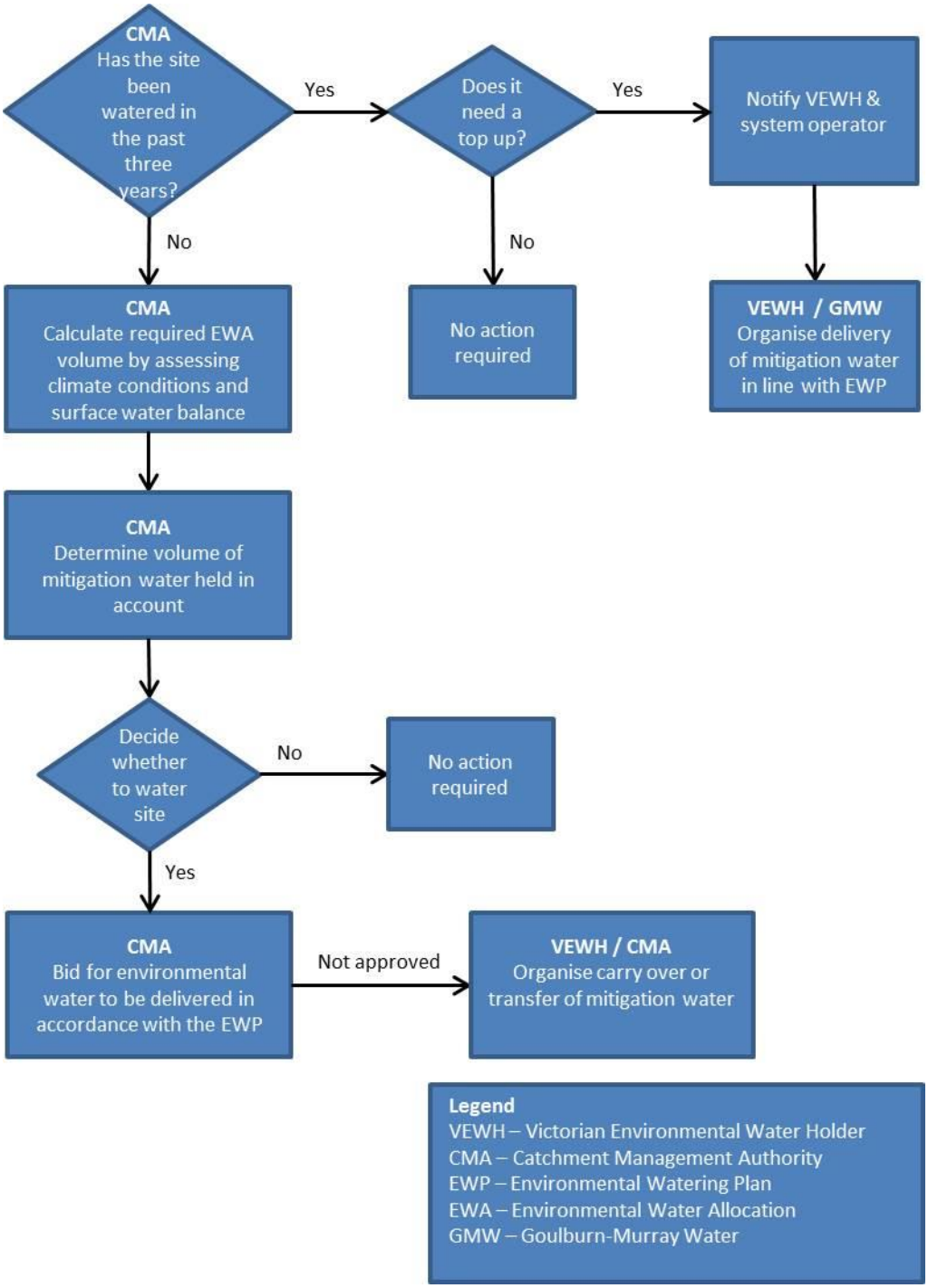


Figure 14: Operational management framework

10. Knowledge gaps

The Pig Swamp EWP has been developed using the best available information. However, a number of information and knowledge gaps exist which may impact on recommendations and/or information presented in the EWP. These are summarised below.

10.1. Works program

Further information on the GMW Connections Project works program in the vicinity of Pig Swamp needs to be confirmed to more specifically assess the potential impacts on the wetland, particularly:

- The future operation of the Straight Cut Channel and modification required (including ownership and maintenance) to enable the delivery of environmental water to the wetland.
- Planning for any work on the channel banks needs to consider possible disturbance of habitat. The Straight Cut Channel has been in place since the 1870s and as such, has become a well-established component of the Pig Swamp habitat. Reptiles, Grey-crowned Babblers and the possible occurrence of Stiff Groundsel should be especially considered.

Refer to Section 7 for details on the potential changes to current infrastructure arrangements and supply point to Pig Swamp.

10.2. Pig Swamp

- Continued monitoring and evaluation of groundwater and surface water data is recommended to ensure no detrimental impacts from implementation of the water regime.
- The relationships between hydrology and ecological response in wetlands are complex. Therefore, it will be important that monitoring and adaptive management is undertaken to enable decisions to be made based on the best available information (Appendix I).
    - Monitoring the composition and distribution of vegetation communities within the wetland will be essential to adaptively managing the desired water regime (Ecological objectives: 1.1, 1.2, 1.3, 3.1).
    - Monitoring of River Red Gum health is required during long-dry periods to assess the need for an environmental flow (Ecological objectives: 1.2).
    - Monitoring of important understorey species, particularly Poong'ort *Carex tereticaulis* and Water Couch *Paspalum distichum*, is required during long-dry periods to assess the need for an environmental flow (Ecological objectives: 1.2).
    - Lack of information on fauna utilising Pig Swamp for habitat, breeding and feeding (including threatened species). Continued waterbird monitoring, particularly in spring, is critical for the implementation and adaptive management of the desired water regime (Ecological objectives: 2.1, 3.1).
    - It is recommended that some basic photographic monitoring points are established in conjunction with aerial photography as an important component of vegetation monitoring. Fourteen photopoint were established in 2011 (Appendix F) and would be a useful baseline for monitoring (Ecological objectives: 1.1, 1.2, 1.3).

10.3. Roles and responsibilities

North Central CMA in its capacity as environmental water manager is responsible, where funding and resourcing allow, for addressing the knowledge gaps listed under Section 10.2.

GMW Connections Project is the responsible party for determining the future operation of the Straight Cut Channel.

11. References

Baldwin, D. S., Nielsen, D. L., Bowen, P. M. and Williams, J. (2005). *Recommended Methods for Monitoring Floodplains and Wetlands*, MDBC Publication No. 72/04, Murray-Darling Basin Commission, Canberra, Australian Capital Territory

Bartley Consulting (2011) *Hydrogeological Overview – Pig Swamp.* Prepared for the North Central Catchment Management Authority by Bartley Consulting, Heidelberg, Victoria

Bogenhuber D. and Campbell, C. (2011). *NVIRP Technical Report: Pig Swamp Watering Requirements*. Report prepared for the North Central Catchment Management Authority by The Murray-Darling Freshwater Research Centre, Huntly.

Bureau of Meteorology (2011). *Climate Statistics for Australian Locations*. Bureau of Meteorology, Available at: http://www.bom.gov.au/climate/averages/tables/ca_vic_names.shtml, Accessed: June 2011

Boulton, A., and Brock, M. (1999). *Australian Freshwater Ecology: Processes and Management*, Gleneagles Publishing, Adelaide.

Campbell, E., Cooling, M. and Hogan, R. (2005). *Ecological accountability in Gunbower Forest*. Paper for International River Symposium, Brisbane.

DEPI (2013). *Advisory List of Threatened Vertebrate Fauna in Victoria.* Department of Environment and Primary Industries, Melbourne.

DEPI (2014). *Flora and Fauna Guarantee Act 1988 Protected Flora List* May 2014, The Department of Environment and Primary Industries, Melbourne.

DEWHA (2009). *Environment Protection and Biodiversity Conservation Act*, Department of the Environment, Water, Heritage and the Arts, Canberra, Australian Capital Territory, Available at: www.environment.gov.au, Accessed: November 2009

DEWHA (2008). Water Requirements of Important Wetlands in the Murray-Darling Basin – Initial *Overview Assessment,* Final Report, Compiled by Fluvial Systems and Lloyd Environmental, Canberra.

DNRE (2002). *FLOWS- a method for determining environmental water requirements in Victoria*. Prepared by SKM, CRC for Freshwater Ecology and Lloyd Environmental Consultants for DNRE, Melbourne.

DNRE (1997). *Victoria's Biodiversity Directions in Management,* Department of Natural Resources and Environment, Melbourne.

DPCD (2009). *Environment Assessment Referrals from July 2008 - June 2009*. Available at: http://www.dse.vic.gov.au/DSE/nrenpl.nsf/LinkView/E6DAFE581144D1FFCA25757B0008A28314CD70100E11BFB5CA2572DA007FAA9C, Accessed: November 2009

DPCD (2007). *General Practice Note The Aboriginal Heritage Act 2006 and the Planning Permit Process* July 2007 (Revised October 2007), the Department of Planning and Community Development, Melbourne.

DPI and HydroEnvironmental (2007). *Irrigation Drainage Memorandum of Understanding Decision Support System: Assumptions for Management Actions – North Central Catchment,* Prepared by Brian Holmes, Department of Primary Industries, Kerang.

DSE (2011a). Biodiversity Interactive Map. Department of Sustainability and Environment http://mapshare2.dse.vic.gov.au/MapShare2EXT/imf.jsp?site=bim (Accessed February 2011)

DSE (2011b) Ecological Vegetation Class (EVC) Benchmarks for each Bioregion. Department of Sustainability and Environment http://www.dse.vic.gov.au/dse/index.htm (Accessed February 2011)

DSE (2010a) Victorian Biodiversity Atlas Fauna Records. Produced by Viridans Biological Databases and the Department of Sustainability and Environment, Victoria.

DSE (2010b) Victorian Biodiversity Atlas Flora Records. Produced by Viridans Biological Databases and the Department of Sustainability and Environment, Victoria.

DSE (2009a). Data Source: 'WETLAND_1788', © The State of Victoria, Department of Sustainability and Environment. The contribution of the Royal Botanical Gardens Melbourne to the data is acknowledged. Accessed: January 2009.

DSE (2009b). Data Source: 'WETLAND_1994', © The State of Victoria, Department of Sustainability and Environment. The contribution of the Royal Botanical Gardens Melbourne to the data is acknowledged. Accessed: January 2009.

DSE (2009c). *Water Savings Protocol Technical Manual for the Quantification of Water Savings Final Version 1.0,* Department of Sustainability and Environment, Melbourne Victoria

DSE (2008) *Northern Region: Sustainable Water Strategy.* Department of Sustainability and Environment, Melbourne.

DSE (2007). *Native Vegetation Information: Overview of Native Vegetation Spatial Datasets Information Sheet No. 1*. Department of Sustainability and Environment, East Melbourne, Victoria.

DSE (2006) *27 600 ML Murray Flora and Fauna Entitlement: Annual Distribution Program 2006/2007*, Compiled by Andrea Joyce, Department of Sustainability and Environment, October, Melbourne.

DSE (2005a). *Advisory List of Rare or Threatened Plants in Victoria*, Department of Sustainability and Environment, Victoria.

DSE (2005b). *Index of Wetland Condition: Conceptual Framework and Selection of Measures*. Department of Sustainability and Environment, Victoria.

DSE (2004) *Gunbower Forest Ramsar Site Strategic Management Plan*, Department of Sustainability and Environment, Melbourne.

Ecological Associates (2004). *Flooding Enhancement of Gunbower Forest – Investigation of Priority Options.* Part B. Report prepared for the North Central CMA, March 2004, Huntly.

Ecos Environmental Consulting (2005). *Pig Swamp Environmental Assessment Scoping Paper*. Report for Parsons Brickenhoff and Sunwater on behalf of Goulburn-Murray Water, April 2005, Tatura.

Feehan Consulting (2009). *Northern Victorian Irrigation Renewal Project. Waterway Short-listing Report.* Report prepared for Northern Victorian Irrigation Renewal Project.

GHD (2007). *Pig Swamp Environmental Assessment: Ecological Assessment*. Report for Goulburn-Murray Water, March 2007, Tatura.

Gippel, C.J. (2011). *Modelling the water regime and potential water savings in Pig Swamp using SWET for the NVIRP.* Report prepared for the North Central CMA, Huntly

Gippel, C.J. (2010). *Comments on Application of SWET Water Balance Model to Terminal Wetlands_V1.* Prepared by Dr. Chris Gippel, Fluvial Systems Pty Ltd, Stockton, NSW

Gippel, C. J. (2005a). *Operational procedure to calculate water recovery from wetlands and lakes at the source (individual wetlands).* Fluvial Systems Pty Ltd, Stockton, NSW. The Living Murray, Murray-Darling Basin Commission, Canberra, Australian Capital Territory.

Gippel, C. J. (2005b). *Model to calculate water recovery from wetlands and lakes at the source (individual wetlands) – Example application to Euston Lakes and Edward Gulpa wetlands.* Fluvial Systems Pty Ltd, Stockton, NSW. The Living Murray, Murray-Darling Basin Commission, Canberra, Australian Capital Territory.

Gippel, C. J. (2005c). *SWET (Savings at Wetlands from Evapotranspiration daily Time-Series)*. *A model to calculate water recovery from wetlands and lakes at the source (individual wetlands). Model Manual.* Fluvial Systems Pty Ltd, Stockton, NSW. The Living Murray, Murray-Darling Basin Commission, Canberra, Australian Capital Territory.

GMW (2008a). *GMW Murray Strategic Monitoring Project*, Goulburn-Murray Water, Shepparton.

GMW (2008b). *Environmental Water Allocations – Calculations for the SIRTEC*, Agenda Paper Compiled by Sam Green and Mary Shi, Tatura

GMW (2013). *Water Change Management Framework*, Version 3, Goulburn-Murray Water Connections Project, Tatura, Victoria

GMW (2015). *Environmental Watering Plan Review 2015. Comparison of Monitoring Data to Ecological Objectives.* Goulburn-Murray Water, Tatura.

Hale, J. and Butcher, R. (2011). *Ecological Character Description for the Gunbower Forest Ramsar Site*. Report to the Department of Sustainability, Environment, Population and Communities, Canberra.

Hydro Environmental (2009). *Northern Victoria Irrigation Renewal Project. Wetland Short-listing Report*. Report prepared for Northern Victoria Irrigation Renewal Project.

McJannet, D.L., Webster, I.T., Stenson, M.P. and Sherman, B.S. (2008). *Estimating Open Water evaporation for the Murray Darling Basin.* A Report to the Australian Government from the CSIRO Murray-Darling Basin Sustainable Yields Project. CSIRO, Australia. Available at: www.clw.csiro.au

MDBA (2011a) *MSM-Bigmod Modelled Current and Natural Conditions for flows downstream of Torrumbarry weir*. Data supplied by Murray-Darling Basin Authority, March 2011.

MDBA (2011b) *Live River Data – Murray River downstream of Torrumbarry Weir*. Murray-Darling Basin Authority website, http://www.mdba.gov.au/water/live-river-data/ (Accessed March 2011.

Natural Heritage Trust (2001). *Your Wetland Hydrology Guidelines – River Murray South Australia*, Prepared by the Natural Heritage Trust – Murray Darling, Renmark, South Australia

North Central CMA (2010). Flooding Enhancement of Gunbower Forest Project Investment Proposal, Repost prepared for the Murray Darling Basin Authority, Bendigo.

North Central CMA (2005). *Wetlands Background Paper,* North Central Catchment Management Authority, Huntly.

NVIRP (2011). *NVIRP Environmental Infrastructure Register.* Version 1, Northern Victoria Irrigation Renewal Project, June 2011, Shepparton, Victoria

NVIRP (2010). *Water Change Management Framework*, Version 2, Northern Victoria Irrigation Renewal Project, May 2010, Shepparton, Victoria

O'Brien R (2011) Community Interaction/Engagement for Pig Swamp Environmental Watering Plan. Unpublished report prepared for North Central CMA, Huntly.

Pels, S., 1964. The present and ancestral Murray River system. Australian Geographical Studies, Vol 2(2) [cited in Salient Solutions, 2007].

Rogers, K. and Ralph, T. (2011). *Floodplain Wetland Biota in the Murray-Darling Basin – Wetland and Habitat Requirements.* CSIRO Publishing, Melbourne.

Salient Solutions, 2007. Assessment of salinity impacts of enhanced flooding in the Koondrook Perricoota Forest on the Wakool and Murray Rivers. Final Report. For Department of Natural Resources, February, 2007.

SKM (2009). *Ecological Assessment of Pig Swamp.* Unpublished file note, North Central Catchment Management Authority, August 2009, Huntly.

SKM (2008). *Food Bowl Modernisation Project – Environmental Referrals*, Document prepared for the Department of Sustainability and Environment, 13th November, Melbourne.

URS 2010, Gunbower Forest environmental watering project – Hipwell Road and associated works concept designs, unpublished report prepared for North Central Catchment Management Authority, Bendigo.

Wrigley Dillon, 2007. Gunbower Forest Soils Project Stage 1 – Soil Profile Documentation. For North Central Catchment Management Authority, June 2007, Draft

VEAC (2008). *River Red Gum Forests Investigation*, Final report, Victorian Environmental Assessment Council, July, Melbourne.

Appendix A: NVIRP TAC, Wetland workshop participants and GMW Connections Project ETAC

Table A1: NVIRP TAC members - 2009

Name	Organisation and Job title
Anne Graesser	Manager – Natural Resources Services Goulburn Murray Water
Carl Walters	Executive Officer SIR Goulburn Broken CMA
Emer Campbell	Manager – NRM Strategy North Central CMA
Jen Pagon	Catchment and Ecosystem Services Team Leader Department of Primary Industries
John Cooke	Manager Sunraysia Department of Sustainability and Environment
Ross Plunkett	Executive Manager Planning GMW Connections Project
Tamara Boyd	State Parks and Environmental Water Coordinator Parks Victoria
Observers	
Jacqui Hickey	Executive Assistant to Executive Manager Planning GMW Connections Project
Chris Solum	Environmental Program Manager GMW Connections Project
Mark Tscharke	Senior Ranger Parks Victoria
Michelle Maher	Strategic Environmental Coordinator North Central CMA
Pat Feehan	Consultant Feehan Consulting
Paulo Lay	Senior Policy Officer Department of Sustainability and Environment

Table A2: Wetland workshop participants – 5 May 2011

Name	Organisation and Job title
Anne Graesser	Manager – Natural Resources Services Goulburn Murray Water
Cherie Campbell	Senior Ecologist Murray Darling Freshwater Research Centre
Deborah Bogenhuber	Ecologist Murray Darling Freshwater Research Centre
Emer Campbell	Manager, NRM Strategy North Central CMA
Glenn Smith	Compliance Officer Department of Sustainability and Environment
Karen Weaver	Biodiversity and Ecosystem Services Department of Sustainability and Environment
Lyndall Rowley	Strategic Technical Officer North Central CMA
Mark Paganini	Connections Manager Planning GMW Connections Project
Mark Tscharke *Engaged via field visit on 18 May 2011*	Senior Ranger Parks Victoria
Melanie Tranter	Project Manager – Gunbower Forest Living Murray Project North Central CMA
Michelle Maher	Strategic Environmental Coordinator North Central CMA
Mick Dedini	Threatened Species Department of Sustainability and Environment
Rob O'Brien	Senior Environmental Officer Department of Primary Industries
Ross Stanton	Operations Coordinator Central Murray Operations Goulburn Murray Water
Scott Morath	Project Manager GMW Connections Project

Table A3: GMW Connections Project ETAC members - 2015

Name	Organisation and Job title
Aaron Gay	Regional Manager, Environment and Natural Resources Department of Environment, Water, Land and Planning
Andrea Keleher	Program Manager – Healthy Landscapes Department of Environment, Water, Land and Planning
Bruce Wehner	Ranger Parks Victoria
Carl Walters	Executive Officer SIR Goulburn Broken CMA
Emer Campbell	Manager – NRM Strategy North Central CMA
Neil McLeod	Irrigation Officer – Dairy and Irrigation Department of Economic Development, Jobs, Transport and Resources
Ross Plunkett	Manager Environment and Water Savings GMW Connections Project
Observers	
Chris Solum	Environmental Project Manager GMW Connections Project
Josie Lester	Environmental Project Officer GMW Connections Project

Appendix B: Community Interaction/Engagement

Community Engagement purpose

An important component of the Pig Swamp EWP involved identifying the goal, the underlying environmental objectives and wetland type. This required an understanding of physical attributes, the history and the main biological processes associated with the wetland.

In many cases, adjoining landholders have had a long association with a wetland and have developed a good understanding that is useful to include in the development of an EWP. This is particularly important if only limited monitoring records exist.

Method

A targeted community/agency engagement process was developed for the first round of EWPs developed in early 2009. A list of people with a good technical understanding of each wetland was developed by the technical working group (DPI, DSE and North Central CMA representatives).

This list included key adjoining landholders that have had a long association with the wetland and proven interest in maintaining its environmental value. A minimum of 2 landholders were invited to provide input for each wetland.

Other community and agency people that can provide useful technical and historic information include GMW water bailiffs, duck hunters (Field & Game Association), bird observers and field naturalists. These people often possess valuable information across several of the wetlands currently being studied.

The method of obtaining information was informal and occurred at the wetland (e.g. oral histories, interviews). The information has been captured in brief dot point form and only technical information and observations are to be noted that will add value to the development of the EWP.

The list of participants involved in the Pig Swamp community engagement has been recorded, however all the comments have been combined for each of the wetlands so individual comments are not referenced back to individuals.

List of community and agency participants (Pig Swamp)

- Bazil Brereton
- Roger & Kurt Brereton
- Ray Harrower
- George and Marion Mc Gilivray
- Graham and Ursler Sutcliff
- Ross Stanton (GMW)

Information provided to the community

It is important that the people approached for this information have a brief, straight summary of the purpose of the EWPs and type of information that will be useful to include in the planning process. Refer to summary below (adapted from O'Brien 2009):

We are currently completing a study for NVIRP Northern Victoria Irrigation Renewal Project. It involves completing a plan for Pig Swamp, a wetland within Gunbower Forest, near the township of Gunbower.

As part of this it would be valuable to gather information that is broadly described below with a focus on the water regime and associated wetland values. It's recognised that this wetland has been altered significantly since European settlement and the expansion of irrigated agriculture. Collecting information on how this has influenced a wetland's values is an important consideration in developing future management options.

Providing information on these changes and how these influenced and altered the wetland is important. It is particularly important to collate information or observations over more recent times, such as the last 30 - 50 years. The general types of information sought and recorded include:

- *The natural (pre-European settlement) condition of the wetland, including any details of the water regime and values (environmental, cultural).*
    - *Tree types (i.e. Red Gum or Black Box)*
    - *Aboriginal occupancy and archaeological sites & values*
    - *Frequency and depth of flooding*
- *The broader changes relating to the wetlands management, with particular emphasis on altered water regimes.*
    - *How has the natural flooding altered (river regulation, farm development)?*
    - *How did surrounding irrigation land influence the swamp?*
    - *How did the "Straight Cut Channel influence the swamp?*
    - *Estimate the time frames for each of the main changes to the water regime*
- *Describe how the values of the wetland had altered over time*
    - *Has the swamp been wetter or drier due to irrigation development over time?*
    - *How have the plants responded?*
    - *How did the birds and animals respond?*
- *Currently what connection does the wetland to the floodplain*
    - *Does it naturally flood (frequency)?*
    - *Does surrounding local catchment rainfall runoff enter the wetland?*
    - *What is the total area of local catchment water shed (land use type)?*
    - *Did irrigation runoff from adjoining paddocks enter the swamp?*
    - *How does drainages water effect the swamp?*
- *Is salinity an issue at the swamp*
    - *Identify saline areas or vegetation affected by salinity*
    - *What are the groundwater levels through the area?*
    - *Note any known groundwater bores*
    - *Will salinity influence the health of the swamp in the future?*
- *To what extent does the "Straight Cut Channel" influence the water regime*
    - *When was it constructed?*
    - *Does it influence natural flood flows?*
    - *How much water flowed from the channel into the swamp over time?*
- *How did blocking the channel in 2007 influence the water regime?*
- *Comment on other influences to the swamp (e.g. Grazing, Weeds, Dominant plants species and Fire)*
    - *How did these influences effect the health of the swamp*
- *Given the history and current condition of the swamp, what type of watering regime do you recommend to preserve the environmental values?*
    - *Flooding frequency*
    - *Natural flooding or improved natural flooding*
    - *Water delivery periodically from the "Straight Cut Channel"*

Comments and feedback from participants for Pig Swamp

(Please note: for the purposes of this EWP "Gunbower Island" can be read as Gunbower Forest, including the Gunbower National Park).

Pre European Settlement Condition

- The water levels in the Murray River would have fluctuated more, prior to the construction of the storages and river regulation. This changing water level would have influenced the flooding on Gunbower Island.
- Pig Swamp is situated high on the Gunbower Island floodplain; therefore it naturally flooded infrequently and only held water for short periods, about 2 – 3 months.
- During minor floods, water would have feed out of the Murray River through the creeks and drainage lines like Baggots and Upper Gunbower Creeks.
- In a major Murray River flood, water would have flooded more broadly over the higher Black Box areas surrounding Pig Swamp.
- Pig Swamp naturally contained large widely spaced red gums through the main drainage depression.
- The area around Pig Swamp was dominated by Black Box trees which indicates it only flooded occasionally.
- Originally the area contained much larger more widely spaced trees. Large "Bull Gums" (term that refers to big old trees) would occupy an area and prevent other trees and vegetation from establishing. The bush had a more open appearance.
- During big floods water naturally broke out of the Murray River upstream of Pig Swamp and flowed through Dry Tree Lagoon and Dry Tree Creek, then on through to Baggots Creek which fed Pig Swamp as well as Upper Gunbower Creek and the lagoon system. Floodwater would then flow northwards inundating areas further downstream.
- Upstream of Torrumbarry, the Cameron's Creek system would flood and feed water into Dry Tree Creek and Baggots Creek.
- Swan Lagoon over the Murray River in NSW carried floodwater across into the NSW forest and then flowed northwards entering Cow and Calf creeks.
- Pre-European settlement the creek systems around Gunbower were deeper and narrower and would rise and fall more quickly in line with the levels in the Murray River. Over time these creeks have silted up.
- Floodwater could also break out of the Murray River during a major floods closer to Pig Swamp (around "Masters House" area) and create shallow sheet flooding through the bush around Pig Swamp.
- In wet years, Mahers Creek (which is) out on the Patho Plains would feed water across into the Upper Gunbower Creek System. This water possibly entered the Gunbower system, prior to the Murray River flooding.
- Aboriginal people would have utilised the southern end of Gunbower Island and associated wetlands including Pigs Swamp.
- Aboriginal people possibly utilised the higher areas of Gunbower Island such as Pig Swamp during a major flood event and then moved north utilising the lower wetlands as water levels receded.
- There is not much evidence of Aboriginal occupation in the Pig Swamp area in the form of scar trees and cooking mounds.

Changed Management

- Early European settlers changed floodwater distribution as they established farms.
- Levees were constructed to protect farms and houses which changed the flood patterns across the southern end of Gunbower Island which influenced the flooding through Pig Swamp.
- Many trees were cut down and utilised by paddle steamers travelling along the Murray River." Masters Landing" east of Pig Swamp was a paddle steamer port and these boats were utilised up until the 1940s.
- Large numbers of trees on the southern end of Gunbower Island were cut for fence posts. Unwanted or lower value trees were ring-barked.
- The Straight Cut Channel was constructed very early in the development of the irrigation supply system - it was built in the 1870s. It was constructed by approximately 200 men with shovels and wheel barrows. It was designed to deliver irrigation water pumped from the Murray River to the

Upper Gunbower Creek. This was a huge engineering task as the channel was dug down possibly 6 to 8 feet below the natural ground level.

- The significant Murray River flood in the 1870s forced large quantities of water up the Straight Cut Channel causing flooding problems in the Upper Gunbower Creek system. Shortly afterwards a large earthen bank was built across the entrance of the Straight Cut Channel to prevent further uncontrolled flooding. This block has been in place for over 100 years.
- The Straight Cut Channel irrigation system proved to be too small. A larger irrigation system was established over time.
- Irrigation syndicates on Baggots Creek were establish very early and may have pre-dated the Straight Cut Channel.
- Baggots Creek was also used as an early irrigation supply system. Water would be pumped across from the Murray River, through Baggots Creek into the Upper Gunbower Creek. Sandbags were used to block the top section of the Upper Gunbower Creek near the Straight Cut Channel. This elevated the water allowing farmers upstream to irrigate then water was allowed the flow on and supply landholders further downstream.
- The Cohuna Irrigation Trust established a larger irrigation supply system downstream of the Straight Cut Channel at the old “Head Works” or “Flume” around 1886 and eventually this was replaced by the construction of the Torrumbarry Weir in 1923.The original weir lasted about 90 years and supplied an extensive irrigation area and allowed water to be gravitated through the Gunbower Creek and Lagoons.
- Large floods in the late 1800 and early 1900s (possibly 1909) broke through the banks on the Straight Cut Channel causing them to leak irrigation water into the swamp. Other major flood events occurred during the 1950s, 1970s and 1990s.
- Much of the water flowing down the Murray River is distributed out on the floodplain. In a flood over 29ft 6inches at Echuca, for every 1 foot rise at Echuca results in only a 1 inch rise in the Murray River at Gunbower.
- Some of the breaches and leaks through the banks of the Straight Cut Channel are likely to be near the deeper sections or flood runner through the swamp.
- The Torrumbarry Weir created elevated water levels in the Upper Gunbower Creek System and this allowed water to flow back along the Straight Cut Channel to supply the landholder adjacent to the Murray River. The Straight Cut Channel was utilised to supply this farm, as water in the Murray River (downstream of Torrumbarry Weir) would need to be lifted 22 – 28 feet which was very expensive. The landholder pumped irrigation water from the east end of the Straight Cut Channel onto the farm.
- The Straight Cut Channel has altered the natural flooding of Pig Swamp by delivering irrigation water into it for over 100 years, maintaining it almost permanently full.
- The Straight Cut Channel was built through the Pig Swamp depression and continuously leaked into both the north and south sections.
- Possibly up to 1000 ML/yr was lost out of the irrigation supply system that flooded out of the Straight Cut Channel into Pig Swamp.
- The banks of the Straight Cut Channel were mechanically excavated to allow flood water to flow northwards during the floods in the 1970s.
- In a major flood event, water would flow through the area around Pig Swamp about 1- 2 feet deep, then flow northwards into the Deep Creek system. This would create flood problems in the Cohuna area.
- Brereton Road flooded in the lowest section, adjacent to Pig Swamp.
- There was a bridge on Gunbower Island Road where the Straight Cut Channel connected to the Upper Gunbower Creek. Historically during a major Murray River flood, water would enter via the breaches in the Straight Cut Channel and flow strongly up the channel into the Upper Gunbower Creek. This assisted in flushing the Upper Gunbower Creek. This bridge was replaced with a 2 ft pipe in the 1960s which greatly restricts flood flows between the channel and the creek.
- The water levels in Pig Swamp were mostly determined by the height of the water in the Straight Cut Channel, which was influenced by the water in the Upper Gunbower Creek. When the water levels rose in the irrigation supply system this resulted in additional water spilling into Pig Swamp.
- The normal summer full supply level of Pig Swamp is lower than indicated on the map. The swamp edge is below the surrounding Black Box tree line as these trees do not tolerate continuous summer watering.
- During winter in non-irrigation season the Gunbower Creek system was lowered. This lowered the water level in the Straight Cut Channel and eliminated flows into Pig Swamp. Water could drain back out of Pig Swamp, via the Straight Cut Channel into the Upper Gunbower Creek, leaving

ponded water in the deeper depression towards the centre of the swamp. The area inundated in Pig Swamp reduced to 510 acres on each side of Straight Cut Channel.

- During wet winters, the water levels in Pig Swamp where partially maintained due to rainfall and cooler temperatures.
- The southern section of Pig Swamp has been historically grazed by cattle for the past 100 years. The area would carry about 25 head for most of the year, and then the stock was moved off and grazed the adjoining farm. The grazing licence was cancelled around 2006/07 and there has been no cattle grazing since.
- The Black Box vegetation was originally sparse and Pig Swamp could be seen from the Murray River. The thick regeneration has occurred over more recent decades resulting in a denser stand of smaller trees.
- The permanent inundation due to the operation of the Straight Cut Channel probably drowned and killed the original scattered large River Red Gums within the swamp.
- Permanent inundation also killed the low lying Black Box vegetation and encouraged River Red Gums and aquatic plants to establish.
- Timber was cut out of Pig Swamp in the 1970s for the Kraft factory. This took place during the irrigation season as it was too wet most winters. Therefore the water levels in Pig Swamp (and Upper Gunbower Creek) may have been operated slightly lower.
- Grazing appeared to keep the vegetation open in Pig Swamp - it reduced Cumbungi dominance and the fire risk.
- Grazing did occur historically in the northern section of Pig Swamp although there has been no grazing in the north section of Pig Swamp for the past 30 years due to the cancellation of the licence.
- Grazing didn't appear to harm the southern section of Pig Swamp.
- Cattle grazing through the southern section of Gunbower Island bared out the vegetation, and with associated pugging, made it more difficult to drive through.
- Goulbourn Murray Water (GMW) was under increased pressure to save water during the recent drought.
- Water has been recently permanently sold off the irrigation farm at the end of the Straight Cut Channel (adjacent to Murray River). This resulted in GMW not being required to supply water via the Straight Cut Channel. Only a small stock and domestic licence of approximately 10ML exists on the farm today.
- As part of water savings measures, GMW constructed an earthen bank in the Straight Cut Channel in 2007 about 300m upstream of Pig Swamp. This prevented irrigation water flowing further down the channel and spilling into Pig Swamp.
- Pig Swamp received slightly less water during the recent drought years and the swamp dried out completely after the Straight Cut Channel was blocked in 2007.
- Two landholders west of Pig Swamp continue to have their irrigation water supplied through the Straight Cut Channel.
- Little irrigation drainage historically entered Pig Swamp as irrigation farmers throughout the area did not have access to good drainage systems and consequently were very careful when irrigating, producing minimal irrigation runoff.
- There is a small agricultural catchment that drains water into Pig Swamp. This comprises of approximately 20ha of annual pasture and 20ha of permanent pasture.
- Drainage off farms into Pig Swamp was probably slightly higher in earlier years. However, this is insignificant now as most farmers have improved their irrigation practices and installed reuse systems.
- The agricultural land around Pig Swamp is very productive.
- During wet years, some of the drainage from surrounding agricultural land enters depressions and creek lines on farmland and does not penetrate through to the forest.
- Some of the catchment runoff south of Pig Swamp flows into Emu Hole and does not reach Pig Swamp.
- Historically irrigated permanent or summer pasture surrounded Pig Swamp (intensive irrigation). However, the recent drought resulted in much less watering. Most of the permanent water rights have been maintained adjacent to Pig Swamp with only one small area where the water has been sold off.
- Salinity does not affect the south end of Gunbower Island. Groundwater levels are very low and the Murray River provides important drainage. The large areas of forest use up additional water and lower the water table which protects the area from salinity.

- The groundwater levels in the bore adjacent to the Upper Gunbower Creek (50m away) are lower than the bed of the creek. This indicates very little seepage or leakage from the creek. Currently the groundwater levels are 15-16ft below ground level.
- The heavy clay soils in the base of Pig Swamp are very tight and hold water with minimal leakage. Some refer to these soils as a "blue plug".
- Historically the watertables were high across some of the farmland around Pig Swamp; however, they did not cause salinity and they drop down very low under the forest.
- The upper or western section of the Straight Cut Channel has had the silt recently removed to improve water movement along the channel. A lot of tree regeneration has occurred in the silt that has been deposited adjacent to the channel banks.
- Pig Swamp has recently been naturally flooded from the Murray River during the December 2010 event and more recently the January 2011 flood event. These are not considered major Murray River flood events.
- There are minimal weeds through Pig Swamp except for scattered African Boxthorns and Scotch Thistles.
- The total area of Pig Swamp is estimated to be approximately 160 acres with 100 acres south of the channel and 60 acres north of the channel.
- The deeper sections in Pig Swamp were the drainage lines which could be up to 4 feet deep when the wetland was flooded.
- The normal water level in Pig Swamp during the irrigation season is less than 18 inches deep (knee deep).
- There have been no fires in the south end of the Swamp over the past 30 -40 yrs and possibly 2 fires in the northern section over the same period of time.
- Fires didn't appear to do much damage. Cumbungi burnt and a few large dead trees were lost and the fires easily distinguished when they reached the surrounding Black Box areas.
- Fire risk to Pig Swamp and Gunbower Forest increases due to visiting campers.

Environmental & Other Values

- Pig Swamp was a valuable and productive wetland, particularly for waterbirds.
- Pig Swamp consistently supported good numbers of waterbirds, particularly ducks, and was a popular duck shooting swamp.
- Pig Swamp has been degraded by keeping it permanently full, reducing its environmental value.
- There are numerous opportunities for waterbirds throughout the Gunbower Creek and associated wetland system without the need to artificially supply Pig Swamp.
- Pig Swamp is not as valuable as the Upper Gunbower Creek system. Ducks and coots were common however it does not support a healthy variety of wildlife.
- Lignum has established sparsely, mostly around the south end and where drainage creeks enter Pig Swamp around the south eastern side.
- Pig Swamp is an important wetland and always held water supporting good numbers of waterbirds particularly ducks. It was popular with hunters.
- Other birds included ibis, dab chicks, hawks and various waders.
- Pig Swamp at times supported hundreds of ducks, mostly Grey Teal and Black Ducks.
- Pig Swamp was an important breeding area for waterbirds, particularly ducks and hawks.
- Common birds that utilised Pig Swamp included ducks, ibis, kingfishers, hawks, mudlarks and jays.
- The swamp supported very high numbers of Red Bellied Black Snakes and Brown Snakes in the surrounding Black Box areas.
- The southern section of Pig Swamp was more diverse and environmentally significant.
- The northern end of Pig Swamp was dominated by Cumbungi and not as significant.
- There are only a small number of Aboriginal scar trees and cooking mounds in the Pig Swamp area.
- River Red Gum trees have encroached into the swamp due to the artificial water and several of these regenerated trees have died during the recent dry periods.
- River Red Gums have also established very thickly in the bed of the Straight Cut Channel after the channel was blocked a few years ago.
- Water Couch (*Paspalum distichum*) grew prolifically in Pig Swamp, particularly south of the channel and provided good cattle feed.
- Paraquata or Reed Sweetgrass (tall aquatic grass) was another water plant that grew well and provided summer feed for livestock. This plant was possibly introduced to the area to increase

productivity. *(Editors note: Reed Sweet Grass, Glyceria maxima, is an introduced weed. It has not been "officially" recorded for Pig Swamp).*

- Paraquata grows in shallow water particularly around the edge of swamps and creeks.
- Paraquata grew adjacent to both sides adjacent to the Straight Cut Channel. It also extended into the southern section of Pig Swamp.
- In the southern section of Pig Swamp, Cumbungi established around the edges in places and did not persist in the deeper water.
- There was no Phragmites (Common Reed) in Pig Swamp and very few weeds with the exception of few scattered African Boxthorns.
- Pig Swamp supports good numbers of kangaroos when it dries up.
- Pig Swamp is well known by duck and fox hunters.
- The wetter River Red Gum sections of Gunbower Island grow more understorey reeds, rushes and grasses than the Black Box areas. Much higher stocking rates were achieved amongst the River Red Gum vegetation were rushes were common.
- Approximately 700 head of cattle were grazed in the southern half of Gunbower Island, most grazed the wetter River Red Gum areas.
- Black Box vegetation naturally has less understorey growth than River Red Gum areas and often looks much barer, even with no cattle grazing.
- Carp did significant damage to the understorey vegetation on Gunbower Island when they entered during a large Murray River flood.
- Carp have damaged the Upper Gunbower Creek system.
- Duck hunters visit the swamp but there is normally no camping. The presence of grazing cattle and associated licence has probably discouraged camping.

Suggested Future Management

- A pipe and structure could be placed in the current block in the Straight Cut Channel to allow water to be intentionally delivered into the swamp. Another structure should be placed in the channel on the east side of Pig Swamp to prevent water from filling the full length of the channel.
- If no water was delivered into Pig Swamp via the Straight Cut Channel then the swamp would only fill only occasionally, during very large floods. This might be as infrequent as once every 10 to 15 years.
- There may be long periods when Pig Swamp does not flood naturally. Floods large enough to fill the swamp occurred in 1956, 1974, 1993 and 2010, with long dry spells in between.
- Water could be delivered via the Straight Cut Channel into Pig Swamp every season if there was sufficient water available.
- In future, Pig Swamp could receive some environmental water from the Straight Cut Channel. It might suit to deliver about once every 3 or 4 years.
- Pig Swamp has been artificially managed for over 100 years and should be allowed to revert back to its original condition. The vegetation may take 100 years to adjust back with reduced flooding. It should be expected that some of the regenerated River Red Gums will die if water is delivered less frequently into Pig Swamp.
- Maintaining permanent irrigation water through many of the Gunbower creeks and wetlands has caused them to degrade. Some of these wetlands should be allowed to fill and dry out, returning them to a more natural watering cycle.
- The Cameron's Creek, One Tree Creek and Baggots Creek system could be opened up to allow natural flooding of the south end of Gunbower Island, including Pig Swamp. This option would require some minor topping up of the levees to protect adjacent farmland.
- The Upper Gunbower Creek System that delivers water through the Straight Cut Channel is very stagnant and should receive some through flow or flushing occasionally.
- Pipes through Dormoyle's Bank at the commencement of the Upper Gunbower Creek could be opened and allow the 10 – 11km of creek to receive a freshening flow. This water would then return back into the Gunbower Creek. Flows could be split between the Gunbower Creek and Upper Gunbower Creek allowing water to flow down both systems.
- Pig Swamp needs to be occasionally grazed to manage the vegetation and reduce the fuel loads and associated fire risk.
- Light grazing of the forest and Pig Swamp is preferable as the licence requires weeds to be controlled. Government agencies do not have the man power or funding to manage weeds across big areas of Crown Land.

Appendix C: Capacity Table and Contour Plan

Capacity Summary for Pig Swamp

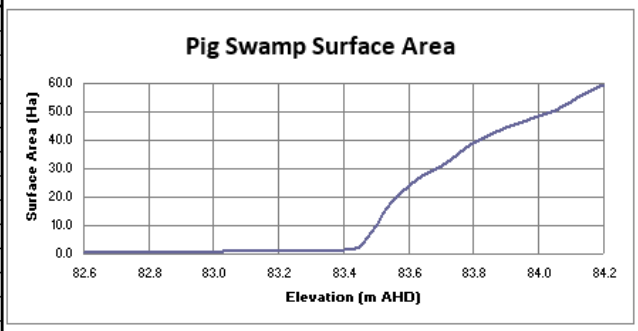
MAy 2011

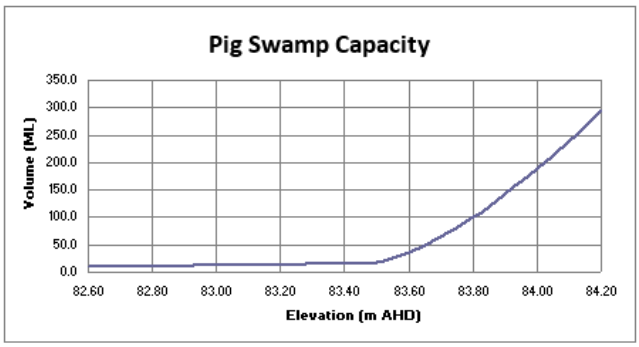
Produced by Wes Pye (Northern Land Solutions, Swan Hill)

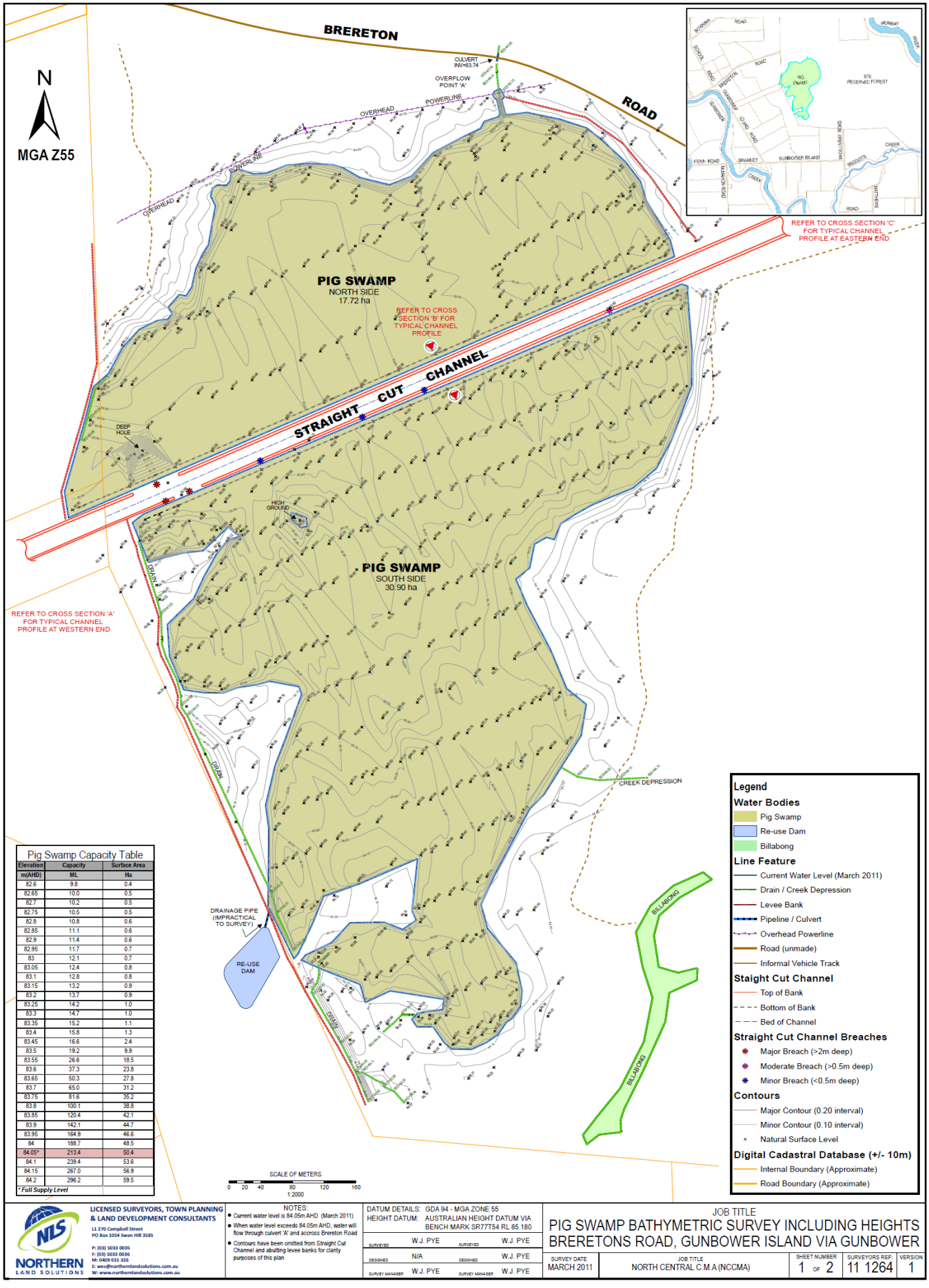
DATUM DETAILS: GDA 94 - MGA ZONE 55
HEIGHT DATUM: AUSTRALIAN HEIGHT DATUM VIA
BENCH MARK SR77T54 RL 85.180
Water level is 84.05m AHD (March 2011), when water level exceeds 84.05m AHD, water will flow through culvert 'A' and accross Brereton Road

Base Level (AHD) 82.6
FSL (AHD) 84.05 (Estimate)

Elevation	Capacity	Surface Area
m(AHD)	ML	Ha
82.60	9.8	0.4
82.65	10.0	0.5
82.70	10.2	0.5
82.75	10.5	0.5
82.80	10.8	0.6
82.85	11.1	0.6
82.90	11.4	0.6
82.95	11.7	0.7
83.00	12.1	0.7
83.05	12.4	0.8
83.10	12.8	0.8
83.15	13.2	0.9
83.20	13.7	0.9
83.25	14.2	1.0
83.30	14.7	1.0
83.35	15.2	1.1
83.40	15.8	1.3
83.45	16.6	2.4
83.50	19.2	9.9
83.55	26.6	18.5
83.60	37.3	23.8
83.65	50.3	27.8
83.70	65.0	31.2
83.75	81.6	35.2
83.80	100.1	38.8
83.85	120.4	42.1
83.90	142.1	44.7
83.95	164.9	46.6
84.00	188.7	48.5
84.05	213.4	50.4
84.10	239.4	53.6
84.15	267.0	56.9
84.20	296.2	59.5







Pig Swamp Capacity Table

Elevation m(AHD)	Capacity ML	Surface Area Ha
82.6	9.8	0.4
82.65	10.0	0.5
82.7	10.2	0.5
82.75	10.5	0.5
82.8	10.8	0.6
82.85	11.1	0.6
82.9	11.4	0.6
82.95	11.7	0.7
83	12.1	0.7
83.05	12.4	0.8
83.1	12.8	0.8
83.15	13.2	0.9
83.2	13.7	0.9
83.25	14.2	1.0
83.3	14.7	1.0
83.35	15.2	1.1
83.4	15.8	1.3
83.45	16.6	2.4
83.5	19.2	9.9
83.55	26.6	18.5
83.6	37.3	23.8
83.65	50.3	27.8
83.7	65.0	31.2
83.75	81.6	35.2
83.8	100.1	38.8
83.85	120.4	42.1
83.9	142.1	44.7
83.95	164.9	46.6
84	188.7	48.5
84.05*	213.4	50.4
84.1	239.4	53.6
84.15	267.0	56.9
84.2	296.2	59.5

*Full Supply Level

Legend
- Water Bodies: Pig Swamp; Re-use Dam; Billabong
- Line Feature: Current Water Level (March 2011); Drain / Creek Depression; Levee Bank; Pipeline / Culvert; Overhead Powerline; Road (unmade); Informal Vehicle Track
- Staight Cut Channel: Top of Bank; Bottom of Bank; Bed of Channel
- Straight Cut Channel Breaches: Major Breach (>2m deep); Moderate Breach (>0.5m deep); Minor Breach (<0.5m deep)
- Contours: Major Contour (0.20 interval); Minor Contour (0.10 interval); Natural Surface Level
- Digital Cadastral Database (+/- 10m): Internal Boundary (Approximate); Road Boundary (Approximate)

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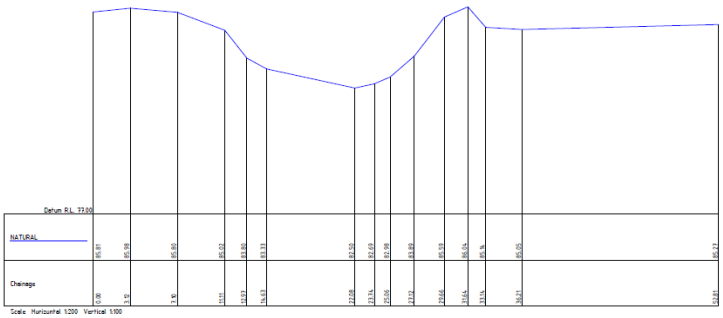
NOTES:
- Current water level is 84.05m AHD (March 2011)
- When water level exceeds 84.05m AHD, water will flow through culvert 'A' and accross Brereton Road
- Contours have been omitted from Straight Cut Channel and abutting levee banks for clarity purposes of this plan

DATUM DETAILS: GDA 94 - MGA ZONE 55
HEIGHT DATUM: AUSTRALIAN HEIGHT DATUM VIA BENCH MARK SR77T54 RL 85.180

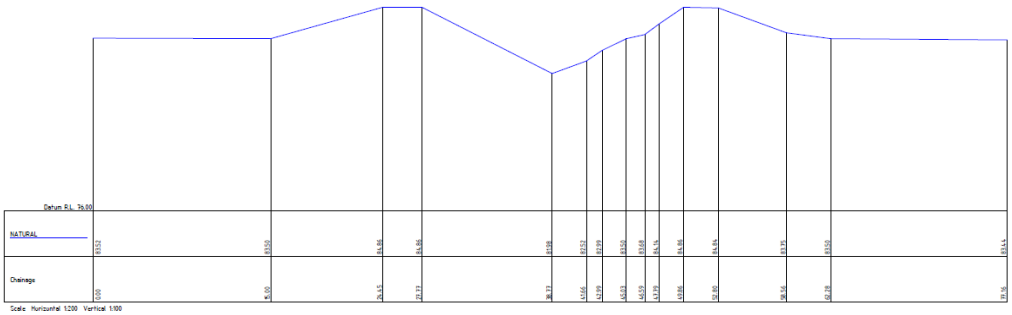
SURVEYED	W.J. PYE	SURVEYED	W.J. PYE
DESIGNED	N/A	DESIGNED	W.J. PYE
SURVEY MANAGER	W.J. PYE	SURVEY MANAGER	W.J. PYE

JOB TITLE
PIG SWAMP BATHYMETRIC SURVEY INCLUDING HEIGHTS BRERETONS ROADS, GUNBOWER ISLAND VIA GUNBOWER

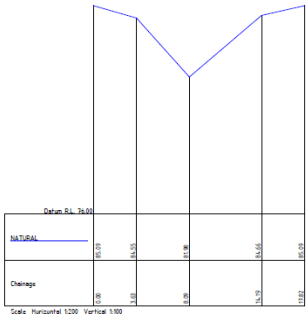
SURVEY DATE	JOB TITLE	SHEET NUMBER	SURVEYORS REF:	VERSION
MARCH 2011	NORTH CENTRAL C.M.A (NCCMA)	1 OF 2	11 1264	1



CROSS SECTION 'C'
FACING DOWN STREAM



CROSS SECTION 'B'
FACING DOWN STREAM



CROSS SECTION 'A'
FACING DOWN STREAM

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W: www.northernlandsolutions.com.au
NORTHERN LAND SOLUTIONS

NOTES:
- Current water level is 84.05m AHD (March 2011)
- Channel cross sections are approximate only and have been modelled by interpolation
- Channel cross sections are plotted facing down stream

DATUM DETAILS: GDA 94 - MGA ZONE 55
HEIGHT DATUM: AUSTRALIAN HEIGHT DATUM VIA BENCH MARK SR77T54 RL 85.180

SURVEYED	W.J. PYE	SURVEYED	W.J. PYE
DESIGNED	N/A	DESIGNED	W.J. PYE
SURVEY MANAGER	W.J. PYE	SURVEY MANAGER	W.J. PYE

JOB TITLE
STRAIGHT CUT CHANNEL CROSS SECTIONS
BRERETONS ROAD, GUNBOWER ISLAND VIA GUNBOWER

SURVEY DATE	JOB TITLE	SHEET NUMBER	SURVEYORS REF.	VERSION
MARCH 2011	NORTH CENTRAL C.M.A (NCCMA)	2 OF 2	11 1264	1

Appendix D: Wetland characteristics

Characteristics	Description
Wetland name	Pig Swamp
Wetland ID	7726 662208
Wetland area	Approx 50 ha
Conservation status	Ramsar Wetland and Directory of Important Wetland
Land manager	Parks Victoria Gunbower National Park (986.31ha), (VEAC Recommendation, 2009)
Surrounding land use	East private land (irrigated agriculture) West: National Park
Water supply	Natural: Dry Tree/Baggots Creek 1970s to 2015 (blocked in 2007): Torrumbarry Irrigation System – Straight Cut Channel • 300 ECl • Capacity of 50-60ML/day
1788 Wetland Classification	Category: Shallow freshwater marsh (<8 months duration, <0.5m depth) Sub-category: n/a
1994 Wetland Classification	Category: Shallow freshwater marsh Sub-categories: red gum, dead timber
Wetland capacity	Full Supply Level: Variable: 84.05 mAHD; Volume: 213 ML
Influence of Straight Cut Channel	The wetland was filled to 84.00mAHD (where it remained for 10-15% of the time) from 15 August fluctuating to the lower level of 83.90 mAHD over the irrigation season until 15 May. Over the winter period (16 May to 14 August) the wetland retreated to a puddle of water, approximately 10ha (83.5mAHD).

Appendix E: Flora and fauna species list

Compiled: May 2011

Sources:

Bogenhuber and Campbell (2011)

Data Source: 'Threatened Fauna 100' © The State of Victoria, Department of Sustainability and Environment.

Data Source: 'Threatened Flora 100' © The State of Victoria, Department of Sustainability and Environment.

Data Source: 'Aquatic Fauna Database', Copyright - The State of Victoria, Department of Sustainability and Environment.

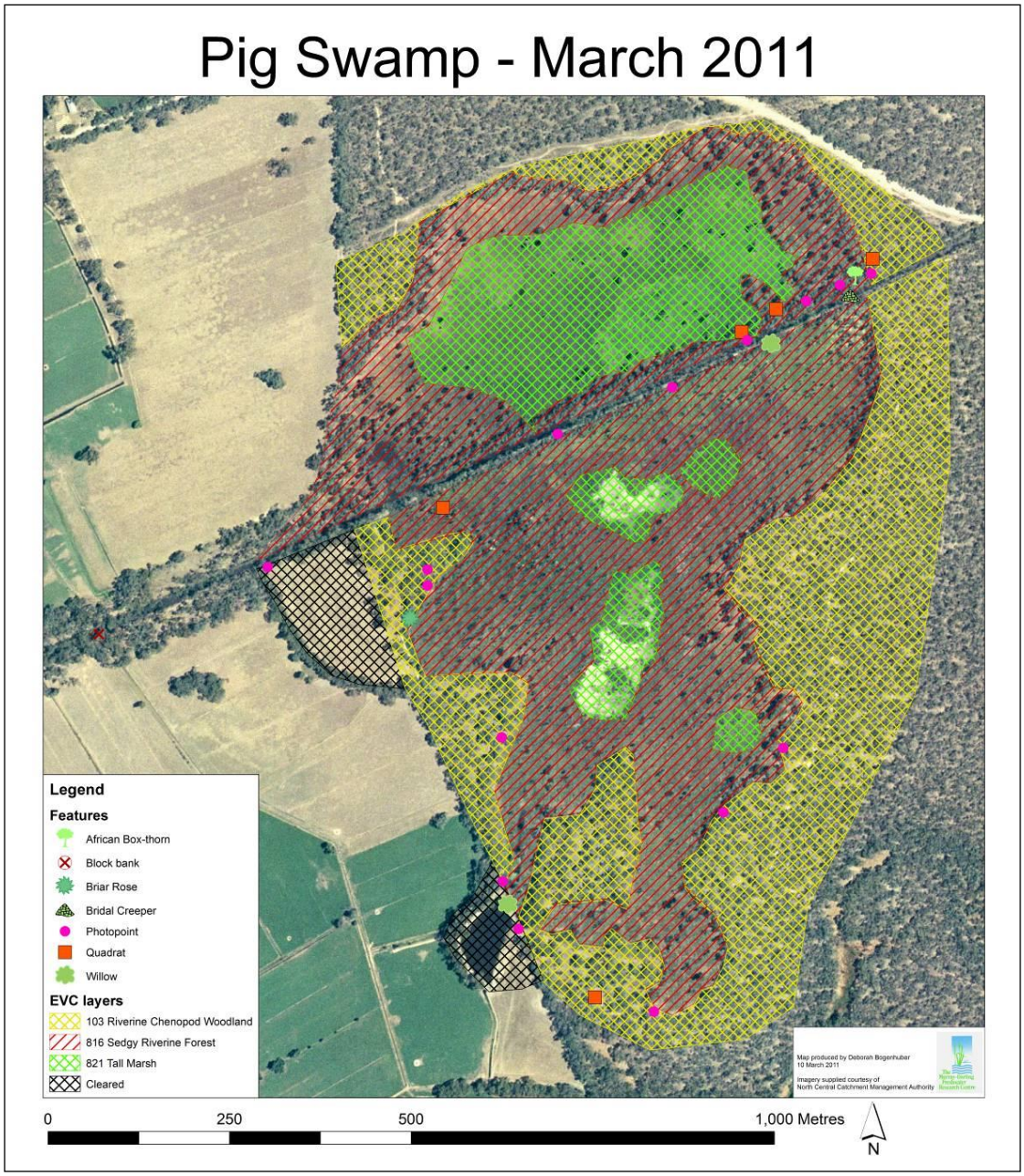
Common Name	Scientific Name	Origin	Last record
Flora species			
Gold-dust Wattle	*Acacia acinacea*		3/03/2011
Lesser Joyweed	*Alternanthera denticulata*		3/03/2011
Bridal Creeper	*Asparagus asparagoides*	*	3/03/2011
Berry Saltbush	*Atriplex semibaccata*		3/03/2011
Sprawling Saltbush	*Atriplex suberecta*		3/03/2011
Common Wallaby-grass	*Austrodanthonia caespitosa*		3/03/2011
Bristly Wallaby-grass	*Austrodanthonia setacea*		3/03/2011
Rough Spear-grass	*Austrostipa scabra*		3/03/2011
Wild Oats	*Avena fatua*	*	3/03/2011
Woodland Swamp-daisy	*Brachyscome basaltica* var. *gracilis*		3/03/2011
Poong'ort	*Carex tereticaulis*		3/03/2011
Common Sneezeweed	*Centipeda cunninghamii*		3/03/2011
Clammy Goosefoot	*Chenopodium pumilio*		3/03/2011
Chicory	*Cichorium intybus*	*	3/03/2011
Spear Thistle	*Cirsium vulgare*	*	3/03/2011
Fleabane	*Conyza sp.*	*	3/03/2011
Common Cotula	*Cotula australis*		3/03/2011
Drain Flat-sedge	*Cyperus eragrostis*	*	3/03/2011
Star Fruit	*Damasonium minus*		3/03/2011
Einadia	*Einadia nutans*		3/03/2011
Einadia	*Einadia nutans* subsp. *linifolia***		3/03/2011
Lax Goosefoot	*Einadia trigonos* subsp. *trigonos*^		3/03/2011
Common Spike-sedge	*Eleocharis acuta*^		3/03/2011
Small Spike-sedge	*Eleocharis pusilla*		3/03/2011
Tall Spike-sedge	*Eleocharis sphacelata*		3/03/2011
Common Wheat-grass	*Elymus scaber*		3/03/2011
Ruby Saltbush	*Enchylaena tomentosa*		3/03/2011
River Red Gum	*Eucalyptus camaldulensis*		3/03/2011
Black Box	*Eucalyptus largiflorens*		3/03/2011
Annual Cudweed	*Euchiton sphaericus*		3/03/2011
Cherry Ballart	*Exocarpus cupressiformis*^		3/03/2011
Cleavers	*Galium aparine*	*	3/03/2011
Spreading Goodenia	*Goodenia heteromera*		3/03/2011
Raspwort	*Haloragis sp.*		3/03/2011
Common Heliotrope	*Heliotropium europaeum*	*	3/03/2011
Ox-tongue	*Helminthotheca echioides*^	*	3/03/2011
Barley-grass	*Hordeum sp.*	*	3/03/2011
Cat's Ear	*Hypochaeris radicata*	*	3/03/2011

Common Name	Scientific Name	Origin	Last record
Finger Rush	*Juncus subsecundus*^		3/03/2011
Common Blown-grass	*Lachnagrostis filiformis*		3/03/2011
Prickly Lettuce	*Lactuca serriola*	*	3/03/2011
Duckweed	*Lemna sp.*		3/03/2011
Common Peppercress	*Lepidium africanum*	*	3/03/2011
Clove-strip	*Ludwigia peploides* subsp. *montevidensis*		3/03/2011
African Box-thorn	*Lycium ferocissimum*	*	3/03/2011
Small Loosestrife	*Lythrum hyssopifolia*		3/03/2011
Short-leaf Bluebush	*Maireana brevifolia*		3/03/2011
Mallow	*Malva sp.*		3/03/2011
Common Nardoo	*Marsilea drummondii*		3/03/2011
Tangled Lignum	*Muehlenbeckia florulenta*		3/03/2011
Scotch Thistle	*Onopordum acanthium* subsp. *acanthium*	*	3/03/2011
Sorrel	*Oxalis sp.*		3/03/2011
Paspalum	*Paspalum dilatatum*	*	3/03/2011
Water Couch	*Paspalum distichum*	*	3/03/2011
Slender Knotweed	*Persicaria decipiens*		3/03/2011
Pale Knotweed	*Persicaria lapathifolia*		3/03/2011
Plantain	*Plantago sp.*		3/03/2011
Prostrate Knotweed	*Polygonum aviculare*	*	3/03/2011
Poison Pratia	*Pratia concolor*		3/03/2011
Sweet Briar	*Rosa rubiginosa*	*	3/03/2011
Curled Dock	*Rumex crispus*	*	3/03/2011
Narrow-leaf Dock	*Rumex tenax*		3/03/2011
Willow	*Salix sp.*	*	3/03/2011
Prickly Saltwort	*Salsola tragus*		3/03/2011
Club-sedge	*Schoenoplectus sp.*		3/03/2011
Two-spined Copperburr	*Sclerolaena uniflora*		3/03/2011
Cotton Fireweed	*Senecio quadridentatus*		3/03/2011
Tall Fireweed	*Senecio runcinifolius*		3/03/2011
	Senecio sp.		3/03/2011
	Senecio sp. 1315		3/03/2011
Black Nightshade	*Solanum nigrum*	*	3/03/2011
Nightshade	*Solanum sp.*		3/03/2011
Sand-spurrey	*Spergularia rubra*	*	3/03/2011
Grey Germander	*Teucrium racemosum*		3/03/2011
Kangaroo Grass	*Themeda triandra*		3/03/2011
Clover	*Trifolium sp.*	*	3/03/2011
Water Ribbons	*Triglochin procera*		3/03/2011
Cumbungi	*Typha spp.*		3/03/2011
Nettle	*Urtica sp.*		3/03/2011
Verbena	*Verbena litoralis*	*	3/03/2011
New Holland Daisy	*Vittadinia sp.*		3/03/2011
River Bluebell	*Wahlenbergia fluminalis*		3/03/2011
Bathurst Burr	*Xanthium spinosum*	*	3/03/2011
Golden Everlasting	*Xerochrysum bracteatum*		3/03/2011
Fauna - Birds			
Australasian Bittern	*Botaurus poiciloptilus*		13/12/1993
Australian Magpie	*Gymnorhina tibicen*		28/03/2007
Australian Raven	*Corvus coronoides*		30/03/2007

Common Name	Scientific Name	Origin	Last record
Australian Shelduck	*Tadorna tadornoides*		12/05/1993
Australian White Ibis	*Threskiornis molucca*		12/05/1993
Azure Kingfisher	*Alcedo azurea*		3/03/2011
Black-faced Cuckoo-shrike	*Coracina novaehollandiae*		28/03/2007
Brown Treecreeper (south-eastern ssp.)	*Climacteris picumnus victoriae*		29/03/2007
Brown-headed Honeyeater	*Melithreptus brevirostris*		30/03/2007
Clamorous Reed Warbler	*Acrocephalus stentoreus*		13/12/1993
Common Bronzewing	*Phaps chalcoptera*		28/03/2007
Crested Pigeon	*Ocyphaps lophotes*		28/03/2007
Crested Shrike-tit	*Falcunculus frontatus*		29/03/2007
Dusky Moorhen	*Gallinula tenebrosa*		27/03/2007
Dusky Woodswallow	*Artamus cyanopterus*		28/03/2007
Eurasian Coot	*Fulica atra*		13/12/1993
European Goldfinch	*Carduelis carduelis*	*	29/03/2007
Galah	*Eolophus roseicapilla*		29/03/2007
Grey-crowned Babbler	*Pomatostomus temporalis temporalis*		21/02/2011
Grey Fantail	*Rhipidura albiscarpa*		29/03/2007
Grey Shrike-thrush	*Colluricincla harmonica*		30/03/2007
Grey Teal	*Anas gracilis*		28/03/2007
Hooded Robin	*Melanodryas cucullata cucullata*		28/03/2007
Jacky Winter	*Microeca fascinans*		29/03/2007
Laughing Kookaburra	*Dacelo novaeguineae*		28/03/2007
Little Corella	*Cacatua sanguinea*		30/03/2007
Little Grassbird	*Megalurus gramineus*		13/12/1993
Little Pied Cormorant	*Microcarbo melanoleucos*		28/03/2007
Little Raven	*Corvus mellori*		30/03/2007
Magpie-lark	*Grallina cyanoleuca*		28/03/2007
Masked Lapwing	*Vanellus miles*		29/03/2007
Noisy Miner	*Manorina melanocephala*		28/03/2007
Pacific Black Duck	*Anas superciliosa*		28/03/2007
Pallid Cuckoo	*Cuculus pallidus*		13/12/1993
Peaceful Dove	*Geopelia striata*		28/03/2007
Pied Butcherbird	*Cracticus nigrogularis*		29/03/2007
Purple Swamphen	*Porphyrio porphyrio*		29/03/2007
Red-browed Finch	*Neochmia temporalis*		28/03/2007
Red-rumped Parrot	*Psephotus haematonotus*		29/03/2007
Restless Flycatcher	*Myiagra inquieta*		28/03/2007
Sacred Kingfisher	*Todiramphus sanctus*		28/03/2007
Southern Boobook	*Ninox novaeseelandiae*		13/12/1993
Straw-necked Ibis	*Threskiornis spinicollis*		28/03/2007
Striated Pardalote	*Pardalotus striatus*		28/03/2007
Sulphur-crested Cockatoo	*Cacatua galerita*		29/03/2007
Superb Fairy-wren	*Malurus cyaneus*		30/03/2007
Swamp Harrier	*Circus approximans*		13/12/1993
Tawny Frogmouth	*Podargus strigoides*		29/03/2007
Wedge-tailed Eagle	*Aquila audax*		29/03/2007
Weebill	*Smicrornis brevirostris*		30/03/2007

Common Name	Scientific Name	Origin	Last record
Welcome Swallow	*Hirundo neoxena*		28/03/2007
Western Gerygone	*Gerygone fusca*		13/12/1993
Whistling Kite	*Haliastur sphenurus*		29/03/2007
White-browed Babbler	*Pomatostomus superciliosus*		29/03/2007
White-browed Scrubwren	*Sericornis frontalis*		28/03/2007
White-necked Heron	*Ardea pacifica*		28/03/2007
White-plumed Honeyeater	*Lichenostomus penicillatus*		30/03/2007
White-throated Treecreeper	*Cormobates leucophaeus*		29/03/2007
White-winged Chough	*Corcorax melanorhamphos*		29/03/2007
Willie Wagtail	*Rhipidura leucophrys*		28/03/2007
Fauna - Amphibians			
Barking Marsh Frog	*Limnodynastes fletcheri*		3/03/2011
Common Froglet	*Crinia signifera*		29/03/2007
Peron's Tree Frog	*Litoria peronii*		29/03/2007
Plains Froglet	*Crinia parinsignifera*		30/03/2007
Pobblebonk Frog	*Limnodynastes dumerilii dumerilii*		28/03/2007
Spotted Marsh Frog (race unknown)	*Limnodynastes tasmaniensis*		27/09/1982
Fauna - Reptiles			
Lace Goanna	*Varanus varius*		15/11/1998
Unidentified Skink	*Egernia sp.*		30/03/2007
Fauna - Fish			
Carp	*Cyprinus carpio*	*	28/03/2007
Gambusia	*Gambusia holbrooki*	*	30/03/2007
Fauna - Mammals			
Black Wallaby	*Wallabia bicolor*		29/03/2007
Common Brushtail Possum	*Trichosurus vulpecula*		29/03/2007
Common Ringtail Possum	*Pseudocheirus peregrinus*		29/03/2007
Eastern Grey Kangaroo	*Macropus giganteus*		28/03/2007
European Rabbit	*Oryctolagus cuniculus*	*	28/03/2007
Platypus	*Ornithorhynchus anatinus*		27/03/2007
Red Fox	*Vulpes vulpes*	*	29/03/2007
Water Rat	*Hydromys chrysogaster*		29/03/2007
Yellow-footed Antechinus	*Antechinus flavipes*		28/03/2007

Appendix F: Vegetation composition map – 3 March 2011



Appendix G: Hydrology (SWET output)

Surface water balance

A daily surface water balance has been modelled as part of the development of the EWP in order to define the hydrological attributes of Pig Swamp. Modelling the daily water balance enables managers to quantify the volumes required in providing the desired water regime. It also allows for consideration of variability in climatic conditions and wetland phase.

The model used is a simplified version of the Savings at Wetlands from Evapotranspiration daily Time-Series (SWET) (Gippel 2005a, Gippel 2005b, Gippel 2005c). This model has been approved by the Murray Darling Basin Authority for estimating the wetland surface water balance. The main components of the model are discussed in brief (following). This information is utilised for the estimation of volumes required for the desired water regime (Section 5.3). For Pig Swamp, the SWET model was utilised to calculate the volume of water that left the irrigation channel in order to maintain the water level in the wetland.

The model has quantified the hydrology of the wetland under two scenarios:

1. Watering regime prior to 2007

   The wetland was filled to 84.0 mAHD from 15 August, fluctuating over the irrigation season until 15 May. Over the winter period the wetland retreated to 83.5 mAHD, refer to Section 4.3.1.

2. Recommended environmental watering regime

   Fill wetland to FSL (84.05 mAHD) in Winter/Spring, 2 in 5 years, for a duration at FSL of 3 to 6 months, refer to Section 5.3.

The main components of the model are:

- **Time Series:** the daily time step is set up to run from July 1895 to June 2011 (inclusive).
- **Wetland capacity:** volume required to fill the wetland to the targeted supply level, (i.e. Pig Swamp filled to 84.05 m AHD equates to 213 ML (Northern land Solutions 2011). The lowest level in the capacity table was 82.6 m AHD, but at this level the surface area is 0.4 ha and volume 9.8 ML, therefore it was assumed that the lowest depth was 82.5 m AHD.
- **Infiltration:** the water balance model included an initial loss component. A porosity value of 0.25 was assumed, which means that upon drying, 25 percent of the bed is void space that could fill with water. A bed thickness of 0.3 m was assumed. These are arbitrary values that together represent the storage capacity of the dry bed upon initial wetting. These parameter values could be improved with calibration.
- **Rainfall/runoff:** this includes rainfall directly falling onto the wetland and surface run-off. Surface water inflows/run-off: an average volumetric figure of 0.1 ML/ha/year and a local catchment area of 40 ha were applied.
- **Climate data:** from SILO DataDrill specific to the wetland area including wind data (Bureau of Meteorology)
- **Evaporation data:** a modelled approach (combination of the Penman-Monteith method with a deBruin adjustment; recommended by the CSIRO) to assess evaporation at the wetland has been incorporated into the water balance (McJannet *et al.* 2009).
- **Murray River contribution:** uncontrolled flow entered Pig Swamp from the Murray River when the flow at Downstream of Torrumbarry gauge exceeded 50,000 ML/day.
- **Water Regime prior to 2007:** the water level time series for Gunbower Lagoon was simulated by first generating the water regime defined (84.0 m AHD from 15 August to 15 May and 83.5 m AHD the rest of the time). A random function was applied to produce the defined fluctuations in level. The simulated Upper Gunbower Creek time

series was assumed to apply also to the Straight Cut Channel, with the modification to account for the effect of pumping.

Daily pumping volumes for the 2004-05 season were modelled which predicted 135 days of pumping in the 2004-05 season, when pumping actually occurred on 136 days. This model was then applied to a daily rainfall series from 1895 to 2009, to simulate daily pumping volumes. The simulated pumping volume data were applied to the simulated Straight Cut Channel water level series converting the water levels in the channel to water volumes through a bathymetric relationship based on channel cross-sections, Appendix C (Northern Land Solutions 2011).

Please note:

- *Groundwater is not included in the model. Previous experience with wetland water balance modelling suggests that the contribution of groundwater to the total water budget is likely to be small (i.e. <5%). This is explained by the relatively impervious nature of the ground, when compared with the high rate of water transfer that is possible in the air (rainfall and evaporation) and the surface (runoff and inflows)* (Gippel, 2011).

The modelling produces a range of volumes required to operate the wetland in accordance with the defined scenarios. The modelling results for Pig Swamp are presented in Sections 4.2.1 and 5.3.

Predicted annual water use for two management scenarios in Pig Swamp (Gippel 2011)

Year	Desired water regime scenario (ML)	Pre-2007 scenario net loss (ML)	Water saving for each year (ML)	Water saving relative to 2004/05 (ML)	Year	Desired water regime scenario (ML)	Pre-2007 scenario net loss (ML)	Water saving for each year (ML)	Water saving relative to 2004/05 (ML)
1896	343	505	162	111	1953	0	253	253	455
1897	0	508	508	455	1954	308	352	45	147
1898	0	510	510	455	1955	0	327	327	455
1899	494	462	-33	-39	1956	225	269	44	230
1900	0	488	488	455	1957	0	188	188	455
1901	501	525	24	-46	1958	0	474	474	455
1902	0	525	525	455	1959	325	337	12	129
1903	0	478	478	455	1960	0	393	393	455
1904	433	390	-44	21	1961	326	417	91	129
1905	0	446	446	455	1962	0	435	435	455
1906	472	412	-60	-17	1963	0	439	439	455
1907	0	395	395	455	1964	466	517	50	-12
1908	0	515	515	455	1965	0	552	552	455
1909	500	432	-68	-45	1966	492	487	-5	-38
1910	0	371	371	455	1967	0	439	439	455
1911	445	299	-146	9	1968	0	487	487	455
1912	0	539	539	455	1969	181	402	220	273
1913	0	441	441	455	1970	0	389	389	455
1914	503	525	22	-49	1971	442	399	-42	13
1915	0	513	513	455	1972	0	342	342	455
1916	439	468	29	16	1973	0	373	373	455
1917	0	362	362	455	1974	232	232	-1	222
1918	0	229	229	455	1975	0	314	314	455
1919	176	400	225	279	1976	273	388	116	182
1920	0	521	521	455	1977	0	466	466	455
1921	348	318	-30	107	1978	0	506	506	455
1922	0	453	453	455	1979	434	445	10	20
1923	0	475	475	455	1980	0	431	431	455
1924	452	404	-48	3	1981	520	508	-12	-65
1925	0	315	315	455	1982	0	394	394	455
1926	509	454	-55	-55	1983	0	554	554	455
1927	0	531	531	455	1984	362	389	27	93
1928	0	423	423	455	1985	0	502	502	455
1929	527	505	-21	-72	1986	420	445	25	35
1930	0	514	514	455	1987	0	426	426	455
1931	403	304	-99	52	1988	0	471	471	455
1932	0	305	305	455	1989	435	396	-39	20
1933	0	400	400	455	1990	0	484	484	455
1934	385	378	-7	70	1991	455	456	1	0
1935	0	429	429	455	1992	0	471	471	455
1936	393	382	-11	61	1993	0	302	302	455
1937	0	436	436	455	1994	322	351	29	132
1938	0	516	516	455	1995	0	510	510	455
1939	563	476	-87	-109	1996	338	470	131	116
1940	0	489	489	455	1997	0	334	334	455
1941	537	480	-57	-82	1998	0	518	518	455
1942	0	458	458	455	1999	482	442	-39	-27
1943	0	499	499	455	2000	0	451	451	455
1944	517	501	-16	-63	2001	503	509	6	-48
1945	0	531	531	455	2002	0	572	572	455
1946	491	411	-80	-36	2003	0	615	615	455
1947	0	482	482	455	2004	476	511	35	-22
1948	0	377	377	455	2005	0	455	455	455
1949	450	393	-57	4	2006	508	522	14	-53
1950	0	296	296	455	2007	0	588	588	455
1951	417	383	-34	38	2008	0	595	595	455
1952	0	445	445	455	2009	520	542	22	-65

Appendix H: Additional risks and limiting factors

The following risks are to be managed by the relevant organisations and agencies as stipulated through their current roles and as is legislated.

Risks/limiting factors	Impacts	Mitigation measures
Delivery of Water		
Limited water availability (e.g. insufficient or no environmental water allocation)	Failure to achieve identified objectives and water management goal	The watering regime includes optimum, minimum and maximum watering times. If limited water is available, a longer drying phase may be required.
Climatic variability	Variability in water availability (e.g. wet seasons during a planned dry phase)	Adaptive management of water regime and delivery options as above. Re-model volumes (SWET modelling) required in light of changing climatic conditions and wetland phase.
Poor water quality (i.e. temperature fluctuations, blackwater events, high turbidity, salinity and nutrient levels)	Reduced primary production (turbid water), limiting food resources for aquatic invertebrates and waterbirds.	Adaptively manage water regime and delivery.
	Encroachment of nutrient tolerant vegetation *Typha* sp.	
	Excessive algal growth	
Lack of connection between wetland, river and floodplain	Altered flow regime (continued lack of flood flows)	Investigate opportunities to remove additional sections of the Straight Cut Channel banks to improve floodwater distribution northwards. Investigate influence of Brereton Rd and access need
Irrigation drainage	Impact to water quality in the wetland	The irrigation drainage is currently small, however water quality monitoring (Appendix I) will be undertaken to assess any impact.

Ecological Response		
Unreliable supply of food/nesting sites	Limited occurrences of waterbirds	Seasonal water delivery, regular monitoring and adaptive management of water regime to ensure suitable habitat is provided throughout the breeding event (Section 8 and Appendix I).
Encroachment or dominance of native flora species: e.g. Monoculture of *Typha* sp.	Loss in species diversity	Active management (spraying, slashing, crash grazing etc)
	Habitat loss	
	Watering events prove unproductive for waterbirds	Seasonal water delivery, regular monitoring and adaptive management of water regime (Section 8 and Appendix I)
Proliferation of invasive plants and animals	Reduced habitat and resource availability	Regular monitoring, active management (invasive plant and animal control) (Section 8 and Appendix I)
	Predation	
	Limited establishment of native vegetation	
Lack of seedbank viability	Emergence of unexpected exotic species	Monitoring (e.g. IWC) and adaptive management (Section 8 and Appendix I). Fluctuation of water levels will be required to support River Red Gum germination.
	Restricted regeneration	
Other		
Fire	Habitat and resource loss	Active management, monitoring (e.g. IWC) and adaptive management (Section 8 and Appendix I)
	Deteriorating water quality	

Appendix I: Monitoring program recommendations

It is not a requirement of the GMW Connections Project to provide long-term condition or intervention monitoring nor does this document represent a comprehensive management plan for Pig Swamp. However, recommendations have been made below for variables to be monitored in order to assess the response to the provision of the desired water regime and inform its adaptive management.

1. Long term condition monitoring

Long term condition monitoring is recommended in order to evaluate any changes to wetland values (particularly vegetation and groundwater) over time. It should be noted that condition monitoring is recommended to be conducted in conjunction with intervention monitoring to comprehensively evaluate any changes to Pig Swamp.

Vegetation condition and distribution

A number of photo points and objectives for long term vegetation monitoring need to be established at Pig Swamp to enable the assessment of changes in wetland condition over time. It is recommended that photos are taken from these points, facing the same direction, on a yearly basis to capture vegetation condition and distribution. Fourteen photopoints were established in March 2011 (see Appendix F) and these would be a useful baseline data set. It is recommended that a database be compiled in order to store details of the monitoring photos captured.

It is also recommended that the condition and distribution of vegetation communities, including exotic species, throughout Pig Swamp, are assessed every five years. A condition assessment of Pig Swamp using the statewide Index of Wetland Condition (IWC) method was conducted as part of this project in March 2011. The IWC not only provides useful information on the condition and distribution of vegetation but also highlights indicators of altered processes (threatening processes). It is recommended that an IWC assessment be completed for Pig Swamp every 5 years.

In addition, information on vegetation communities gathered on aerial photography during this project has been digitised and is available in a GIS format to enable comparison in distribution over time (distribution mapping) (Baldwin *et al*. 2005).

Surface water monitoring

Surface water gauges need to be installed at Pig Swamp to monitor the water level over time. Environmental watering events should be reviewed in an attempt to report on the volume, timing, inundation depth and duration of wetland watering.

Groundwater monitoring

Long term monitoring of groundwater within the immediate vicinity of Pig Swamp is currently conducted by DEDJTR (Section 4.3). It is recommended that this monitoring continue in order to identify any potential risks associated with the delivery of the desired water regime and for consideration in adaptive management.

It is recommended that the environmental monitoring plan to be prepared for the wetland includes a groundwater monitoring component setting out the monitoring objectives, the linkages with other monitoring programs, the monitoring approach, and the reporting and review process.

Table I1 identifies additional recommendations for improving the long-term groundwater monitoring at Pig Swamp and to enhance the quality of data being collected (Bartley Consulting 2011).

Table I1: Additional groundwater monitoring recommendations (Bartley Consulting 2011)

Target	Recommendation
Long-term groundwater monitoring	A review of the groundwater-related aspects of the site, including a re-assessment of environmental risks, is undertaken at least every seven years and sooner if the watering regime is changed or regional groundwater levels rise.
	The impact of any watering regime change is reviewed and assessed in

Target	Recommendation
	accordance with the requirements of the environmental monitoring plan, and subject to the availability of suitable data should include an appraisal of the movement of the wetting front and salt, impacts on surrounding groundwater levels and neighbouring land, and a water budget that includes estimates of accessions to groundwater.
Data quality	Installing data loggers within the wetland and in selected groundwater bores, to provide data before watering and throughout the wetting and drying cycle at the site.
	Establishing a surface water level gauge, and use volume rating tables to assist recording level and volume, to verify support the surface water data logger readings.
Breadth of data collected	Regular liaison with neighbouring landholders to understand their water use and irrigation practices, and how these change over time.
	Installation of shallow and deep (to approximately 10 m and 20 m) groundwater monitoring bores, at two locations adjacent the site.
	Assessing the watertable depth and soil and salinity profile beneath the lowest part of the site floor.

2. Intervention Monitoring

Monitoring the response of key environmental values to the provision of water is imperative in informing adaptive management of the desired water regime. Monitoring will also assess the success of implementation, the achievement of ecological objectives and the progress towards achieving the water management goal outlined in Section 5.

It is essential that analysis of monitoring results is regularly undertaken in order to develop an understanding of changes occurring at the wetland.

Vegetation

Following the provision of water it is important that the response of vegetation is monitored. A number of previous surveys and records are available to provide baseline data in order to evaluate any response. Seasonal monitoring is recommended to inform the adaptive management program (Section 8) and snapshot assessments should incorporate the components outlined in Table I2. A database of any previous flora records has been compiled for Pig Swamp and should be updated following regular monitoring.

Table I2: Components of vegetation intervention monitoring

Component	Target	Method	Objective
Vegetation distribution	Sedgy Riverine Forest/River Red Gum/Tall Marsh/open water mosaic	• Distribution mapping • Photo points	Habitat objectives 1.1, 1.2 and 1.3, Species/community objective 2.1
Vegetation condition		• Photo points	Habitat objectives 1.1, 1.2 and 1.3,
Species diversity	Additional species with a focus on aquatic and amphibious species	• Species list comparison	Habitat objectives 1.1, 1.2 and 1.3, Species/community objective 2.1

Waterbirds

The diversity and abundance of waterbirds at Pig Swamp needs to be monitored following watering for the duration of the inundation period in order to assess the success of implementation and achievement of objectives. It is essential that commentary on abundance and breeding events informs the adaptive management of the delivered water regime.

Monthly monitoring as water levels fluctuate will ensure changes in bird communities are captured (Baldwin *et al*. 2005). It is essential that spring surveys are conducted to inform the adaptive management of the water regime. A database is required to compile recordings

made at Pig Swamp, and this should be updated regularly following monitoring. Table I3 outlines the recommended components of waterbird monitoring.

Table I3: Components of intervention monitoring of waterbirds

Component	Target	Method	Objective
Species diversity	All species including those of conservation significance	• Area searches (Baldwin *et al*. 2005)	Habitat objective 2.2
Waterbird abundance			Habitat objective 2.2
Habitat availability	Sedgy Riverine Forest/River Red Gum/Tall Marsh/open water mosaic	• Undertaken in conjunction with vegetation monitoring	Habitat objective 2.2
Breeding populations	Opportunistic bird breeding	• Nest surveys (Baldwin *et al*. 2005)	No objective

Grey-crowned Babblers are also present at Pig Swamp and should be monitored over time. Any other incidental observations of fauna including mammals, reptiles, amphibians and terrestrial birds in the vicinity of the wetland should be recorded.

Frogs, Fish and Macroinvertebrates

It is recommended that the response of frogs, fish and macroinvertebrates is monitored following watering. A database is required to compile recordings made at Pig Swamp, and this should be updated regularly following monitoring. Table I4 details the components to be incorporated in monitoring fish and macroinvertebrates. Incidental observations of reptiles should also be recorded.

The results of the monitoring should also be used to inform the assessment of habitat availability for waterbirds as they provide a significant food source for a number of species.

Table I4: Components of intervention monitoring for fish and macroinvertebrates

Component	Target	Method	Objective
Species diversity	All species including those of conservation significance	• Bait trapping, seine and fyke netting (Baldwin *et al*. 2005) • Sweep netting/AusRivas • Call playback, funnel trapping, drift fences and pit traps (Baldwin *et al*. 2005)	Habitat objectives 2.3, 2.4 and 2.5
Species abundance			

Water Quality

A monthly water quality monitoring program is required for development prior to watering the wetland. The program will assess water quality in conjunction with water level fluctuations. Table I5 identifies elements to be considered as part of the water quality monitoring program

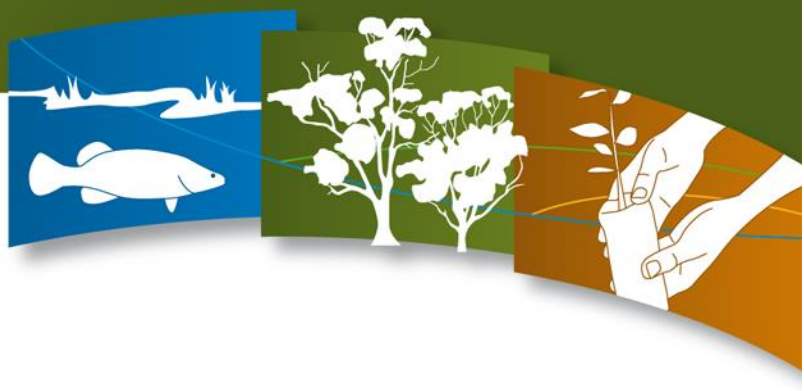
Table I5: Components of intervention monitoring for water quality

Component	Target	Method		Objective
Water quality	Electrical conductivity	Conductivity metre	Water quality meter	There is potential for blackwater events (and algal blooms) to be limiting factors to the success of ecological objectives (Bogenhuber and Campbell 2011)
	pH	pH metre		
	Turbidity	Turbidity metre		
	Dissolved oxygen	Oxygen metre		
	Nutrients	Laboratory analysis		

Data management

A database is required to compile recordings made at Pig Swamp, and this should be updated regularly following monitoring and supplied to the VBA. A monitoring and survey template is recommended to ensure consistency in the data recorded.

Appendix J: Contour and vegetation map



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