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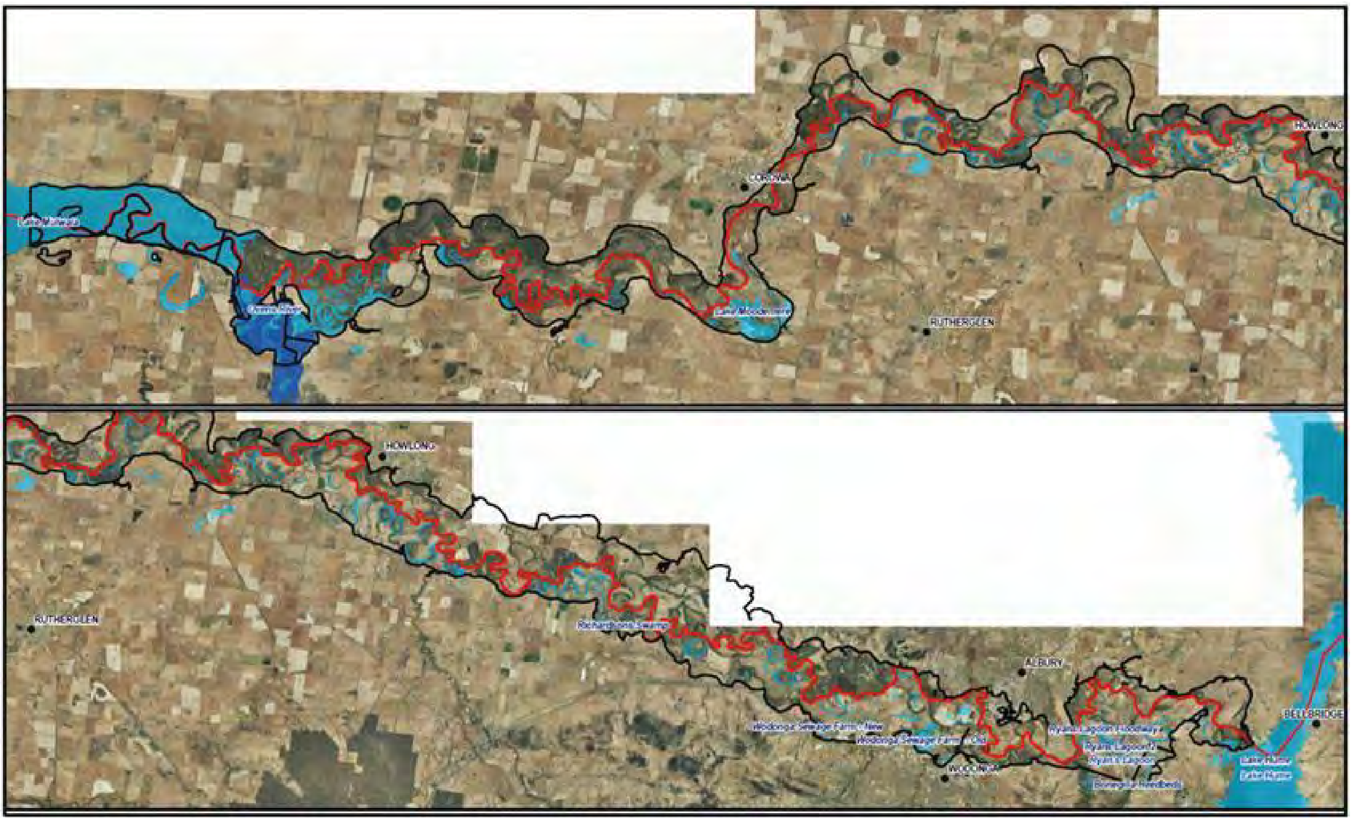
Victorian Murray Floodplain Environmental Water Management Plan

NORTH EAST CATCHMENT MANAGEMENT AUTHORITY

Final Report

7th July, 2015



Victorian Murray Floodplain Investigations and EWMP

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Draft V2.0	01/06/2015	Update of draft following CMA review in preparation for key stakeholder review	Jodi Braszell	Simon Treadwell	Jodi Braszell
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Contents

Important note about your report

The sole purpose of this report and the associated services performed by Jacobs is to prepare an Environmental Water Management Plan for the Victorian Murray Floodplain in accordance with the scope of services set out in the contract between Jacobs and North East Catchment Management Authority (CMA). That scope of services, as described in this report, was developed with North East CMA.

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Project specific limitations - Due to circumstances out of the control of Jacobs, engagement and consultation with some stakeholders was minimal during the development of the EWMP. Please note that recommendations for continuing consultation with these stakeholders have been provided within the EWMP, and are rated as a high priority for North East CMA.

This report has been prepared on behalf of, and for the exclusive use of North East CMA and is subject to, and issued in accordance with, the provisions of the contract between Jacobs and North East CMA. Jacobs accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by any third party

1. Executive Summary

The Murray floodplain Environmental Water Management Plan (EWMP) is a ten-year management plan that describes the water-dependent ecological values present in the floodplain, the long-term goals and ecological objectives for the management of the floodplain, and the recommended flow regime that is needed to achieve these objectives and goals. The EWMP is based on best available scientific information and stakeholder consultation and will be used by the North East CMA and other agencies for both short and long-term planning for environmental watering.

The extent of the floodplain considered for the EWMP is defined as the land on the southern (Victorian) side of the River Murray that is inundated by 1:100 year flood events (i.e. flows of approximately 230,000 ML/day). The EWMP covers a large area of approximately 14,800 hectares (ha), and approximately 233 kilometres (km) in length.

The Murray floodplain, by way of its intrinsic ecological, cultural, social and economic values, and because of its connectivity to the iconic Murray River, is deeply significant to many people in Australia and internationally. Perhaps ironically in light of this significance, it is only relatively recently that work has been undertaken to understand the water-dependent ecological needs of the floodplain, and to understand the implications of not supplying adequate watering regimes for both the floodplain and the river. In some ways, the section of the Murray floodplain between Hume Dam and Yarrawonga Weir is the 'forgotten floodplain', valued for its function as a working system for transporting water for consumptive use within the Murray Darling Basin and further afield, and for its social values, but not yet highly noted for its environmental values and the critical ecosystem services it provides.

The floodplain contains hundreds of wetlands. Improving the connectivity between these wetlands and the River Murray will help to protect and rehabilitate habitat for many wetland species, and will also support aspects of the life cycles of many riverine plant and animal species, including a significant number of species of national and international significance. The high biodiversity values of the floodplain, the presence of rare and endangered species, the very high water-dependent social and economic values, and the critical ecosystem functions that the floodplain provides all build a strong argument for supporting the floodplain with appropriate and adequate inundation regimes.

1.1 Management of the Murray floodplain

Unlike a number of other priority regulated waterways and wetlands in Victoria, the Murray floodplain does not have its own environmental entitlement. Environmental water holders, such as the Victorian Environmental Water Holder (VEWH), The Living Murray Program, and the Commonwealth Environmental Water Holder (CEWH), will be able to specifically address Murray floodplain ecological objectives by leveraging from the releases of available environmental water as it travels downstream to other locations.

Given its position within North East Victoria as well as the broader Murray-Darling Basin, a large number of management strategies, plans and legislation direct its management. The River Murray and its connected floodplain are important because of their significant contributions of water to the Murray-Darling Basin for consumptive purposes, their high environmental values and high social values, as well as for their cross-jurisdictional location. The Murray-Darling Basin Plan has significant oversight and influence regarding how the Murray floodplain is managed through its interests in protecting and improving ecological outcomes for both the River Murray and the floodplain. A large number of the floodplain's wetlands have suffered marked degradation as a consequence of altered hydrology associated with river regulation. Murray Darling Basin planning processes have recognised the importance of the entire length of the Murray floodplain, and have placed a strong emphasis on its protection and rehabilitation through the Basin Plan and the Basin-wide Environmental Watering Strategy.

In the River Murray system, environmental water holdings can be used to directly target the River Murray's environmental values between Hume Dam and Yarrawonga Weir, including the floodplain, if adequate volumes are provided. Environmental water travelling through the reach to address environmental objectives downstream of Yarrawonga Weir, can also provide benefits to the floodplain prior to reaching the final intended watering destination. There is no specific environmental water holding solely intended for the environmental objectives of the Murray floodplain, and North East CMA will work in collaboration with VEWH, CEWH, other

Victorian CMAs and the Murray Darling Basin Authority (MDBA) to explore options for leveraging from environmental water entitlements held by the Commonwealth, Murray Darling Basin Authority, and also the three separate states of Victoria, NSW and South Australia.

1.2 The values of the Murray floodplain

The Murray floodplain plays an extremely important role in the landscape ecology of the North East region as well as the broader Murray-Darling Basin, supporting unique and iconic biota in an otherwise semi-arid environment. Flood events come from rainfall in the headwaters of the Murray River and its tributaries and help to maintain ecological connectivity laterally across the floodplain, and between the rivers and the floodplain, and play an extremely important role in the landscape ecology of the region. The floodplain forests of the project area provide important habitat for a range of forest-adapted plants and animals, many of which are protected under State, National and International legislation. The Murray floodplain also acts as a corridor for extending the geographic range of a number of species.

The more specific ecological values within the floodplain that are included for management are as follows:

- Submerged macrophyte communities
- Emergent macrophyte (in the wet-dry littoral zone) communities
- Small bodied native fish community in the permanently inundated zone
- Waterbird, frog and reptile communities
- Zooplankton
- Carbon and nutrient cycling
- Connectivity.

1.3 The ecological condition of the floodplain

The ecological functioning of the Murray floodplain is adapted to conditions of seasonal flow variability, temperature variations, drought, and wet and dry cycles to form a rich biodiversity. River regulation has significantly altered the natural variation of the River Murray. Mid-range floods and low flows have been largely eliminated. There is now serious degradation in the ecological condition of large areas of the floodplain. Broader Basin-wide condition assessments show that the Murray catchment is in poor condition, with native fish species significantly reduced in terms of their presence and abundance, the presence of significant numbers of pest plants and animals having devastating effects on native species and communities; and vegetation such as River Red Gums in poor condition with very little recruitment occurring. Poor water quality, unsustainable land use impacts, and bed and bank destabilisation are also key issues for the floodplain. Climate change is predicted to have severe impacts on the already compromised condition of the catchment. Waterbirds are known to be in decline in the area also. Trend data, although not much is available, indicates a general decline downwards for the condition of waterways in the catchment, which implies a general trend downwards for the floodplain too.

A key impact on the condition of the catchment is the alteration of flow regimes through river regulation, and the River Murray and its floodplain are significantly stressed in terms of the amount of water they receive and the insufficient volumes and inappropriate patterns of inundation and flow that are now occurring in the system.

1.4 Impacts of river regulation on the floodplain

The key driver of the floodplain’s character and function is its hydrological connectivity to the River Murray. Due to extensive river regulation brought about by the construction of Hume Dam and Yarrawonga Weir for the storage and supply of water for consumptive purposes, the natural water flow regime of the River Murray has been extensively modified, in terms of the rate, variability, total volume and seasonality of flows. These changes have affected both the river itself and the floodplain wetlands that are connected to the river. Since regulation of the River Murray:

- Flows in the River Murray are now much less variable downstream of Hume Dam, particularly in winter and spring because smaller floods are now stored in the dam
- The seasonality of flows has been reversed, with low flows in winter and high flows in summer and autumn
- Flows are at or near channel capacity for much of the year, with a release constraint of 25,000 ML/day
- The frequency and duration of flooding in winter and spring is now significantly decreased
- Opportunities for low lying wetlands along the floodplain to dry out in autumn have reduced
- Rain rejection events can cause unseasonal flooding during summer and autumn downstream of Yarrawonga Weir.

The regulation of river flows, particularly downstream of Hume Dam, is a critical driver of floodplain condition. Elevated flows during the irrigation season inundate lower lying parts of the floodplain at the wrong time of the year, while storage of winter and spring runoff in Hume Dam reduces the frequency and magnitude of seasonal flood events that are critical for supporting floodplain assets at higher elevations. Hence the floodplain and wetlands along the Murray River from Hume Dam to Yarrawonga Weir suffer from too much water and at the wrong time in some locations, through to too little water at all times in other locations.

1.4.1 Constraints

An important constraint on the release of water from Hume Dam is the current requirement that flows do not exceed 25,000 ML/day at Doctors Point just downstream of the dam. This constraint has been in operation for some time, mostly to prevent flooding of low lying private land along the floodplain. Management objectives and the operational management of the system for beneficial environmental outcomes must be developed in recognition of this current constraint. Work is being undertaken by the MDBA to assess the feasibility of relaxing this constraint through its Constraints Management Strategy.

1.5 Ecological and Management Objectives

There is a paucity of data regarding the ecological values present within the floodplain and their water regime requirements. Because of this the EWMP has taken a broader approach to the development of ecological and management objectives for the area. Instead of focusing on the objectives and watering requirements for specific species and/or communities, the EWMP focuses on management objectives for different wetland types across the floodplain, on the assumption that providing adequate watering regimes for these wetland types will assist in improving outcomes for the water-dependent values present within and near them. Objectives are organised according to a three tier system, with the first tier focused on the broader vision for the floodplain, the second tier focused on objectives for the different wetland types within the floodplain, and the third tier focused on management objectives for specific species and/or communities within these wetlands.

Wetlands and floodplain surfaces in the EWMP area are categorised based on their morphology and hydrology (water regime), and their typical ecological characteristics, assets and values. The EWMP identifies four wetland types based on morphology:

1. Floodplain depressions / lakes
2. Cut-off meanders
3. Flood runners
4. Shedding floodplain.

Extensive hydraulic modelling conducted for the development of the EWMP has assessed the extent to which each of these wetland types is inundated under variety of flow regimes.

1.5.1 Ecological objectives

The vision for the reach of Murray floodplain between Hume Dam and Yarrawonga Weir is to:

"*Improve and maintain the ecological health of the range of wetland types in the floodplain, which have water regimes that vary from permanently inundated through to occasionally inundated, to realise the full range of*

ecological values expected to occur in the floodplain."

This vision acknowledges that there are distinct plant and animal communities associated with different wetland types and hydrological regimes within the floodplain.

Because of river regulation, some wetlands on the floodplain now have a reduced frequency and/or duration of inundation, while others have an increased frequency and/or duration of inundation.

To support the ecological objectives for the floodplain, it is important to:

- Reduce the number/area of wetlands permanently inundated at regulated flows; and
- Increase the number/area of wetlands that experience a seasonal water regime, with inundation in winter/spring and drawdown in summer/autumn.

The overall objective for wetlands along the Victorian Murray River floodplain from Hume Dam to Yarrawonga Weir is to establish a suite of wetland types from: deep, permanently inundated cut-off meanders but with a seasonally variable regime that allows for drawdown in water level during summer yet retains a permanent pool habitat for small bodied native fish and macrophytes; through to shallow depressions and shedding floodplain surfaces that are mostly dry and occasionally wet for short durations every few years. The broad changes in water regime required to meet these objectives are to:

1) Introduce a more variable water regime for wetlands that are currently inundated at flows <25,000 ML/d.
2) Increase the frequency of inundation for wetlands connected at flows >25,000 ML/d.

Table 1 summarises the EWMP's second tier ecological objectives for floodplain wetlands. Note that the ecological objectives for cut-off meanders and floodplain depressions are virtually identical, and for the purposes of the EWMP, are merged.

Table 1: Summary of the ecological objectives for floodplain wetlands

Wetland type	Ecological objectives
Cut-off meanders and floodplain depressions	Rehabilitate cut-off meanders and floodplain depressions inundated at flows <25,000 ML/d by introducing a more variable water level regime with inundation in winter/spring and a period of draw down, preferably in summer / autumn yet retains a permanent aquatic habitat zone
	Rehabilitate cut-off meanders and floodplain depressions inundated at flows >25,000 ML/d by implementing a seasonally variable regime that inundates cut-off meanders during winter and spring and allows summer and autumn draw down and drying of wetland margins yet retains a permanent aquatic habitat zone
Flood runners	Rehabilitate flood runners inundated at flows <25,000 ML/d by introducing a more variable flow regime that provides a period of low flow, preferably in summer / autumn
	Rehabilitate flood runners engaged at flows >25,000 ML/d by implementing a seasonally variable flow regime that engages flood runners during winter and spring
Shedding floodplain	Rehabilitate shedding floodplains by introducing a seasonally variable inundation regime with a range of inundation recurrence intervals from annual through once every 3-5 years

1.6 Technical input to the EWMP

1.6.1 Hydraulic Modelling

To inform the development of the EWMP a hydraulic model of the floodplain was developed in order to determine wetland inundation extents and depths for a variety of River Murray flows. Only the Victorian side of the floodplain model was analysed for the EWMP. The hydraulic model was run for the following steady state flows:

- 20,000 ML/d
- 25,000 ML/d (approximate bank full flow)
- 30,000 ML/d

- 35,000 ML/d
- 40,000 ML/d (this is the probable upper limit of potential environmental flow releases from Hume Dam)
- 50,000 ML/d.

The inundation datasets produced from the hydraulic model were used to plot inundation maps and to determine the extent of wetlands that were inundated. This information helped to develop a recommended water regime for the floodplain wetlands, relating river flow thresholds to wetland and floodplain inundation frequency. This analysis and recommendations are detailed in the accompanying synthesis report.

The inundation maps for all thresholds modelled are included in Appendix B-1.

1.6.2 Technical Panel

A Technical Panel was also convened for the EWMP development, with members of the Murray Darling Freshwater Research Centre providing expert advice regarding: the ecological values present within the floodplain; the nature, structure and functioning of the floodplain; the preferable management objectives and watering requirements; and risks and threats to these values.

1.7 Environmental Watering Requirements

Detailed hydrological objectives are specified for the floodplain, and specify the frequency, timing, duration and depth of inundation for the third tier ecological values in each of the four wetland types across the floodplain. It should be noted that in order to achieve rehabilitation objectives for wetlands that commence-to-fill at flows >25,000 ML/d, a long-term commitment is needed to establish and maintain seasonal inundation in the winter/spring. This is important because once the desired fish and macrophyte communities establish, they will be reliant on these managed flow releases to maintain their condition. On this basis, and referring to the recommended water regimes for the wetland types identified in the EWMP area, the extent of wetland inundation achieved with flows up to 40,000 ML/d and the frequency analysis of flows up to 40,000 ML/d, a simplified water regime recommendation for flows >25,000 ML/d is provided (Table 2).

Figure 1 summarises the recommended inundation regime for third tier ecological values on the floodplain, describing the frequency and timing of wetting and drying for the different wetland types. The symbol of a crossed out water drop indicates drying or drawdown, while the symbol of a water drop indicates wetting. The dot points under each wetland type indicate the frequency of wetting or drying, the timing of wetting or drying, and the duration of the event.

It is recommended that a flow in the Murray River up to 30,000 ML/d is delivered once every year in winter/spring to maintain a suite of permanent cut-off meander / floodplain depressions but with a variable water level that is high in winter/spring (during the inundation event) and that this then draws down over the summer/autumn period yet retains a permanent pool as refuge for fish and other aquatic flora and fauna that require access to permanently inundated wetland habitat. It is further recommended that flows in the range of 30,000 to 40,000 ML/d are delivered on average once every one to four times in every five year period with a maximum dry phase of 3-5 years. This regime would provide a range of flow frequencies that would create a variable water regime at different floodplain elevations sufficient to create a mosaic of wetland and floodplain vegetation types.

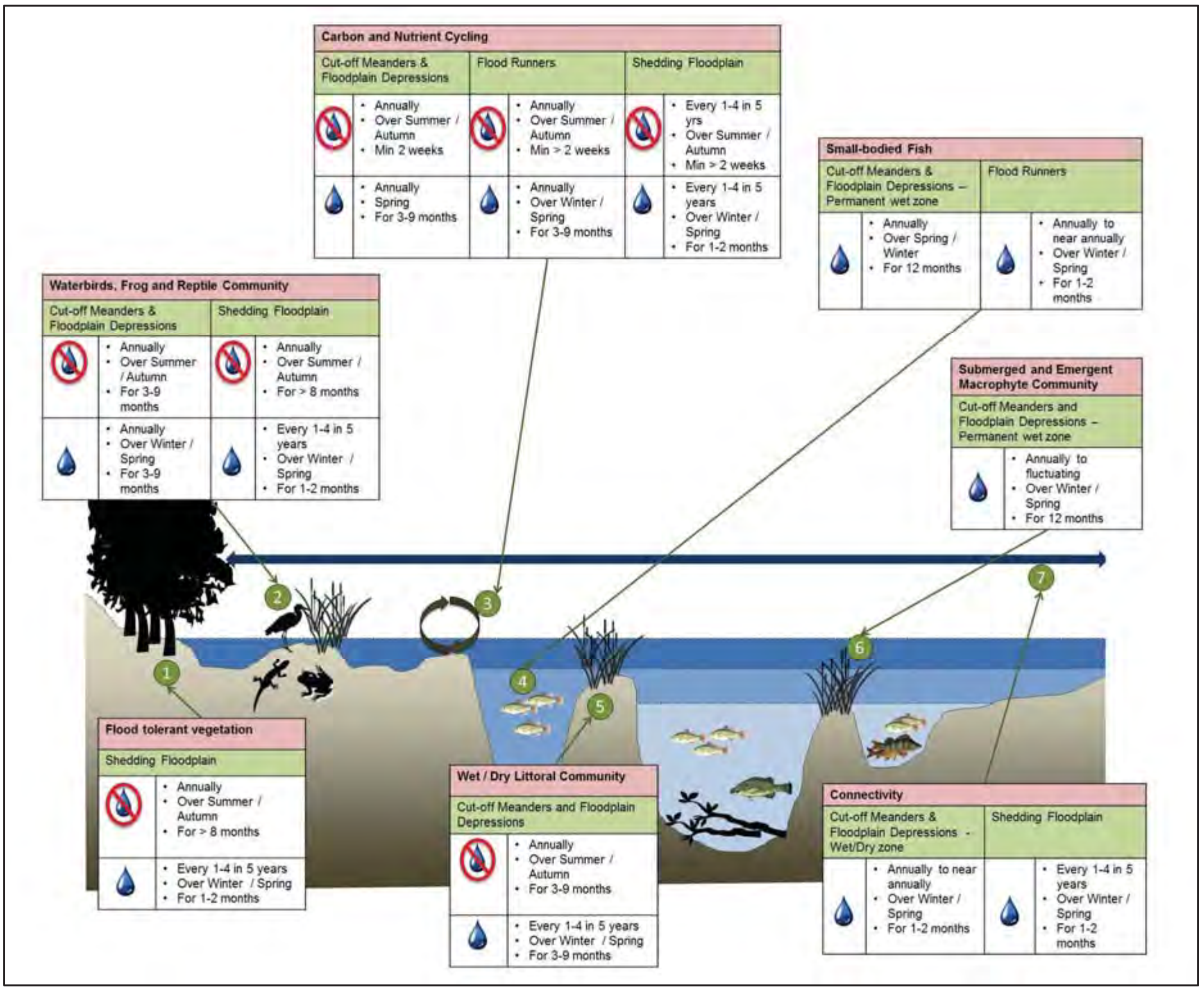

Figure 1: The temporal variation in inundation regimes required to meet floodplain ecological objectives for each of the different wetland types

Table 2: Simplified water regime recommendation for flows >25,000 ML/d

Murray River flow	Frequency	Timing	Duration of river flow event	Maximum dry phase	Target wetlands
30,000 ML/d	Annual	August to October	Sufficient to fill flood runners and wetlands (a few days to several weeks). Water will then pond in depressions and remain in wetlands and on the floodplain even after the river level falls.	12 months once every 5 years (to retain permanent habitat for small bodied native fish)	Cut-off meanders / floodplain depressions with a variable water level regime that is high in winter/spring and draws down over summer/autumn yet retains a permanently inundated zone for native fish and other aquatic flora and fauna.
35,000 ML/d	Twice in every 3 to 4 years	August to October		3 years (to maintain seed bank for flood dependant plant species)	Cut-off meanders / floodplain depressions and shedding floodplain with a variable water level that is high in most winter/spring periods and dries out over summer/autumn.
40,000 ML/d	One to two times every five years	August to October		5 years ((to maintain seed bank for flood dependant plant species)	

1.8 Risks

Risks assessment and mitigation planning for the Murray floodplain EWMP covered two different categories:

- The level of risk posed by potential threats to the water-dependent ecological values, because this may impact on achieving the ecological objectives of the EWMP
- The potential risks to the broader floodplain and catchment environment when watering targets (sometimes referred to as the 'third party components'), because these could reduce the gains achieved from more effectively managing environmental water.

Risks include river regulation, pest plants and animals, and land use change, poor water quality, livestock grazing and climate change. Risks also include flooding of private land, personal injury and insufficient knowledge regarding the environmental watering requirements of the floodplain.

1.9 Demonstrating outcomes

Monitoring is essential to enable North East CMA to adaptively manage environmental flows for the Murray floodplain. The EWMP describes a range of monitoring activities to help meet these monitoring requirements, including

- Compliance monitoring (such as hydrological monitoring) – to determine if environmental flow release targets have been met
- Administrative compliance – To determine if the management arrangements have been implemented as intended
- Short-term event monitoring – To see how environmental values on the floodplain respond in the short-term to watering events
- Long-term ecological response monitoring – To determine if short-term environmental responses lead to long-term change on the floodplain
- Long-term condition/health monitoring – To measure any trends in the environmental condition of the floodplain over time.

Baseline condition and the longer term ecological responses of values on the Murray floodplain are not well known at present, and monitoring and research will target these information gaps. Monitoring and studying the responses to watering events will be particularly important to provide feedback on how the floodplain system is responding and if any amendments need to be made to its operational management or ecological objectives.

1.10 Knowledge Gaps

Traditionally, the Murray floodplain has been managed for its water conveyance values, and the environmental watering requirements of the area have only recently become a priority for State and Commonwealth agencies. Current data and knowledge regarding the ecological values, functions, and watering objectives of the floodplain reflects this previous priority, and in comparison with other wetland complexes and systems about Victoria, is relatively under-developed.

Continuing to improve knowledge about the Murray floodplain, its water-dependent ecological values and its most appropriate inundation regimes is thus an imperative for North East CMA. A number of knowledge gaps exist, and will be targeted for future work. A range of knowledge gaps and weaknesses were identified during the preparation of the EWMP. These include:

- The baseline condition and trajectories of different wetlands types on the floodplain
- The floodplain ecological values associated with specific wetland categories
- Indigenous cultural values of the floodplain, including risks to their management
- The communications and engagement requirements of key EWMP stakeholders
- The most appropriate adaptive management responses for climate change impacts

- The possible impacts of extended drought on the resilience of the floodplain
- Wetland works and measures to improve environmental water delivery for the system
- The status of high value species such as the Southern Pygmy Perch in the floodplain.

1.11 Consultation

Consultation activities that have contributed to the preparation of the EWMP include extensive community engagement during the development of North East CMA's Waterway Strategy, Regional Catchment Strategy and Wetlands Strategy for the determination of ecological values and objectives.

Consultation during the development of the EWMP included liaising with representatives from the Murray Darling Basin Authority, the Victorian Environmental Water Holder, DELWP, Goulburn Murray Water, the Murray River Action Group, the Commonwealth Environmental Water Holder, NSW Office of Water, Parks Victoria and the Advisory Group for Hume to Yarrawonga Waterway Management. Technical experts from the Murray Darling Freshwater Research Centre provided valuable technical input for the development of the ecological and hydrological management objectives.

2. Acknowledgements

2.1 Acknowledgement of Country

The North East Catchment Management Authority acknowledges the Traditional Owners of land in the North East region and strongly respects the rich culture and intrinsic connection the Traditional Owners have to the land and its waterways.

2.2 Contributions to the Murray Floodplain EWMP

The information contained in the Murray Floodplain EWMP has been sourced from a variety of reports and individual knowledge and expertise. The North East Catchment Management Authority acknowledges the assistance of the following agencies, groups and individuals in preparing this EWMP:

- Murray Darling Basin Authority – Rachel Clarke, Sarah Commens, Damian Green, Gill Whiting, Hugo Bowman, Joseph Davis and Rebecca White
- Commonwealth Environmental Water Holder - David Straccione
- Victorian Environmental Water Holder – Keith Chalmers and Chloe Wiesenfeld
- Murray River Action Group – Richard Sargood (Chair), Marie Dunn (Secretary), and Greg Lumby (Vice-Chair)
- Advisory Group for Hume to Yarrawonga Waterway Management
- Parks Victoria – Andrew McDougall
- Victorian Department of Environment, Land, Water and Planning – Susan Watson and Suzanne Witteveen, and an independent consultant assisting DELWP, Melanie Tranter
- Goulburn Broken Catchment Management Authority – Neville Atkinson (Yorta Yorta) and Geoff Earl
- Goulburn Murray Water – Andrew Shields
- NSW Department of Primary Industries – Ben Berry
- Aboriginal Elders - Uncle Freddie Dowling (Bangerang) and Uncle Wally Cooper (Yorta Yorta / Bangerang)
- Murray Darling Freshwater Research Centre – Dr Daryl Nielsen and Dr Lee Baumgartner.

3. Introduction

This Environmental Watering Management Plan (EWMP) has been prepared by the North East Catchment Management Authority (CMA) to establish the long-term management goals for the Victorian side of the River Murray floodplain that extends between Hume Dam and Yarrawonga Weir, a reach of approximately 233 km in length. The North East CMA is being funded through the Victorian Department of Environment, Land, Water and Planning (DELWP) to prepare the EWMP for the Murray floodplain under the Victorian Basin Plan Environmental Water Management Plan Program.

The Murray floodplain EWMP is a ten-year management plan that describes the water-dependent ecological values present in the floodplain, the long-term goals and ecological objectives for the management of the floodplain, and the recommended flow regime that is needed to achieve these objectives and goals. The EWMP is based on best available scientific information and stakeholder consultation and will be used by the North East CMA and other agencies for both short and long-term planning for environmental watering.

Unlike a number of other priority regulated waterways and wetlands in Victoria, the Murray floodplain does not have its own environmental entitlement. Environmental water holders, such as the Victorian Environmental Water Holder (VEWH) and the Commonwealth Environmental Water Holder (CEWH), will be able to specifically address Murray floodplain ecological objectives by leveraging from the releases of available Victorian and Commonwealth environmental water as it travels downstream to other locations.

Given the location of the Murray floodplain within the Murray Darling Basin as well as North East Victoria, the EWMP will assist in the long-term planning mechanisms for a number of agencies, including the North East CMA, the Victorian Department of Environment, Land, Water and Planning (DELWP), the Murray Darling Basin Authority (MDBA), as well as VEWH and CEWH.

3.1 What is a floodplain?

Floodplains can be defined from a variety of different perspectives. For example, geomorphologists may view the Murray floodplain as a temporary storage area of alluvial sediment adjacent to the main River Murray channel, while hydrologists would define the floodplain as the area of land inundated by a flow of particular magnitude (in Australia, a floodplain is defined as the area of land inundated by a 1-in-100-year (i.e. 1:100) flood). From an ecological perspective, the Murray floodplain would be considered an area of high productivity, providing cover, shelter and food for biota in times of inundation, and supporting a significant diversity of plants and animals that can emerge during flooding (Capon *et al.*. 2009).

Like other floodplains, the Murray floodplain is both a source and sink of materials to and from a river channel. Floodwaters coming from rainfall in the catchment enter the floodplain through ephemeral creeks and overflows from the banks of inundated rivers and streams. Also similar to other floodplains, the Murray floodplain has been built, layer upon layer, by nutrient-rich sediment deposited during floods. This results in a complex system of differently functioning wetlands holding water for different periods of time (Rogers and Ralph 2011).

As a riparian zone, floodplains are sometimes referred to as an ‘ecotone’[1] between terrestrial and aquatic areas. In practice, there can be several transition zones in a floodplain, and riverine floodplains like the Murray floodplain contain a complex mix of many different wetland types (Tockner and Stanford 2002). The ecological ‘makeup’ of floodplains is determined by their hydrology; the influence of catchment rainfall and nearby waterways’ flooding flows and periods of dryness. As a consequence, pulsed flooding is the major factor influencing biota in river-floodplain ecosystems such as the Murray floodplain (Ballinger and MacNally 2006). Floodplain flora and fauna respond to the characteristics of these flood pulses - the timing, duration and rates of rise and fall of water levels - and five flow regime variables are critical for floodplain ecosystems:

- Flow magnitude – the maximum volume and extent of areas inundated, as well as the duration of flooding events
- Flow variability – the frequency and periodicity of certain flood volumes and water levels
- Magnitude and frequency – the volume, or size and length of time between severe or prolonged floods and droughts

[1] An ecotone is a transitional zone, or area, between two different ecosystems.

- Rates of flow change – which describes the speed at which floodwater levels rise and fall
- Flow seasonality – which describes the timing of flows for a series of months or for a season in the year (Rogers and Ralph 2011).

Each of these flow variables determines the pattern and the duration of inundation in the Murray floodplain, which in turn then determines its ecological structure and functioning.

Natural floodplains are some of the most diverse and productive ecosystems on Earth. They are also among the most threatened ecosystems, and floodplain degradation is closely linked to the rapid decline in freshwater biodiversity. In Europe and North America for example, up to 90% of floodplains are already 'cultivated' and therefore considered functionally extinct (Tockner and Standford 2002). Globally, there is an urgent need to preserve and improve the ecological health of existing floodplains and their rivers to avoid dramatic extinctions of aquatic and riparian species and loss of ecosystem services (Tockner and Stanford 2002).

Floodplains provide ecosystem services[2] such as: filtration, purification and delivery of water; provision of nursery habitat for fish and birds; maintenance of soil fertility and structure; pollination of crops and other vegetation; control of potential pests, diseases and weeds; production of goods like food and fibre; and provision of cultural, spiritual and intellectual values (Capon *et al.* 2009). Providing environmental water for the wetlands of the Murray floodplain is vitally important to protect these ecosystem services.

The Murray floodplain plays an extremely important role in the landscape ecology of the region, supporting unique biota in an otherwise semi-arid environment. Flood events come from rainfall in the headwaters of the Murray River and its tributaries and help to maintain ecological connectivity laterally across the floodplain, and between the rivers and the floodplain, and play an extremely important role in the landscape ecology of the region. The floodplain forests of the project area not only provide important habitat for a range of forest-adapted plants and animals, but also act as a pathway for extending the geographic range of a number of species, particularly birds.

3.2 Scope of the EWMP

3.2.1 EWMP objectives

The main objectives of this EWMP are to:

- Identify the long-term management objectives and water requirements for the floodplain
- Provide a vehicle for community consultation during the development and implementation of this EWMP
- Inform the development of seasonal watering proposals and seasonal watering plans for linked waterways
- Inform the long-term watering plans that are being developed under Basin Plan requirements (DEPI 2014).

3.2.2 Extent of floodplain covered by the EWMP

Floodplains associated with the River Murray extend for the majority of its length (approximately 870,000 ha). The area of Murray floodplain of concern for this EWMP is found on the southern side of the River Murray, extending between Hume Dam and Yarrawonga Weir in North East Victoria. The extent of the floodplain considered for the EWMP is defined as the land on the southern side of the River Murray that is inundated by 1:100 year flood events (flows of approximately 230,000 ML/day) (Jacobs 2015c). The EWMP covers an area of approximately 14,800 hectares (ha), and is approximately 233 kilometres (km) in length. Figure 2, Figure 3, Figure 4 and Figure 5 show the extent of the floodplain under consideration for the EWMP. Note that while the maps demarcate the 1:100 floodplain extent for both sides of the River Murray, the EWMP is only concerned with floodplain on the Victorian side of the river.

The River Murray channel and Victorian tributary waterways such as the Kiewa River and Ovens River are not included within the scope of the EWMP. A separate EWMP has been developed for the Ovens River by North East CMA, and is focused on the in-channel values of this waterway.

[2] Ecosystem services are the benefits provided to humans through the transformations of resources (or environmental assets, including land, water, vegetation and atmosphere) into a flow of essential goods and services e.g. clean air, water, and food.

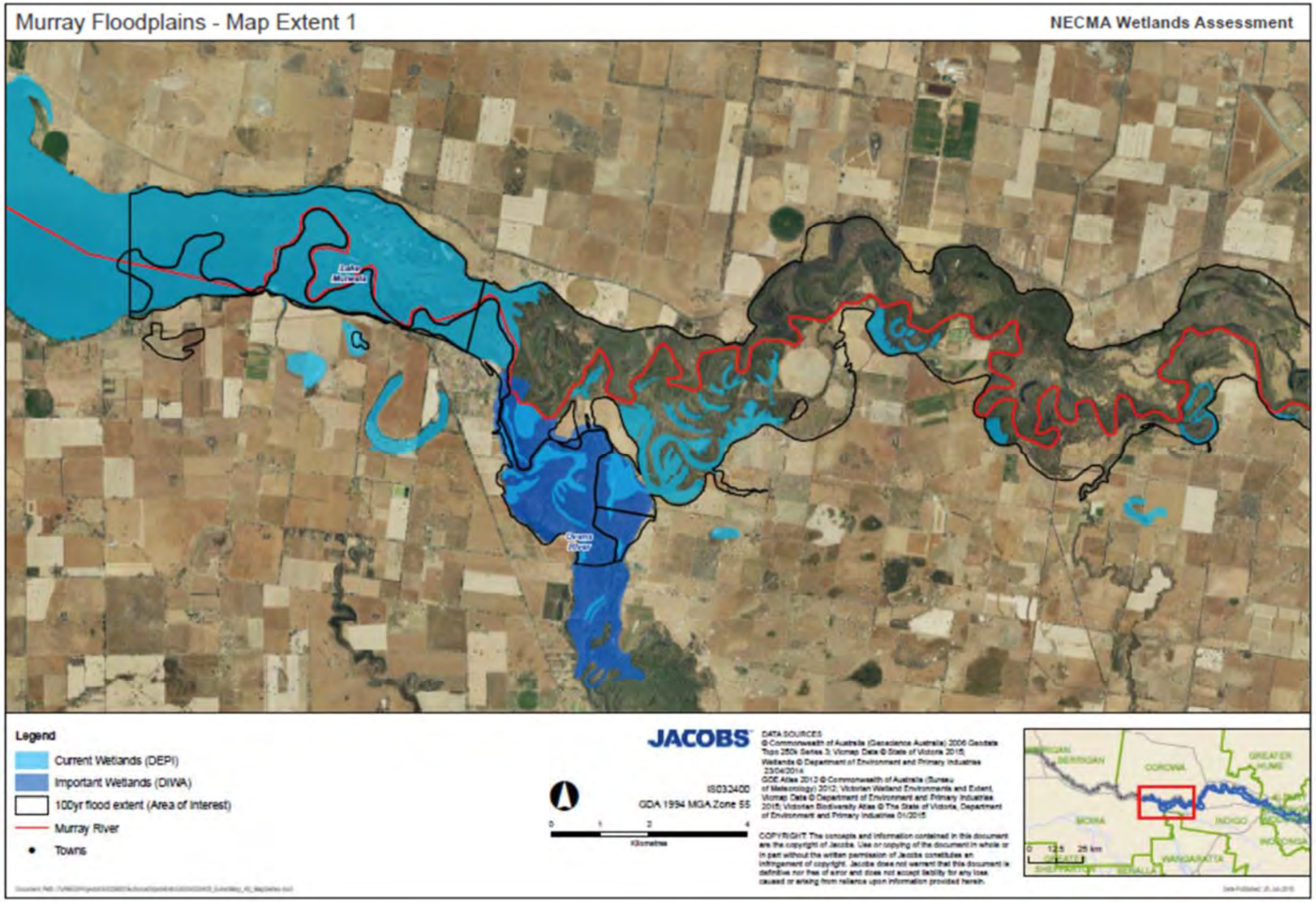

Figure 2: Murray floodplain area extending from Lake Mulwala, incorporating the Ovens River confluence, and heading east towards Rutherglen and Corowa

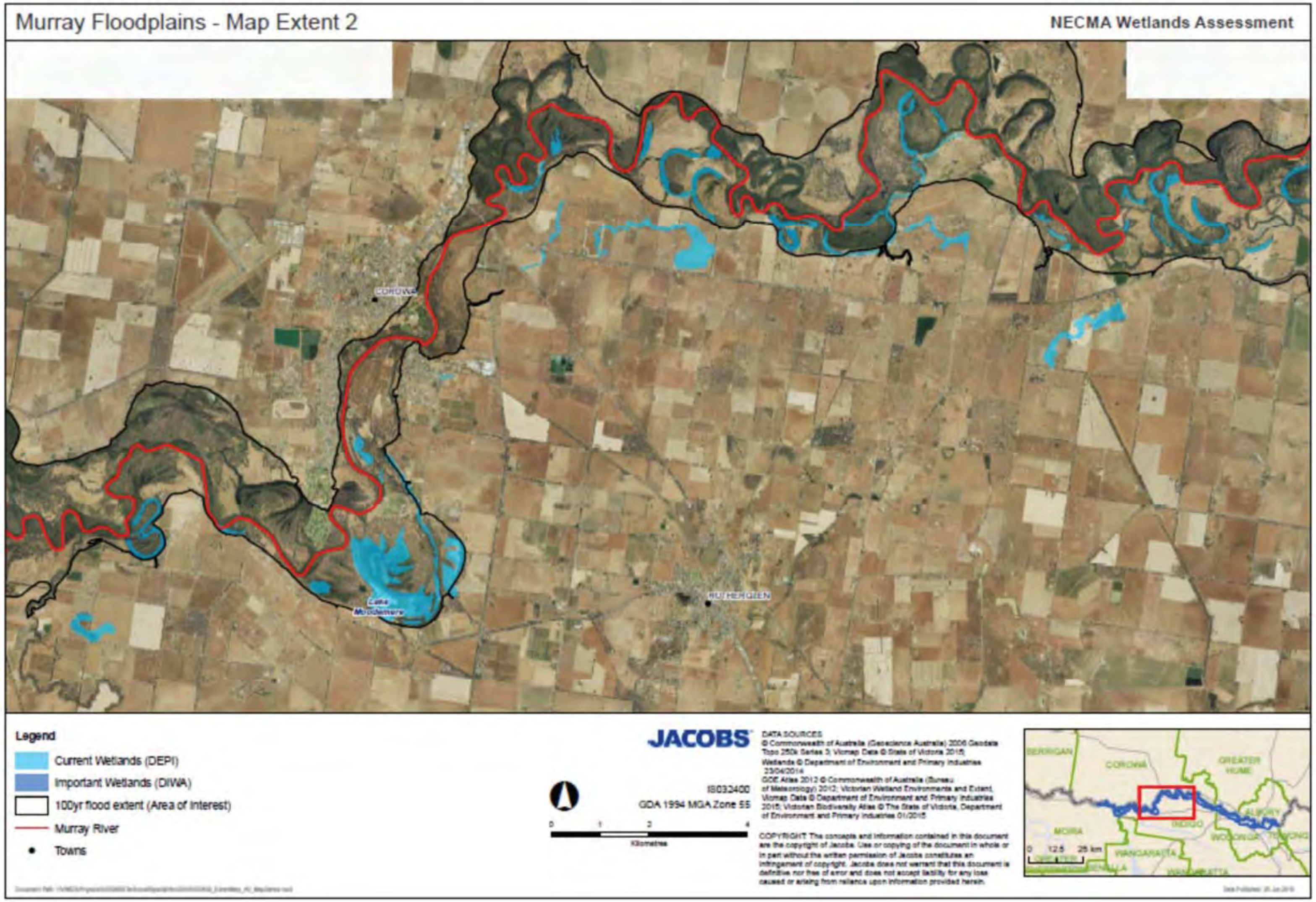

Figure 3: Murray floodplain area incorporating Corowa and Rutherglen, heading east towards Howlong

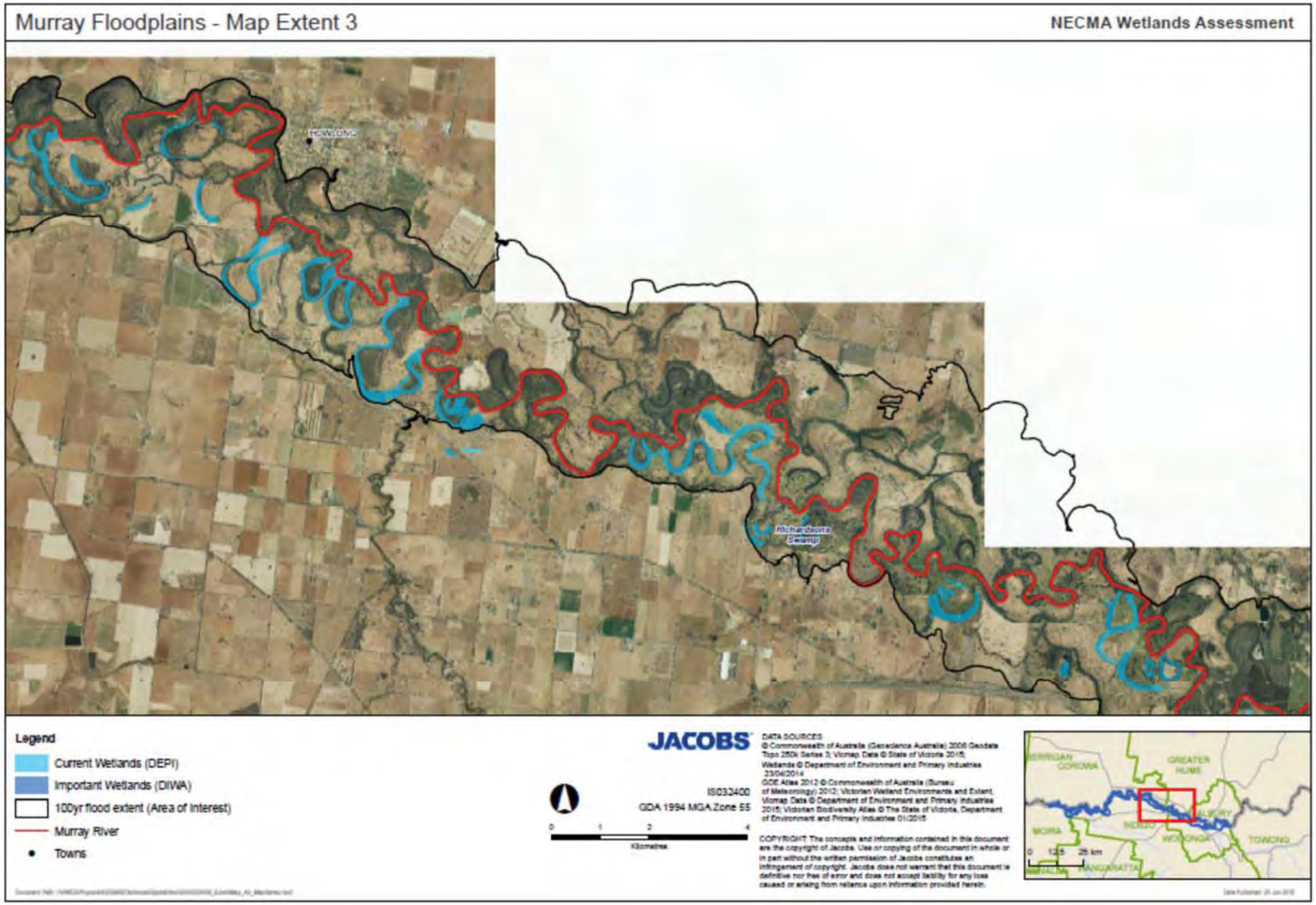

Figure 4: Murray floodplain area incorporating the Howlong area, and heading east towards Wodonga

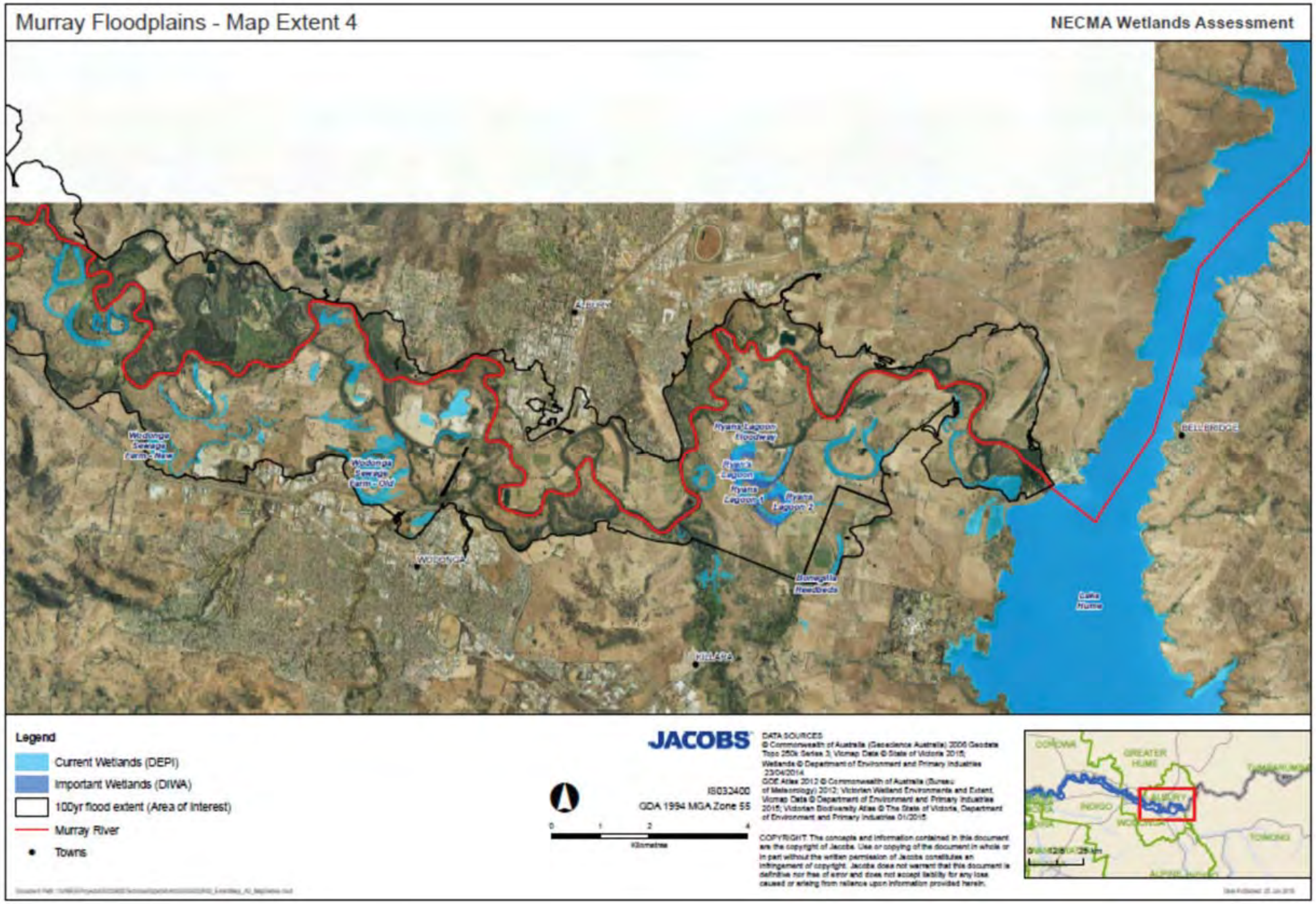

Figure 5: Murray floodplain area incorporating Wodonga and Hume Dam

3.3 Relevant policies, plans and activities

A wide variety of legislation, policies, strategies and plans are relevant to the management of environmental water for the Murray floodplain.

3.3.1 Victorian Waterway Management Strategy

The Victorian Waterway Management Strategy (VWMS) provides the policy direction for managing Victoria's waterways over an eight-year period. Particularly relevant to the Murray floodplain wetlands, the VWMS integrates the management of wetlands with the management of rivers and commits to environmental watering of high value wetlands on the floodplains of regulated rivers, on a priority basis. The VWMS also outlines approaches for maintaining and improving connectivity between rivers and floodplain wetlands (DEPI 2013a).

3.3.2 North East Regional Catchment Strategy (2013)

The North East Regional Catchment Strategy (RCS) is the primary integrated planning framework for land, water and biodiversity management in the North East CMA region. It includes processes that can be used to assess the condition of land, water and biodiversity and seeks to encourage and support participation of landholders, resource managers and other members of the community in catchment management. It provides:

- A 50 year vision for the region
- 20 year high level objectives for desired outcomes
- 6 year management measures that set priorities for landscape scale and asset based programs for the life of the RCS (North East CMA 2013).

The Murray floodplain, referred to as the Murray Corridor in the RCS, is highlighted as a priority catchment asset for management. Management measures directly address floodplain concerns, such as improving connectivity, in the urban, forest and agricultural landscapes of the region.

3.3.3 North East Waterway Strategy (2014)

The North East Waterway Strategy is an eight-year planning document for waterway management in the North East CMA region. The Strategy outlines the regional goals for waterway management and aligns with the objectives for waterways described in the North East RCS. In the Strategy, priority waterways are determined and a strategic regional work program of management activities for these priority waterways guides investment over the eight-year period. The term 'waterway' is used throughout the Strategy to mean rivers, their associated floodplains (including floodplain wetlands) and non-riverine wetlands (North East CMA 2014).

The Murray floodplain is identified as a priority wetland complex within the Strategy, and is called the Murray River Floodplain Complex (including wetlands). Long term resource conditions targets relevant to the floodplain include:

- High priority threatened frog species (Giant Bullfrog and Growling Grass Frog) increase in distribution, and produce young
- The waterway and riparian zones throughout the system contain populations of high and medium priority threatened bird species (Eastern Great Egret, Australasian Bittern, Nankeen Night Heron)
- Stands of significant Ecological Vegetation Classes continue to be found along many reaches and wetlands in the system
- Water quality and quantity are suitable for an urban/rural township source
- Access to waterways for recreational fishing, swimming and near-waterway activities is maintained.

Strategic actions to address these condition targets include: working with the Urban and Lifestyle Landscape communities to maintain and improve waterway values; supporting the targeted protection of priority wetlands within the Murray Plains System; and protecting the iconic Murray River and its associated floodplain by undertaking targeted management activities within the Agriculture and Lifestyle Landscapes (North East CMA 2014).

3.3.4 North East Wetland Management Strategy (2007)

The North East Regional Wetland Management Strategy provides a framework for North East CMA to protect and enhance the biodiversity and ecological values of the region's wetlands. The Wetlands Strategy identifies the priority wetlands within the region, documents their values and condition, and sets their management objectives and actions. Murray floodplain wetlands are included within the Wetland Management Strategy under the Floodplains/Plains wetlands management unit (BMT WBM 2007a, 2007b). Wetlands identified through the strategy were assessed for their condition and prioritised according to environmental values that were present. This information directly contributed to the prioritisation of waterways and wetlands in the North East Waterway Strategy, and as a consequence, the Murray floodplain is marked as a high value priority catchment asset within the North East region.

3.3.5 Ovens River Environmental Water Management Plan (2015)

The Ovens River is a major tributary of the River Murray in the North East, joining the Murray in the backwaters of Lake Mulwala. The Ovens region generates approximately 6 percent of the runoff within the Murray Darling Basin, is critical for environmental flows in the River Murray, and sustains a high value forest and wetlands system in its lower reaches (CSIRO 2008a; Cottingham *et al* 2001). Under a Partnership Agreement between CEWH and VEWH, a five year environmental watering schedule (July 2014 - June 2019) has committed the use of up to 70 ML per year of Commonwealth environmental water in the Ovens River. The Ovens River EWMP is concerned with using this 70 ML allocation to target the in-channel management of water dependent environmental values. The riparian and floodplain zone of the Ovens River is not included within the scope of the Ovens River EWMP for management, nor is the EWMP intended to be a whole-of-river management plan that considers the entire flow regime.

The scope of the area covered by the Murray floodplain EWMP however includes the lower floodplain of the Ovens River where it overlaps with that of the River Murray at its confluence. Environmental watering events for the Murray floodplain that target water dependent values near the confluence are likely to provide collateral benefits for the lower reaches of the Ovens River.

3.3.6 Murray-Darling Basin Plan

The Commonwealth Murray-Darling Basin Plan (the Plan), released in 2012 by the MDBA, aims to at least partially reinstate the connectivity between rivers in the Basin and their lower-lying floodplains. The Plan sets limits on the amount of water that can be taken out of the system for consumptive use in order to protect the environmental assets of the Basin (MDBA 2012b)

MDBA estimated that, on a long–term average annual basis, a reduction of 2,750 GL in diversions is required to achieve a sustainable level of water extraction. This water is in addition to other water available for the environment, such as 500 GL through the Living Murray environmental holdings.

The Murray floodplain is considered a priority for improvement in the Plan, and acknowledges that it can be actively managed with water recovered for the environment within the traditional operational constraints of the Basin (MDBA 2012b).

3.3.6.1 MDBA Constraints Management Strategy

The Constraints Management Strategy identifies and describes the physical, operational and management constraints that are affecting, or have the potential to affect, environmental water delivery and is evaluating options, opportunities and risks to water users, communities and the environment, associated with addressing these constraints (MDBA 2013b). Relaxing or removing particular constraints will help to improve the delivery of environmental water recovered under the Basin Plan, and will increase the environmental benefits that can be achieved with any additional environmental water.

The Hume Dam to Yarrawonga Weir reach is one of seven areas of the Basin that MDBA is studying for this strategy. The Hume–Yarrawonga focus area covers the River Murray channel and its associated anabranches between Hume Dam and Yarrawonga Weir for both the NSW and Victorian sides of the river, incorporating all of the Murray floodplain under consideration in this EWMP (MDBA 2014b). Through the Constraints Management Strategy, a ten-year investigatory process, MDBA is assessing the potential to increase the regulated flow limit from 25,000 ML/day to up to 40,000 ML/day, as measured at the Doctors Point gauge. MDBA has indicated to landholders that 40,000 ML/day will be the upper limit for flows to be investigated (MDBA 2014b). This strategy is discussed further in Section 12.1.

3.3.6.2 Basin-wide Environmental Watering Strategy

The Basin-wide environmental watering strategy is one of the most important parts of the implementation of the Basin Plan. The strategy identifies how best to achieve environmental outcomes in the Basin through coordination and cooperation between agencies and across State borders (MDBA 2014a). The environmental watering strategy defines the desired environmental objectives for four components: river flows and connectivity; native vegetation; waterbirds; and native fish. Table 3 shows the expected environmental outcomes for these four components, with many applicable to the Murray floodplain area.

Table 3: Summary of quantified environmental expected outcomes in the Basin-wide Environmental Watering Strategy (Source: MDBA 2014a)

River flows and connectivity	Vegetation	Waterbirds	Fish
Improve connections along rivers and between rivers and their floodplains	Maintain the extent and improve the condition	Maintain current species diversity, improve breeding success and numbers	Maintain current species diversity, extend distributions, improve breeding success and numbers
Maintained base flows: • At least 60% of natural levels **Improved overall flow:** • 10% more into the Barwon–Darling1 • 30% more into the River Murray • 30–40% more to the Murray mouth (and it open to the sea 90% of the time) **Maintained connectivity in areas where it is relatively unaffected:** •Bbetween rivers and floodplains in the Paroo, Moonie, Nebine, Warrego and Ovens **Improved connectivity with bank-full and/or low floodplain flows:** • By 30–60% in the Murray, Murrumbidgee, Goulburn and Condamine–Balonne • By 10–20% in remaining catchments **Maintain the Lower Lakes above sea level**	**Maintenance of the current extent of:** • About 360,000 hectares of river red gum; 409,000 ha of black box; 310,000 ha of Coolibah forest and woodlands; and existing large communities of lignum • Non-woody communities near or in wetlands, streams and on low-lying floodplains **Maintain the current condition of lowland floodplain forests and woodlands of:** • River red gum • Black box • Coolibah **Improved condition of:** • southern river red gum	**Maintained current species diversity of:** • All current Basin waterbirds • Current migratory shorebirds at the Coorong **Increased abundance:** • 20–25% increase in waterbirds by 2024 **Improved breeding:** • Up to 50% more breeding events for colonial nesting waterbird species • A 30–40% increase in nests and broods for other waterbirds	**Improved distribution:** • Of key short and long-lived fish species across the Basin **Improved breeding success for:** • Short-lived species (every 1–2 years) • Long-lived species in at least 8/10 years at 80% of key sites • Mulloway in at least 5/10 years **Improved populations of:** • Short -lived species (numbers at pre-2007 levels) • Long-lived species (with a spread of age classes represented) • Murray Cod and Golden Perch (10–15% more mature fish at key sites) **Improved movement:** • More native fish using fish passages

3.3.7 Legislation, Agreements and Conventions

Table 4 lists the management instruments - legislation, agreements and conventions - that are relevant to the Murray floodplain.

Table 4: Management instruments relevant to the management of Murray floodplain ecological values (Source: Adapted from BMT WBM (2007a, 2007b))

Management Instrument	Description
Victorian Legislation	• Victorian Water Act (1989) • Catchment and Land Protection Act (1994) • Flora and Fauna Guarantee Act (1988) • Aboriginal Heritage Act (2006) • Conservation, Forests and Lands Act (1987) • Crown Land (Reserves) Act (1978) • Planning and Environment Act (1987) • Environmental Effects Act (1978) • Victorian Wildlife Act (1975) • Heritage Rivers Act (1992) • Environment Protection Act (1970) • Wildlife Act (1975) • Parks and Crown Land Legislation Amendment (River Red Gums) Act (2009)
Commonwealth Legislation	• Water Act (2007) • Environment Protection and Biodiversity Conservation Act (1999) • Native Title Act (1993)
Commonwealth Agreements	• Intergovernmental Agreement on Addressing Water Over-allocation and Achieving Environmental Objectives in the Murray–Darling Basin (2004)
Commonwealth Plans	• Basin Plan (2012) - (Refer to Section 3.3.6 of this EWMP for a more detailed description of the Basin Plan)
International Agreements	• Ramsar Convention on Wetlands of International Importance • Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention) • Bilateral Migratory Bird Agreements: o Japan-Australia Migratory Bird Agreement (JAMBA) o China-Australia Migratory Bird Agreement (CAMBA) o Republic of Korea Migratory Bird Agreement (ROKAMBA)

3.4 The EWMP development process

The Murray floodplain EWMP has been developed in consultation with agency stakeholders and the community. A number of activities were undertaken to develop the EWMP, including:

- Collating and reviewing information such as reports, studies, and relevant management plans and strategies
- Convening a Technical Panel to provide expert scientific advice regarding:
  - The water dependent ecological values present within the floodplain system

  - The ecological condition of these values and any threats to them
  - The predicted trajectories for the condition of the ecological values identified should no environmental watering occur
- Developing a hydraulic model to determine wetland inundation extents and depths for various River Murray flows (Jacobs 2015c)
- Developing a conceptual model to summarise the water-dependent ecological values and management objectives for the floodplain
- Consultation with key stakeholders to identify and document:
  - Operational processes and protocols for the River Murray system
  - The ecological values and management objectives
  - Management strategies for the release of environmental water
  - Risks and issues associated with environmental watering of the floodplain.
- Facilitating a workshop with the Technical Panel to identify and document:
  - The ecological values present within the floodplain and the hydrological objectives for their management
  - Risks to achieving the ecological objectives and also the potential risks associated with the delivery of environmental water
- Preparing a floodplain assets report (Jacobs 2015a), analysing the wetland types within the floodplain, the ecological values present, and their environmental watering requirements
- Preparing a technical synthesis report (Jacobs 2015b), to amalgamate the results of the hydraulic modelling with the floodplain assets report
- Assessing current environmental water delivery infrastructure, and also assessing any constraints to delivering water for environmental purposes, providing recommendations for improvement
- Determining appropriate methods to monitor and demonstrate the outcomes against ecological objectives
- Assessing and documenting knowledge gaps and providing recommendations to address these gaps
- Facilitating a review of the draft EWMP by key stakeholders.

4. Site Overview

4.1 Site location

The Murray floodplain lies on the northern border of the North East CMA region in Northern Victoria, on the Victorian side of the River Murray. Looking more broadly, the floodplain is located within the Murray-Darling Basin and is part of the Southern Basin group of catchments. The River Murray's headwaters are in the Great Dividing Range, flowing 2,530 km downstream to exit into the Southern Ocean near Goolwa in South Australia. The River is divided into three main reaches for Basin management purposes; the Upper Murray, Mid Murray, and Lower Murray. There are floodplain areas extending for most of the extent of the Murray, but the floodplain relevant for this EWMP is located in the Upper Murray reach. Figure 6 shows the location of the floodplain in relation to its position in the Upper Murray reach, with the extent of the floodplain indicated by red brackets. Subsequent references to the 'Murray floodplain' in this EWMP will refer to this area only.

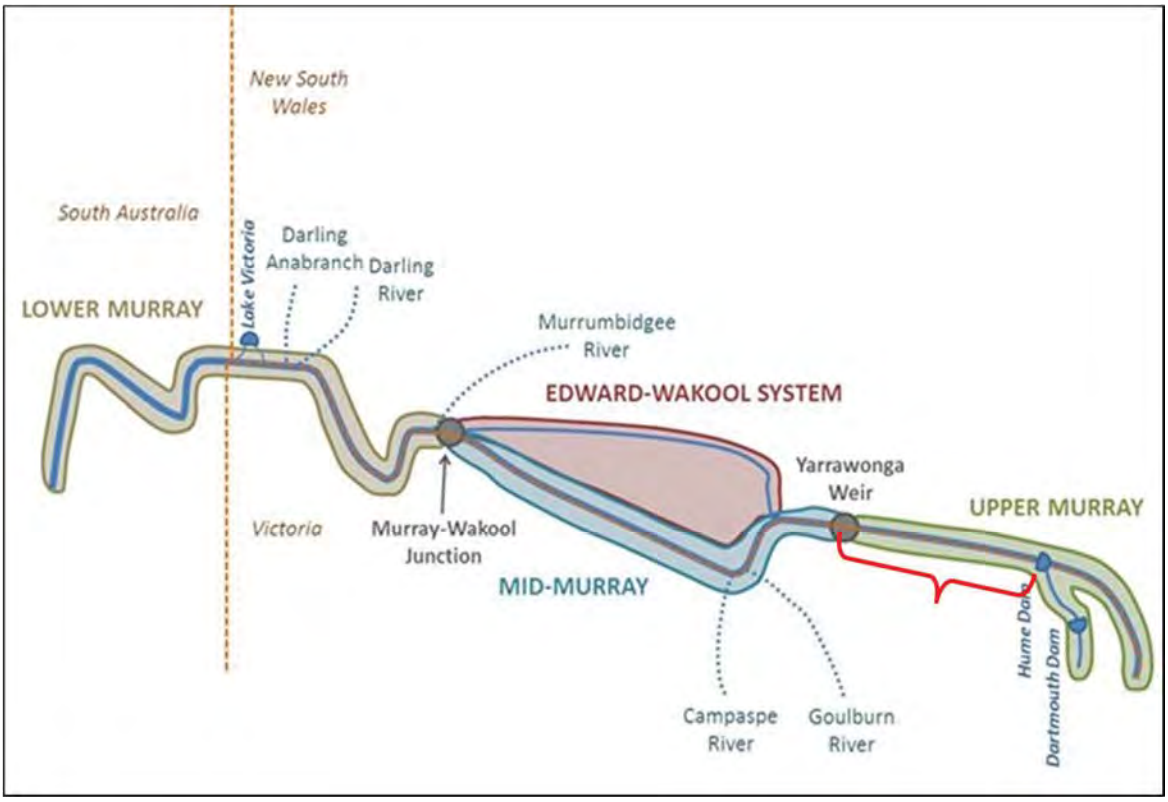

Figure 6: Location of the Victorian Murray floodplain in the Upper Murray reach (Source: Adapted from MDBA (2013b)

4.1.1 Catchment setting

The North East catchment covers approximately 1.9 million hectares of North East Victoria, including three major catchments: the Upper Murray; Kiewa; and Ovens. The catchment is bounded by the Murray River in the north, the Victorian Alps in the south, the NSW border in the east and Warby Ranges in the west. It includes the local government municipalities of Indigo, Wodonga, Wangaratta, Towong and Alpine, as well as parts of Moira and East Gippsland. The catchment is one of the most important water catchments in Australia because of its high water shed, contributing 38% of the total water to the Murray-Darling system (North East CMA 2014).

The main industries in North East Victoria are agriculture (dairy, beef, lamb, wool, cropping and horticulture), forest products, tourism, value-added processing industries and manufacturing (North East CMA 2014). These industries contribute an estimated $3.24 billion every year to the State's economic wealth (North East CMA 2014). The population in the region is approximately 102,000, mostly concentrated in the major urban centres of Wodonga and Wangaratta.

More than 55% of the North East Victoria region is public land, with over 200 parks and reserves. Natural resource assets in the catchment are a major drawcard for visitors, particularly the region's rivers and streams, which offer some of the best recreational opportunities in Victoria, particularly for fishing and camping.

One of the North East region's most valuable resources is the high quality water it produces. The region includes several major river systems, including the Mitta Mitta, the Ovens/King, and the Kiewa. There are eight nationally important wetlands, including Davies Plain, Mount Buffalo Peatlands, Lake Hume, Ryans Lagoon, Black Swamp, Lake Dartmouth, the Mitta Mitta Heritage River and the Ovens Heritage River (BMT WBM 2007a). The region also contains a variety of wetland types, representing significant areas of the State's most depleted wetland habitats, and some are among the least represented in Victoria's protected area network (BMT WBM 2007a). Permanent artificial water storages, including Lake Hume and Lake Dartmouth, also occur within the region.

4.1.2 Climate

The climate of the North East region varies greatly between the alpine regions and the floodplains along the River Murray. Temperature varies widely according to topography, with mean daily summer temperatures historically ranging between 11°C and 19.5°C in the alpine areas, and between 14°C and 31°C on the lower slopes and plains. Mean daily winter temperatures have historically ranged between -0.7°C and 3.7°C in the alpine areas, and between 2°C and 12°C on the plains. Average annual rainfall varies from 2000 millimetres in the alpine areas to less than 500 millimetres on the plains, with most rainfall occurring in winter and spring. Summer thunderstorms are common, contributing to the risk of fires and floods in the region, and on average, there are 130 days each year where at least 1 millimetre of rain falls.

About 80% of the volume of stream flow in the River Murray occurs during the winter-spring rainfall period, with conditions during the summer and autumn usually much drier. A consequence of the highly variable climate is that the River Murray has highly variable flows, resulting in the prolonged periods of drought and flood that are typical for the southern Murray-Darling Basin environment (MDBA 2015).

The Millennium drought from 1997 to 2009 in parts of the southern Basin significantly reduced rainfall in the catchments that feed water to the River Murray. A return to wetter conditions in 2010 led to widespread flooding, resulting in the inundation of the floodplains and the refilling of water storages. Using rainfall reconstructions based on climate proxy data, studies have shown that there is a very high likelihood that the Millennium drought resulted in the lowest volume of streamflows in the Murray–Darling Basin since 1783 (CSIRO 2010).

Climatic conditions in North East Victoria in future years are becoming less certain, with the impact of climate change on rainfall patterns, the intensity of droughts and the magnitude and timing of floods in the catchment difficult to predict (MDBA 2014a). It is thought however that the climatic conditions experienced during the Millennium drought will become more common as the effects of climate change are realised (CSIRO 2008a, 2008b, 2008c).

4.1.3 Land status and management

Approximately 80% of the land along the floodplain between Hume Dam and Yarrawonga Weir is privately owned, with the remainder being publicly owned (VEAC 2008). Between Hume Dam and Yarrawonga Weir the floodplain winds through urban, peri-urban and regional areas. The predominant land use along the floodplain is agriculture, particularly livestock grazing of both dryland and irrigated pastures. Livestock grazing is common on the floodplain between Wodonga and Howlong, and includes beef cattle with some sheep and other livestock enterprises. Dryland and irrigated cropping occurs in the lower sections of the floodplain towards Lake Mulwala, with the main crops here being winter cereals and oilseeds as well as fodder and hay crops (lucerne and pasture). Some horticultural activity is also present along the middle parts of the floodplain, including citrus, stonefruit, grapes, nuts and berry production.

A comprehensive reservation of Crown land, called the River Murray Reserve, is established along the entire length of the River Murray in Victoria, including the reach of Murray floodplain for this EWMP (VEAC 2008). The Reserve includes the existing 60 m wide Crown Land reserve, except where other public land reserves extend to the river, and excludes a small number of areas that were alienated for private use prior to the original Crown Land reservation. Parks Victoria is responsible for managing this Reserve.

Limited resource use is permitted within the River Murray Reserve at the discretion of land managers. Uses include bee keeping, grazing, hunting, limited extraction of timber products from specified areas (but not within the 60-metre Crown Land reserve), water management or extraction, and operations for the maintenance of bank stability for public safety, flood mitigation or erosion control. Adjoining private land owner encroachments occur in some places along the River Murray Reserve. Management of these encroachments can be difficult and requires systematic and prolonged consultation with local communities.

4.1.3.1 Indigenous Land Management

Registered Aboriginal Parties (RAPs) represent Aboriginal people in the management and protection of Aboriginal cultural heritage in Victoria. The Registered Aboriginal Party for the majority of the Murray floodplain area relevant to the EWMP is the Yorta Yorta Nation Aboriginal Corporation. The RAP area for the Yorta Yorta includes the south bank of the Murray River from Yarrawonga, continuing easterly along the Victoria-NSW border (including the floodplain) to a point about 4 km south-east of the Barnawartha-Howlong Road Bridge crossing of the Murray River, west of Wodonga. The remainder of the floodplain extending further east from Lake Hume is not currently covered under a RAP (DPC 2015).

There is also a RAP in application for the Bangerang Aboriginal Corporation, with a significant area of country similar to the Yorta Yorta RAP, particularly along the Murray. At the time of writing the EWMP, no decision had been made regarding this application (DPC 2015).

5. Environmental Water Management

Victorian Regional Waterway Strategies, which determine the waterways in a region that are priorities for receiving environmental water, guide EWMPs by outlining the long-term objectives and management arrangements for priority waterways. EWMPs rely on the delivery of environmental water and are based on environmental flow studies. Figure 7 illustrates the environmental water planning and management framework for Victoria.

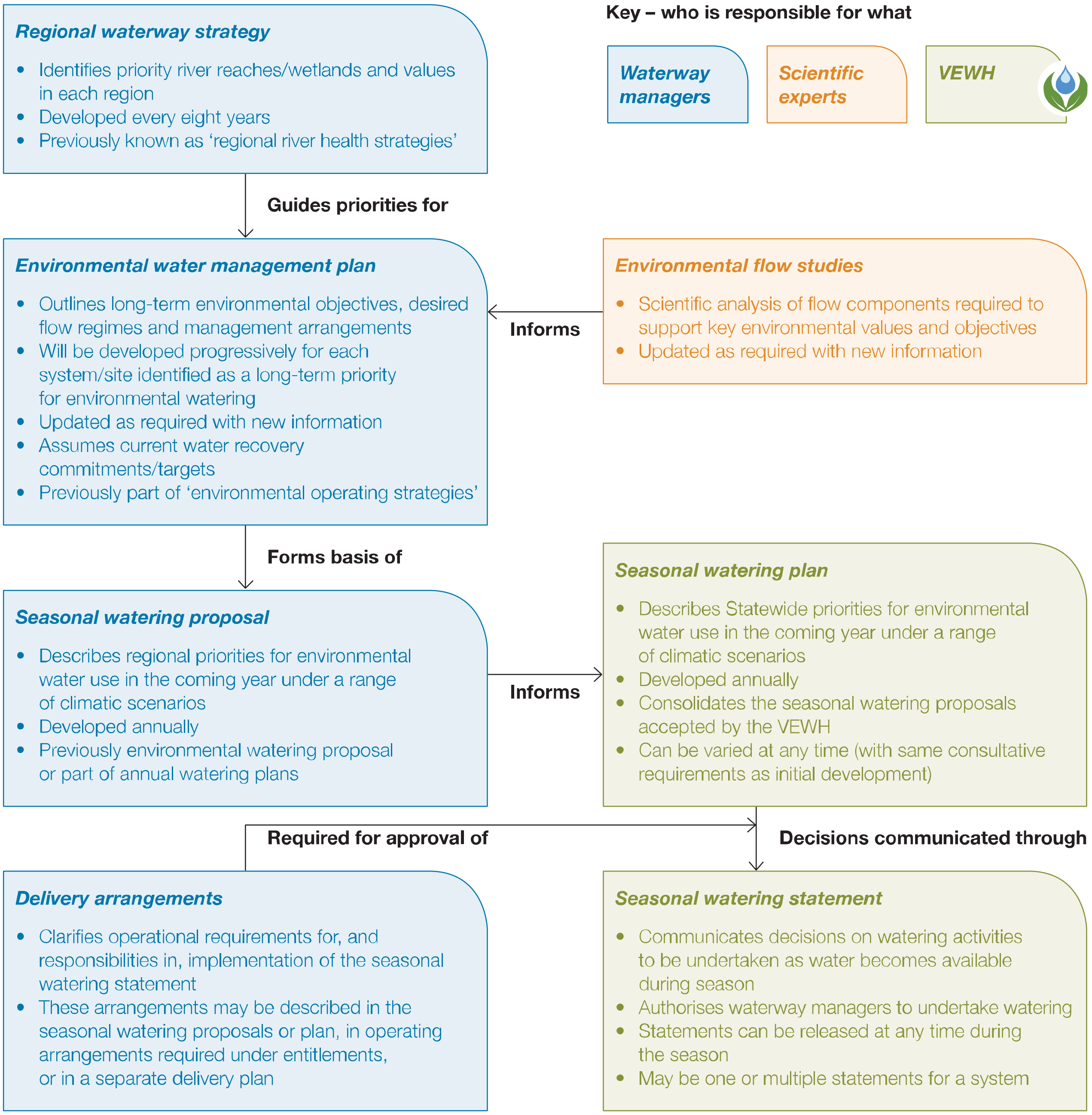

Figure 7: Victorian environmental water planning and management framework

5.1.1 Integration of Commonwealth and State planning processes for environmental watering of the Murray floodplain

The VEWH, CEWH and MDBA are each responsible for different portions of the environmental water holdings available for use in Victoria's Murray-Darling Basin waterways, including the Murray floodplain. Planning processes integrate these portions of water, and delivery is achieved through following an overarching operational framework. The Basin Plan sets the objectives and targets to guide the use of water recovered for the environment, and the planning framework of each individual water holder then guides the water management needed to meet the Basin Plan's ecological objectives.

As designated Waterway Managers under the Victorian Water Act (1989), Catchment Management Authorities are responsible for preparing annual Seasonal Watering Proposals for the application or use of water in water holdings. Seasonal Watering Proposals outline the priority environmental water requirements for waterways within a region in order to protect and/or enhance their environmental values and health, and need to be consistent with the region's Waterway Strategy. Environmental water holdings are held by the Victorian Environmental Water Holder (VEWH), who is responsible for prioritising and making decisions on their use. The VEWH communicates these decisions through its Seasonal Watering Plan and Seasonal Watering Statements (DEPI 2013a).

VEWH submits its Seasonal Watering Plan into the annual MDBA-facilitated environmental watering priorities negotiations process, which determines the watering priorities each year for the Murray-Darling Basin. A Basin Environmental Watering Strategy outlines the quantified environmental outcomes for the Basin, and the water management strategies to achieve these outcomes. This Strategy sets out the MDBA's best assessment of how four important components of the Basin's water-dependent ecosystems are expected to respond over a ten-year period given appropriate and coordinated management of the available water. The four components are:

- River flows and connectivity
- Native vegetation
- Waterbirds
- Native fish (MDBA 2014a).

The agencies and groups that have involvement in environmental water management for the Murray floodplain are summarised in Table 5.

Table 5: Agencies involved in environmental water management relevant to the Murray floodplain

Agency / Group	Responsibilities
North East CMA	• In consultation with communities, identifies regional priorities for environmental water management in the North East region, through documents such as the North East Waterway Strategy and North East Regional Catchment Strategy • Determines the water-dependent ecological objectives for the management of priority waterways, and assesses environmental water regime requirements of priority rivers, floodplains and wetlands to meet ecological objectives • Proposes annual environmental watering actions to the VEWH and other relevant agencies such as MDBA, DELWP and CEWH • Provides input and advice regarding the management and use of sources of environmental water, including passing flows, above-cap water and environmental water passing through the North East region for Basin purposes • Reports on the use and outcomes of environmental watering actions

Agency / Group	Responsibilities
Victorian Department of Land, Environment, Water and Planning (DELWP)	• Manages the water allocation and entitlements framework • Develops state policy on water resource management and waterway management, including the management of environmental water in regulated and unregulated systems • Acts on behalf of the Minister for Environment, Climate Change and water to maintain oversight of the VEWH and waterway managers • Management of land use licences such as grazing and bee keeping on public land
Murray Darling Basin Authority (MDBA)	• Under the rules of the Murray-Darling Basin Agreement, the MDBA has a specific role to: - Share the waters between the states - Direct River Murray operations - Manage the assets of the system. • Under the Water Act (2007): - Coordinates environmental watering - Facilitates the effective use of environmental water - Develops the Basin-wide environmental watering strategy and determines Basin annual environmental watering priorities - Develops environmental watering schedules. • A participating party to the management of flood easements along the River Murray between Hume Reservoir and Yarrawonga Weir • Coordinates The Living Murray water entitlements • River channel and riparian land management, including works and measures, erosion control and land rehabilitation • River Murray Water: - An internal business division of the Murray-Darling Basin Authority, responsible for operating and managing the River Murray system - Works with the other divisions of MDBA, as well as VEWH and CMAs, in planning for the delivery of environmental watering - Operational manager of Hume Dam
Commonwealth Environmental Water Holder (CEWH)	• Responsible for government policies and programs that seek to protect and restore environmental assets – rivers, floodplains and wetlands • Manages the Commonwealth's environmental water portfolio, including research projects, environmental watering policy, and major projects to improve water quality and the ecological health of waterway assets in the Murray Darling Basin

Agency / Group	Responsibilities
Victorian Environmental Water Holder (VEWH)	• Independent statutory body responsible for holding and managing Victoria's environmental water entitlements and allocations • Makes decisions on the most effective use of the Water Holdings, including use, carryover, and trade and authorises waterway managers to implement watering decisions • Liaises with other agencies to ensure coordinated use of all sources of environmental water and works with storage managers to coordinate and maximise environmental outcomes from the delivery of all water • Publicly communicates environmental watering decisions and outcomes.
Environmental Watering Group (EWG)	• Coordination of the delivery of environmental water to maximise environmental outcomes in the southern connected system • Decision making on the use of The Living Murray portfolio, River Murray Unregulated Flows, and River Murray Increased Flows
River Murray Water	• An internal business division of the Murray-Darling Basin Authority, responsible for operating and managing the River Murray system • Works with the other divisions of MDBA, as well as VEWH and CMAs, in planning for the delivery of environmental watering • Operational manager of Hume Dam
Goulburn Murray Water (GMW)	• Water Corporation - Storage Manager and Resource Manager • Is the designated Resource Manager for all northern Victorian regulated river systems including the Goulburn, Broken, Campaspe, Loddon, Bullarook and Murray regulated river systems. • Makes seasonal determinations of how much water is in dams and expected inflows, to decide how much water can be allocated to entitlement holders • Operational management of storage infrastructure, including Yarrawonga Weir • Ensures the provision of passing flows and compliance with diversion limits in unregulated and groundwater systems in the North East Region • Provision of advice for, and participation in, environmental water planning activities • Owns and manages most of the land surrounding the Victorian side of Lake Mulwala • Owner of Hume Reservoir (but operated by Murray Darling Basin Authority under the Murray Darling Basin Agreement)
Goulburn Broken Catchment Management Authority	• Identifies and manages regional environmental watering priorities for the Goulburn Broken waterways and floodplain immediately downstream of NECMA's Murray floodplain area
NSW Office of Water	• Responsible for day-to-day operations and management of major remedial works at Hume Dam, subject to funding and direction by the MDBA • Works collaboratively with Goulburn Murray Water, who manages land and water located in Victoria

Agency / Group	Responsibilities
Parks Victoria	• Manages the State's parks system, including National Parks, Wilderness Parks, State Parks, reserves, heritage properties and historic places. This includes the management of wetlands that occur within parks and conservation reserves for which it is the managing authority • Reviews and endorses watering proposals prepared by waterway managers where they propose to address the environmental watering needs of public land and/or where public land will be inundated by environmental watering actions • Operates, maintains and replaces, as agreed, the infrastructure required for delivery of environmental water, where the infrastructure is not part of the MDBA delivery system • Where agreed, participate in the periodic review of EWMPs • Manage and report on other relevant catchment management and risk management actions required due to the implementation of environmental water
Traditional Owners: • Yorta Yorta • Duduroa • Bangerang	• Significant connections to the Murray floodplain, and provide advice to agencies on matters relating to indigenous cultural heritage along the reach of the River Murray from Hume Dam to Yarrawonga Weir • Ensure indigenous community interests are represented in strategic management programs for waterways within North East Victoria • Joint managers of Barmah National Park immediately downstream of Yarrawonga Weir (Yorta Yorta)
Murray River Action Group (MRAG)	• Key community advisory group to State and Commonwealth agencies regarding the management of the River Murray • Represents private landholders and businesses on all aspects of river operations and management • Participants in the Hume to Yarrawonga Advisory Group forum
Advisory Group for Hume to Yarrawonga Waterway Management	• A cross jurisdictional group comprising representatives of government agencies and local stakeholders • Provides advice to MDBA on matters relating to waterway management in the reach of the River Murray from Hume Dam to Yarrawonga Weir
Local Councils	• An important influence on water management through their responsibility for land-use planning, development approvals, programs that aim to conserve and improve the environment, rates, and a variety of services such as road construction and maintenance. • Local councils also own and manage large areas of land • Provide input and advice into the development and implementation of the EWMP

Other stakeholders with an interest in environmental watering along the floodplain include local businesses, environmental groups, recreational users, local government, primary and secondary schools, landholders, and local communities.

5.2 Environmental Water Sources

The sources of water for the floodplain's water-dependent values can be provided through:

- Statutory environmental water entitlements (or holdings), such as a volume of water held in storage - These entitlements are the components of the environmental water that can be actively managed

- Water set aside for the environment as obligations on consumptive water entitlements held by urban and rural water corporations - These are usually called ‘passing flows’ that need to be released from storages or provided at a particular point on a river, and are usually more passively managed
- Unregulated flows and spills from storages, usually created by heavy rainfall.

This EWMP is focused on water that can be actively managed to address management objectives for the floodplain.

5.2.1 Environmental water holdings

In the River Murray system, environmental water holdings can be used to directly target the River Murray’s environmental values between Hume Dam and Yarrawonga Weir, including the floodplain if adequate volumes are provided. Environmental water travelling through the reach to address environmental objectives downstream of Yarrawonga Weir, can also provide benefits to the floodplain prior to reaching the final intended watering destination.

There is no specific entitlement solely intended for the environmental objectives of the Murray floodplain, and North East CMA will work in collaboration with VEWH, CEWH, other Victorian CMAs and the MDBA to explore options for leveraging from environmental water entitlements held by the Commonwealth, Murray Darling Basin Authority, and also the three separate states of Victoria, NSW and South Australia. These holdings are briefly described below.

5.2.1.1 Commonwealth environmental water

By far the largest holder of environmental water for the Murray River is the Commonwealth Environmental Water Holder (CEWH). To build environmental water holdings, the Commonwealth Government has either purchased water from willing sellers, or obtained water by investment in infrastructure improvements and other water recovery programs. CEWH has been buying water for the environment through the ‘Restoring the Balance in the Murray–Darling Basin’ Program since 2008–09 (National Water Commission 2010)

Following the ratification of the Murray Darling Basin Plan on 21st November 2012, the CEWH’s decisions on water use, carryover and trade have been made in the context of, and consistent with, the Basin Plan’s Environmental Watering Plan and annual priorities (DOE 2015).

As at 30th April 2015, the Commonwealth environmental water holdings for the Murray-Darling Basin totalled 2,275,347 ML of registered entitlements with a long-term average annual yield of 1,563,013 ML. Water holdings relevant to the Southern Connected Basin which includes the Murray basin (along with the Murrumbidgee, Lower Darling, Goulburn-Broken, Campaspe (excluding Coliban), and Loddon basins), were 1,731,160 ML of registered entitlements with a long-term average annual yield of 1,290,314 ML (DOE 2015).

For Murray basin entitlements, this includes:

- 293,492 ML for Victoria, comprising a mix of high security and low security water
- 348,386 ML for NSW, comprising a variety of licenced volumes with differing securities
- 129,411 ML for South Australia, comprising one high security entitlement.

Basin-scale environmental watering needs generally determine how Commonwealth environmental water is used. A key input to this process is the setting of Basin annual environmental watering priorities, which is facilitated by the MDBA. The annual environmental watering priorities are developed in consultation with participating Basin states, which for the Murray system is NSW, Victoria and South Australia (CEWO 2013). Releases from Hume Dam, contributing natural inflows to the Murray from tributary waterways such as Kiewa and Ovens River, and releases from Yarrawonga Weir are used to help achieve these environmental watering objectives. Depending on the volumes travelling through and any current constraints, environmental water travelling through this part of the Murray system for downstream uses has the potential to also address Murray floodplain needs as it is in transit.

5.2.1.2 Victorian environmental water

Table 6 shows the Victorian environmental holdings for the Murray system.

Table 6 : VEWH environmental holdings (Source: VEWH (2014))

Environmental Holding	Volume and Reliability
Bulk Entitlement: (River Murray – Flora and Fauna) Conversion Order 1999	• 29,783 ML high reliability • 3,993 ML low reliability • 40,000 ML unregulated
Bulk Entitlement (River Murray – Flora and Fauna) Conversion Order 1999 – Barmah-Millewa Forest Environmental Water Allocation	• 50,000 ML high reliability • 25,000 ML low reliability
Bulk Entitlement: (River Murray – Flora and Fauna) Conversion Order 1999 – Living Murray	• 9,589 ML high reliability • 101,850 ML low reliability • 34,300 ML unregulated
River Murray Increased Flows	• 70,000 ML[1]
Bulk Environment: (River Murray – Snowy Environmental Reserve) Conversion Order 2004[1]	• 29,794 ML high reliability
Water Shares: Snowy Environmental Reserve	• 14,671 ML high reliability • 6,423 ML low reliability
Environmental Entitlement (River Murray – NVIRP Stage 1) 2012	The entitlement volume is equal to one-third of the total phase 4 water savings from GMW Connections Project Stage 1 achieved in the Murray component of the Goulburn Murray Irrigation District, as verified in the latest audit; and any mitigation water available in the River Murray System in that year.

[1] River Murray Increased Flows (RMIF) is water recovered under investment in the Snowy Joint Government Enterprise and available as environmental water for the River Murray. The VEWH holds water entitlements in trust for the Snowy program, a joint initiative with the New South Wales and Commonwealth governments. Decisions about the preferred environmental water releases for the Snowy are made by the New South Wales Ministerial Corporation, on recommendation of the Snowy Scientific Committee. The VEWH does not have a direct role in planning for or delivering this water.

5.2.1.3 The Living Murray Environmental Water

Table 7 shows the environmental holdings coordinated by MDBA on behalf of The Living Murray initiative.

Table 7 : MDBA environmental holdings (Source: MDBA 2013 – TLM annual watering plan)

Source	Entitlement
The Living Murray Environmental Entitlement	**Regulated systems** 590,800 ML of multi-state entitlements in regulated systems for use at the six Living Murray Icon Sites, comprising: • Victoria – 63,580 ML high reliability and 263,880 ML low reliability water • NSW – 5,620 ML high security and 212,680 ML general security water • SA - 45,020 ML water licence

Source	Entitlement
	Unregulated systems 397,270 ML, comprising: • 350,000 ML - NSW Supplementary water • 12,970 ML - NSW Unregulated • 34,300 ML - Victorian Unregulated
	Total entitlement of 988,050 ML.

6. Management Units

For management purposes, North East Regional Waterway Strategy divides the region up into nine waterway management units; one Whole of Region System, and eight smaller sub-catchment systems. The eight sub-catchment systems are:

- Upper Murray
- Upper Mitta Mitta
- Lower Mitta Mitta
- Kiewa
- Upper Ovens
- Lower Ovens
- King
- Murray Plains (North East CMA 2014).

The Murray floodplain covered by this EWMP is predominantly located in the Murray Plains system, with a smaller area of the floodplain located in the Upper Murray and Kiewa systems between Hume Dam and Wodonga (Figure 8).

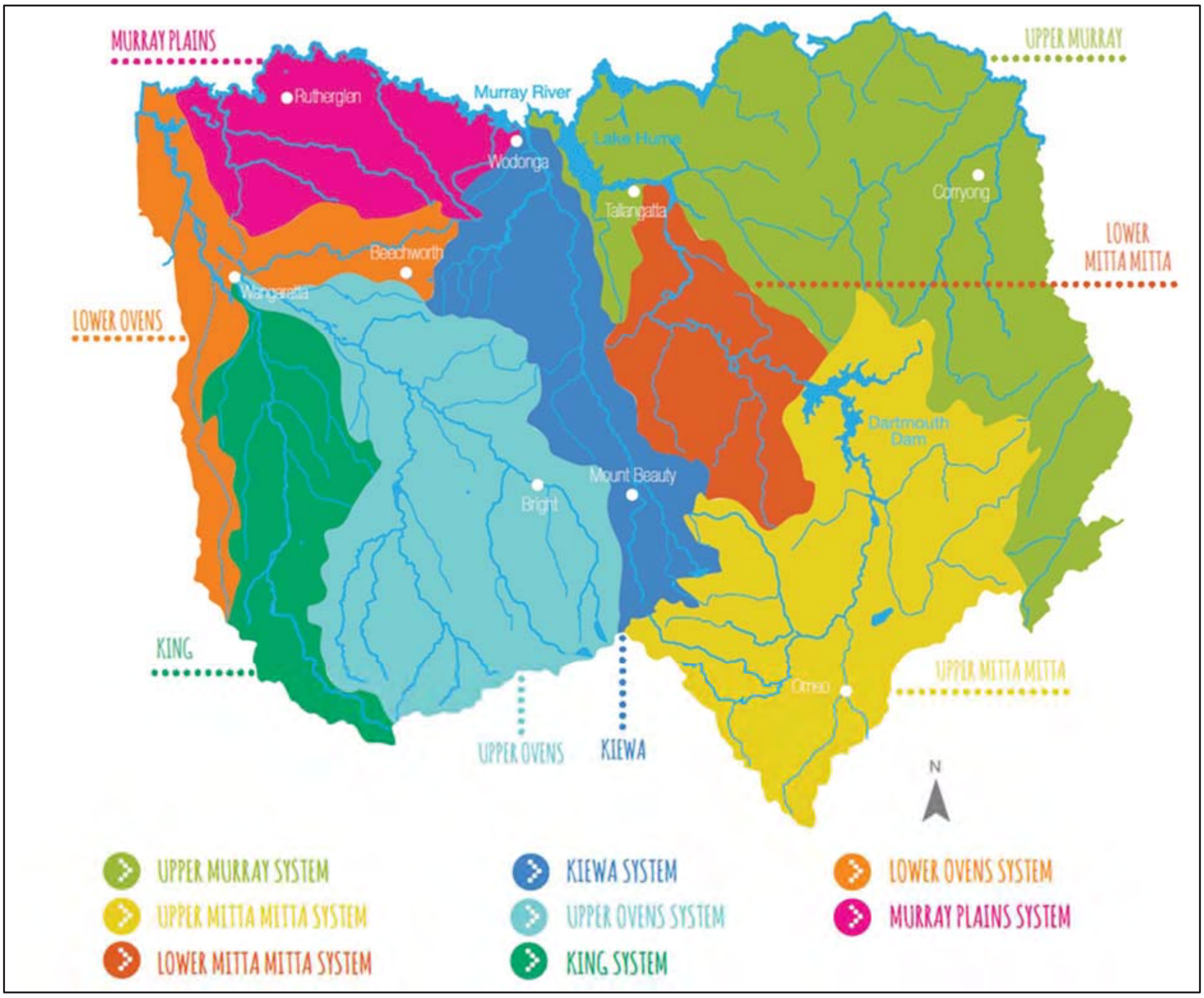

Figure 8: Location of the Murray floodplain in the Murray Plains and Upper Murray management units (Source: North East CMA 2014)

The Victorian Murray floodplain is also part of one of the six Icon Sites under the MDBA's The Living Murray initiative (TLM). The extent of the river and floodplain between Hume Dam and Yarrawonga Weir is categorised as Reach 1 of the River Murray Channel Icon Site.

6.1 Hydrophysical characteristics of the floodplain

Technical experts participating in a workshop held during the development of the EWMP (Jacobs 2015a), recommended that the North East CMA would need to consider both wetland type and water regime when planning strategies for the restoration or conservation of the Murray floodplain wetland vegetation. Workshop participants recommended that wetlands and floodplain surfaces in the floodplain be categorised based on their morphology and hydrology and that typical ecological values should be assigned to each identified wetland/floodplain type. This recommendation is based on recent research by Barrett *et al.* (2010), who studied floodplain wetlands adjacent to the Murray River between Hume Dam and Tocumwal in south-eastern Australia. Barrett *et al.* (2010) found plant community structure to be related to water regime, with clear differences between the communities of wetlands with historical 'Wet', 'Dry' and 'Intermediate' water regimes. Plant community structure was also related to wetland type, with differences found between the communities of floodplain depressions, flood-runners and cut-off meanders. Along this reach of the Murray River *et al.*three wetland types were identified based on morphology:

1. Floodplain depressions / lakes
2. Cut-off meanders
3. Flood runners.

The technical workshop participants also recommended a fourth type, which describes the floodplain surfaces that are inundated during a flood event but which don't retain standing water once the flood recedes, called a Shedding Floodplain surface. Each of these wetland types is described below.

6.1.1 Floodplain depressions / lakes

Figure 9: Example of a floodplain depression / lake

Floodplain depressions (Figure 9) are characterised by shallow depressions that resemble lakes (if inundated) rather than river channels. When inundated, they comprise open water typically with a zone of fringing vegetation. When dry they are likely to become colonised with annual grasses and other low growing species. An example of a floodplain depression in the EWMP area is Lake Moodemere.

6.1.2 Cut-off meanders

Figure 10 : Example of a cut-off meander

Cut-off meanders are wetlands that originate from a change in the course of a river over time (Barrett *et al.* 2010). They are also called ox-bow lakes, billabongs or cut-off channels (Figure 10). They resemble the main channel in width and sinuosity, but may exhibit areas of sedimentation and shallowing. Ryans Lagoon downstream of Lake Hume is an example of a cut-off meander. Ryans Lagoon is listed on the Directory of Important Wetlands because of its environmental and educational values.

6.1.3 Flood runners

Figure 11: Example of a flood runner

Flood runners are floodplain features that carry water away from the main channel during high flows (Barrett *et al.* 2010). Unlike cut-off meanders, they are not historically part of the main channel and they tend to be narrow and more incised (Figure 11).

6.1.4 Shedding floodplain surfaces

Shedding floodplain surfaces are those parts of the floodplain that are inundated during a flood event but which shed water quickly once floods recede (Figure 12). They are technically not a wetland because they do not hold water for a period of time after the flood event. However, they are important floodplain features and require inundation to provide watering of flood tolerant vegetation, replenishment of soil moisture, and recharge of groundwater across the floodplain. Vegetation communities on shedding floodplains are often quite different to those communities present in the wetlands due to the significant difference in water regime and flooding requirements.

Figure 12: Example of a shedding floodplain

Due to their similarity in management objectives, cut-off meanders and floodplain depressions will be considered as a single management unit for the purposes of this EWMP.

6.1.5 Wetland water regimes on the floodplain

Wetland types in the floodplain are classified according to the frequency, depth, duration and timing of the inundations they receive (Table 8). This variation in inundation patterns is further related to their elevation on the floodplain relative to the river level.

Table 8: Components of wetland water regimes (modified from:).

Component	Definition
Timing	**When water is present.** Within year patterns are most important in seasonal wetlands, whereas among year patterns and variability may be more important for temporary wetlands.
Frequency	**How often filling and drying occur.** Some wetlands permanently contain water whereas others are subjected to wetting and drying cycles at a range of intervals from several times a year, on an annual basis, or less frequently.
Duration	**The period of inundation.** Duration of inundation can be as short as days and may extend to years. Duration can also vary within and among wetlands.
Rate of rise and recession	**The rate at which water level rises or falls.** The rate of rise and fall can be critical for species adapted to different conditions or may provide cues for life history stages such as spawning, seed set or germination.
Extent and depth	**The area of inundation and the depth of water.** Area inundated and depth of water will influence the dynamics of a wetland, for example depth affects light penetration. Area and depth can vary within a wetland at different times, thus different processes will occur in the one wetland across a range of temporal and spatial-scales.
Variability	**The degree to which the above features change.** All of the above components of the water regime can change at a range of time-scales from short to long. Variability is often dramatically altered under management and is also influenced by climate conditions. For example, during dry climate periods some components of the water regime may be vary (e.g. the duration of inundation may be shorter, or there is a longer interval between events).

Wetland water regime is highly variable across the Murray-Darling Basin, with examples of wetlands from all of these hydrological categories. River regulation across the Basin is such that there are now relatively few, if any floodplain wetlands that have not been impacted by changed water regimes.

For the purposes of the EWMP, the Murray floodplain wetlands are classified as:

1) **Permanent**: Wetlands permanently inundated and often dominated by open water with some fringing emergent and/or submerged aquatic vegetation
2) **Seasonal**: Wetlands connected to the river at or just above bank full that are typically inundated every year in winter/spring and then drawn down over summer / autumn
3) **Intermittent**: Wetlands located higher on the floodplain that are only intermittently inundated by moderate flood events, typically once every 3-5 years. These wetlands can hold water for some periods of time, but dry out more frequently between inundation events than category 2 wetlands
4) **Episodic**: Wetlands located at even higher elevations that are infrequently (episodic) inundated during large flood events, typically once every 5-10 years or so. These wetlands would be predominantly dry with occasional periods of inundation.

The Murray floodplain wetlands generally fall within the bounds of the red circle in Figure 13, while less frequent inundation is a characteristic of more arid zones in the Basin. Note that for Figure 13:

- Ephemeral means containing water only after unpredictable rain and surface water drying within days
- Episodic means dry most of the time, with rare and very irregular wet phases that may persist for months
- Intermittent means alternatively wet and dry, with surface water persisting for months to years.

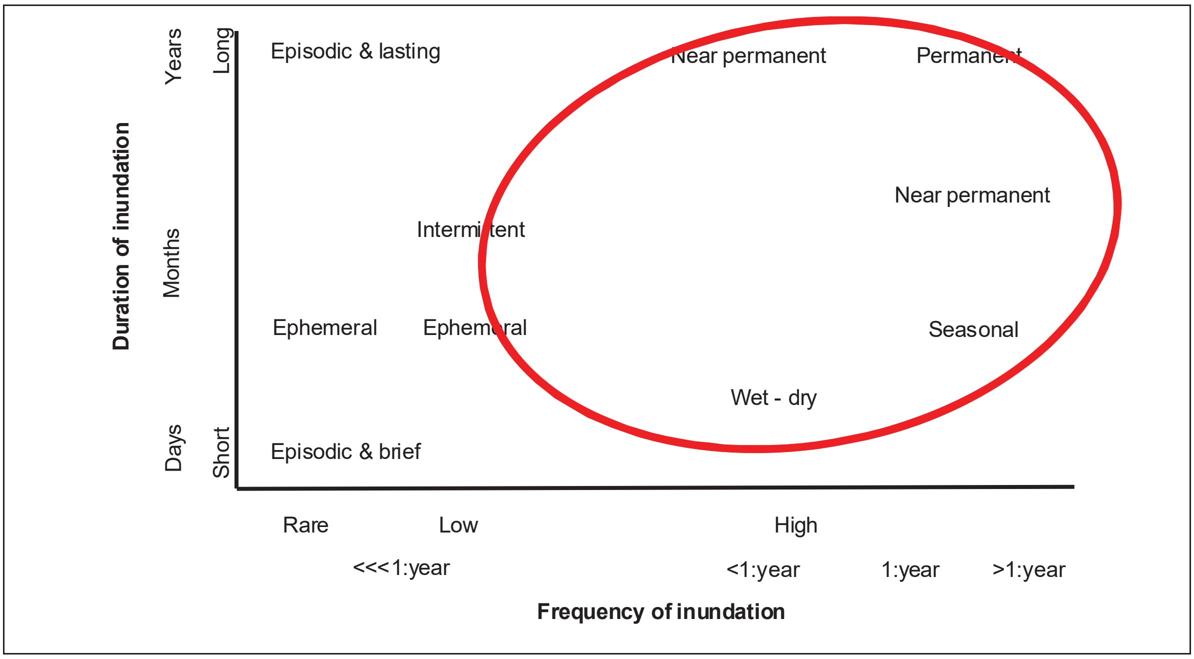

Figure 13: Water regime types characterised by frequency of flooding and length of time with surface water (Roberts and Marston 2000).

Because of regulation of the Murray, some wetlands in the Murray floodplain now experience a reduced frequency and/or reduced duration of inundation because of the overall reduction in river discharge. For other wetlands, they now experience an increased frequency and/or duration of inundation, to the point where they seldom dry out. Pressey (1990) identified four wetland categories along the River Murray based on hydrological classification and the impacts regulation has on these wetland types (Table 9). Wetlands near bank full and in low lying areas close to river channels are inundated more frequently and for longer durations as a result of high summer flows (irrigation flows), while wetlands located further from the channel and above the maximum regulated level are inundated less frequently. Category 1 and 2 wetlands on the Murray floodplain generally correspond to the permanent wetland category, while Category 3 and 4 wetlands correspond to the seasonal, intermittent and episodic categories.

Table 9: Hydrological classification of Murray River wetlands (Pressey 1990; Reid 1998)

Category	Description	Effect of regulation on hydrology
1	Wetlands connected to the river at minimum regulated flows or at pool level.	More frequent inundation
2	Wetlands connected to the river above minimum regulated flow but at, or below, maximum regulated flow.	More frequent inundation
3	Wetlands above maximum regulated flow, filled only by surplus flows.	Less frequent inundation
4	Wetlands above maximum regulated flow and which receive water from adjacent irrigated areas via drainage, runoff or seepage.	Variable, but with declining water quality

7. Hydrology and System Operations

While comprising only 2% of the total Murray-Darling Basin area, the North East region contributes a significant proportion of the inflows into the Murray-Darling Basin, with approximately 38% of the total water supplied to the Basin coming from the following basins:

- Upper Murray and Mitta Mitta Rivers Basin
- Kiewa Basin
- Ovens River Basin (North East CMA 2014).

The major unregulated tributaries that contribute flows to the reach of floodplain between Hume Dam and Yarrawonga Weir are the Kiewa River and the Ovens River. Contributions also come from the smaller unregulated tributaries of Indigo Creek and Black Dog Creek. The reach is controlled by Hume Dam and Yarrawonga Weir, and it receives the full hydrological impact of flow regulation (Gippel and Blackham 2002). For a distance of 180 km, the channel conveys all regulated flow destined for downstream users (Figure 14).

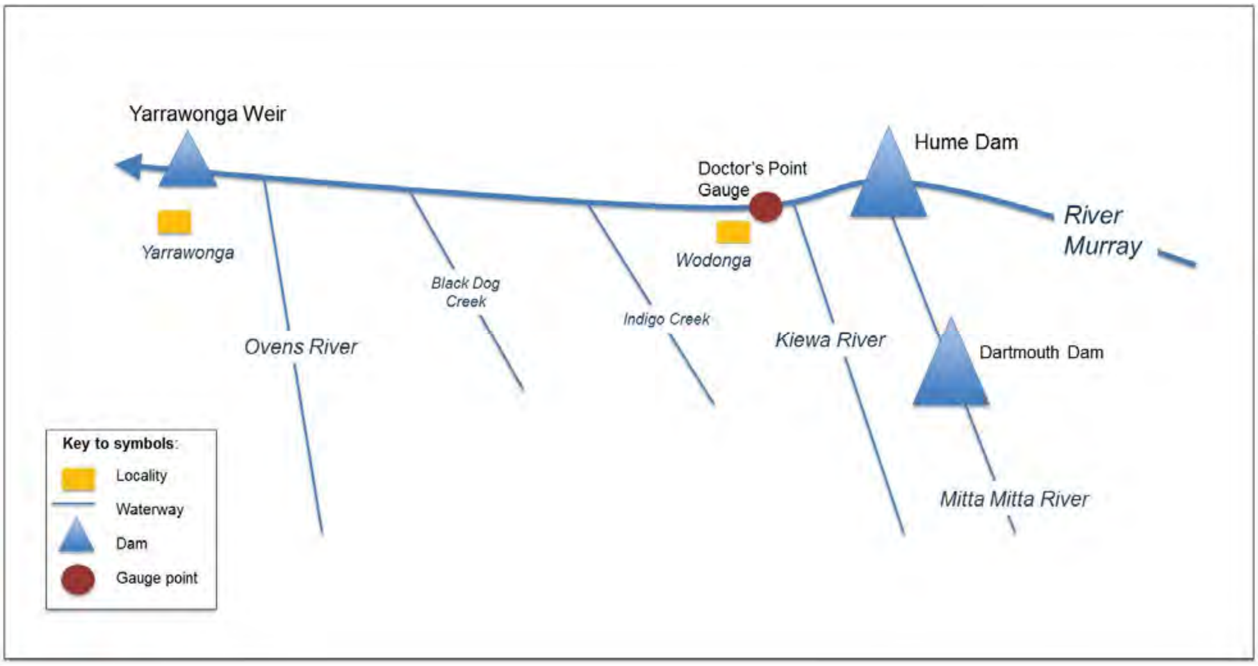

Figure 14 : Schematic diagram of Hume Dam to Yarrawonga Weir

7.1 Major storages in the region

The major storages in the region are Hume Dam, Dartmouth Dam and Yarrawonga Weir. The primary purpose of Hume Dam is to conserve water in periods of high flow, for release later during periods of low flow. The main use of the water is for irrigation, but significant volumes of water are also used for domestic, industrial and environmental purposes, and to supply South Australian entitlements. About 30% of the total inflow to the River Murray is generated upstream of Hume Dam and the dam also has a flood mitigation role, although not originally designed to do so. Construction of the dam commenced in 1919, with the first stage of construction completed in 1936 and an original storage volume of 1,522 GL. This was subsequently increased to 1,800 GL in 1949, 2,460 GL in 1958 and to its current storage volume of 3,000 GL in 1961. Water released from the dam is gauged at Heywood Bridge immediately downstream of the dam. It is also gauged at Doctors Point, which picks up the flow in both the Murray and Kiewa about 6 km downstream of the dam. The valve capacity of Hume Dam is greater than 50,000 ML/d, and is therefore not expected to constrain environmental water releases to any great degree. Under current operations, releases from Hume Dam are limited to up to 25,000 ML/day at Doctors Point, with releases predominantly driven by irrigation demand. During summer, releases have historically been close to channel capacity for long periods before they decline in autumn when the demand for irrigation water drops. A minimum flow requirement of 1,200 ML/day at Doctors Point is intended to provide flow for some in-stream and riparian environmental needs during winter when irrigation releases are minimal.

Dartmouth Dam on the Mitta Mitta River also influences the management of Hume Dam. Dartmouth Dam is the tallest dam in Australia (180 m) and the largest storage in the Murray–Darling Basin (3,850 GL). The dam was commissioned in 1979 and is primarily used for drought storage. Nearly 10% of the inflows to the River Murray system are generated above Dartmouth Dam. Because of its large storage capacity (about five times its average annual inflow), Dartmouth Dam rarely experiences uncontrolled spills. The Mitta Mitta River joins the River Murray upstream of Hume Dam, and the dams are operated ‘in harmony’, with rules in place to maximise water storage and minimise flood risks downstream.

Yarrawonga Weir is located about 237 km downstream of Hume Dam. Completed in 1939, the main purpose of the weir is to raise the water level of the River Murray to allow diversions of water under gravity for irrigation via Mulwala Canal into New South Wales, and via the Yarrawonga Main Channel in Victoria. The water impounded by the Yarrawonga Weir forms Lake Mulwala, which has a capacity of 117,500 ML. An average of 1,900 GL or 17% of the River Murray’s annual flow is diverted annually to the Yarrawonga Main Channel and the Mulwala Canal. The Yarrawonga Main Channel services the Murray Valley Irrigation Area in Victoria. The channel has a discharge capacity of 3,100 ML/d and distributes water to an area of 128,000 ha via a network of six main channels and 261 spur channels (GMW 2015).

7.2 Operating the system

Operation of the entire River Murray system is classified into three modes, providing a useful framework for understanding how environmental flow management is integrated with existing practices for the reach of the River Murray relevant to Murray floodplain. The main operating modes are:

- Supplying mode – When some or all of the headwork storages (Dartmouth and Hume Reservoirs, Lake Victoria or Menindee Lakes) release water and are drawn down to meet downstream demands
- Storing mode – When the headwork storages are filling and the flows downstream of these storages are largely contained within the channel to meet downstream requirements
- Spilling mode – When at least one of the headwork storages is spilling, and is commonly associated with flooding downstream.

Locks and weirs along the Murray system tend to be operated in two modes: holding at pool level; and passing inflows (MDBA 2014b). The key storage relevant to the management of environmental water for the floodplain is Hume Dam, with a significant amount of the water released for environmental purposes along the River Murray originating from this storage.

7.2.1 Institutional Arrangements

Under the MDB Agreement (MDBC 2006), water resources that flow into the Murray River upstream of Doctors Point, including Hume Dam, Dartmouth Dam and the Kiewa River, are shared equally between New South Wales and Victoria. Victoria and New South Wales have respective rights to all tributary inflows downstream of Doctors Point except for the Darling River. The water sharing arrangements between New South Wales, South Australia and Victoria of water made available in the catchment of River Murray above Hume Dam by the Snowy Mountains Hydroelectric Scheme are detailed within Schedule G of the Agreement (MDBC 2006).

MDBA directs operations for the River Murray system, including flood operations and release decisions for Hume Dam, and liaises with relevant state-based agencies and the community to provide advice on releases, planned changes and other matters. Acting on direction from MDBA, the NSW State Water Corporation operates Hume Dam, and the Victorian water authority Goulburn Murray Water (GMW) operates Yarrawonga Weir. GMW is the delegated resource manager and makes water allocations for all Murray water authorities and private diverters according to the water sharing arrangements set out in the Murray water holdings.

7.2.2 Hume Dam Operations

Water levels in Hume Dam fluctuate on a regular annual cycle and are typically drawn down between November and May each year to between 10 and 50 percent capacity. The dam stores water in winter and spring and spills one in two years on average, although it can go many years without spilling during periods of low rainfall.

During the storing phase of the dam, which runs from the end of the irrigation season in mid-May to late winter or spring, releases from Hume Dam are kept at a minimum for as long as possible. The minimum release from the storage is 600 ML/d, but usually a minimum flow of 1,200 ML/d is maintained at Doctor's Point to provide flows for some environmental needs.

In the supplying mode, daily water demands from South Australia and the irrigation areas along the Murray River during peak farming season can exceed 30,000 ML/d. The river channel between Hume and Yarrawonga has a capacity to pass 25,000 ML/d without flooding surrounding land, so efforts are made to get the required water down to mid-river storages such as Lake Victoria over a longer period earlier in the season. This operational constraint is based on the nominal channel capacity of the River Murray in this reach, for which easements have been obtained, and is designed to minimise the inundation of privately owned agricultural land associated with the delivery of regulated flows (80% of the floodplain in the reach extending from Hume Dam to Yarrawonga Weir is privately owned). This flow limitation at Doctor's Point forms a key constraint for supplying flow to the floodplain areas. A discussion regarding the constraints and issues associated with increasing flows above 25,000 ML/d is provided in greater detail in Section 12.1.1.

When the Hume Dam storage level and inflows are high, usually in winter/spring, pre-releases may be made to provide airspace for flood mitigation. Pre-releases are initially made at rates up to channel capacity. However when the storage is near full, pre-releases at rates above channel capacity are sometimes made after consultation with affected landholders downstream. If the dam is full or near full, the spillway gates at the dam are used, together with the power station and irrigation valves, to pass flood inflows downstream. Although its primary function is water storage, Hume Dam provides significant flood attenuation downstream. It can fully absorb many floods during the storing mode, typically during autumn and early winter, and can also significantly attenuate floods later in the season.

The Snowy Mountains Hydro-electric Scheme diverts an extra 620 GL/year of water from the Snowy River into Hume Dam, increasing the amount of water that passes from Hume Dam to Yarrawonga Weir as regulated flows.

7.2.3 Yarrawonga Weir Operations

Yarrawonga Weir is the largest of 14 weirs along the River Murray downstream of Hume Dam, and is the point of greatest water diversions from the River Murray. Lake Mulwala is formed by Yarrawonga Weir and has a Full Supply Level (FSL) of 124.90 m relative to the Australian Height Datum and a capacity of 118 GL. Most of this storage space is 'dead' storage space, being used primarily to keep the pool level at full supply level to allow gravity diversion down irrigation channels, and the active storage is about 5 GL.

The weir is made up of 2 groups of gates: 8 on a southern structure and 2 on a northern structure. The southern side gates are used at all flow levels. The northern gates are only used during floods larger than 60,000 ML/day for flood mitigation.

The River Murray downstream of Yarrawonga Weir enters a reach known as the 'Barmah Choke', where the river channel becomes very narrow and shallow. The current operating limit at the Choke is 15,000 ML/day. This is a natural constriction, and results in frequent overbank flooding to the Barmah-Millewa Forest, one of the River Murray's Icon Sites. The entire reach between Hume Dam and Yarrawonga Weir is managed to store and supply winter-spring flows and increase summer-autumn flows. An impact of this change is an increase in the frequency of unseasonal forest flooding during times when it would typically remain dry, and can occur when unexpected changes in weather alter water demands resulting in a 'rainfall rejection' of previously ordered irrigation water that has been released from Hume Dam. If Lake Mulwala is already full, then this additional water needs to be released into the River Murray downstream. If the release rate exceeds the channel capacity at the Barmah Choke, the water spills into the forest causing unseasonal flooding and adverse effects to the forest ecology. As a result of this risk, Hume Dam and Yarrawonga Weir are operated in conjunction to try to minimise the risk of unseasonal flooding in Barmah-Millewa Forest.

The Mulwala Canal supplying NSW has a discharge capacity up to about 10,000 ML/day, and the Yarrawonga Main Channel supplying Victoria has a discharge capacity of 3,200 ML/day. These two channels serve a total area of over 8,000 square kilometres of irrigated land over the two states.

The water level in Lake Mulwala varies between 124.6 m AHD to 125.15 m AHD. During the irrigation season River Murray Water assesses daily orders for irrigation water supplies and releases water from Hume Dam to meet these orders. It takes about four days for water released at Hume Dam to reach Lake Mulwala.

During the winter, the water level in Lake Mulwala can vary significantly. The water may be lowered to allow for maintenance or to make way for floodwaters, and recently the lake has also been lowered on several occasions to control the spread of Dense Waterweed (*Egeria densa*) (MDBA 2013).

7.3 Floodplain hydrology

7.3.1 The impacts of river regulation on hydrology

Due to regulation, the natural water flow regime of the River Murray has been extensively modified, in terms of the rate, variability, total volume and seasonality of flows. These changes have affected both the river itself and the floodplain wetlands that are connected to the river. Under natural conditions (i.e. prior to river regulation), about half of the surface water run-off from the catchments of the River Murray reached the sea. About 11,300 GL of water would have flowed down the River Murray to its mouth during a typical year, but in a dry year this could reduce to about 2500 GL. During a very wet year, this could increase up to about 40,000 GL (VEAC 2008). This variation is a key feature of the flooding and flow regime of the Murray floodplain.

Large-scale floods along the River Murray generally occur once every 20 to 100 years, and extend from the river channel out over the floodplain. Depending on rainfall and snow in the upper catchment, these large-scale inundations often coincide with large-scale floods in Victorian rivers such as the Ovens, Broken, Goulburn, Kiewa and King. Large flood events along the Murray have occurred in 1917, 1956, 1973 and 2010-11. According to Gippel and Blackham (2002), the frequency of these events has remained relatively unchanged even with river regulation. This is thought to be the case because major floods are usually preceded by a wet period that fills storages and reduces demand for diversions. The runoff from very large events overwhelms the storages, so that their flood attenuation influence becomes negligible.

The most severe impact of regulation is seen in the reduction of small to mid-range floods (approximately 30,000 to 40,000 ML/d) (Thoms *et al.* 2000). Prior to regulation, mid-range floods occurred approximately every 2 to 10 years along the River Murray and were usually of shorter duration than the large floods (Gippel and Blackham 2002). With regulation, these floods are now only expected to last between one to three months, and occur much less frequently now than they did prior to river regulation. These types of floods, which previously occurred every second year, now occur every 6 to 8 years, and floods that once occurred every 10 years now only occur every 25 to 30 years (Thoms *et al*. 2000).

The third type of flow regime is low flows, which includes periods of no flow and sometimes drying of the river bed so that the River is reduced to a chain of ponds. Such events are now highly unlikely to occur on the River Murray because there is nearly always some flow in the River other than at the most downstream reaches in SA, where regulation is thought to have actually increased the frequency and degree of low flows (Gippel and Blackham, 2002).

Downstream of Hume Dam, Thoms *et al.* (2000) found that since regulation of the River Murray:

- Flows are now much less variable, particularly in winter and spring because smaller floods are now stored in Hume Dam
- The seasonality of flows has been reversed, with low flows in winter and high flows in summer and autumn
- Flows are at or near channel capacity for much of the year
- The average annual flow at Albury/Wodonga has increased because of the additional water transferred from the Snowy River
- The frequency and duration of flooding in winter and spring is now significantly decreased
- Opportunities for low lying wetlands to dry out in autumn have reduced
- Rain rejection events can cause unseasonal flooding during summer and autumn downstream of Yarrawonga Weir.

7.3.2 Historical Flow Data

Technical investigations contributing towards the development of the EWMP (Jacobs 2015a), used flow data from the Corowa gauge (409002), located approximately midway along the reach to assess historical changes to flow in the River Murray. Daily historical data available from 1909 to 2014 was used.

Figure 15 shows the historical daily flow at Corowa. The time series shows that flows from 1909 to 1936 followed a natural seasonal pattern of low flows in summer and high flows in winter. Winter flows were regularly in excess of 25,000 ML/d, and often above 50,000 ML/d. The construction of Hume Weir was completed in 1936, and from this point in time onwards the flow regime changed, with increased flow in summer associated with regulated releases for downstream irrigation. At this time, peak winter and spring flows continued to occur. In 1961 however, an extension to Hume Weir was completed and very clear effects of flow regulation can be seen in the historical record, with flow rarely exceeding 25,000 ML/d. This is particularly evident from 2000 until 2009, during the time of the Millennium Drought[3].

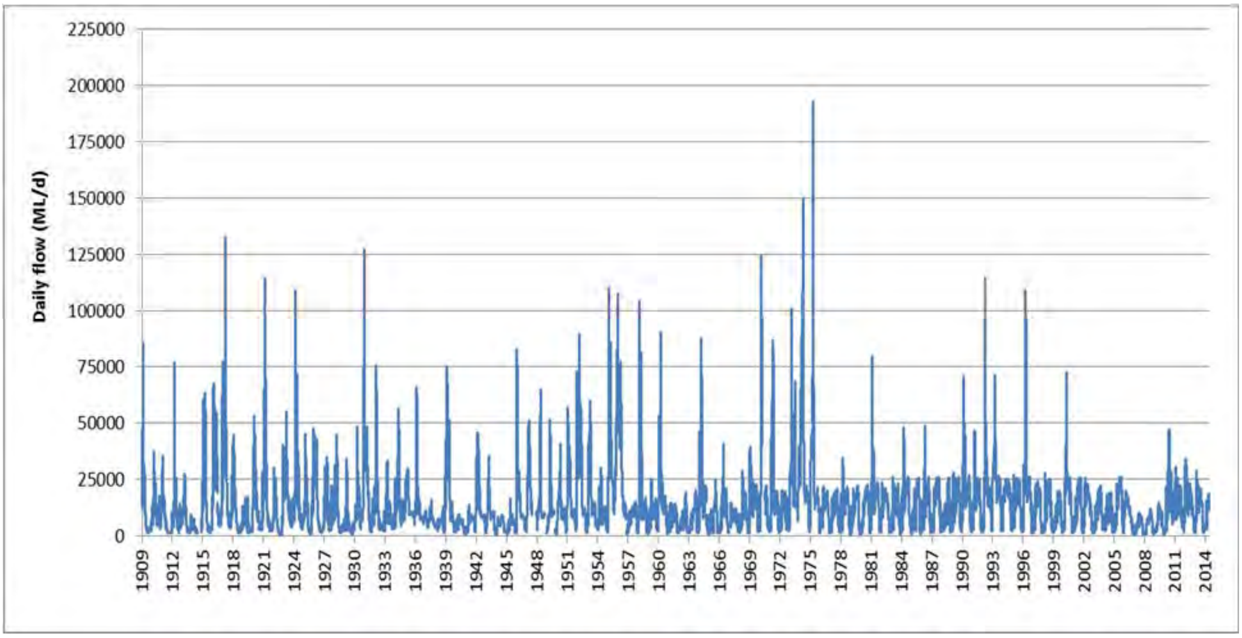

Figure 15: Time series of daily flow at Corowa (409002) (data source - http://riverdata.mdba.gov.au/sitereports/409002/)

An analysis of the Average Recurrence Interval of peak flows since 1962 indicates that on average, a flow of 40,000 ML/d would have occurred about once every 3 to 4 years (Figure 16). However, with the Millennium Drought and more efficient river operations, only one flow above 40,000 ML/d has occurred in the past 15 years. Prior to 1962, an event of 40,000 ML/d would have occurred once every one to two years (Jacobs 2015a).

The effect of river regulation is further evident in Figure 17, which shows median monthly flow[4] data from 1980 onwards. Under regulated conditions, the highest median flows occur between December to March, corresponding with the irrigation season, and the lowest median monthly flows occur between May to September. This represents a seasonal reversal of the natural flow regime.

Also notable in Figure 17 is the variation in flow. Between December to July, flow variability (based on the 25th – 75th percentile flow range) is very narrow. During late winter and spring however, stream flow variability increases, with higher flows occurring for a greater percentage of time. This reflects unregulated flood events in tributary streams and the pre-irrigation season managed releases from Hume Dam.

[3] Between 1997 and 2009, south-eastern Australia experienced the most persistent rainfall deficit since the start of the 20th century. Annual rainfall during the so-called 'Millennium Drought' was 73 mm below average (or 12.4% below the 20th century mean) for the years 1997–2009 inclusive. The drought broke in 2010/11, with large-scale floods across south-eastern Australia.

[4] Median flow provides a good representation of flows that occur often in a system (i.e. they are exceeded 50% of the time).

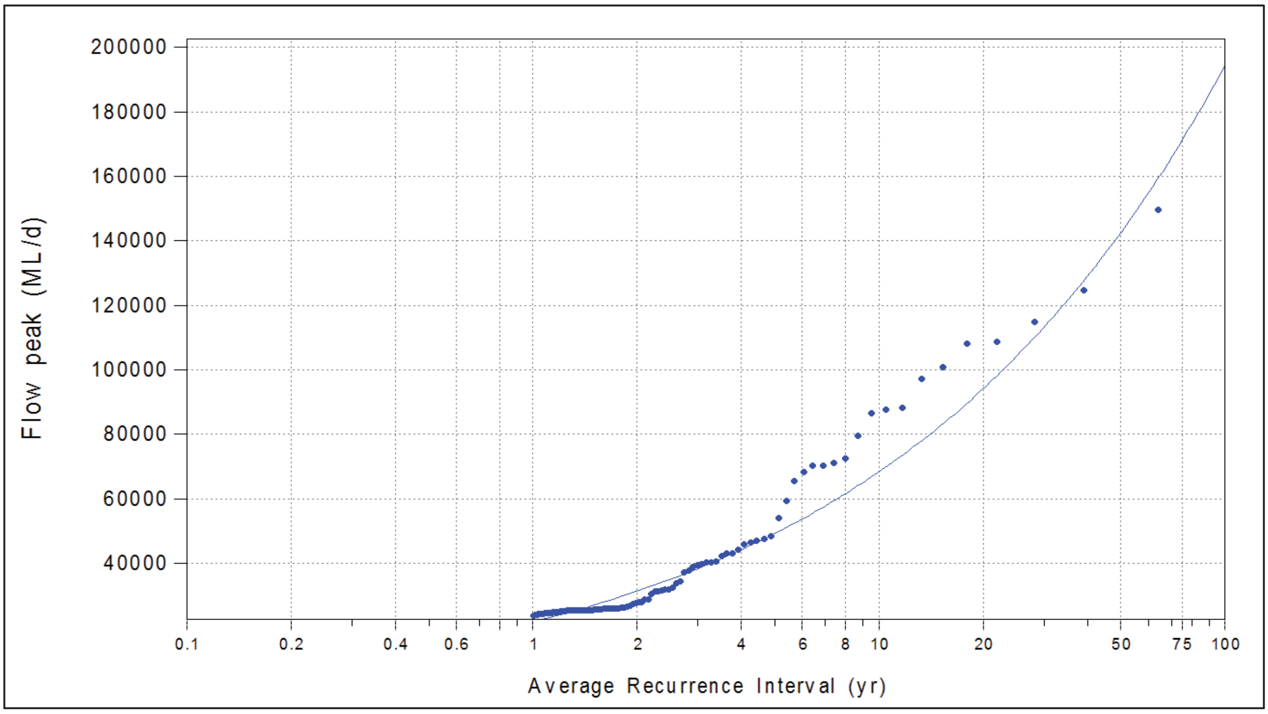

Figure 16: Average Recurrence Interval flows for Corowa (1962 to 2014)

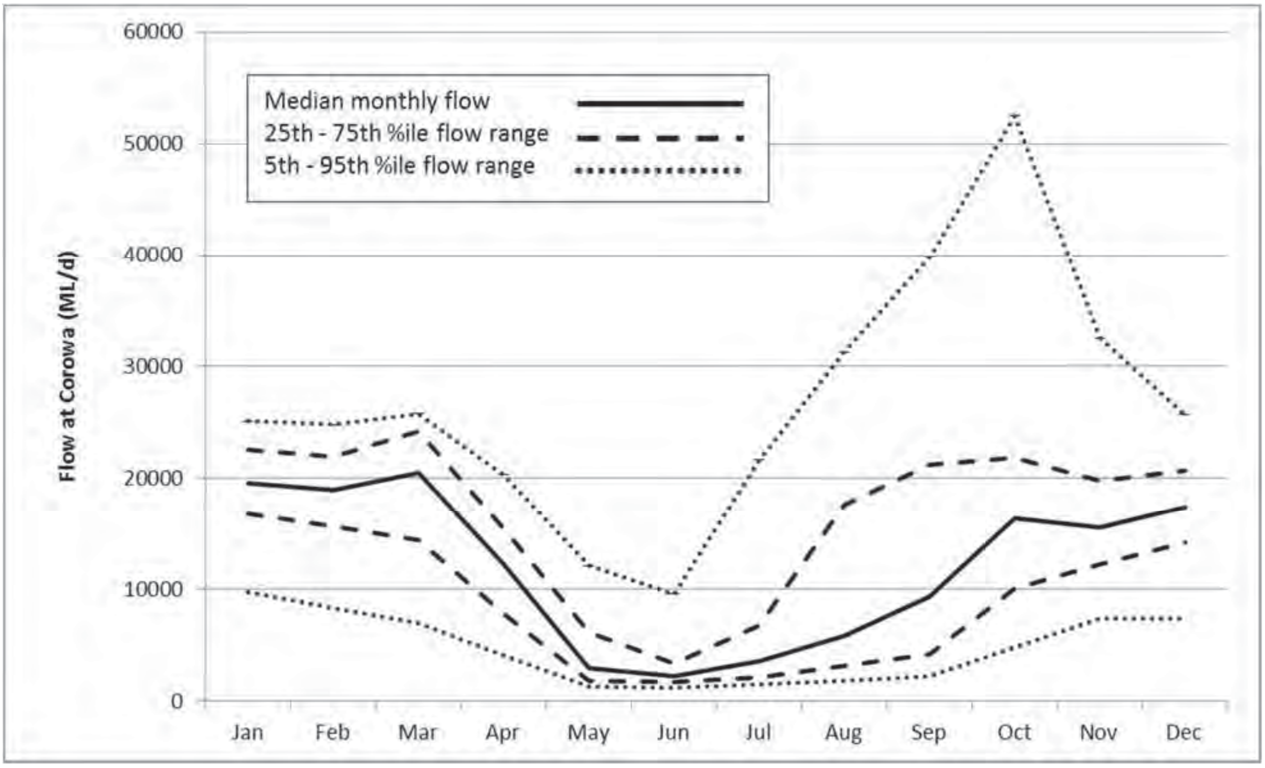

Figure 17: Median monthly flow and flow percentile ranges at Corowa from 1980 onwards

The shift in seasonality of the flow regime is also evident from the 1960s onwards when looking at spells analysis data[5], with an increase in the frequency and duration of flows >20,000 ML/d during summer associated

[5] A 'spell' is the total period of time when stream flows are either continuously above or continuously below a nominated threshold value.

with flow releases for irrigation (Figure 18). There is also a decrease in the frequency and duration of higher winter/spring flows (flows >30,000 ML/d) that would have inundated the floodplain (Figure 19).

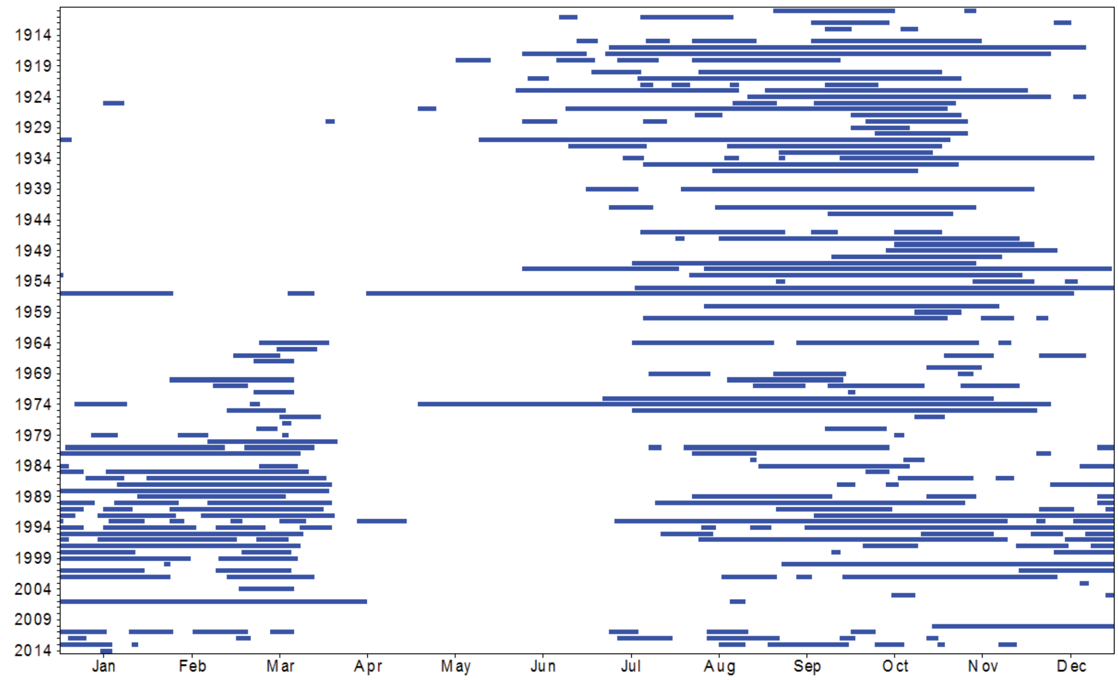

Figure 18: Historical pattern and duration of flow spells >20,000 ML/d at Corowa

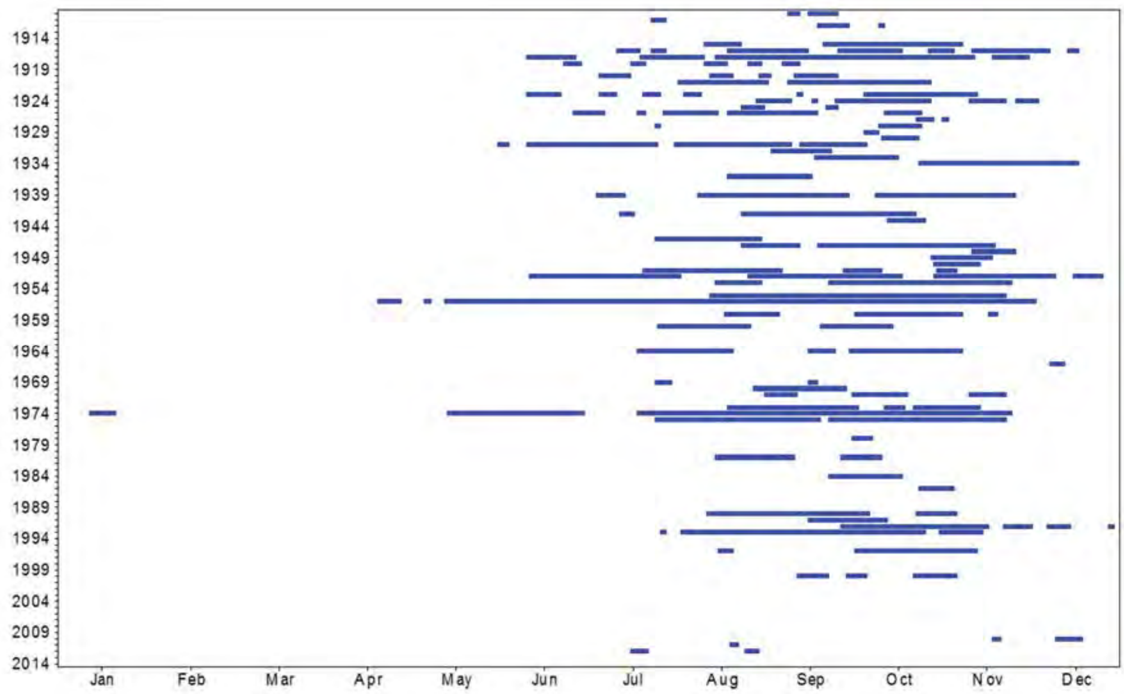

Figure 19: Historical pattern and duration of flow spells >30,000 ML/d at Corowa

7.3.3 The extent of wetlands inundated under different flow thresholds

To inform the development of the EWMP a hydraulic model of the floodplain was developed in order to determine wetland inundation extents and depths for various River Murray flows (Jacobs 2015b). Note that only the Victorian side of the floodplain model was analysed for the EWMP. The hydraulic model was developed using the MIKE two dimensional (2D) modelling software package by the Danish Hydraulic Institute (DHI), and was run for the following steady state flows:

- 20,000 ML/d
- 25,000 ML/d (approximate bank full flow)
- 30,000 ML/d
- 35,000 ML/d
- 40,000 ML/d (probable upper limit of potential environmental flow releases from Hume Dam)
- 50,000 ML/d.

The inundation datasets produced from the hydraulic model were used to plot inundation maps and to determine wetland extents inundated. This information helped to develop a recommended water regime for the floodplain wetlands, relating river flow thresholds to wetland and floodplain inundation frequency. This analysis and recommendations are detailed in the accompanying synthesis report.

Figure 20 and Figure 21 show the extent of inundation of the floodplain at 25,000 ML/d and 40,000 ML/d

Inundation maps for all thresholds modelled are included in Appendix B-1.

For each flow threshold, the area, number, and depth of inundation of different wetland types and different EVC types has also been assessed. Table 10 presents a summary of the estimated area, number and/or length of the different wetland types inundated at various River Murray flow thresholds. For the purposes of the analysis, cut-off meanders and floodplain depressions have been combined because there is limited information to enable them to be distinguished from each other based on mapping attributes, and their water regime requirements are generally similar.

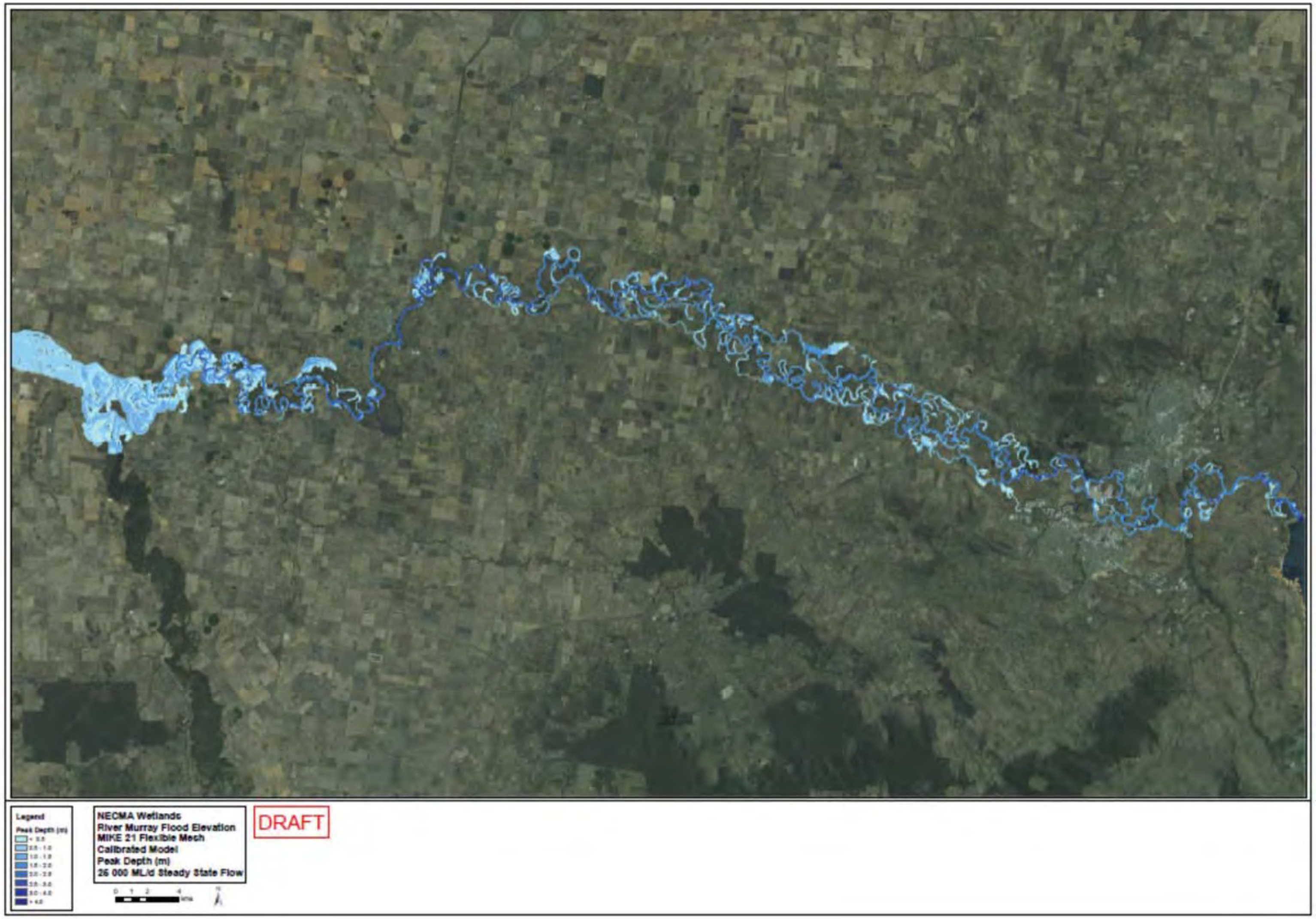

Figure 20: Extent of inundation at 25,000 ML/d

Figure 21: Extent of inundation at 40,000 ML/d

Table 10: Wetland inundation characteristics for various River Murray flow thresholds (% of total is in parentheses).

Wetland type / attribute	Murray River flow threshold (ML/d)						
	20000	25000	30000	35000	40000	50000	Total (1:100 year floodplain extent)
Cut-off meanders / floodplain depressions							
Number of wetlands inundated	148 (33%)	165 (37%)	205 (46%)	263 (59%)	317 (71%)	383 (86%)	445 (100%)
Area inundated (Ha)	1205 (48%)	1326 (53%)	1480 (59%)	1884 (75%)	2023 (81%)	2228 (89%)	2499 (100%)
Flood runners							
Length of flood runner inundated (km)	105 (54%)	113 (58%)	121 (62%)	138 (71%)	148 (76%)	162 (83%)	196 (100%)
Shedding floodplain							
Area inundated (Ha)	1840 (16%)	2163 (18%)	2745 (23%)	3765 (32%)	4805 (41%)	6675 (57%)	11,702 (100%)

The data sets used to compile the wetland type layers are provided in Appendix D.

7.3.4 Wetlands connected at current flow constraints (<25,000 ML/d)

Under current regulated river conditions, flow is regularly held at around 20,000-25,000 ML/d during the summer irrigation season. The River Murray Wetlands database (NSW MWWG 2006) estimates that at a flow of 25,000 ML/d, 244 wetlands (38% of total wetland number) and 2025 Ha (62% of total wetland area) are unseasonally inundated (Figure 22). These wetlands are inundated in most summers during irrigation season flows. They may draw down during winter when irrigation releases are reduced, but may also experience prolonged high levels of inundation if there are high flows in tributary streams (i.e. the Kiewa River) that causes higher flows above the non-irrigation season base flow in the Murray River.

Although water level may vary in these wetlands through a drawdown in winter and spring, this is the time of the year when they should be experiencing inundation, not drawdown. In effect, the seasonality of the watering regime for these wetlands is reversed compared with the recommended regime.

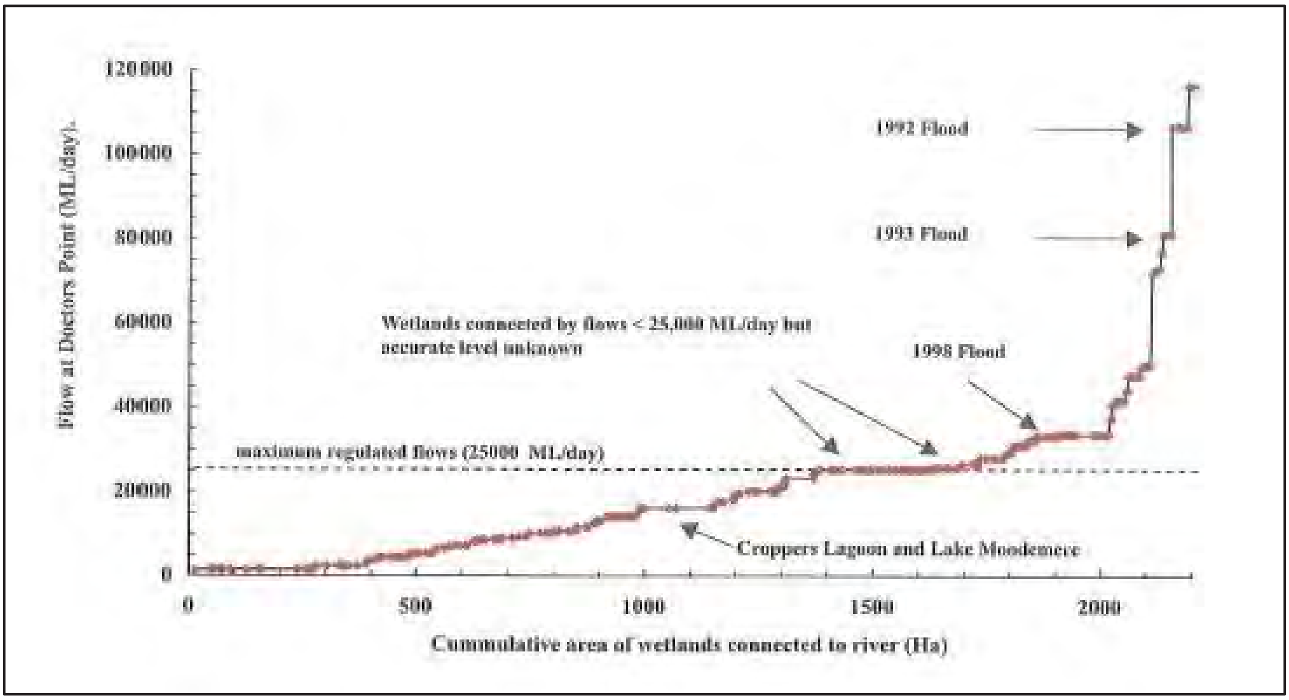

Figure 22: Commence-to-fill levels for wetlands from Hume Dam to Yarrawonga Weir showing cumulative area of wetlands inundated for flow at Doctors Point (Source: Reproduced from NSW MWWG 2006).

7.3.5 Wetlands connected at >25,000 ML/d

Wetlands on the floodplain that commence-to-fill at a river flow higher than 25,000 ML/d at Doctor's Point are currently mostly dry, and would only receive water in wet years when floods in tributary streams result in winter flows exceeding 25,000 ML/d and/or Lake Hume is spilling.

Historically these wetlands, which are located higher on the floodplain, would have been inundated once every 2 or 3 years, sometimes for long durations of inflow (e.g. 30-90 days, and refer back to Figure 19 for spells above 30,000 ML/d). Flows above 30,000 ML/d frequently occurred prior to 2000, but during the 2000s when the Millennium Drought was occurring, there was 9 straight years without an event over 25,000 ML/d. Flows above 30,000 ML/d have only occurred a few times in the last 15 years, and events above 40,000 ML/d have occurred just twice in the last 15 years (Figure 23).

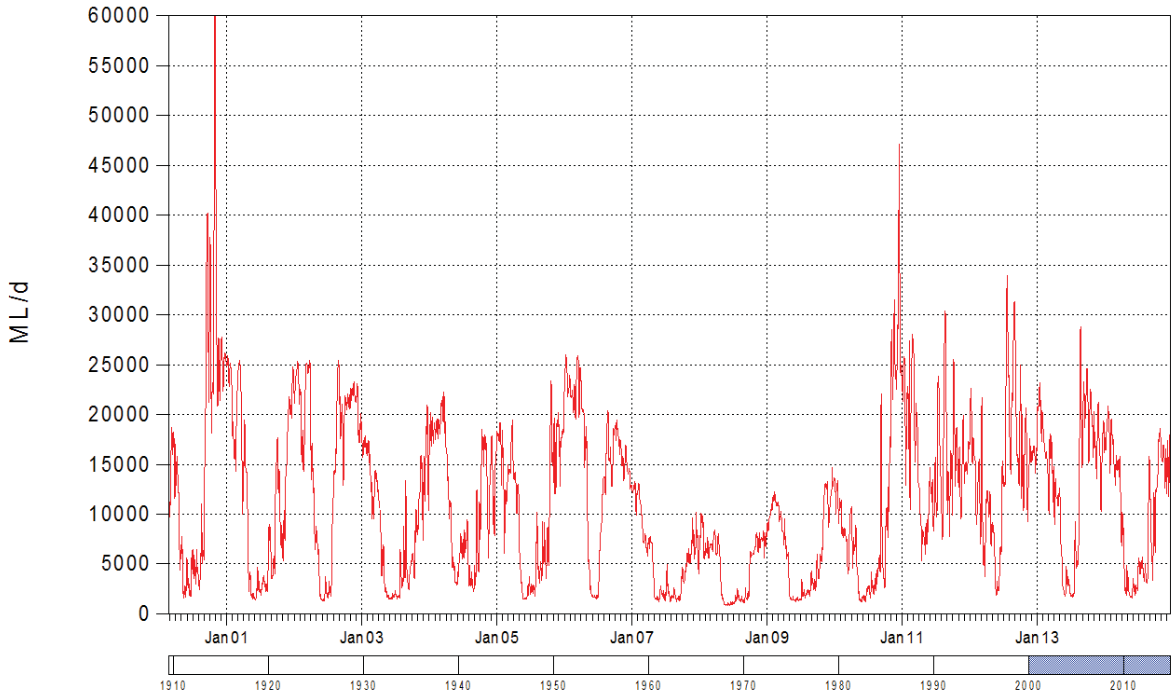

Figure 23: Time series flow over the past 15 years at Corowa showing the effect of drought on high flows.

7.3.6 Cut-off meanders / floodplain depressions

Appendix B-2 provides inundation maps for cut-off meanders and floodplain depressions for the range of flows modelled.

The majority of the modelled cut-off meanders / floodplain depressions on the floodplain are between 0.5 m and 2 m in depth (considered a medium depth) (Figure 24). As the area of inundation increases, the area of shallow wetlands inundated decreases slightly, while the area of medium and deep-water wetlands that are inundated increases.

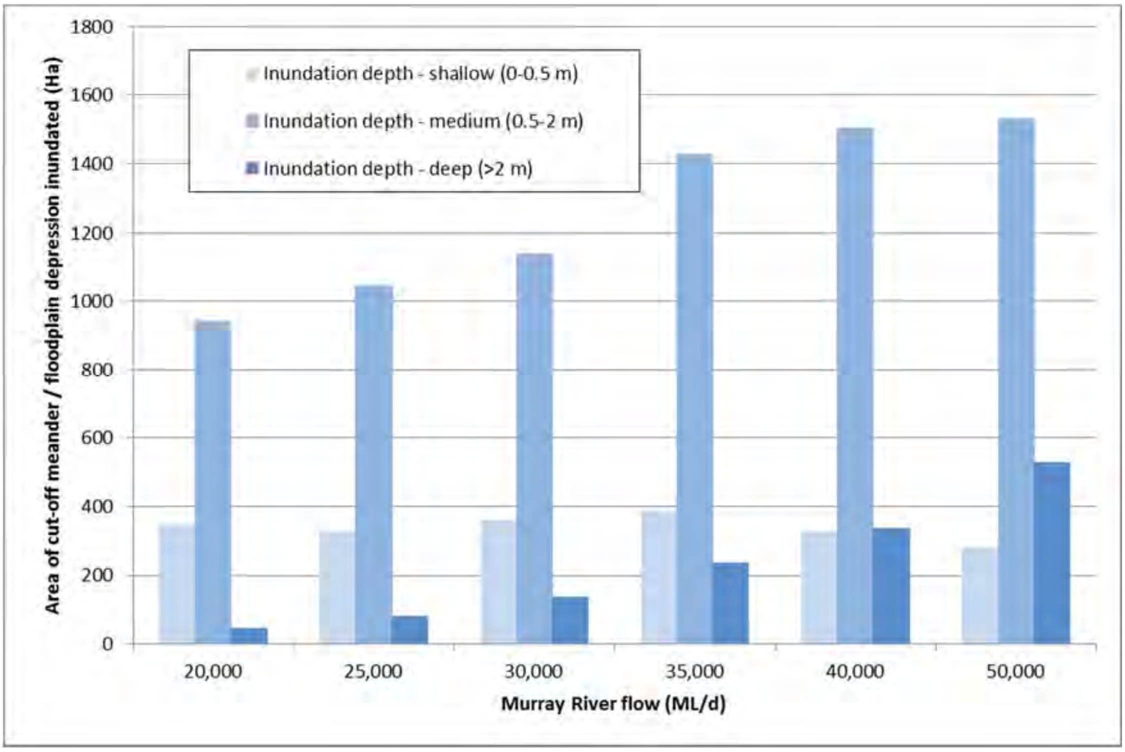

Figure 24: Depth distribution of cut-off meanders / floodplain depressions inundated at modelled River Murray flow thresholds.

7.3.7 Flood runners

Appendix B-3 provides inundation maps for flood runners for the range of modelled flows.

7.3.8 Shedding floodplains

Appendix B-4 provides inundation maps for shedding floodplains for the range of modelled flows.

Depth distribution analysis shows that the majority of the shedding floodplain is in the shallow (0 - 0.5 m) and medium (0.5 - 2 m) depth categories (Figure 25). As the area of inundation increases, the area of deep (>2m) shedding floodplain increases slightly, while the area of shallow to medium depth shedding floodplain increases markedly.

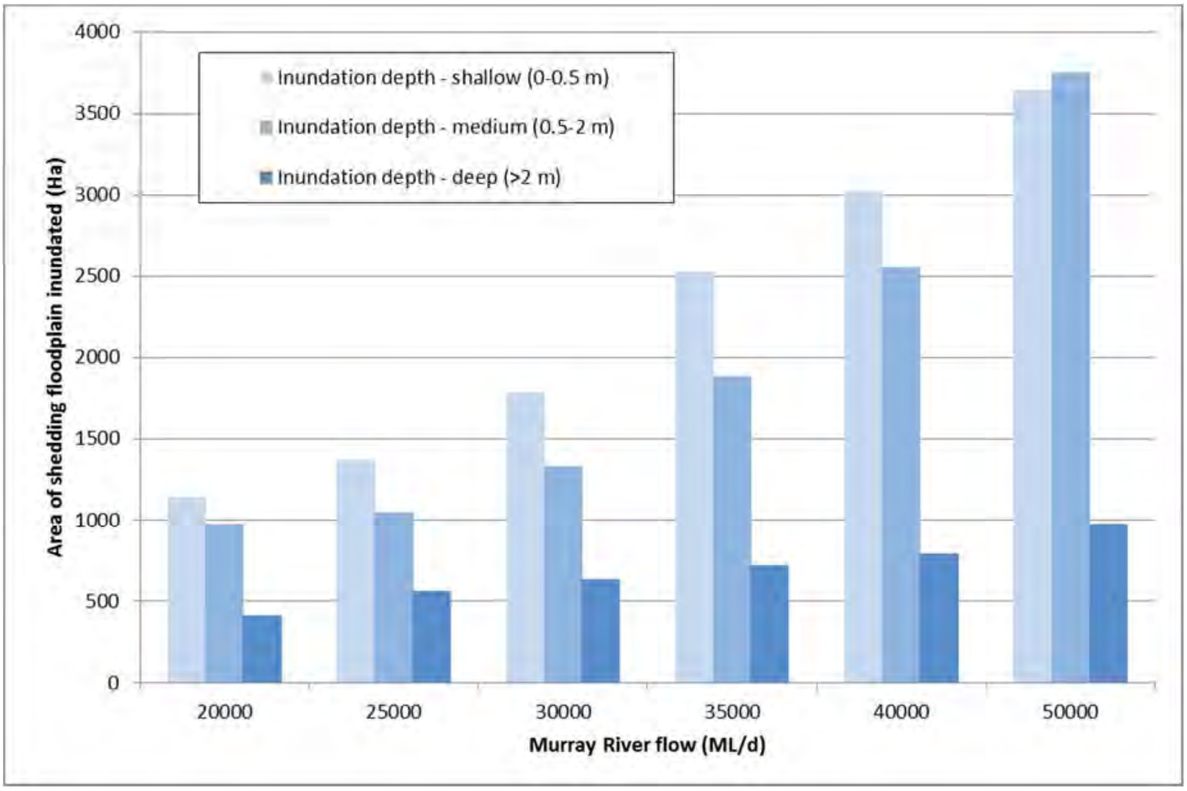

Figure 25: Depth distribution of shedding floodplain inundated at modelled River Murray flow thresholds.

7.4 Groundwater / Surface water interactions

In floodplain wetlands, the water regime is characterised by episodic events linked with bank-full and over-bank flows. For the remainder of the time, however, many floodplain wetlands are supported at least in part by groundwater inputs that are critical for the maintenance of deep-rooted plant communities (BMT WBM 2007a, 2007b). Groundwater aquifers in North East Victoria have been divided into hydrogeological subsystems on the bases of similar groundwater behaviour, as detailed in Table 11.

Table 11: Hydrogeological subsystems of North East Victoria

Hydrogeological Sub-system	Description
North East Highlands	Fractured rock landscapes with local and intermediate groundwater flow systems. Local flow systems commonly occur in high relief landscapes where flow is restricted to individual valleys. The North East Highlands cover approximately 90% of the North East region including the entire portion of the Upper Murray Catchment.
Calivil	Alluvial sequence of clean channel sands and gravels resulting from high-energy alluvial activity in the Highland area. Significant groundwater resource in North East Victoria. Hydraulically connected to overlying Shepparton Subsystem to varying degrees
Lachlan	The Lachlan and Cowra Subsystems are the highland equivalents of the Calivil and Shepparton Subsystems respectively, and their occurrence is relatively minor in the region
Cowra Subsystem	
Shepparton	Coarse river deposited sands and gravels. Yields are high and water quality is relatively good, making this aquifer system a significant resource

The Lachlan and Cowra Subsystems are the highland equivalents of the Calivil and Shepparton Subsystems respectively, and their occurrence is relatively minor in the region (Ife and Skelt 2004).

The relationship between the hydrogeological subsystems is shown in the schematic cross section in Figure 26.

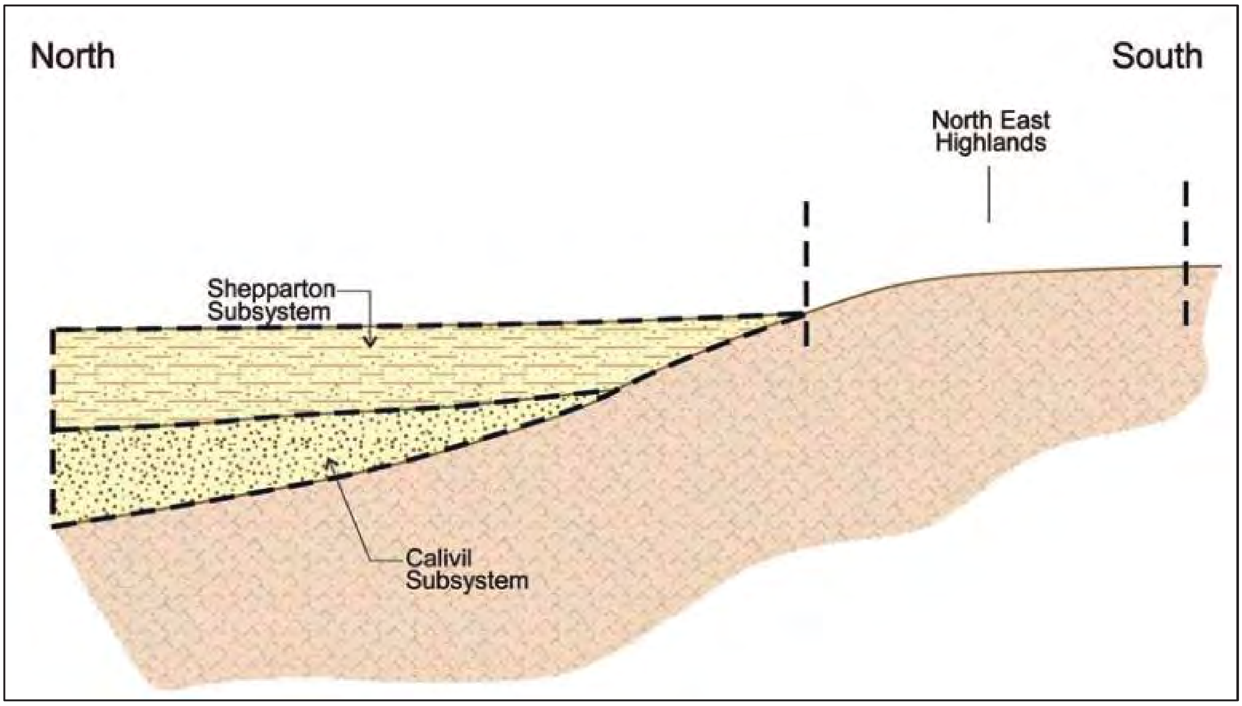

Figure 26: Schematic cross-section of the major groundwater subsystems in North East Victoria (Source: Ife and Skelt 2004)

Figure 27 illustrates the depth to the watertable for the North East Victoria region between Hume Dam and Yarrawonga Weir, using the Victorian State Government's 'Visualising Victoria's Groundwater' interactive website (FedUni 2014). As can be seen, the watertable depth is relatively shallow along the River Murray, and where the floodplain can be approximated (although not marked on this map), is generally within the range of less than 5 m, to 10 to 20 m in depth.

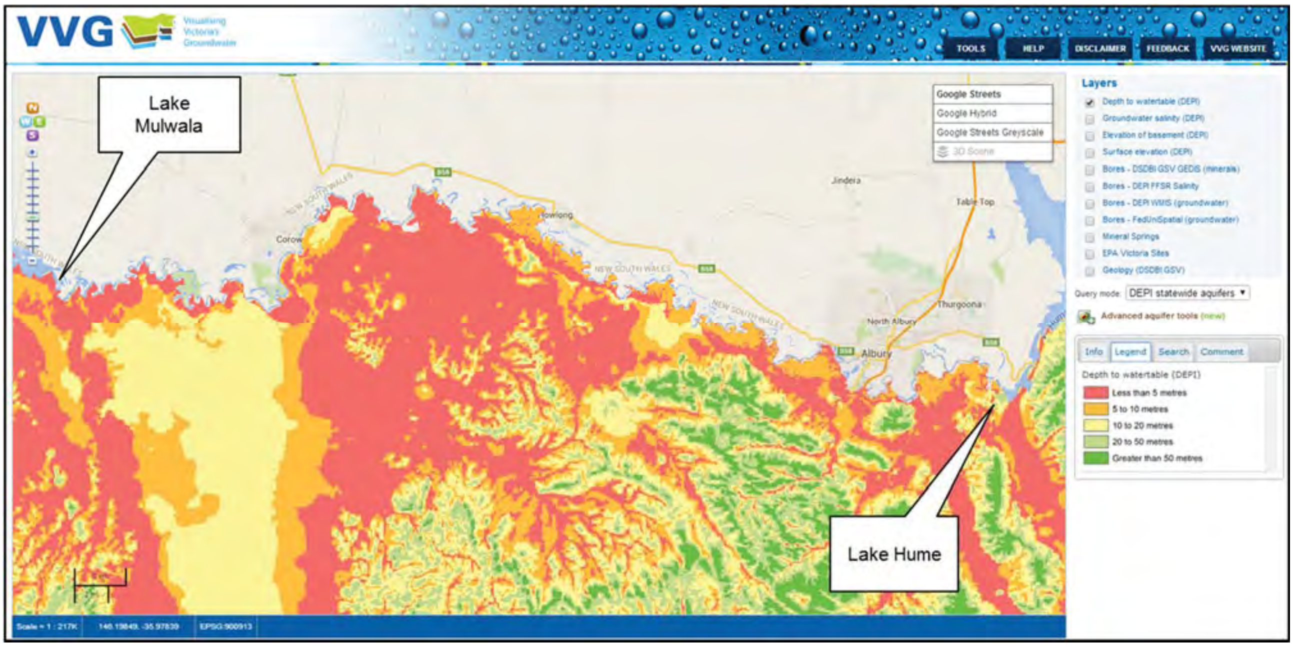

Figure 27: Depth to watertable (Source: FedUni (2014))

The length of the River Murray between Lake Hume and Yarrawonga Weir contains both losing and gaining reaches (Figure 28). The variation from reach to reach is likely to be due to a combination of river regulation, floodplain groundwater flow processes, and the influence of irrigation development near the river (Parsons *et al*. 2008).

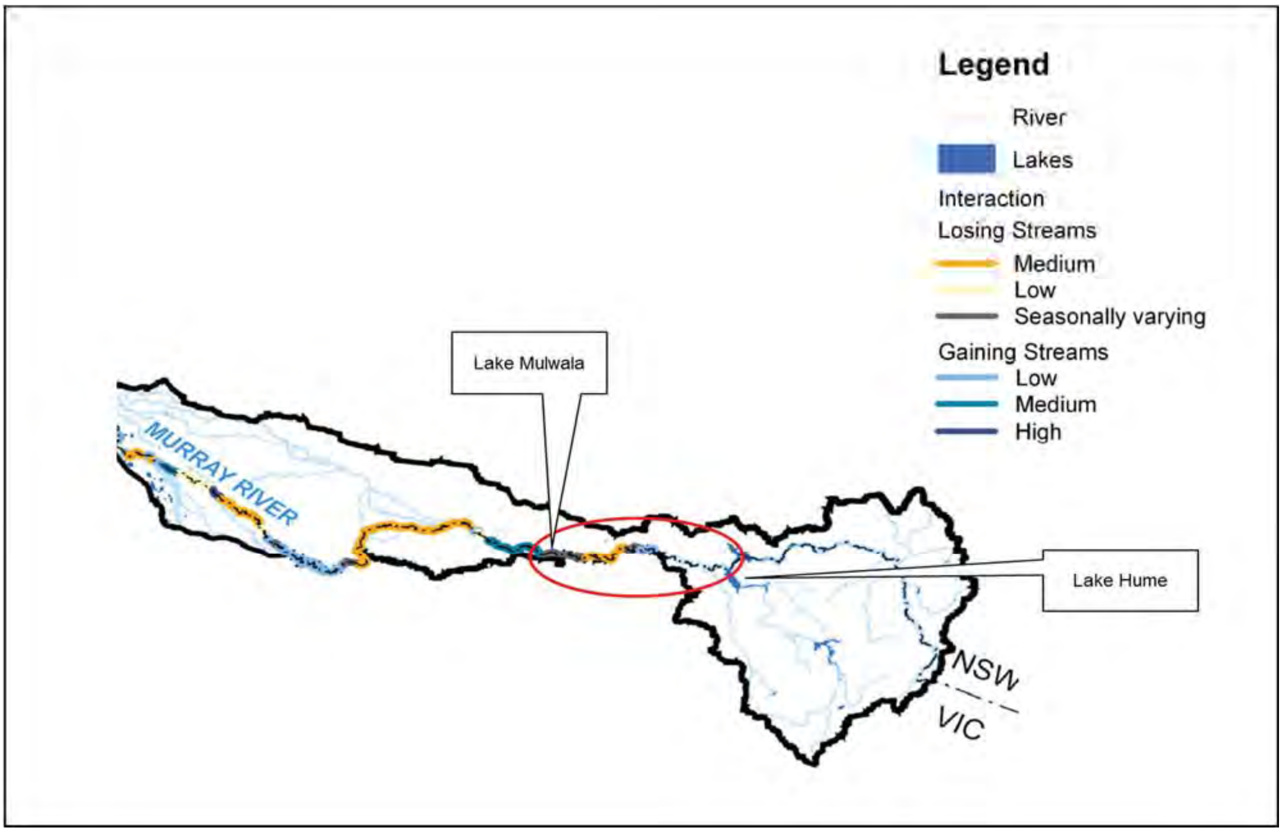

Figure 28: Groundwater and surface water connectivity between Hume Dam and Yarrawonga Weir (Source: Adapted from Parsons *et al.*. 2008)

Connectivity mapping has found that:

- Upland tributaries to the Murray are typically gaining water from groundwater sources at low rates as groundwater moves downhill from bedrock highlands
- The river loses water to groundwater on the alluvial plain leading up to Lake Mulwala
- The river is approximately hydraulically neutral in the vicinity of the convergence of the Murray and Ovens rivers near Lake Mulwala (Parsons *et al.*. 2008).

Some wetlands along the floodplain are likely to be surface expressions of shallow unconfined groundwater in the floodplain region, and changes in the level of the surrounding watertable may have a large impact on water levels and plant dynamics in these wetlands (Raisin *et al*. (1999) in BMT WBM (2007a)).

Even though it is widely acknowledged that the water and salt regimes are key drivers of semi-arid wetland ecology, there has been little research on the interaction between surface water and groundwater for these systems (BMT WBM (2007a). This applies to the surface water and groundwater interactions for wetlands of the Murray floodplain, and is a key knowledge gap to be addressed.

8. Water Dependent Values

The floodplain along the Murray River supports a large range of plant and animal values and also provides a range of ecosystem services, such as flood storage, groundwater recharge and nutrient processing. The different wetland types in the floodplain support unique value sets, typically associated with wetland morphology and water regime.

Across the EWMP area there are few individual wetlands that have been previously identified (or highlighted) for supporting specific high values that need to be managed on an individual wetland scale. The types of ecological values (plant and animal species/communities and ecosystem process) that are present in each wetland type are generally known however, and survey data and relevant literature has been used to identify the types of ecological values that are known to occur, or would be expected to occur in the EWMP area and then assign values to each wetland type.

Data used on the identification of values includes the DELWP wetlands layer, the Victorian Flora and Fauna Database, Ecological Vegetation Class (EVC) mapping and various scientific reports. Appendix A provides species lists for flora and fauna.

8.1 Fauna

8.1.1 Fish

Within the EWMP floodplain area, including the Murray River main channel, 16 native and 7 introduced fish species have been recorded (Table 12). This high diversity of native fish species makes the area significant for its biodiversity values. Of these species, seven are of conservation significance, being listed under State and/or Federal threatened species legislation. Note that Macquarie Perch is likely to be locally extinct in the floodplain, and Short-finned eel and Common galaxias are likely to have been translocated from coastal catchments via water transfers from the Snowy Mountains.

Table 12: Native and introduced fish recorded in the study area (source: Victorian Flora and Fauna database)

Scientific name	Common name	FFG	VICADV	EPBC
Native				
Retropinna semoni	Australian Smelt			
Macculochella macquariensis	Trout Cod	L	CR	EN
Hypseleotris spp.	Carp Gudgeon			
Galaxias maculatus	Common Galaxias			
Galaxias olidus	Mountain Galaxias			
Galaxias rostratus	Flat-headed Galaxias	X	VU	
Philypnodon grandiceps	Flat-headed Gudgeon			
Craterocephalus stercusmuscarum fulvus	Unspecked Hardyhead			
Macquaria ambigua	Golden Perch	X	NT	
Macquaria australasica	Macquarie Perch	L	EN	EN
Macculochella peelii	Murray Cod	L	VU	VU
Melanotaenia fluviatilis	Murray-Darling Rainbowfish	L	VU	
Gadopsis marmoratus	River Blackfish			
Anguilla australis	Short-finned Eel			
Bidyanus bidyanus	Silver Perch	L	VU	
Nannoperca australis	Southern Pygmy Perch		VU	
Introduced				
Salmo trutta	Brown Trout			

Scientific name	Common name	FFG	VICADV	EPBC
Cyprinus carpio	Carp			
Gambusia holbrooki	Eastern Gambusia			
Carassius auratus	Goldfish			
Misgurnus anguillicaudatus	Oriental Weatherloach			
Perca fluviatilis	Redfin			
Tinca tinca	Tench			

Key to classifications:

- *FFG Act: L – listed, X – nominated but rejected*
- *VICADV (Victorian threatened species advisory listing); NT – near threatened, VU – vulnerable, EN – endangered, CR – critically endangered*
- *EPBC Act: VU – vulnerable, EN – endangered*

8.1.1.1 Fish habitat and watering requirements

The fish species most likely to be present in the EWMP area have varying habitat and flow requirements, with some of these species considered main-channel specialists rarely recorded in floodplain habitats, and others preferring wetland and floodplain habitats, only using the main channels for dispersal.

Surveys of wetlands in the EWMP area have indicated considerable variability in the fish communities related to wetland size and bathymetry, such as water depth and water quality (Closs *et al.*. 2005). Large permanent wetlands tend to have sufficient volume and water depth to buffer physical and chemical variation, and as a consequence, temperature and dissolved oxygen rarely becomes lethal for large bodied fish. The fish community in these wetland types tends to be relatively consistent both spatially and temporally. In these wetlands, the community is dominated by large bodied introduced species such as Common carp, Redfin perch and Goldfish. Small native fish, such as Australian smelt and Carp Gudgeons are also abundant (Shirley 2002).

In contrast, smaller wetlands can be highly variable in both depth, volume and water quality. Hence the fish community can exhibit greater variation in both species composition and abundance compared with the larger billabongs (Closs *et al.*. 2005). In these systems, variable water quality, particularly low dissolved oxygen conditions at certain times, means that larger predatory (piscivorous) species such as Redfin perch tend to be absent. This allows a greater diversity of smaller species to colonise, including the native Southern pygmy perch and Flatheaded galaxias, and the introduced Eastern Gambusia (McNeil 2004).

Within both large and small wetlands, small native fish are strongly associated with the presence of macrophytes (Balcombe and Closs 2004). These habitats provide food resources and protection from larger predators, and hence managing wetlands for a diversity of macrophyte habitat is critical in providing suitable habitat for small native fish (Table 13).

Table 13: Fish species likely to be associated with different wetland types on the floodplain

Main channel	Cut-off meanders / billabongs		Floodplain depressions / lakes	Flood runners and Shedding floodplain
	Deep / permanent	Shallow / seasonal		
Native species				
Murray Cod Trout Cod Golden Perch River Blackfish Silver Perch Murray-Darling Rainbowfish Mountain galaxias	Australian Smelt Carp gudgeon Unspecked hardyhead	Carp gudgeon Flat-headed gudgeon Flat headed galaxias Southern pygmy perch	Golden perch Australian smelt Carp gudgeon	Opportunistic - All species use these habitats for dispersal and movement between river and wetland habitats

Main channel	Cut-off meanders / billabongs		Floodplain depressions / lakes	Flood runners and Shedding floodplain
	Deep / permanent	Shallow / seasonal		
Unspecked hardyhead Australian smelt Carp gudgeon				
Introduced species				
Redfin perch Common carp Goldfish Brown trout Tench Oriental weather loach	Redfin perch Common carp Goldfish Oriental weather loach	Goldfish Eastern gambusia Oriental weather loach	Redfin perch Common carp Goldfish Tench Oriental weather loach	As above

8.1.2 Amphibians and reptiles

Within the study area, six species of frogs, two turtle and 15 snakes and lizards have been recorded (see Appendix A). Of these, the Giant bullfrog and Broad-shelled turtle are of conservation significance. Frogs and turtles require access to a range of permanent river and wetland habitats for breeding (i.e. permanent and seasonally inundated wetlands and floodplains).

8.1.3 Birds

Within the EWMP area, over 180 species of birds have been recorded as present at some time, and of these, 47 species are considered water dependent (see Appendix A). Of the water dependent species, 18 are of conservation significance, being listed under State and/or Federal threatened species legislation and/or international migratory bird treaties (Table 14).

Table 14: Water dependent birds recorded in the study area (source: Victorian Flora and Fauna database)

Scientific name	Common name	FFG	VICADV	EPBC	Treaty
Anas rhynchotis	Australasian Shoveler		vu		
Alcedo azurea	Azure Kingfisher		nt		
Oxyura australis	Blue-billed Duck	L	en		
Grus rubicunda	Brolga	L	vu		
Ardea ibis	Cattle Egret				CAMBA,JAMBA
Acrocephalus stentoreus	Clamorous Reed Warbler				BONN A2H
Ardea modesta	Eastern Great Egret	L	vu		CAMBA,JAMBA
Stictonetta naevosa	Freckled Duck	L	en		
Aythya australis	Hardhead		vu		
Ardea intermedia	Intermediate Egret	L	en		
Egretta garzetta nigripes	Little Egret	L	en		
Anseranas semipalmata	Magpie Goose	L	nt		
Biziura lobata	Musk Duck		vu		
Nycticorax caledonicus hillii	Nankeen Night Heron		nt		
Phalacrocorax varius	Pied Cormorant		nt		
Merops ornatus	Rainbow Bee-eater				JAMBA

Scientific name	Common name	FFG	VICADV	EPBC	Treaty
Platalea regia	Royal Spoonbill		nt		
Haliaeetus leucogaster	White-bellied Sea-Eagle	L	vu		CAMBA

Key to classifications:

- *FFG Act: L – listed, X – nominated but rejected*
- *VICADV (Victorian threatened species advisory listing); NT – near threatened, VU – vulnerable, EN – endangered, CR – critically endangered*
- *EPBC Act: NT – near threatened, VU – vulnerable, EN – endangered*
- *Treaty: JAMBA – Japan Australia Migratory Bird Agreement, CAMBA – China Australia Migratory Bird Agreement, BONN A2H – listed under the Bonn Convention on the Conservation of Migratory Species of Wild Animals as a species which is part of a family that is listed in Appendix II*

Some waterbird species are very mobile and will move large distances around the landscape looking for water, while others are more local and require permanent water within the local landscape. A range of habitat types are required to support a diverse water bird community, including fringing reed beds (e.g. for reed warblers and as cover for coots and native hens), open water (e.g. for ducks and grebes, cormorants, herons etc), and mud flats (e.g. for wading birds such as stints and spoonbills). In addition, suitable perching, roosting and nesting sites are required, such as trees around the edges of wetlands and large woody debris that extends above the water surface. The EWMP area is likely to be important for waterbird breeding and it is important that further knowledge is gained about its significance as a breeding habitat for local and migratory birds.

Previous studies have found that waterbirds species found in the Basin take about three months (the range for most species is 2.5-3.5 months) to lay and incubate their eggs and to fledge their young (Briggs and Thornton 1999). The time lag between flooding under nest sites and commencement of egg laying will vary between species of waterbird, with wetland conditions elsewhere, and with the time of year that flooding commences. This time is needed by birds to prepare their nest, and prepare behaviourally, nutritionally and hormonally for breeding (Briggs and Thornton 1999).

8.1.4 Mammals

Within the EWMP area, twenty-seven species of mammals have been recorded, with 5 of these being introduced (Appendix A). Two of these species are of conservation significance, with the Squirrel Glider (*Petaurus norfolcensis*) currently listed as Threatened in Victoria under the *Flora and Fauna Guarantee Act 1988*, and the Grey-headed Flying-fox (*Pteropus poliocephalus*) listed as Vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999*.

Mammal species require seasonally appropriate and variable inundation regimes on the floodplain to ensure a continuing supply of drinking water, if needed, and an appropriate diversity and abundance of food sources, habitat types and shelter. They may also use inundation events to disperse about the floodplain, following food sources or using waterways and wetlands as corridors to new areas.

8.1.5 Zooplankton

Zooplankton accumulate large numbers of dormant eggs in wetland sediment that can persist for extended periods but in general numbers of viable eggs begin to decline after 10 years of being dry. These dormant eggs provide means of surviving and persisting in unfavourable environments such as wetlands drying. When wetlands are re-wetted by incoming floodwaters these dormant eggs hatch and provided a pulse of zooplankton (Nielsen *et al.*. 2000). Incoming floodwaters also transport nutrients into the wetlands and make available nutrients from decaying material. The release of nutrients fuels a pulse of primary productivity, which in turn further stimulates zooplankton growth and abundance. The increased biomass of zooplankton may form a resource for juvenile fish either in the billabong or in the river channel as flood waters recede (Nielsen 2000).

Hence, providing a variable wetting and drying regime is important for promoting and sustaining zooplankton production as an important component of food webs for higher organisms.

8.2 Flora

Five Ecological Vegetation Communities (EVC) groups are represented (mapped) within the study area (Table 15), which is located within the Victorian Riverina bioregion. Within each EVC group there are a number of sub-groups and individual EVCs. Across the study area, Grassy Riverine Forest/Sedgy Riverine Forest Mosaic represents the largest vegetation community (74 Ha), followed by Riverine Grassy Woodland/Sedgy Riverine Forest Mosaic (24 Ha). These communities represent the types of vegetation that can be expected across the broader floodplain and both fall within the Riverine Grassy Woodlands or Forests EVC group. Other EVCs occur in small (typically <1 Ha), isolated patches.

Around 20 Ha of Wetland EVCs are mapped in the study area, predominantly Billabong Wetland Aggregate (11 Ha). However, there is over 2000 Ha of wetlands mapped in the study area (NSW Murray Wetland Working Group 2006), so the EVC mapping provides an indication of the vegetation communities present, but is not a definitive analysis of the total area of different vegetation communities.

Table 15: Ecological Vegetation Communities mapped in the study area. The numbers in parentheses correspond to the relevant group, sub-group or EVC identification code

EVC group name	EVC sub-group	EVC name	Conservation status in the bioregion	Hectares
Wetlands (18)	Freshwater (18.1)	Billabong Wetland Aggregate (334)	Vulnerable	246
		Floodplain Wetland Aggregate (172)	Vulnerable	262
		Wetland Formation (74)	Endangered	<1
		Floodplain Grassy Wetland/Riverine Swampy Woodland Mosaic (1052)	Endangered	<1
		Tall Marsh/Aquatic Herbland Mosaic (1087)	Vulnerable	7.1
		Floodway Pond Herbland (810)	Vulnerable	1.3
Riverine Grassy Woodlands or Forests (14)	Broader plain (14.1)	Riverine Grassy Woodland (295)	Vulnerable	2176
		Riverine Swampy Woodland (815)	Vulnerable	988
		Riverine Grassy Woodland/Riverine Swampy Woodland Mosaic (1040)	Endangered	439
		Riverine Grassy Woodland/Sedgy Riverine Forest/Wetland Formation Mosaic (255)	Vulnerable	17
		Riverine Grassy Woodland/Sedgy Riverine Forest Mosaic (1041)	Vulnerable	29
		Grassy Riverine Forest/Sedgy Riverine Forest Mosaic (1063)	Vulnerable	74
	Creekline and/or swampy (14.2)	Riverine Swamp Forest (814)	Depleted	486
		Drainage-line Aggregate (168)	Endangered	274
		Creekline Grassy Woodland (68)	Endangered	1.3
		Floodplain Riparian Woodland (56)	Vulnerable	1291
		Sedgy Riverine Forest (816)	Vulnerable	1379
		Floodplain Riparian Woodland/Riverine Swamp Forest Mosaic (1034)	Vulnerable	141
		Floodplain Riparian Woodland/Sedgy Riverine Forest Mosaic (1035)	Vulnerable	53
Plains Woodlands or Forests (13)	Freely-draining (13.1)	Plains Grassy Woodland/Grassy Woodland Complex (187)	Endangered	<1
		Plains Grassy Woodland (55)	Endangered	28
	Lunettes or beach ridges or shallow sands (13.3)	Sand Ridge Woodland (264)	Endangered	3.8
		Shallow Sands Woodland (882)	Endangered	<1
	Poorly-draining (13.2)	Plains Woodland (803)	Endangered	99
Herb-rich	Alluvial terraces	Alluvial Terraces Herb-rich Woodland/Creekline	Vulnerable	<1

EVC group name	EVC sub-group	EVC name	Conservation status in the bioregion	Hectares
Woodlands (15)	and/or creeklines (15.1)	Grassy Woodland Mosaic (81)		
Lower Slopes or Hills Woodlands (5)	Grassy (5.2)	Grassy Woodland (175)	Endangered	3.0
Not classified – cleared land not mapped as containing an EVC				6066

In addition to mapped EVCs a large number of individual plant species have been identified, many of which are water regime dependent (see Appendix A.3).

Based on the mapped vegetation communities present on the floodplain, different EVCs can be assigned to each wetland type (Table 16). Notable in the study area is the River red gum community associated with the riverine grassy woodland and forest EVCs. River red gums are an iconic species along the Murray floodplain.

Table 16: Vegetation communities associated with different wetland types

Flood runners	Cut-off meanders / billabongs / floodplain lakes		Shedding floodplain
	Deep / permanent	**Shallow / seasonal**	
EVC types			
• Floodway Pond Herbland • Sedgy Riverine Forest	• Billabong wetland aggregate • Wetland Formation	• Tall Marsh/Aquatic Herbland Mosaic • Wetland Formation	• Riverine Grassy Woodland/Sedgy Riverine Forest Mosaic • Grassy Riverine Forest/Sedgy Riverine Forest Mosaic
Characteristic species			
Submerged and floating macrophytes that require permanent or near permanent inundation (e.g. *Triglochin, Vallisneria, Potamogeton*). Emergent macrophytes that require seasonal water level variation (e.g. *Phragmites*, rushes, sedges)	Submerged and floating macrophytes that require permanent or near permanent inundation (e.g. *Triglochin, Vallisneria, Potamogeton*). Emergent macrophytes within the wet/dry (littoral) zone that require seasonal water level variation (e.g. *Phragmites*, rushes, sedges, herbs and forbs)	Emergent macrophytes, flood dependent macrophytes that require seasonal to occasional inundation (e.g. Phragmites, rushes, sedges, herbs and forbs)	Flood dependent and flood tolerant terrestrial species (e.g. River red gum, grasses, sedges)

In developing the EWMP, the extent that different EVCs were inundated at varying flow thresholds was also investigated (Jacobs 2015c). The area of different EVC groups that are inundated at varying flow thresholds across the floodplain is shown in Figure 29. The largest EVC group present on the floodplain is ‘Plains Grassy Woodland or Forests’ and River Red Gums (*E. camaldulensis*) are a common species in this EVC group. As the river flow increases, the area inundated for this EVC also increases. At 25,000 ML/d for example, around 30% of the total Plains Grassy Woodland/Forest is inundated, which increases to 55% at 40,000 ML/d. This indicates that flows up to 40,000 ML/d could nearly double the area of River Red Gum woodlands and forests that are inundated compared to the current regulated flow level of 25,000 ML/d.

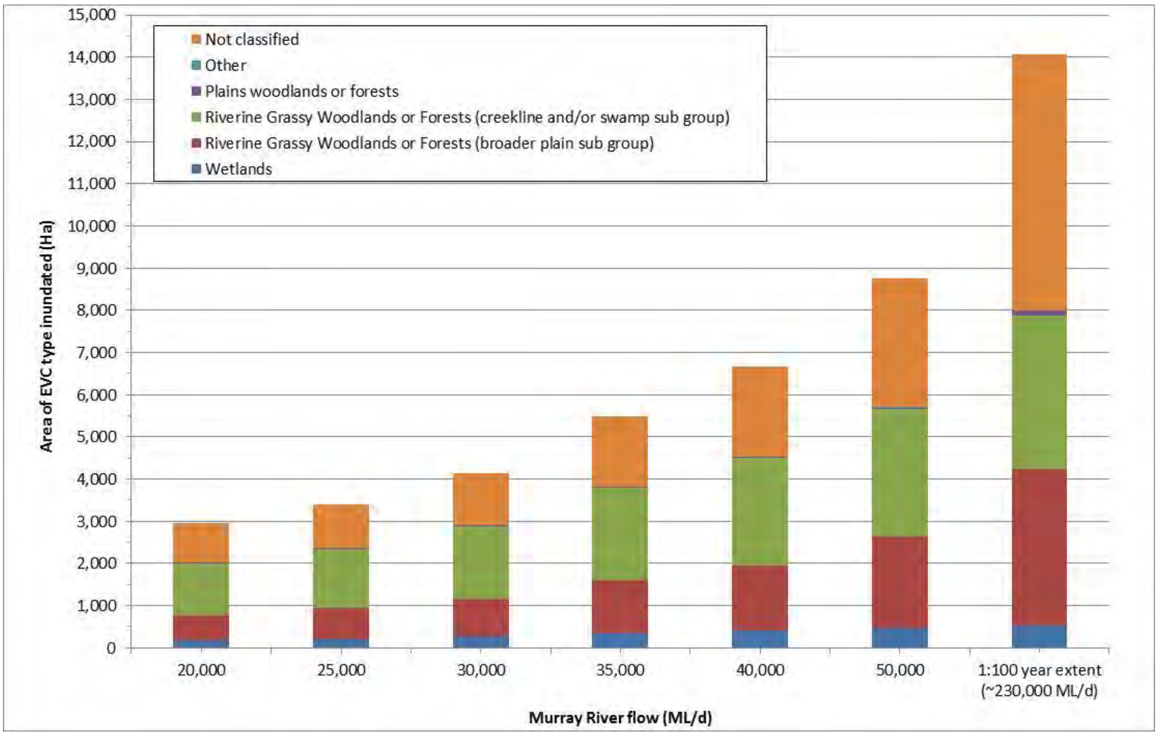

Figure 29: Area of EVC groups inundated ate each river flow threshold. Not classified represents areas of the floodplain not allocated an EVC and includes cleared land and other non-classified land

Figure 30 shows that at flows less than 40,000 ML/d, the area of floodplain inundated that is a not classified as an EVC (i.e. an area assumed to be cleared of native vegetation) is a relatively low (35%) proportion of the total area of cleared land within the 1:100 year flood extent. However, at flows of 40,000 ML/d, the area of cleared land inundated increases significantly (50% at 50,000 ML/d). On this basis, an inundation extent associated with flows up to 40,000 ML/d appears to represent a good balance between the area of EVCs inundated and the area of cleared land inundated.

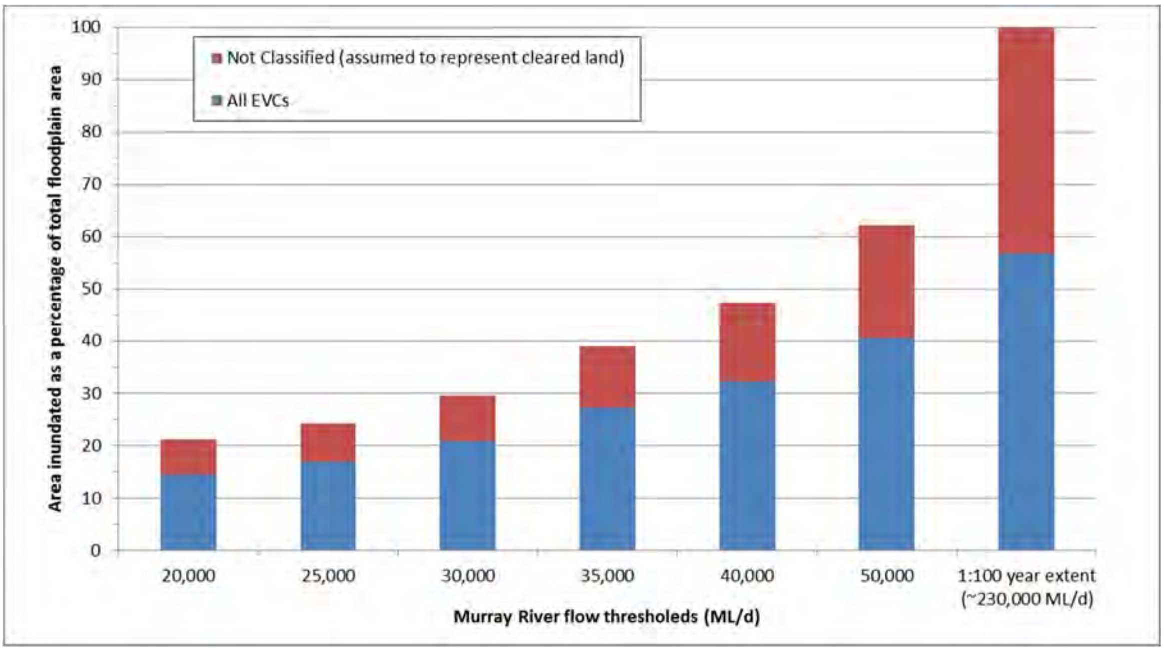

Figure 30: Cumulative area inundated of EVC and cleared land as a percentage of total floodplain area for modelled Murray River flow thresholds.

8.3 Ecosystem Services

There are very good practical reasons for better managing floodplains and floodplain wetlands because they provide a wide range of ecosystem services for people. As well as providing services such as water purification, food and fibre production, regulation of flows, biodiversity, pollination, and tourism and recreation, wetlands on floodplains help to intercept and modify nutrients such as nitrogen and phosphorus, and assist in the carbon cycling and sequestration.

Wetland services can be broken into several functions related to hydrology, biogeochemical processes and habitat as summarised in Table 17.

Table 17: Wetland functions and their values to the community (Source: modified from Smith *et al.*. 1995).

Wetland function	Benefits, products and services derived from wetland function
a) Functions related to hydrology	
Short-term storage of surface waters	• Reductions in downstream peak discharge • Improvement of water quality • Conduit for biota
Long-term storage of surface waters	• Water supply for human use • Provision of habitat for biota • Maintenance physical and biogeochemical services • Reductions in particulate loading downstream
Moderation of groundwater flow or discharge	• Maintenance of habitat • Recharging of local groundwater • Maintenance of groundwater storage, baseflow *etc.*
Dissipation of energy of moving water	• Reducing erosion • Reductions in particulate loading downstream
b) Functions related to biogeochemical processes	
Nutrient cycling	• Contributing to the nutrient capital of wetland • Ensuring ecological integrity • Reductions in downstream loading of nutrients
Removal of elements or compounds	• Removal of contaminants • Ensuring ecological integrity • Reducing downstream loading of pollutants
Retention of particulate matter	• Supporting detrital food webs • Ensuring ongoing geomorphological development • Reducing downstream sediment loading
Export of organic matter	• Supporting downstream food webs • Enhancing sequestering of metals
c) Functions related to habitat	
Maintenance of wetland plant and animal communities	• Maintaining habitat for endangered species • Providing recreational activities (e.g. bird watching) • Creating educational opportunities • Maintaining habitat corridors between wetlands across the landscape • Contributing to regional biodiversity

Of particular note for the Murray floodplain are the services associated with carbon and nutrient cycling, and connectivity.

8.3.1 Carbon and nutrient cycling

There is increasing evidence that wetlands have an important and under-estimated role in both carbon storage and the regulation of greenhouse gas emissions and the degradation of wetlands is known to be a significant source of emissions of carbon dioxide to the atmosphere (DSEWPAC 2012).

All wetlands are capable of sequestering and storing carbon, through photosynthesis and the accumulation of organic matter in soils, sediments and plant biomass (DSEWPAC 2012). These are very complex processes, but in general, because wetland plants grow at a faster rate than they decompose, they can contribute to a net annual carbon sink. For this reason, wetlands have an important role to play in managing climate change, by providing services that will help in adapting to the impacts of climate change, and by helping to mitigate climate change by capturing and storing carbon from the atmosphere (DSEWPAC).

8.3.2 Connectivity

Connectivity between river channels, wetlands, floodplains and groundwater systems is essential for the viability of many flow-dependent species, and floodplains are ecotones that facilitate the connectivity between aquatic and terrestrial environments. Hydrological connectivity facilitates the exchange of carbon and nutrients between the river channel and the floodplain and has a significant influence on the productivity of the entire river system (Thoms 2003).

8.4 Social and Cultural Values

The Murray floodplain sees many people visiting every year from local communities and further afield to experience its attractions. This is not a recent phenomenon, and there is strong physical evidence of Aboriginal use of the area for food, camp sites, ceremonial sites, spiritual sites and meeting places, with the oldest evidence for occupation along the Murray dated at approximately 23,000 years ago. The geomorphically dynamic nature of floodplain probably means that older cultural deposits have been reworked.

The River Murray and its floodplain attract people from both within and outside the area. People regularly take advantage of the recreational pursuits associated with the waterways in the system (fishing, rowing, boating, kayaking, water-skiing, wake-boarding and bushwalking). The River along the floodplain is particularly popular for recreational fishing and Lake Mulwala is considered one of the best freshwater fishing locations in Victoria (NECMA 2014). Recreational activities in the system revolve around nature based tourism linked to the Murray River and Lake Moodemere, together with food and wine tourism around the well-established vineyards in the region. There is also a very strong focus on tourism based on the area’s heritage values.

The traditional culture of Aboriginal communities in the North East region is deeply embedded in the River Murray system and its floodplain, forming an extremely important aspect of their identity. Water forms the basis of many creation stories, including the Murray Cod dreaming story that honours the creation of the River Murray, and the Rainbow Serpent stories, which are widely recognised as the oldest continuing beliefs in the world (NCFRC 2014).

The River Murray and its floodplain contains many places of significance – Dreaming stories, songs, tribal traditions, burials, mounds, initiation sites, men’s and women’s places, ceremonial grounds, meeting and gathering places. It is rich in relics and artefacts, middens, camping sites, ovens, and scar trees that relate to past occupation (Goulding *et al.* 2008). Rivers and streams and their associated floodplains provided a rich resource zone supplying food (animal and vegetable) and water, and a variety of tools. Assessments conducted for the development of the Northern Victoria Sustainable Water Strategy found a large list of values associated with water (Goulding *et al.* 2008), which are listed in Appendix E. More recently, the River and its floodplain has included a valuable commercial element for local Aboriginal communities, with livelihoods derived from water-based enterprises such as pastoralism, horticulture, natural resource management services and sport fishing (VEAC 2008).

Unfortunately, little of the rich traditional material culture remains along the Murray and its floodplain in the EWMP area. What is remaining is of high significance to the contemporary Aboriginal population.

It is important to ensure that Aboriginal peoples’ knowledge of the Murray floodplain and its wetlands is documented within the EWMP, and that this knowledge helps to ensure the floodplain’s cultural values and issues are appropriately managed in collaboration with Aboriginal communities. The EWMP is considered a ‘living document’ to be updated as required, and as part of its adaptive management processes for the floodplain, North East CMA will work with relevant Aboriginal groups to ensure this knowledge is captured and incorporated into the EWMP.

8.5 Economic values

Economic values associated with the Murray floodplain include consumptive industries (irrigated agriculture and urban water), and non-consumptive industries that are dependent, or partially dependent, on a healthy river and floodplain. Non-consumptive industries include tourism and recreation, real estate, and fishing.

It is difficult to find publicly available studies of the economic values associated with the Murray floodplain. However, a study of the economic value of river dependent industries between Hume Dam and Euston Weir Pool (located in the Sunraysia region on the River Murray near Robinvale) (Hassall and Associates and Gillespie Economics (2004) found significant high value industries along this stretch of the river, that provide large financial contributions to the local and national economy. These are listed in Table 18.

Table 18: Summary of economic values, Hume Dam to Euston Weir Pool (Source: Hassall and Associates and Gillespie Economics 2004)

Activity	Economic Values
Accommodation	$283.3M
Commercial fishing	N/A
Recreational fishing	$41.6M
Fishing charters	-
Houseboat hire	-
Private houseboat operation	-
Commercial boating (paddleboats and tours)	$6.2M
Non-commercial boating	$14.0M
Birdwatching	-
Water-skiing	$3.2M
Special events	$2.2M
Marinas	$1.6M
Amenity value	$251.7M
Flood plain grazing	$1.1M
Total	**$605.0M**

8.6 Conceptualisation of the Floodplain

The conceptual model illustrated in Figure 31 shows how different inundation levels and ecological processes interact for the different wetland types in the Murray floodplain.

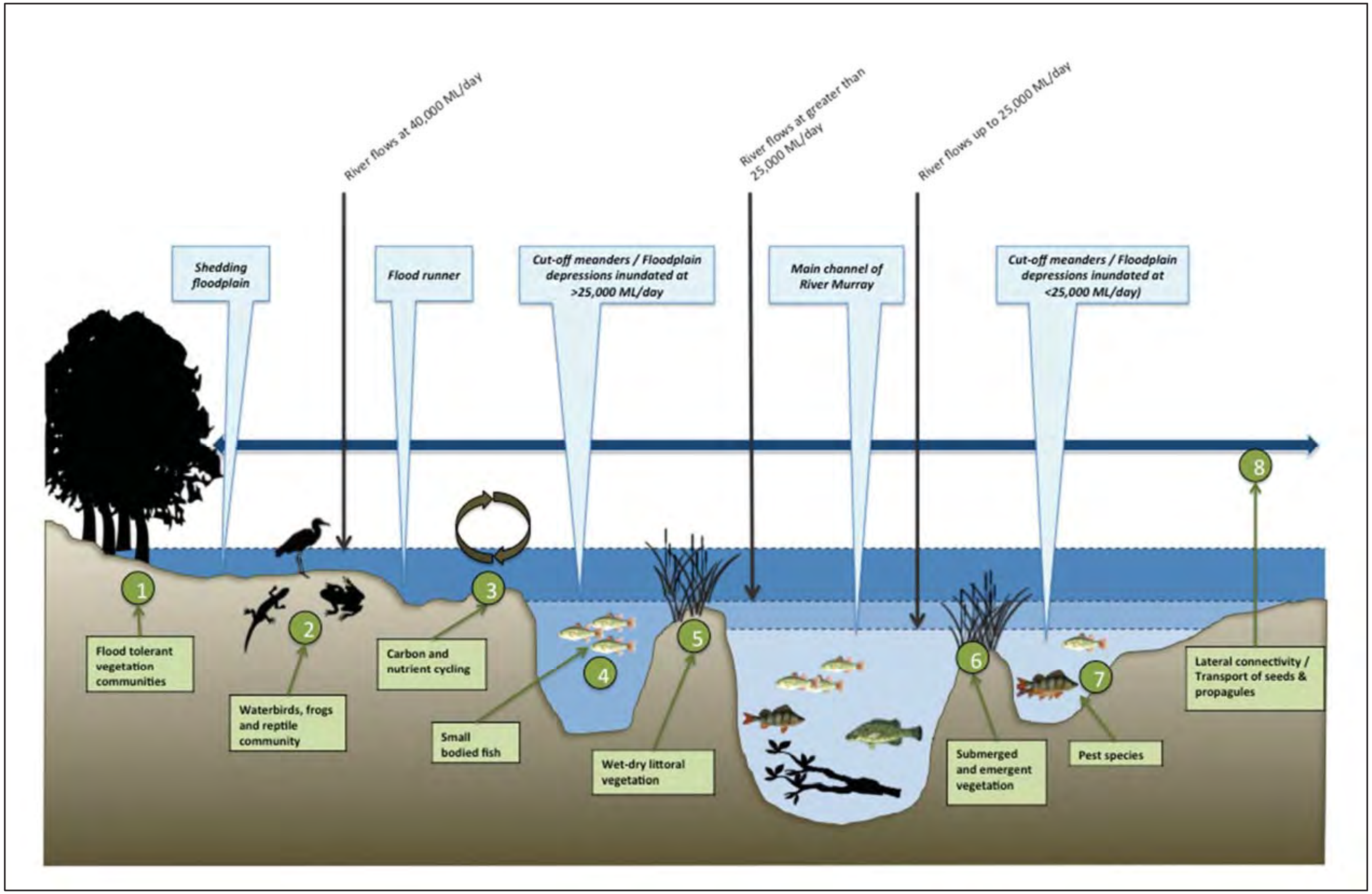

Figure 31: Ecological objectives conceptual model for the Murray floodplain

The conceptual model in Figure 31 represents a hypothetical cross-section of the Murray floodplain, and includes a selection of the different waterways present, such as:

- The main river channel
- A wetland (cut-off meander or floodplain depression) that is mostly or permanently connected at the current flow constraint for the River Murray of 25,000 ML/day
- Another wetland (cut-off meander or floodplain depression) connected at flows greater than 25,000 ML/day
- A flood runner
- The shedding floodplain.

Three different inundation levels are represented: river flows at 25,000 ML/day; river flows at greater than 25,000 ML/day, and river flows at the maximum level proposed through MDBA's Constraints Management Strategy, 40,000 ML/day.

A range of ecological objectives for the values of the floodplain are numbered and are as follows:

- Flood tolerant vegetation communities (1) on the shedding floodplain, such as River Red Gum, require regular inundation to enhance their recruitment success, and to maintain and enhance their extent and diversity.
- Waterbirds, frogs and reptiles (2), rely on a diverse range of habitat types on the shedding floodplain that have been created by an increased frequency of high river flows (i.e. > 25,000 ML/day), and also rely on the improved feeding and breeding opportunities created by more seasonal patterns of inundation for floodplain depressions and cut-off meanders.
- Carbon decomposition, nutrient cycling and sedimentation and transport processes (3) on the floodplain are enhanced with a more variable and seasonal regime of inundation and drying. This in turn increases the abundance of zooplankton for fish to feed on (4).
- Pest species such as Redfin (7) are less able to tolerate a seasonal draw down of permanent wetlands, which will in turn benefit small-bodied native fish such as Southern Pygmy Perch (4).
- A more diverse submerged and emergent vegetation community (6) will also benefit small-bodied native fish by providing better refuge from predation.
- Emergent macrophytes (e.g. sedges and rushes) in the wet-dry littoral zones of cut-off meanders and floodplain depressions (5) will improve in extent and diversity with a more seasonal wetting and drying regime.
- Lateral connectivity (8) is enhanced and maintained between the different wetland types of the floodplain and the river with the introduction of seasonal inundation regimes.

8.7 Significance

The Murray floodplain, by way of its intrinsic ecological, cultural, social and economic values, and because of its connectivity to the iconic Murray River, is deeply significant to many people in Australia and internationally. Perhaps ironically in light of this significance, it is only relatively recently that work has been undertaken to understand the water-dependent ecological needs of the floodplain, and to understand the implications of not supplying adequate watering regimes for both the floodplain and the river. In some ways, the section of the Murray floodplain between Hume Dam and Yarrawonga Weir is the 'forgotten floodplain', valued for its function as a working system for transporting water for consumptive use within the Murray Darling Basin and further afield, and for its social values, but not yet highly noted for its environmental values and the critical ecosystem services it provides.

The floodplain contains hundreds of wetlands. Improving the connectivity between these wetlands and the Murray River will help to protect and rehabilitate habitat for many wetland species, and will also support aspects of the life cycles of many riverine plant and animal species, including a significant number of species of national and international significance. For example, nearly half of the sixteen native fish species recorded in the area are rare or endangered. These species include the endangered Trout Cod and Macquarie Perch, and the vulnerable Murray Cod. Many of the plant species and EVCs in the area are also endangered or vulnerable, and the iconic River Red Gum is found in significant areas of the floodplain. The high biodiversity values of the floodplain, the presence of rare and endangered species, the very high water-dependent social and economic values, and the critical ecosystem functions that the floodplain provides all build a strong argument for supporting the floodplain with appropriate and adequate inundation regimes.

A large number of the floodplain’s wetlands have suffered marked degradation as a consequence of altered hydrology associated with river regulation. Murray Darling Basin planning processes have recognised the importance of the entire length of the Murray floodplain, and have placed a strong emphasis on its protection and rehabilitation through the Basin Plan.

The limited research on floodplains to date indicates that improving their water regimes and connectivity is critical for improving floodplain and river resilience and for achieving effective management of biodiversity, ecosystem functioning and productivity. In light of impending climate change impacts and the significant likelihood of less water availability in the Murray Darling Basin over the coming decades, it is important that adequate inundation regimes are provided to the floodplain to improve its resilience to these impacts. Given that many floodplains across the globe are now considered functionally extinct (Tockner and Stanford 2002), building this resilience becomes even more important from a global perspective.

Floodplains are also significant for people because of their less tangible but equally important life-sustaining and spiritual values. Our evolution and advance as a species has been dependent on rivers and the rich soils of floodplains, and healthy floodplains and healthy connected rivers generally mean healthy communities. The continuing decline in health of the Murray floodplain has consequences difficult to define but no less important for community well-being and resilience, particularly in light of the predicted impacts of climate change.

9. Ecological Condition and Threats

Ecosystems of the Murray floodplain are adapted to conditions of seasonal flow variability, temperature variations, drought, and wet and dry cycles to form a rich biodiversity. Because river regulation has significantly altered the natural variation of the River Murray however, with mid-range floods and low flows largely eliminated, there is now a serious degradation in the condition of large areas of the floodplain and its associated ecosystems. Despite this impact, it is only relatively recently that scientific investigations of the impacts of changed flow regimes on the ecological condition of the River Murray and its associated floodplains have been undertaken.

9.1 Current Condition

Despite the Murray-Darling Basin being a well-studied area, the current ecological condition of the Murray floodplain between Hume Dam and Yarrawonga Weir is not well known, and managers must infer its condition by synthesising information from a range of broader accumulated studies, long-term and short-term surveys, and strategic management plans. These include Basin-wide condition assessments such as the Sustainable Rivers Audit, which conducted Basin valley condition assessments, and a small number of River Murray reach-specific assessments that have incorporated some areas of the Murray floodplain within their scope.

9.1.1 Basin-wide floodplain condition

It is generally accepted that most water-dependent ecosystems within the Basin, including its floodplains, are in poor ecological condition, particularly the southern Basin (Davies *et al.* 2010, 2012). Human-induced habitat degradation, over-fishing, overgrazing, alien species introductions, barriers to fish movement, and water abstraction have all drastically changed the character and function of the Basin (Beeton *et al.* 2006), and it is estimated that there has been a loss of 90% of its floodplain wetlands since European settlement (State of the Environment 2011 Committee, 2011).

Floodplain communities have evolved to survive in a disturbance-prone ecosystem (Colloff and Baldwin 2010). It is difficult to tell if the variation in ecological responses that is seen for different floodplain species and communities falls within or outside what might be expected under the range of flow variations within the Basin (Colloff *et al.* 2015). Lag times for ecological recovery can also vary considerably for different species depending on their tolerance thresholds, their resilience, and the interplay of a combination of stressors (Colloff *et al.*. 2015). What is known however is that the overall trend for ecological condition in the Basin is a downwards decline. In response to mounting concerns about the current poor ecological condition of the Basin and its general declining trend, the Australian Government initiated major water reforms which culminated in the Commonwealth *Water Act 2007* and the Basin Plan to address the over allocation of irrigation water and restore flows to rivers (Colloff *et al.* 2015).

9.1.1.1 Sustainable Rivers Audit

To understand the ecological condition of the Murray floodplain, it is also useful to look at the condition of the Murray-Darling Basin catchments (or valleys) that feed water into the floodplain. The Sustainable Rivers Audit (SRA) is a continuing, systematic assessment of the health of river ecosystems across the Basin, and is a useful tool for understanding catchment-scale health relevant to the Murray floodplain. The first SRA (SRA1) was conducted in 2008 (Davies *et al.*. 2008), while the second SRA (SRA2) was conducted at the end of the Millennium Drought using data gathered between 2008 and 2010 (Davies *et al.*. 2012). Both SRAs have provided assessment of ecosystem health for each of 23 major catchments of the Basin, looking at five key ecological themes and comparing them to reference condition. The themes were: fish, benthic macroinvertebrates, riverine vegetation, physical form and hydrology (MDBA 2012a).

Overall, the SRA results have shown that the health of the Basin's catchments ranged from good to very poor, with most catchments rated as being in poor condition. Of the 23 catchments assessed for the SRA, three are relevant to the Murray floodplain: the Kiewa Valley; Ovens Valley; and Central Murray. The findings for SRA2 are presented in Table 19.

Table 19: Murray-Darling Basin sub-catchment condition assessments for the 2008-2010 Sustainable Rivers Audit (Source: Adapted from Davies *et al.*. 2012)

Catchment	Ovens	Kiewa	Central Murray
Catchment zones most closely corresponding to the Murray floodplain EWMP area	Lowland Zone	Lowland Zone	Middle and Upper Zone
Ecosystem Health	Poor	Very Poor	Poor
Fish	Very Poor	Poor.	Very Poor
Macroinvertebrates	Very Poor	Moderate	Poor
Vegetation	Very Poor	Extremely Poor	Good
Physical form	Good	Good	Poor
Hydrology	Good	N/A	Very Poor / Poor

Generally, the ecosystem health of catchments relevant to the Murray floodplain ranged from very poor to poor at the time of SRA2, with no component considered to be in excellent condition. All three catchments' lowland areas, which generally correspond to the area of the Murray floodplain relevant to the EWMP, showed poor condition for fish, varying condition for macroinvertebrates and vegetation, mostly good condition for physical form, poor hydrology scores where there was river regulation (Murray Central) and good hydrology scores for the mostly unregulated Ovens catchment. A summary of the findings for each of the catchments is provided in Table 20.

Table 20: Summary of SRA2 findings (Source: Adapted from Davies *et al.*. (2012))

Valley	Summary of condition
Kiewa	The Kiewa Valley was among the four lowest valleys rated in poor health across the Basin. The condition of the catchment's vegetation reflected the fact that a significant part of the upper catchment of the Kiewa is public land whereas the slopes and floodplain are given over to horticulture and dairying. Hydrology and physical form were in uniformly good condition in all three zones along the Kiewa (although no mainstem reaches were assessed for the hydrology theme). For macroinvertebrates, the lowland zone near the Murray floodplain was in slightly worse condition than were the two upstream zones, whereas the opposite applied for the fish community which was in significantly better condition in the lowland zone relative to the others. Native fish were outnumbered nearly 5:1 by large-bodied alien predators, which might be expected to exert considerable predation pressure on small native species (and recruits) in stream habitats severely reduced in size, complexity and connectivity by drought conditions which were experienced during the period of the SRA2 assessment.
Ovens	The Ovens Valley is ranked eighth highest amongst the 23 Basin SRA valleys in terms of its river ecosystem health. It is ranked in the upper 50% of valleys for all themes except vegetation in which it is ranked 16th. The Ovens Valley, with some of its neighbouring valleys, experienced the most extreme of the drought conditions that affected much of the Murray–Darling Basin during the Millennium Drought. Unlike some nearby river systems (e.g. Goulburn and Mitta Mitta) the Ovens is not highly regulated, and the hydrological effects of drought – especially extreme low-flow and zero-flow events – were not ameliorated in downstream reaches by releases for consumptive requirements, exposing lowland and slopes zones to the same drought effects as the catchment streams and tributaries. Because data had not been collected under non-drought conditions it was difficult for the SRA analysis to assess to what degree the observed shortfalls in condition were responses to the climatic

	factors of the time, rather than more independent or objective reflections of ecosystem health.
Central Murray	The Central Murray Valley ranked equal first in terms of vegetation condition with three other valleys, all from the northern sub-basin. For the other four themes it ranked in the lower 50% of all valleys—in the lowest quartile for hydrology and macroinvertebrates. The socioeconomic values of floodplain forests, as a valued product in the 19th century and as an ecological resource in the 21st century, are thought to have afforded this catchment a degree of protection which is reflected in its high scores for abundance and fragmentation of the riverine vegetation in the lowland floodplain zone. The Central Murray riverine ecosystem is strongly influenced by major tributaries. The channel also has a number of in-stream structures (weirs at Yarrawonga, Torrumbarry, Mildura and Wentworth) and its poor hydrology rating reflects significant regional irrigation diversions, the management of major storages upstream in the Murray and tributaries, and the delivery of water to supply substantial down-stream demands. Severe drought conditions over the whole SRA program monitoring period were thought to have exacerbated this situation, in particular in terms of the natural high flow events which support lateral connectivity to the floodplain. All three indicators of the condition of the fish community, expectedness, nativeness, and recruitment, showed a significant downward trend from SRA1 to SRA2. The Central Murray together with the Lower Murray showed the sharpest decline in recruitment at the valley scale.

9.1.2 Wetland condition assessments

There is currently very little available data regarding the condition of specific floodplain wetlands within the EWMP area. In Victoria, a method for assessing wetland extent, distribution and condition is the Index of Wetland Condition (IWC). Using the IWC method, an assessment of the condition of approximately 600 Victorian wetlands of national and international significance was conducted in 2009, and a further assessment of approximately 300 wetlands in 2010. The IWC measures six aspects (sub-indices) of wetland condition: wetland catchment, physical form, hydrology, water properties, soils, and biota.

While there are no wetlands of international significance in the Murray floodplain EWMP area, five wetlands that approximately correspond to a location within EWMP floodplain area are listed in the Directory of Important Wetlands Australia. Two wetlands within the Kiewa basin were assessed for the IWC, and three in the Ovens basin. The results of the assessment are presented in Table 21.

Table 21: Wetlands in the Murray floodplain EWMP assessed for IWC (Ref)

Basin	Wetland Number	Wetland Name	Wetland Catchment	Physical Form	Hydrology	Water Properties	Soils	Biota	Overall	Condition
Ovens	75153	None	8	16	0	7	9	12	4	Poor
Ovens	75154	None	18	20	0	15	18	16	7	Good
Ovens	75156	None	18	20	0	15	18	18	7	Good
Kiewa	76197	Ryans Lagoon Floodway	5	12	0	10	0	9	3	Poor
Kiewa	76198	Ryans Lagoon #1	8	14	10	10	10	8	4	Poor

9.1.3 Reach specific condition

The River Murray Scientific Panel assessed the condition of the River Murray and its riparian zones and floodplains in 2000 for the MDBA (Thoms *et al.* (2000). The Panel found that for the river and floodplain between Hume Dam and Yarrawonga Weir:

- Anabranch channels in the floodplain are an important feature of the floodplain environment and require flooding for their development. Some anabranch channels were showing signs of active erosion due to de-snagging (in a few cases) and constant high flows, while others have experienced a reduction in flooding.
- Decreases in river–floodplain linkages, reducing the exchange of organic material, are likely to have affected fish breeding, particularly of the smaller-bodied species.
- Modification of the floodplain is greatest for the higher flood inundation levels (infrequent floods) and is least for low flood-prone areas (particularly on the inside of bends). The inverse relationship between floodplain alienation and flood frequency has resulted in a reduction in effective floodplain size in downstream reaches as well as a reduction in the benefits of floodplain–river interaction during major floods.
- River banks were considered to be in very poor condition along almost the entire length of the river zone, with erosion virtually eliminating much of the physical bank habitat, such as benches, in certain areas.
- The combined pressure of modified flows, bank erosion, and grazing and trampling by stock on the riverbanks has resulted in a serious depletion of emergent plants, grasses and native shrubs – a major agent in combating bank erosion from surface wave action.
- The native riparian zone vegetation communities (especially the 'non-tree' species) are in relatively poor condition, often restricted to relatively inaccessible areas. Much of the vegetation has been cleared or grazed. These riparian vegetation communities have also been affected by a reduction in flooding frequency. The loss of vegetation from riverbanks also contributes to their instability.

Further to this high level condition assessment by Thoms *et al*. (2000), a rapid qualitative assessment of the condition of geomorphic features, aquatic habitat and riparian vegetation between Hume Dam and Yarrawonga Weir was completed for the then NSW Department of Water and Energy between 2005 and 2008. This assessment provides a more reach-specific understanding of condition, and includes within the scope of the assessment area the anabranch system and floodplain on both sides of the River Murray. The work was commissioned to assist in the management of the reach, and river management plans were prepared for fifteen sub-reaches of the system (Earth Tech 2005a; 2005b; 2006; 2007b; 2008a, 2008b, 2008c, 2008d, 2008e, 2008f, 2008g, 2008h, 2008i; 2008j; and Water Technology 2008). The following key habitat features were assessed:

- Aquatic habitat
- Riparian vegetation
- Geomorphology.

Table 22 presents a summary of the findings of these condition assessments. Where possible, conditional information from the Thoms *et al*. (2000) report is also included.

Table 22: Summary of river reach and anabranch condition (Source: Earth Tech 2005 to 2008, and Thoms *et al*.. 2000)

Condition component	Findings
Aquatic habitat	• Aquatic habitat condition ranged from poor to fair between Hume Dam and Yarrawonga Weir. Numerous reaches lacked instream cover such as large woody debris, and there was little diversity in depth and substrates. • River flow is significantly affected by releases from Hume Dam, particularly in the reaches closer to the dam, and waterways were exposed to a variety of flows depending on irrigation and hydroelectric generation requirements. The thermal regime of the waterway was also an issue as water released from the dam is colder than would be occurring naturally, and a number of native fish require warmer temperatures to successfully complete their lifecycle. • In the lower reaches, fish populations are reasonably healthy due to increased snags providing good habitat, and because of Lake Mulwala, which appears to be an effective nursery ground for Murray cod and may assist in warming water temperatures. • The physical habitat has been modified from the natural state by the impacts of constant high summer flows and from riparian clearing and habitat change due to introduced willows and de-snagging. It is estimated that approximately 24,500 snags were removed from the reach

Condition component	Findings
	between 1976 and 1987, and only 5000 woody habitats were estimated to be present at the time of the assessment, many of which were not considered suitable for native fish habitat due to their location in shallow areas and small size. De-snagging has significantly reduced available instream habitat, especially for fish species such as Murray cod. It has also had an important impact on instream productivity by limiting habitat for instream biofilm development and macroinvertebrate production. • Stream substrate in the main river channel has been significantly modified from natural in parts of the reach, with gravel smothering much of the streambed, limiting habitat variation and diversity. • Water quality is poor in some areas. In addition to the changes in water temperature caused by low level releases from Hume Dam, changes in nutrient concentrations have been observed. Nitrate data shows a peak concentration in November–December, and a minimum in autumn–winter (at almost undetectable levels). The filterable and total phosphorous data shows much greater variance.
Riparian vegetation	• Vegetation condition is highly variable throughout the reach. The floodplain has been extensively cleared for agricultural purposes. The overstorey layer, which would have been almost exclusively River Red Gum forest or woodland, is massively depleted but still present. These gums line most of the river, anabranches, wetlands and flood runners, but usually lack any width. Mature Red Gum are present, but regeneration is limited. The understorey layers are even more depleted, with shrub and ground layer species scarce to patchy. • Willows are common, and in some areas provide the only overstorey cover. Other woody weeds such as Elms, Hawthorn and Ash are also common. The structure of the remaining native vegetation is highly modified, with ground cover and macrophytes such as *Phragmites* the most depleted. Pasture grasses and weeds such as Blackberry, Patterson's Curse and Bathurst Burr dominate the ground layer in substantial areas of the reach, replacing native grasses. Many of the weeds observed are listed as noxious weeds within NSW and Victoria. • Unrestricted grazing has caused a decline in native vegetation due to preventing successful regeneration of seedlings, and eating and/or trampling young plants. Grazing pressure tends to be determined by stock access. Low lying areas are grazed lightly, particularly when access is restricted by anabranches during high flow.
Geomorphology	• Geomorphology is significantly modified in the main channel and anabranches of this reach. The key issues are river regulation, floods, de-snagging, changes in riparian vegetation and boat waves. • Stretches of the reach have experienced an increased rate of widening both in the main channel and anabranches due to the increased duration of near bank full flows and severely depleted riparian vegetation. This widening has resulted in an over-enlarged main channel, lateral migration of the waterway, and assisted in sediment migration into downstream reaches. Significant areas of rock beaching are being placed throughout the reach to manage the increased lateral migration. • Boat waves and wake-boarding are increasing the rate of bank erosion, as is cattle grazing. De-snagging has contributed towards a loss of in-stream morphologic diversity, and has also contributed to increasing rates of erosions. • There is some risk in parts of the reach that anabranches and meanders will take the greater proportion of river flows, diverting water from the main course of the river. Significant works are needed to reduce the rate of meander migration.

9.1.4 Trajectories for floodplain condition under a more variable water regime

Under current flow conditions on the floodplain, permanently inundated wetlands (those inundated at flows <25,000 ML/d) tend to be dominated by introduced fish species, particularly Redfin Perch, which preys on smaller native fish. The permanent and relatively stable water regime also means that aquatic vegetation diversity is low and limited to a narrow band around wetland margins and is dominated by Common reed compared with those that experience periodic drying (Barrett *et al.*. 2010). During the summer period this marginal vegetation may be inundated, but during winter it is likely that water levels will drop a little, although permanent water may be retained within the wetland due to lower evaporation rates over winter. It is unlikely that vegetation will establish at the lower winter level because 1) it is drowned out in summer, and 2) growing conditions are poor in winter due to lower temperatures and short photo period (D. Nielsen, MDFRC, pers. com.).

By contrast, wetlands inundated by flows >25,000 ML/d tend to be dry for long periods of time, which results in degradation of floodplain vegetation which requires periodic inundation for growth and recruitment and restricts available habitat for native fish, which require variable water levels, but maintenance of permanent pools.

9.1.4.1 Cut-off Meanders

Under a more variable water regime it is expected that the diversity of aquatic plants would increase. In particular, a variable water regime with increased seasonality and wetting and drying of the wetland margins would be expected to promote the establishment of a range of submerged and emergent species that prefer a seasonal wetting and drying regime (e.g. sedges and rushes). Shallower water depths would also promote submerged species such as Pond Weed (*Potamogeton sp.)* and Milfoil (*Myriophyllum* sp.). A more diverse submerged and emergent plant community would provide increased habitat complexity for native fish. This is particularly important for small-bodied native fish because it will provide refuge habitat to escape predatory Redfin perch. Increased habitat diversity and refuge from predation is especially critical to help increase the distribution and abundance of Southern Pygmy Perch, which has experienced a notable decline in wetlands along the Murray River since the late 1990s (Lee Baumgartner, MDFRC, pers. com).

9.1.4.2 Floodplain Depressions

As with cut-off meanders, permanently inundated floodplain depressions tend to be dominated by open water habitats and introduced fish species, particularly Redfin perch and Common carp.

Under a more variable water regime it would be expected that the diversity of aquatic plants in the littoral zone would increase. In particular, a variable water regime with increased seasonality and wetting and drying of the wetland margins would be expected to promote the establishment of a range of submerged and emergent species that prefer a seasonal wetting and drying regime (e.g. sedges and rushes). A more variable water regime would help to expose shallow lake margins, which creates important foraging habitat for a range of water bird species, such as shoreline waders (e.g. egrets and spoonbills), shallow water in important for ducks and grebes.

9.1.4.3 Flood Runners

Under natural conditions, flood runners are dry for extended periods of time, but when inundated they provide opportunities for native fish and other animals, plant seeds and propagules, and nutrients to move and redistribute across the floodplain. Improving the water regime of flood runners is integral to improving the water regime and ecological condition of the full range of wetland types inundated at flows >25,000 ML/d. By improving the water regime of flood runners there will be increased opportunities for fish to disperse among wetland types and this will help with recolonisation and expansion of native fish communities.

9.1.4.4 Shedding Floodplain

A lack of inundation of shedding floodplains has resulted in degradation of the floodplain vegetation which requires periodic inundation for growth and recruitment. Restoration of seasonal inundation would help to recharge floodplain soil moisture and provide recruitment opportunities for plant species that require short term inundation to promote recruitment. Seasonal inundation will also help to reduce colonisation of the floodplain by species (especially weeds species) that prefer drier conditions.

9.2 Threats

9.2.1 Altered Hydrology

A priority threat to wetland values along the Murray floodplain is the altered hydrology of the River Murray through river regulation. With the extensive modification of the rate, variability, total volume and seasonality of river flow, significant changes have occurred to the connectivity of the floodplain with the river. These changes in connectivity pose a significant threat to water-dependent values of the floodplain and are likely to have significantly altered the character and functioning of the floodplain. This threat can be broken down further according to:

- The current connectivity and water regime requirements of the different wetland types across the floodplain
- The water-dependent values within these wetlands.

The key threat to floodplain wetlands currently inundated at flows less than 25,000 ML/day (Category 1 and 2 wetlands, refer to Table 9 and Figure 13), is that too many of them are now permanently inundated. Although water level may vary in these wetlands through a drawdown in winter and spring, it is reduced through low evaporation rates, and this is the time of the year when they should be experiencing inundation, not drawdown. In effect, the seasonality of the watering regime for these wetlands is reversed compared with the recommended regime.

For wetlands that only receive water at flows greater than 25,000 ML/day from the River Murray (Category 3 and 4 wetlands), the threat is that they are not experiencing seasonal watering regimes with inundation in winter/spring and a drawdown during the summer/autumn period.

This lack of seasonally appropriate and variable water regimes produces a number of impacts on the water-dependent values within these wetlands. Table 23 provides a high level summary of these threats.

Table 23: Summary of the threats of altered hydrology to water-dependent values of the Murray floodplain

Water-dependent value	Description of threat
Submerged macrophytes	For submerged macrophyte communities in cut-off meanders and floodplain depressions, it is important they have a permanently inundated zone. For those macrophyte communities found in category 3 and 4 wetlands however, which are currently connected only at flows greater than 25,000 ML/day, the threat is that the failure to maintain a permanently inundated zone will result in the loss of these species, and as a consequence, habitat diversity in these wetlands is reduced
Emergent macrophytes	For emergent macrophytes in cut-off meanders and floodplain depressions, they require a variable wet and dry zone, which allows for growth, seeding (wet phase) and seed germination (dry phase). For those communities currently found in Category 1 and 2 wetlands, which are currently connected at flows less than 25,000 ML/day, the threat is that the loss of a variable water level through constant flows results in reduced species diversity.
Small-bodied native fish	Small bodied fish such as Southern Pygmy Perch and Australian Smelt require a permanently inundated zone to ensure suitable habitat conditions for their survival. Failure to provide this inundation, because wetlands are no longer connected to river flows (such as category 3 and 4 cut-off meander and floodplain depression wetlands), resulting in the loss of fish fauna. Small bodied fish also use flood runners to disperse between waterways and wetlands. The reduced inundation patterns for these wetland types reduces dispersal opportunities, and particularly after dry phases, limits the opportunities for recolonisation of native fish.
Waterbirds, frogs and reptiles	These communities rely on a variable wet and dry zone to provide a mosaic of habitat types. For category 1 and 2 cut-off meanders, floodplain depressions and the shedding floodplain, the failure to provide a variable water level with drawdown results in: • A narrow littoral zone • A loss of flow cues for breeding, such as variable inundation levels • A reduction in the diversity and abundance of food sources • A consequent reduction in species diversity and abundance. For category 3 and 4 wetlands, a failure to provide regular and varied inundation reduces habitat availability and sources of food, and reduces opportunities for dispersal across the floodplain. This in turn produces a reduction in species diversity and abundance.
Flood tolerant vegetation	Occasional wetting is important for promoting the seed set of flood tolerant vegetation, while

Water-dependent value	Description of threat
communities (e.g. River Red Gum)	dry phases provide the right conditions for seed germination. For example, for River Red Gum on the shedding floodplain, the reductions in inundation events in terms of both timing and duration have reduced. River Red Gum communities on the floodplain require periodic inundation (every 3–5 years) for a duration of up to 64 days to remain in moderate to good condition. The loss of inundation events is known to cause dieback and in many areas of the broader Murray floodplain, River Red Gum recruitment is minimal. As older trees die and are not replaced, there is a threat that this species will significantly contract in size and distribution across the Basin.

The consequences of altered hydrology for water-dependent values are further discussed in Section 10.3.

9.2.2 Other Threats

Other major threats to the maintenance of ecological character in wetlands of the region, including the Murray floodplain wetlands are as follows:

- Altered water quality, especially changes in:
  - Temperature
  - Salinity
  - Nutrients
  - Toxicants.
- Pest plants and animals
- Resource use, land use change and habitat modification, effected through processes such as:
  - Reclamation and clearing
  - Levees
  - Fish barriers
  - Firewood collection
  - Livestock grazing
- Recreation and tourism, including:
  - Hunting and fishing
  - Boating and wake-boarding
  - Trampling and general issues of access and weed spread.
- Climate change, via:
  - Direct changes in air temperatures and rainfall patterns
  - Indirect impacts effected through altered hydrology.

9.2.3 Altered Water Quality

Altered water quality components are known to cause significant negative impacts to floodplain habitat and biota. These components include temperature, salinity, nutrients, toxicants and blackwater (dissolved oxygen)

9.2.3.1 Temperature

The water quality changes can be brought about by thermal stratification in Hume Dam during the spring and summer. Releases from the dam are known to cause both substantial decreases in downstream water temperature, and increases in nutrient load and concentrations of natural toxicants, such as hydrogen sulphide and heavy metals (Thoms *et al*. 2000). These changes can lead to negative impacts on native fish, either through the direct effects of low temperature on fish behaviour and reproduction, or through the negative metabolic effects of low oxygen or high hydrogen sulphide and/or heavy metal concentrations. The increased nutrient loads from the anoxic hypolimnion (bottom cold water layer) can also lead to increased algal growth downstream, particularly of epiphytic or benthic algae (Thoms *et al.* 2000).

9.2.3.2 Salinity

The main cause of dryland salinity in the North East region is believed to be the clearing and loss of deep-rooted native vegetation since European settlement. This has led to increased groundwater recharge, which has the potential to lead to shallow water tables and land salinisation. Basin salinity audits have shown that salt, previously stored in the landscape, is now being mobilised on a massive scale across the Basin by rising groundwater tables due to land use changes (MDBA 2001). Average river salinities in key Basin rivers including the River Murray are predicted to rise significantly within 20 to 50 years, endangering their use for irrigation and urban purposes, and about 3.4 million ha of land in the eastern and southern regions of the Basin, will be salt-affected within 50 years (MDBA 2001). Although the environmental implications are not well understood, river salinity levels are thought to be having serious impacts on floodplain wetlands of national and international importance (MDBA 2001).

Any gradual rise in water tables mobilises salt to the land surface and eventually to the river and floodplain system. Without intervention, the salinity of rivers, streams and wetlands in the North East and downstream catchments will increase, with associated social, economic and environmental impacts. The most obvious impact of salinisation is the impact on biota, with excessive levels of salinity being toxic to many species. Salinisation can also have ecosystem-wide impacts for wetlands, with effects on dissolved oxygen, pH, water density, nutrients and the bioavailability of heavy metals (WBM BMT 2007b). Salinity can also affect a range of decomposition pathways in wetlands, changing the rate at which organic-matter decays and also producing toxic hydrogen sulphide, which can have major impacts on plant growth and may be a factor leading to fish kills in receiving waters (WBM BMT 2007b).

9.2.3.3 Nutrients

Nutrient enrichment via runoff from agricultural and urban landscapes within and near the Murray floodplain poses a number of potential hazards for its wetlands. It can lead to blue-green algae blooms, which can be toxic to wetland ecosystems (Morris *et al*., 2006, in WBM BMT 2007b). Excessive growth of algae in the water column (phytoplankton) and attached to plant surfaces (epiphytes) can also lead to the loss of submerged plants, usually through reductions in available light and deoxygenation of the water column (Thoms *et al.* 2000). This has flow on effects for water-dependent species such as fish, waterbirds and macroinvertebrates dependent on good water quality for their habitat and food sources.

9.2.3.4 Toxicants

Although high nutrient and salt levels are the water-quality variables that most commonly impact wetlands in the floodplain (WBM BMT 2007b), a range of toxicants can also pose threats to the floodplain's wetland biota. As floodplain wetlands are often at the lowest point in a landscape, they are natural depositories for pollutants that have come from higher in the catchment or from use of the floodplain for agriculture, industry or urban populations. Heavy metals, such as cadmium from phosphate fertilisers (agricultural landscapes), arsenic from sheep dips (organophosphate insecticides), or mercury from gold mining, may be deposited in wetlands as particle-bound toxicants (WBM BMT 2007b). Other toxicants that pose threats to wetlands, particularly in agricultural landscapes, are pesticides and, in urban landscapes, polychlorinated biphenyls (PCB's). These can have significant toxic effects on biota within the floodplain wetlands.

There is currently very little data available on toxicants and their impacts on biota in the Murray floodplain.

9.2.3.5 Blackwater

Blackwater is oxygen-depleted water caused by the decay of organic matter. The decay process darkens the water and the oxygen in the water is consumed, sometimes at a rate faster than it can be replenished. Floodwaters flush organic matter such as leaves from floodplains to the river system. As they are flushed down the river this material rapidly breaks down and releases tannins and other compounds. The tannins and other compounds released during the breakdown of this organic material discolour the river water, making it appear blackish. This blackwater can sometimes become very low in dissolved oxygen, which may cause stress to fish, crayfish and other aquatic animals. When the dissolved oxygen reaches a very low level it can result in fish deaths. Blackwater caused fish kills were known to occur following the large flood events of 2010 and 2011 on the Murray floodplain downstream of Yarrawonga Weir (King *et al.* 2012).

9.2.4 Pest plants and animals

9.2.4.1 Pest fish

Introduced pest species of fish now make up a quarter of the Basin's total fish species (including on the floodplain, Carp, Eatern Gambusia, Oriental Weatherloach, Roach, Tench, Goldfish, Redfin Perch, and Brown Trout). These fish compete with native fish for food and habitat, and also prey on smaller fish species (MDBC 2003). For example, Carp now make up an estimated 60 to 90 per cent of the total fish biomass at many sites, with densities as high as one carp per square metre of river surface area (MDBC 2003). When carp are present in high densities, the resultant suspended sediment can result in a number of problems, including the direct deterioration of water quality due to sediment and increased nutrient levels, reduced plant growth, the clogging of gills of other fish species, and fewer plant species because they have either been eaten or uprooted (Rowe *et al.et al.*. 2008).

Gambusia's aggressive nature, high reproductive potential, fast maturation rate, flexible behaviour and broad environmental tolerances have contributed to its success as invader, and the species is considered to pose a serious threat to native fishes in Australia and overseas (Macdonald and Tonkin 2008). Competitive behaviour that excludes native fish from food resources and habitat, as well as aggressive interactions in confined environments have resulted in reduced condition of native fish and reduced population sizes and distribution. Small bodied wetland specialists that occupy similar habitat and dietary niches as Gambusia, such as the Southern Pygmy Perch, have undergone a major decline in distribution and abundance throughout the MDB, particularly throughout NSW. Surveys across the lower Murray River have found Southern Pygmy Perch absent in sites of suitable habitat but with an abundance of Gambusia, suggesting the interaction between these species could be responsible (Macdonald and Tonkin 2008).

Redfin Perch are a popular sport fish with some anglers because of their fighting qualities and taste. Redfin are voracious predators which consume a wide variety of fish and invertebrates, including small native species such as Pygmy Perch and Carp Gudgeon, and the eggs and fry of larger fish such as Murray Cod. They can also devastate native fish populations by carrying the epizootic haematopoietic necrosis (EHN) virus. For these reasons, redfin are considered a serious pest and are listed as a noxious species.

9.2.4.2 Foxes, cats and pigs

In Australia, foxes and cats are classified as keystone species that by predating on native animals, have reduced biodiversity and impacted on the survival of native prey over large areas of entire ecosystems, including the Murray floodplain. The impact of foxes and cats, combined with habitat degradation, is the most likely cause of 'at risk' native animal declines. For example, approximately 80 endangered and threatened species are at risk from feral cat predation in Australia (DEPI 2015).

Feral pigs are known to live in isolated areas of the Murray floodplain. They are considered an environmental pest due to their selective feeding, trampling and rooting for underground parts of plants and invertebrates, as well as predation on, competition with, or disturbance of a range of native animal species. Feral pigs are known to prey on earthworms, insects, amphibians, reptiles, ground-nesting birds, small mammals, freshwater crayfish, frogs, turtles and their eggs. Feral pig activity also has a significant effect on watercourses and wetlands. By wallowing and rooting around the waterline, they destroy the riparian vegetation which provides food and nesting sites for native wildlife and helps to prevent soil erosion. Water quality is also affected and their diggings may spread undesirable plant and animal species, and plant diseases in these areas (DEPI 2015).

9.2.4.3 Invasive plants

Wetlands across the North East are colonised by introduced plants such as Willows (*Salix spp.).* Bridal Creeper (*Myrsiphyllul asparagoides*), Boxthorn (*Lycium ferocissimum*), Box Elder (*Acer negundo*), Honeysuckle (*Leycesteria spp.),* Hawthorn (*Crataegus monogyna*) and Blackberry (*Rubus spp*.) are common on wetland fringes. There are also submerged exotic weeds such as Canadian Pondweed (*Elodea canadensis*), Umbrella Sedge (*Cyperus eragrostis*) is a common emergent fringing weed, and Brazilian Milfoil (*Myriophyllum aquaticum)* is a widely spread amphibious aquatic weed (BMT WBM 2007b).

Invasive plants outcompete native plants for habitat, and in some cases are harmful to native animals that eat them. Willows are particularly problematic for waterways because they clog up the channel with their large matted roots, consume large amounts of water via transpiration, and out-compete native plants. This reduces native species diversity and abundance.

9.2.5 Resource Use

9.2.5.1 Reclamation and land clearing

Reclamation and land clearing continues to threaten the Murray floodplain as almost 80% is located on private land, with most clearing occurring on productive agricultural land or in close proximity to townships along the floodplain. The floodplain has already been severely fragmented by past clearing and is further threatened by continuing fragmentation and degradation, flood mitigation and drainage works for urban areas such as Wodonga, landfilling and earthworks associated with urban and industrial development, and pollution from urban and agricultural runoff.

Land clearing and wetland reclamation significantly reduces habitat diversity and availability, removes food sources for dependent animals, and further alters the hydrology of the floodplain by removing connectivity opportunities. The impact of this is further declines in the biodiversity and ecosystem functioning of the floodplain.

9.2.5.2 Fish barriers

The capacity to move is crucial to fish recolonisation after disturbance, for breeding and recruitment of larvae, and for migration. Fish movement along the River Murray channel and laterally across the floodplain can be obstructed by barriers to their passage. Large dams, weirs, locks, regulators, levees and road crossings can all act as blockages, and can apply in both directions; upstream and downstream, as well as on to and off the floodplain (Thoms *et al.* 2000). The presence of regulatory structures along the River Murray prevents such movements and is of major concern. Smaller regulatory structures on flood runners also blocks fish movement through channels and onto the floodplain, while the presence of other small structures such as culverts and levee banks on the floodplain constrain their movements across the floodplain. Unless high flows can over-top such structures, fish can also become stranded as water levels recede (Thoms *et al*. 2000).

A fish lift has been constructed at Yarrawonga Weir to partly address this issue, but many barriers still remain across the Murray floodplain reach, particularly levee banks and other flood attenuation structures such as regulators (Thoms *et al.* 2000).

9.2.5.3 Firewood collection

Commercial firewood cutters, local communities and recreational tourists collect significant amounts of firewood from the Murray floodplain area each year (VEAC 2008). This has important implications for floodplain habitat availability and quality because fallen timber is an important structural element in floodplain forests. Many animals, plants and fungi species rely on fallen timber for shelter, foraging habitat and nutrient cycling and refuge from predation, and the larger pieces provide a structure to trap fine debris, sediments and nutrients providing microhabitat (MacNally *et al.* 2002).

Fallen timber is also important for floodplain wetlands and the shedding floodplain because it provides vital habitat for fish and aquatic invertebrates. The removal of fallen timber for firewood impacts greatly on many species and is one of the major threatening processes for aquatic habitats (VEAC 2008; Thoms *et al.* 2000).

9.2.5.4 Livestock Grazing

Livestock grazing is common on much of the River Red Gum forest of the Murray floodplain area (VEAC 2008). Domestic stock grazing can potentially lead to pugging, selective plant removal, weed invasion, soil compaction, erosion and increased sediment and pollutants in rivers and wetlands. Grazing stock also compete for food with native animals and damage habitat (such as damaging invertebrate burrows because of soil compaction) (VEAC 2008). Grazing can result in habitat loss or modification, the introduction and spread of exotic plants as well as the inhibition of native vegetation establishment and growth, particularly River Red Gums and other seedlings. Damage to wetlands by grazing has also been demonstrated to affect habitat values for animals such as frogs and birds (VEAC 2008). Livestock grazing may also adversely affect soil structure, bed and bank stability, and water quality (VEAC 2008). Grazing can also reduce the capacity of riparian zone vegetation to act as a nutrient ‘filter’ by compacting the soil, increasing erosion and sediment input into waterways. These effects are strongest where grazing is continuous (VEAC 2008).

9.2.5.5 Snag removal

Snag or timber removal was once a very common management practice along the River Murray and its floodplain waterways. Desnagging used to be considered an essential component of river management, and desnagging practices aimed to improve stream flow, reduce severity of flooding, and improve the passage for navigation. Aquatic and terrestrial floodplain flora and fauna require woody habitat for:

- In-stream habitat
- A food source
- Sites to spawn and rear juveniles
- Protection from strong currents and sunlight
- Orientation points to identify habitat and territory
- Shelter from predators
- Vantage points to help capture prey (Treadwell *et al.* 1999).

Removing these timber structures has a huge impact on entire food chains affecting algae, fungi, aquatic plants, invertebrates, mammals, birds, reptiles, amphibians and fish. For example, studies have shown that most Murray cod within a stream are located amongst woody debris. After their spring spawning migration Murray cod will return to exactly the same log or hollow, sometimes travelling 100 kilometres upstream (Treadwell *et al.* 1999).

9.2.5.6 Recreation and tourism

Recreation and tourism, while bringing significant economic benefits to the North East region, also pose significant ecological threats to the Murray floodplain. Recreational boating and wake-boarding for example are known to cause bank erosion and slumping via the wave actions following behind water craft if they move at speed on waterways. Significant bed and bank stabilisation works are being undertaken along many of the anabranches and the main channel of the River Murray to ameliorate this effect, but concerns are that as both of these sports gain in popularity, the impacts on the stability of the waterways in the floodplain will be further compromised. Erosion of banks is causing siltation and sedimentation effects in connected waterways and wetlands. This is likely to have the effect of smothering habitats, reducing water quality and habitat availability and as a consequence, the diversity and abundance of water-dependent species.

Recreational use of the floodplain also increases the occurrence of human disturbance (particularly noise and light) of breeding areas for waterbirds and frogs, causes soil compaction by recreational vehicles and camping, introduces new weeds and/or spreads current weeds about the area, increases the amount of rubbish dumped in the area, and also increases the risk of fires in the area. All of these threats significantly reduce the water-dependent values and visual amenity of the area.

Recreational fishing and hunting is popular along the Murray floodplain, and while fishing in particular can be useful for the removal or reduction of pest species such as wild pigs, Carp and Redfin from floodplain wetlands, these activities also target native fish and waterbirds, and can directly reduce their abundance and diversity and slow their time to recovery following major stressors such as drought. Recreational fishing and hunting is particularly a risk for vulnerable and threatened species found in the floodplain given their already reduced distribution and/or abundance.

9.2.6 Climate change

The 13-year Millennium Drought in the southern Murray-Darling Basin and Victoria was unprecedented compared with other recorded droughts since 1900. This was because it was largely constrained to the southern‐Australian region, with lower year-to-year rainfall variability but no ‘wet’ years through this period, and because the seasonal pattern of the rainfall decline was at a maximum in autumn but also included losses in winter and spring (CSIRO 2010). Scientists have analysed the observed climate record and have found a strong relationship between the rainfall decline in south-eastern Australia and global warming, and they now believe that the Millennium Drought was in part created by the effects of climate change (CSIRO 2008b, 2010).

There are no climate change impact assessments directly applying to the Murray floodplain between Hume Dam and Yarrawonga Weir. However, a CSIRO modelling study of the effects of climate change on the hydrology of the Basin found that a median climate change scenario resulted in the average volume of the surface water resource falling by 11% by 2030, surface water use falling by 4%, and flows at the Murray Mouth falling by 24% (CSIRO 2008b, 2008c). In addition, the relative impact of climate change on surface water use is estimated to be much greater in dry years. The project concluded that the hydrological impacts of climate change in the MDB remain very uncertain. For example, average surface water availability could reduce by as much as 34% by 2030, or increase by up to 11% (CSIRO 2008b, 2008c).

Fire frequency is also expected to increase with climate change (Pittock and Finlayson 2011), potentially further reducing water quality and flows. The regeneration of Eucalyptus forests after fires in 2003, the largest of four major bushfires since 2000, which burnt 1,390 000 ha of the headwaters of the Basin, is also expected to reduce inflows (van Dijk *et al*. 2006).

The implications of climate change for the condition and health of the Murray floodplain are profound and water practitioners must focus on the need to develop ways to cope with potential changes in such extremes (Neave *et al*. 2015). Reductions in water availability, increasing temperatures, and changes in rainfall patterns will all significantly affect the pattern and volume of inundation events experienced by the floodplain as well as the quality of the water it receives. This in turn will significantly change the structure and ecosystem functioning of the floodplain, and is likely to cause widespread changes to the floodplain's biodiversity in terms of the water-dependent species that are able to survive as well as their relative abundance and distribution.

Associated with the threat of climate change is the threat of an inadequate understanding by managers of the potential implications of climate change for the condition and functioning of the Murray floodplain. Without an adequate understanding of what changes may occur to inundation regimes and the ecology of the floodplain, there is a threat that planning, mitigation and amelioration activities will be insufficient to manage or reduce these impacts and widespread loss of species and ecosystem functions will occur.

10. Management Objectives

Developed under the Victorian Waterway Management Strategy framework, the North East Waterway Strategy, has a fifty-year vision for the management of the region's waterways. This is as follows:

"Our waterways are valued, healthy and well-managed; supporting environmental, social, cultural and economic values" (NECMA 2014)."

Under this vision, the high level (twenty-year) goals for the management of waterways in the North East are to:

1) Maintain or improve populations of threatened species and communities that are dependent upon waterways in the North East region.
2) Maintain or improve the connectivity within and between the different types of waterways
3) Maintain or improve water quality in priority water supply catchments
4) Maintain waterways that are formally recognised and in a near-natural or ecologically healthy state
5) Raise awareness of and protect the social and cultural heritage values of waterways (NECMA, 2014).

The management objectives for the Murray floodplain EWMP are guided by these high level objectives, and are intended to provide a level of environmental condition in the system that supports key environmental, social and economic values, as well as provide public benefits.

10.1 Vision Statement

The vision for the reach of Murray floodplain between Hume Dam and Yarrawonga Weir is to:

Improve and maintain the ecological health of the range of wetland types in the floodplain, which have water regimes that vary from permanently inundated through to occasionally inundated, to realise the full range of ecological values expected to occur in the floodplain."

This vision acknowledges that there are distinct plant and animal communities associated with different wetland types and hydrological regimes within the floodplain.

Because of river regulation, some wetlands on the floodplain now have a reduced frequency and/or duration of inundation, while others have an increased frequency and/or duration of inundation.

To support the ecological objectives for the floodplain, it is important to:

- Reduce the number/area of wetlands permanently inundated at regulated flows; and
- Increase the number/area of wetlands that experience a seasonal water regime, with inundation in winter/spring and drawdown in summer/autumn.

10.2 Objective Setting

The extent of the Murray floodplain between Hume Dam and Yarrawonga Weir functions as a single hydrological unit, with no major water sources downstream of the Kiewa River confluence, and because of this the area is considered to be a single reach for management purposes.

The ecological objectives for the floodplain are structured using a three-tiered approach. The first tier is the overarching vision, or highest level objective for the floodplain. The second tier focuses on the ecological objectives for each wetland type within the floodplain, and the third tier focuses on ecological objectives for specific water-dependent species and/or communities recognised as having high ecological value.

The process for setting environmental and flow objectives for water dependent assets is well described in the FLOWS method manual (DEPI 2013b) and is equably applicable to floodplain wetlands as it is to rivers.

The process involves first identifying the water-dependent environmental assets, setting objectives to support those assets and then identifying the components of the water regime (e.g. timing, duration, frequency and depth of inundation) that are important to achieving the environmental objective. Objectives must be measurable and include target statements describing the expected ecological response and water regime required to produce the desired response. Objectives also need to be consistent with the existing the North East Waterway Strategy.

Common types of wetland management objectives and their possible achievement through water regime manipulation are provided in Table 24.

Table 24: Common types of wetland management objectives and their possible achievement through water regime management (adapted from SKM 2005).

Management objective type	Achieve through water regime management
Maintain/enhance wetland function	• Manipulate the frequency and duration of wetting and drying.
Maintain/enhance flora (e.g. macrophyte communities, river red gum communities)	• Manipulate the frequency and duration of wetting and drying. • Control the rate of rise and fall. • Manage the timing of inundation.
Maintain/enhance fish communities	• Manipulate the frequency and duration of wetting and drying. • Control the rate of rise and fall. • Manage the timing of inundation. • Increase the duration of wet periods.
Maintain/enhance waterbird communities	• Control the duration of wet periods when breeding events occur. • Manage the timing of inundation to support breeding events. • Manage depth of inundation to support foraging. • Control the rate of rise and fall.
Maintain/enhance habitat	• Manage depth of inundation. • Control the rate of rise and fall.
Maintain/enhance carbon and nutrient processing / water quality	• Manipulate the wetting and drying regime. • Provide a flushing regime.
Control pest or nuisance species	• Allow the wetland to dry out to control pest fish. • Hold at an elevated water level for a period of time to disadvantage species that prefer a drier environment (e.g. terrestrial vegetation / weeds).
Reduce salinity	• Provide a flushing regime. • Encourage sufficient deep rooted vegetation to reduce water table levels during wet periods.

10.3 Ecological Objectives

The following section describes the second and third tier objectives for the floodplain, with the ecological objectives primarily focused on wetland types and wetland categories. Note that the ecological objectives take into account the wetland category i.e. categories 1 and 2 wetlands which are currently connected at flows <25,000 ML/day and categories 3 and 4, those connected at flows >25,000 ML/day. The intention of this division is to assist with management priorities. Figure 32 illustrates the division of ecological objectives into those for wetlands connected at flows less than 25,000 ML/day and those connected at flows greater than 25,000 ML/day.

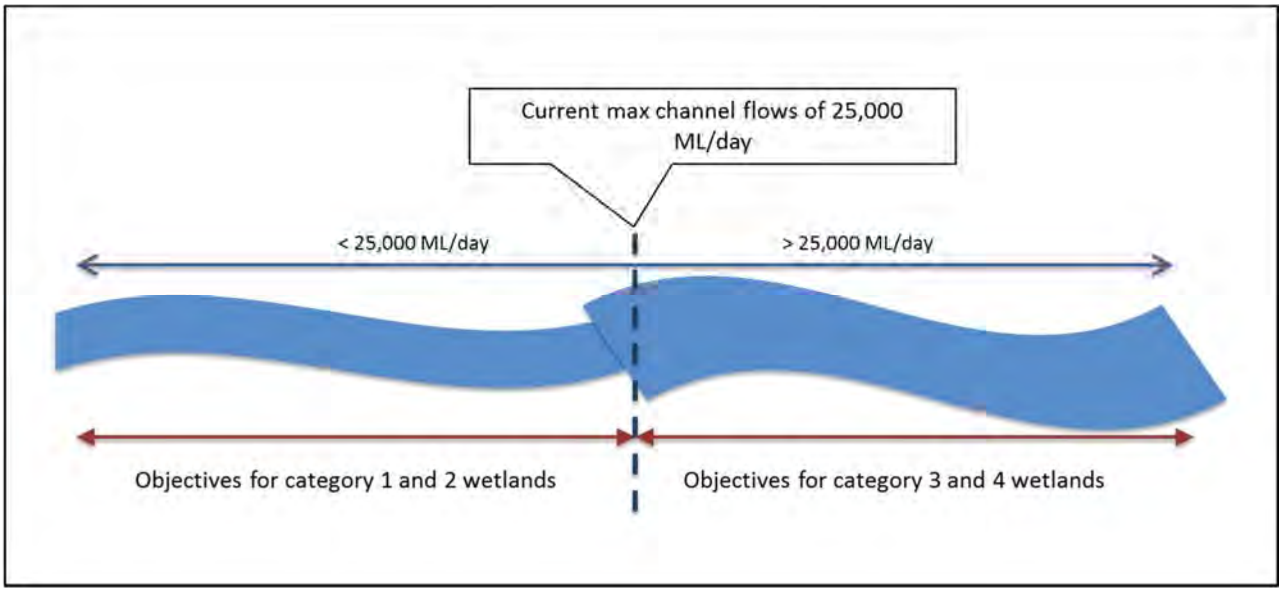

Figure 32: Organisation of ecological objectives

The overall objective for wetlands along the Victorian Murray River floodplain from Hume Dam to Yarrawonga Weir is to establish a suite of wetland types from: deep, permanently inundated cut-off meanders but with a seasonally variable regime that allows for drawdown in water level during summer yet retains a permanent pool habitat for small bodied native fish and macrophytes; through to shallow depressions and shedding floodplain surfaces that are mostly dry and occasionally wet for short durations every few years. The broad changes in water regime required to meet these objectives are to:

1) Introduce a more variable water regime for wetlands that are currently inundated at flows <25,000 ML/d.

2) Increase the frequency of inundation for wetlands connected at flows >25,000 ML/d.

Table 25: Summary of the ecological objectives for floodplain wetlands

Wetland type	Ecological objectives
Cut-off meanders	Rehabilitate cut-off meanders inundated at flows <25,000 ML/d by introducing a more variable water level regime with inundation in winter/spring and a period of draw down, preferably in summer / autumn yet retains a permanent aquatic habitat zone
	Rehabilitate cut-off meanders inundated at flows >25,000 ML/d by implementing a seasonally variable regime that inundates cut-off meanders during winter and spring and allows summer and autumn draw down and drying of wetland margins yet retains a permanent aquatic habitat zone
Floodplain depressions	Rehabilitate floodplain depressions inundated at flows <25,000 ML/d by introducing a more variable water level regime with inundation in winter/spring and a period of draw down, preferably in summer / autumn yet retains a permanent aquatic habitat zone.
	Rehabilitate floodplain depressions inundated at flows >25,000 ML/d by implementing a seasonally variable regime that inundates floodplain lakes during winter and spring and allows summer and autumn draw down and drying
Flood runners	Rehabilitate flood runners inundated at flows <25,000 ML/d by introducing a more variable flow regime that provides a period of low flow, preferably in summer / autumn
	Rehabilitate flood runners engaged at flows >25,000 ML/d by implementing a seasonally variable flow regime that engages flood runners during winter and spring
Shedding floodplain	Rehabilitate shedding floodplains by introducing a seasonally variable inundation regime with a range of inundation recurrence intervals from annual through once every 3-5 years

The ecological objectives for cut-off meanders and floodplain depressions are virtually identical, and for the purposes of this EWMP, have been merged.

Section 10.4 provides more details on the specific hydrological elements of the water regime required for values associated with each wetland type.

10.3.1 Management objectives for cut-off meanders and floodplain depressions

Cut-off meanders and floodplain depressions are the most common wetland types in the study area. Under current flow constraints, the majority of these wetlands are inundated at regulated river levels (i.e. flows up to 25,000 ML/d).

The second tier objective for cut-off meanders and floodplain depressions connected at flows up to 25,000 ML/d is to:

Rehabilitate cut-off meanders and floodplain depressions inundated at flows <25,000 ML/d by introducing a more variable water level regime that provides a period of draw down, preferably in summer / autumn"

For cut-off meanders and floodplain depressions inundated at flows >25,000 ML/d the second tier objective is to:

Rehabilitate cut-off meanders and floodplain depressions inundated at flows >25,000 ML/d by implementing a seasonally variable regime that inundates cut-off meanders during winter and spring and allows summer and autumn draw down and drying

The third tier objectives for cut-off meanders and floodplain depressions are presented in Table 26. In applying these objectives, it is acceptable for some of these wetlands to dry out completely in some years, provided other wetlands retain permanent water as refuge habitat for small bodied native fish.

Table 26: Third tier ecological objectives for cut-off meanders and floodplain depressions

Value	Environmental objective	Broad water dependency of values	Predicted ecological outcome	Consequence of not achieving the recommended regime
Submerged macrophyte community	Maintain and enhance extent and diversity	A permanently inundated zone is required to provided suitable conditions	Increased diversity and abundance of aquatic habitats through increased diversity of submerged and emergent plant species	Failure to maintain a permanently inundated zone will result in the loss of submerged macrophytes and associated habitat diversity.
Emergent macrophyte (in the wet-dry littoral zone) community	Rehabilitate extent and diversity	A variably wet and dry zone is required to provide conditions suitable for growth, vegetative recruitment and seed set (wet phase) and seed germination (dry phase)	Increased diversity of emergent macrophytes and other flood tolerant plants. Provides a mosaic of habitat types for other biota.	Failure to provide a variable water level regime (e.g. by maintaining a constant water level) will result in a narrow littoral zone with limited species diversity. Stable water levels will also reduce diversity of submerged macrophytes and promote excessive open water habitat.
Small bodied native fish community in the permanently inundated zone (e.g. Australian Smelt, Southern Pygmy Perch,	Rehabilitate habitat, breeding and feeding opportunities	A permanently inundated zone is required to provided suitable conditions for fish survival	Increased diversity and abundance of small bodied native fish (e.g. Southern pygmy perch)	Failure to maintain a permanently inundated zone will result in loss of fish fauna. Stable water levels and open water habitat will favour fish such as Redfin perch which predate on small

Value	Environmental objective	Broad water dependency of values	Predicted ecological outcome	Consequence of not achieving the recommended regime
Carp Gudgeon etc)				native fish and lead to loss of diversity and abundance.
Waterbird, frog and reptile community	Rehabilitate habitat, breeding and feeding opportunities	Variable wet and dry zone provides a mosaic of different wet and dry habitat types e.g. wet phase for frog breeding, dry phase for foraging	Increased diversity and abundance of waterbirds, frogs and reptiles	Failure to provide a variable water level regime will result in a narrow littoral zone with reduced habitat and limited species diversity
Zooplankton	Enhance zooplankton productivity	Variable wet and dry phase promotes and sustains zooplankton production and food webs for higher organisms.	Increased abundance of zooplankton for fish food	Lack of sufficient food resources for higher organisms which limits abundance
Carbon and nutrient cycling	Enhance carbon decomposition, nutrient cycling, and sedimentation and transport processes	Variable wet and dry phases are required to wet sediments and then expose, dry and re-oxygenate sediments to promote ecosystem processing	Increased carbon and nutrient processing enhances food resources for zooplankton	Lack of food resources reduces overall wetland productivity
Connectivity	Maintain and enhance seasonal patterns of connectivity between different floodplain wetland types and the river	A wet phase is required to connect wetland habitats and provide pathways for movement of biota, nutrients etc.	Increased opportunities for movement and redistribution of biota and nutrients across floodplain, which increases species diversity and abundance	Reduction in opportunities for dispersal and recolonization could reduce diversity and abundance of aquatic biota.

10.3.2 Flood runners

The majority of flood runners within the Murray floodplain are connected at river flows < 25,000 ML/d.

The second tier ecological objective for flood runners connected at flows <25,000 ML/d is to:

Rehabilitate flood runners inundated at flows <25,000 ML/d, by introducing a more variable flow regime that provides a period of low flow, preferably in summer / autumn

For flood runners engaged at river flows >25,000 ML/d the second tier objective is to:

Rehabilitate flood runners engaged at flows >25,000 ML/d, by implementing a seasonally variable flow regime that engages flood runners during winter and spring

The third tier ecological objectives for ecological values associated with flood runners are presented in Table 27.

Table 27: Objectives for values associated with flood runners

Value	Environmental objective	Broad water dependency of values	Predicted ecological outcome	Consequence of not achieving recommended regime
Small and large bodied native fish	Maintain and enhance movement opportunities for small and large bodied native fish to enable fish to use flood runners to opportunistically move between floodplain and river habitats. Rehabilitate habitat and opportunistic breeding and feeding opportunities associated with flood runners	A wet phase is required to connect wetland habitats and provide pathways for movement of adult fish, eggs, larvae and juveniles between the main river channel and various floodplain environments	Increased movement opportunities for native fish (and other aquatic animal), which will help to disperse fish and provide opportunities for recolonisation, especially after dry phases.	Lack of movement and dispersal opportunities may limit fish abundance and diversity. Poor connectivity will limit recovery of native communities after dry phases.
Connectivity	Maintain and enhance seasonal patterns of connectivity between different floodplain wetland types and the river	A wet phase is required to connect wetland habitats and provide pathways for movement of biota, nutrients etc.	Increased opportunities for movement and redistribution of biota and nutrients across floodplain, which increases species diversity and abundance.	Reduction in opportunities for dispersal and recolonisation could reduce diversity and abundance of aquatic biota, especially after dry phases
Vegetation	Maintain and enhance dispersal opportunities for vegetation seeds and propagules	A wet phase is required to connect wetland habitats and provide pathways for movement of plant seeds and propagules	Dispersal of plant seeds and propagules helps to maintain species diversity across floodplain environments	Reduction in opportunities for dispersal and recolonisation could reduce diversity and abundance of aquatic plants, especially after dry phases

10.3.3 Shedding floodplains

Shedding floodplains are inundated at flows above the current regulated flow (i.e. flows >25,000 ML/d).

The second tier ecological objective for shedding floodplains is to:

Rehabilitate shedding floodplains by introducing a seasonally variable inundation regime with a range of inundation recurrence intervals

Third tier ecological objectives for the values associated with shedding floodplains are presented in Table 28.

Table 28: Third tier ecological objectives for values associated with shedding floodplains

Value	Environmental objective	Broad water dependency of values	Predicted ecological outcome	Consequence of not achieving recommended regime
Flood tolerant vegetation communities (e.g. Riverine Grassy Woodlands and Forest EVCs,	Maintain and enhance extent and diversity	Occasional wetting is important for promoting seed set of flood tolerant vegetation, subsequent dry phase provides suitable conditions for seed germination	Enhanced recruitment of plants that require seasonal / occasional inundation (e.g. River red gums)	Loss of vigour and recruitment success for floodplain species reliant on occasional inundation

Value	Environmental objective	Broad water dependency of values	Predicted ecological outcome	Consequence of not achieving recommended regime
River red gums)				
Waterbird, frog and reptile community	Rehabilitate opportunistic habitat, breeding and feeding opportunities	Occasional wetting promotes the creation of a mosaic of vegetation communities and associated habitat types that are suitable for a range of floodplain biota	Creation of a diverse range of habitat types for amphibians, reptiles and birds associated with a mosaic of floodplain vegetation communities	Low diversity of habitat types across the floodplain that leads to low diversity and abundance of habitat dependent biota
Carbon and nutrient cycling	Enhance carbon decomposition, nutrient cycling, and sedimentation and transport processes	Occasional wetting and drying phases are required to wet sediments and then expose, dry and re-oxygenate sediments to promote ecosystem processing, especially of accumulated leaf material on the floodplain surfaces.	Increased carbon and nutrient processing enhances food resources for zooplankton. Wetting and drying reduces carbon load	Lack of food resources reduces overall wetland productivity Lack of occasional wetting can allow organic material to accumulate, this increases the risk of blackwater (low dissolved oxygen) events when floods do occur
Connectivity	Maintain and enhance seasonal patterns of connectivity between different floodplain wetland types and the river	A wet phase is required to connect wetland habitats and provide pathways for movement of biota, nutrients etc	Increased opportunities for movement and redistribution of biota and nutrients across floodplain, which increases species diversity and abundance.	Reduction in opportunities for dispersal and recolonisation could reduce diversity and abundance of aquatic biota, especially after dry phases

10.4 Hydrological Objectives

The recommended water regimes for each wetland type on the floodplain are based on the values present, the ecological objectives, and the water regime required to enable the objectives to be met.

For each wetland type the preferred water regime is expressed in terms of the water regime component, the frequency (including maximum interval between inundation events), timing, duration and depth of inundation. The regime is developed based on the requirements of specific ecological values for which objectives have been developed. For some values, the specific water regime requirements may not be well understood, so the recommended regime is based on the known requirements for those plant and animal species and/or ecological processes likely to be present or desirable for each wetland type. References are provided to indicate the evidence base used for each recommendation.

10.4.1 Cut-off meanders and floodplain depressions

The recommended water regime for cut-off meanders and floodplain depressions is similar: a seasonally variable water level with inundation in winter and spring and draw down over summer and autumn but with maintenance of a zone of permanent inundation to provide off-channel habitat for small-bodied native fish (Table 29). Occasional complete drying is acceptable (no more frequent than once every 5 years), provided not all wetlands of this type are dry at the same time and that upon re-wetting there are landscape scale opportunities for dry wetlands to be recolonised by native fish.

For shallow depressions (<1 m deep) and/or those located at higher elevations on the floodplain, longer dry phases are acceptable, including complete drying, provided deeper wetlands located closer to the river channel retain permanent water.

10.4.2 Flood runners

Flood runners are conduits for dispersing water across the floodplain. During this time they provide important pathways for dispersal of aquatic plants and animals and offer opportunistic habitat for aquatic biota during periods of inundation. The recommended water regime for flood runners is for occasional inundation during periods of high river flow that connect different wetland types across the floodplain (Table 30).

10.4.3 Shedding floodplain

Shedding floodplain surfaces experience inundation for the duration of elevated river flows and as the river level falls, water drains from the floodplain surfaces. The recommended inundation regime for shedding floodplains is variable, but generally they require inundation annually to once every few years for short periods of time (1-2 months) (Table 31). Floodplain surfaces at low elevations would generally be inundated more frequently and for longer periods than floodplain surfaces at higher elevations. The variable inundation frequency and duration is important for creating a mosaic of vegetation types that are adapted to variations in inundation frequency (Fitzsimons *et al.* 2011; James *et al.* 2011) The mosaic of vegetation types that establish in response to the variable inundation regime is important for then also creating a mosaic of habitat types for various animals.

Table 29: Recommended water regime for cut-off meanders and floodplain depressions

Wetland value	Environmental objective	Water regime requirement						Reference
		Component	Frequency	Maximum inter-flood dry period	Timing	Duration	Inundation depth	
Wet-dry littoral vegetation community (reeds and rushes)	Rehabilitate extent and diversity	Dry out wet-dry zone	Annual	6 months - 2 years	Summer/autumn	3-9 months	0-100 cm	Fitzsimons *et al.* (2011) Rogers (2011a)
		Inundate wet-dry zone			Winter/spring	3-9 months		
Submerged and emergent macrophyte community (Billabong wetland aggregate EVC)	Maintain and enhance extent and diversity	Inundate permanent wet zone	Annual / fluctuating	6-12 months	Winter/spring	12 months	100-200 cm	Fitzsimons *et al.* (2011) Rogers (2011a)
Small native fish in the permanent zone (e.g. Southern pygmy perch, Carp gudgeon)	Rehabilitate habitat, breeding and feeding opportunities	Inundate permanent wet zone	Annual	<3 month once every 5 years	Winter/spring	12 months	>50 cm	King *et al.* (2003), SKM (2003), McNeil and Closs (2007), Ralph *et al.* (2011), Baumgartner *et al.* (2014)
Waterbird, frog and reptile community	Rehabilitate habitat, breeding and feeding opportunities	Dry out wet-dry zone	Annual	6 months - 2 years	Summer/autumn	3-9 months	5-50 cm	Rogers (2011b), Wassens (2011)
		Inundate wet-dry zone			Winter/spring	3-9 months		
Carbon and nutrient cycling	Enhance decomposition and nutrient cycling and transport processes	Dry out wet-dry zone	Annual	2 years	Summer/autumn	Minimum 2 weeks	5-50 cm	Boon (1990), Baldwin and Mitchell (2000), Baldwin *et al.* (2012)
		Inundate wet-dry zone			Spring	3-9 months		
Lateral connectivity	Maintain and enhance seasonal patterns of connectivity between different floodplain wetland types and the river	Inundate wet-dry zone	Annual to near annual	3-5 years	Winter/spring	1-2 months	5-100 cm	Amoros and Bornette (2002), Lyon *et al.* (2010), Reid *et al.* (2012), Stoffels *et al.* (2013)

Table 30: Recommended water regime for flood runners

Wetland value	Environmental objective	Water regime requirement						Reference
		Component	Frequency	Maximum inter-flood dry period	Timing	Duration	Inundation depth	
Small and large bodied native fish (e.g. Southern pygmy perch, Carp Gudgeon, Golden perch, Murray cod, Trout cod)	Maintain and enhance movement opportunities Provide opportunistic breeding and feeding	Inundation	Annual to near annual	3 years for short lived species 5 years for long lived species	Winter/spring	1-2 months	50-200 cm	King *et al*.. (2003), SKM (2003), McNeil and Closs (2007), Lyon *et al*.. (2010), Ralph *et al*.. (2011), (2013), Baumgartner *et al*.. (2014)
Carbon and nutrient cycling	Enhance carbon decomposition, nutrient cycling, and sedimentation and transport processes	Drying	Annual to near annual	3-5 years	Summer/autumn	Minimum 2 weeks	5-50 cm	Boon (1990), Baldwin and Mitchell (2000), Baldwin *et al*.. (2012)
		Inundation			Winter/spring	3-9 months		
Connectivity and transport of vegetation seeds and propagules	Maintain and hence dispersal opportunities for vegetation seeds and propagules	Inundation	Annual to near annual	3-5 years	Winter/spring	1-2 months	50-100 cm	Amoros and Bornette (2002), Rogers (2011a), Reid *et al*.. (2012)

Table 31: Recommended water regime for shedding floodplain

Wetland value	Environmental objective	Water regime requirement						Reference
		Component	Frequency	Maximum inter-flood dry period	Timing	Duration	Inundation depth	
Flood tolerant vegetation communities (e.g. Riverine Grassy Woodlands and Forest EVCs, River red gums)	Maintain and enhance extent and diversity	Dry phase	Annual	5 years	Summer/autumn	>8 months	5-50 cm	Fitzsimons *et al*.. (2011) Rogers (2011a)
		Wet phase	1-4 in every 5 years		Winter/spring	1-2 months		
Waterbird, frog and reptile community	Rehabilitate opportunistic habitat, breeding and feeding opportunities	Dry phase	Annual	5 years	Summer/autumn	>8 months	5-50 cm	Rogers (2011b), Wassens (2011)
		Wet phase	1-4 in every 5 years		Winter/spring	1-2 months		

Wetland value	Environmental objective	Water regime requirement						Reference
		Component	Frequency	Maximum inter-flood dry period	Timing	Duration	Inundation depth	
Carbon and nutrient cycling	Enhance carbon decomposition, nutrient cycling, and sedimentation and transport processes	Dry phase	1-4 in every 5 years	5 years	Summer/autumn	Minimum 2 weeks	5-50 cm	Boon (1990), Baldwin and Mitchell (2000), Baldwin *et al.* (2012)
		Wet phase			Winter/Spring	1-2 months		
Connectivity and transport of vegetation seeds and propagules	Maintain and hence dispersal opportunities for vegetation seeds and propagules	Wet phase	1-4 in every 5 years	5 years	Winter/spring	1-2 months	50-100 cm	Amoros and Bornette (2002), Rogers (2011a), Reid *et al.* (2012)

10.5 Summary of Hydrological Objectives

Figure 33 summarises the recommended inundation regime for ecological values on the floodplain, summarising the frequency and timing of wetting and drying for the different wetland types. The symbol of a crossed out water drop indicates drying or drawdown, while the symbol of a water drop indicates wetting. The dot points under each wetland type indicate the frequency of wetting or drying, the timing of wetting or drying, and the duration of the event.

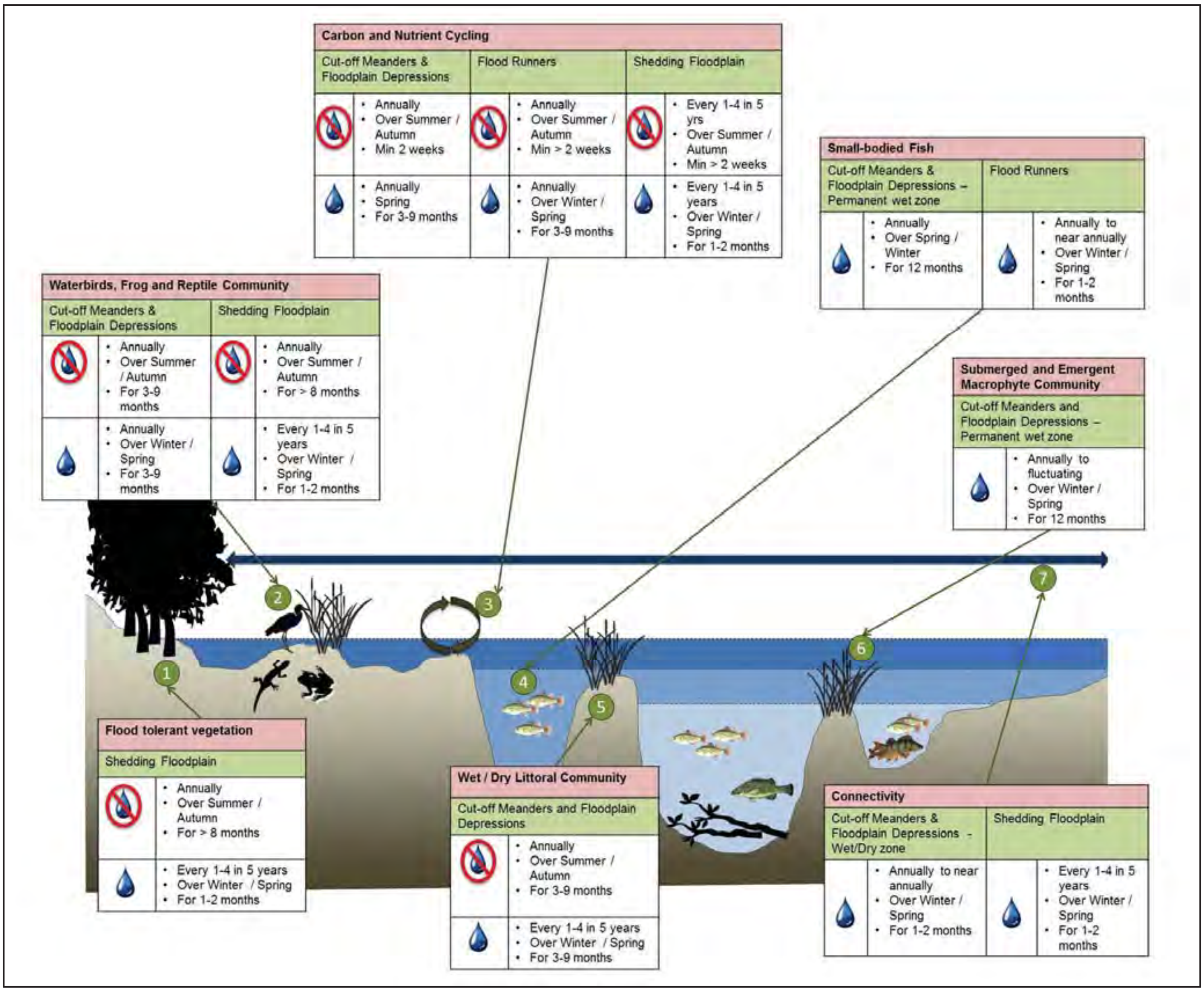

Figure 33: The temporal variation in inundation regimes required to meet floodplain ecological objectives for each of the different wetland types

10.6 Prioritisation of Objectives

Due to the wetland types present and their relatively similar water regime requirements, the water regime recommendations can be simplified according to how they are related to river flow, and can then be prioritised according to the feasibility of meeting particular river flow levels.

All wetland types generally require inundation during winter and spring and drawdown over summer and autumn. River flows do not need to be elevated for the duration of an inundation event as the wetlands will hold water for a period of time once the river level recedes (Figure 34). The period of time that wetlands retain water depends on their seepage and evapotranspiration rates – which determines the rate of water level decline and wetland depth – which then determines whether wetlands will fully dry before the next inundation event. Generally, deeper wetlands will retain water for longer compared to shallow wetlands.

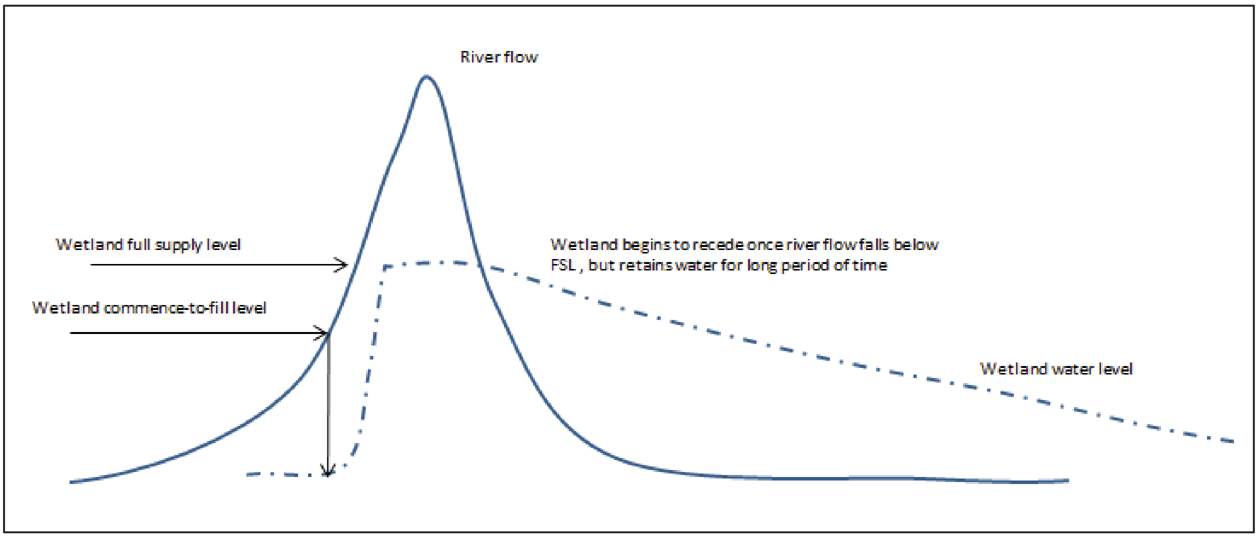

Figure 34: Conceptual model of wetland filling and drying regime associated with a river high flow event

For wetlands in the EWMP area, the proportion of wetlands inundated increases with increased flow levels because more flood runners become engaged and more floodplain areas become inundated. Ideally, deep cut-off meanders and floodplain depressions require an annual inundation event in order to retain permanent aquatic habitat (i.e. annual inundation means that the wetland does not fully dry before the next inundation event). Shallower wetlands, and those located higher on the floodplain (including shedding floodplain surfaces), do not require inundation every year and can go completely dry between inundation events.

There are thus two main options to achieve the overall objectives for wetland rehabilitation:

1. Alter the seasonality of inundation of wetlands that commence-to-fill at flow <25,000 ML/d

2. Increase the frequency of inundation of wetlands that commence-to-fill at flows >25,000 ML/d.

For wetlands that commence-to-fill at <25,000 ML/d it may be possible to introduce a winter/spring inundation by increasing within-channel flows during the August to October period. However, introducing a summer drawdown is likely to require site-specific works and measures to isolate targeted wetlands from the river channel during high irrigation flows.

Future work: NECMA will liaise with MDBA about opportunities to undertake a feasibility assessment of wetlands along the floodplain that commence to fill at flows less than 25,000 ML/d for ecological values present, and the nature and type of works and measures that may be required to enable summer drawdown and winter/spring filling.

For wetlands that commence-to-fill at >25,000 ML/d, water level manipulation could be achieved via increased flow releases from Hume Weir during the winter and spring season in accordance with the water regime recommendations in Section 10.4.

Future work: The MDBA Constraints Management Strategy Project will have reached a decision point by June of 2016 regarding the feasibility of building on in-stream flows, topping up using water from flow releases from Hume Dam up to a maximum of 40,000 ML/d. North East CMA will liaise with MDBA to determine if any water will be available to address the floodplain ecological objectives between Hume Dam and Yarrawonga Weir.

It should be noted that in order to achieve rehabilitation objectives for wetlands that commence-to-fill at flows >25,000 ML/d, a long-term commitment is needed to establish and maintain seasonal inundation in the winter/spring. This is important because once the desired fish and macrophyte communities establish, they will be reliant on these managed flow releases to maintain their condition.

On this basis, an overall floodplain water regime can be developed related to the recurrence interval of various overbank river flows. For example, in order to annually inundate cut-off meanders that are not currently inundated, it would necessary to provide flows over 25,000 ML/d at least once a year in the winter/spring period. As the flow level increases, the frequency of occurrence can be less.

Based on the recommended water regimes for the wetland types identified in this study area, the extent of wetland inundation achieved with flows up to 40,000 ML/d and the frequency analysis of flows up to 40,000 ML/d, a simplified water regime recommendation for flows >25,000 ML/d is provided in Table 32.

It is recommended that a flow in the Murray River up to 30,000 ML/d is delivered once every year in winter/spring to maintain a suite of permanent cut-off meander / floodplain depressions but with a variable water level that is high in winter/spring (during the inundation event) and that then draws down over the summer/autumn period yet retains a permanent pool as refuge for fish and other aquatic flora and fauna that require access to permanently inundated wetland habitat. It is further recommended that flows in the range of 30,000 to 40,000 ML/d are delivered on average once every one to four times in every five year period with a maximum dry phase of 3-5 years. This regime would provide a range of flow frequencies that would create a variable water regime at different floodplain elevations sufficient to create a mosaic of wetland and floodplain vegetation types.

Table 32: Simplified water regime recommendation for flows >25,000 ML/d

Murray River flow	Frequency	Timing	Duration of river flow event	Maximum dry phase	Target wetlands
30,000 ML/d	Annual	August to October	Sufficient to fill flood runners and wetlands (a few days to several weeks). Water will then pond in depressions and remain in wetlands and on the floodplain even after the river level falls.	12 months once every 5 years (to retain permanent habitat for small bodied native fish)	Cut-off meanders / floodplain depressions with a variable water level regime that is high in winter/spring and draws down over summer/autumn yet retains a permanently inundated zone for native fish and other aquatic flora and fauna.
35,000 ML/d	Twice in every 3 to 4 years	August to October		3 years (to maintain seed bank for flood dependant plant species)	Cut-off meanders / floodplain depressions and shedding floodplain with a variable water level that is high in most winter/spring periods and dries out over summer/autumn.
40,000 ML/d	One to two times every five years	August to October		5 years ((to maintain seed bank for flood dependant plant species)	

11. Managing the Risks to Objectives

11.1 Risk Assessment Methodology

When assessing risk to the water-dependent ecological values of the Murray floodplain, NECMA has sought to understand the following:

- The level of risk posed by threats to the water-dependent ecological values of the floodplain, because this may impact on achieving the ecological objectives of the EWMP
- The threats to externalities due to the release and delivery of environmental water to the floodplain.

11.1.1 Risk Matrix

When assessing the risks to water-dependent ecological values for the Murray floodplain, the relationship between the likelihood (probability of occurrence) and the consequences of a risk occurring provides the basis for evaluating the level of risk (Table 33).

Table 33: Risk matrix

		Consequence		
		Major	**Moderate**	**Minor**
Likelihood	**Certain**	High	High	Moderate
	Possible	High	Moderate	Low
	Unlikely	Moderate	Low	Low

The results from the risk assessment are presented in Table 34. Management actions to address these risks are also included, and residual risk is assessed, based on the assumption that risk mitigation actions are successful.

Table 34: Murray floodplain risk assessment

Risk Category	Impact of the Risk Occurring	Water-Dependent Ecological Values Impacted	Likelihood (Unlikely / Possible / Certain)	Consequence (Minor / Moderate / Major)	R	Management Actions	RR
Threats to achieving ecological objectives							
Further consumptive extraction of surface water, causing an alteration of natural flow regimes	Impacts include: • Reduction of hydrologically connected floodplain habitat due to change in area, frequency and duration of flooding of floodplains and terminal wetlands • Loss of breeding and migration cues for native fauna • Increased habitat for invasive species • Loss or disruption of ecological functions • Increased bank erosion and changes to channel geomorphology.	All	Possible	Major	H	A cap has been placed on surface water extractions in the Murray-Darling Basin, preventing extraction over and above these limits. Improved operational management of the River Murray system includes relaxing the 'Six-Inch Rule' at Hume Dam, which currently restricts the rate of reduction in releases from the Dam to a maximum of six inches (150 mm) per day at Doctors Point. This is currently under review by MDBA. Residual risk is based on the assumption that likelihood is reduced to 'Unlikely' following intervention actions and improved operational management of the system through work being undertaken by MDBA.	M
Consumptive releases from Hume Dam continuing the alteration of the natural flow regime	The targets for seasonality, variability and drying regimes are not able to be achieved.	All	Certain	Major	H	Raise awareness of the environmental watering needs of the floodplain, with the view to implement a more ecologically sensitive consumptive water release arrangement. Residual risk is based on the assumption that likelihood is reduced to 'Possible'	M

Risk Category	Impact of the Risk Occurring	Water-Dependent Ecological Values Impacted	Likelihood (Unlikely / Possible / Certain)	Consequence (Minor / Moderate / Major)	R	Management Actions	RR
						following intervention actions and improved operational management of the system through work being undertaken by MDBA	
The 25,000 ML/d flow constraint on releases from Hume Dam remains.	The ecological objectives for wetlands connected at flows greater than 25,000 ML/d will not be able to be met.	All	Possible	Major	H	Information from the EWMP will help to provide a valuable information for the ecological, social and economic benefits around any consideration of relaxing the 25,000 ML/d constraint. Residual risk is based on the assumption that likelihood is reduced to 'Unlikely' following the extensive work being undertaken by MDBA to develop the Constraints Management Strategy.	M
Constraints downstream of Yarrawonga Weir are not addressed	Not addressing the Barmah Choke flow constraints downstream of Yarrawonga Weir will minimise the volumes that can be released from Hume Dam	All	Possible	Major	H	Information from the EWMP will help to provide information to assist in the the Barmah Choke constraints management strategy. Residual risk is based on the assumption that likelihood is reduced to 'Unlikely' following the extensive work being undertaken by MDBA to develop the Constraints Management Strategy.	M
Increased groundwater extractions	Groundwater extraction can cause shifts in the groundwater / fresh water interactions near and along the floodplain.	All	Possible	Moderate	M	A cap has been placed on the volume of groundwater extractions allowed in the catchment through licenced groundwater entitlements managed by GMW, which limit	L

Risk Category	Impact of the Risk Occurring	Water-Dependent Ecological Values Impacted	Likelihood (Unlikely / Possible / Certain)	Consequence (Minor / Moderate / Major)	R	Management Actions	RR
	Groundwater extraction may also reduce habitat availability for groundwater dependent ecosystems along the floodplain.					the amount of groundwater that can be taken each year. These extraction limits are reviewed regularly to ensure their continuing effectiveness and sustainability. Improve knowledge of groundwater dependent ecosystems along the floodplain corridor. Residual risk is calculated based on assumption that the likelihood is reduced to 'Unlikely' following intervention actions.	
Construction of additional water regulation structures along the River Murray (e.g. levee banks, dams, weirs, gauging stations)	The construction of water regulation infrastructure can result in: • A loss of longitudinal and lateral connectivity along the floodplain, blocking passage for fish and movement of plant propagules. Impacts often increase cumulatively downstream. Connectivity between the river and the floodplain allows the movement of aquatic biota • Disruptions to sediment and nutrient transport processes • Loss of hydrodynamic diversity, particularly important for fish and macroinvertebrates for the provision of habitat • Reduced water quality, for example through releases of cold water from storage, or hypoxic water	All	Possible	Major	H	Planning controls flood and land subject to inundation overlays along the floodplain corridor, enable to the North East CMA to provide floodplain management advice to local government to prevent or minimise the impact of any new works in these areas. The North East CMA also regulates works on waterways though a Waterways Projection By-law. The risks of cold water and hypoxic water releases can be reduced by altering structures such that offtakes are located in the upper and warmer layers of storage water. Residual risk calculations assume that the	M

Risk Category	Impact of the Risk Occurring	Water-Dependent Ecological Values Impacted	Likelihood (Unlikely / Possible / Certain)	Consequence (Minor / Moderate / Major)	R	Management Actions	RR
	• Increased risk to fauna being preyed on if they are required to travel overland to move between wetlands. • Alter the geomorphology of waterways downstream, including deepening of channels and bed and bank erosion					consequences are reduced to 'Moderate' following intervention actions.	
Infrastructure funding to improve variable flow supply to floodplain wetlands	Funding is not provided for North East CMA and other agencies to investigate and implement appropriate infrastructure requirements to allow for drawdown and a more variable inundation regime for low lying wetlands.	Wetland category 1 and 2 ecological objectives	Possible	Major	H	North East CMA will look for opportunities to liaise with MDBA, DELWP and VEWH to consider undertaking a feasibility assessment for assessing and installing appropriate flow regulating infrastructure along the floodplain. A feasibility assessment could provide a suitable business case for funding any installations as required. Residual risk calculations assume that the likelihood is reduced to 'Unlikely' following intervention actions.	M
Reductions in water availability to the floodplain as a result of drought	Drought will reduce water availability within the Murray River catchment, alter flow regimes and reduce inundation of the floodplain through reductions in the occurrence and volume of seasonal rainfall and tributary inflows. Impacts on the floodplain include loss of habitat, loss of flow regime cues for breeding and migration, and a consequent reductions in biodiversity and ecosystem services	All	Certain	Major	H	Drought resilience planning and targeted flows releases to priority drought refuge wetlands and/or environmental values along the floodplain may help to somewhat ameliorate the impacts of drought, but the residual risk still remains high due to inadequate volumes of environmental water.	H

Risk Category	Impact of the Risk Occurring	Water-Dependent Ecological Values Impacted	Likelihood (Unlikely / Possible / Certain)	Consequence (Minor / Moderate / Major)	R	Management Actions	RR
Land use change: Urban development along the floodplain	Urban development causes loss of habitat and reductions in habitat quality. Urban development also has impacts such as: • Removal of riparian and catchment vegetation • Recreational or commercial activities near urban centres disturbing bird behaviour, causing them to stop feeding or breeding • Sewage effluent and septic tank discharges affecting water quality • Industrial discharges decreasing water quality and increasing toxicant loads within the river and floodplain wetlands • Increasing capture of rainfall and stormwater runoff, reducing inflows to the floodplain • Increasing salinity.	All	Certain	High	H	Through local planning schemes , the North East CMA has opportunity to provide advice to local government on development in relation to flood protection and waterway health Local government is a key player in the success of managing the impacts of development because of its role and responsibilities in land use planning, development, rates, and a variety of services including road infrastructure development and maintenance, water supply and the disposal of wastewater. NECMA will continue to work in collaboration with DELWP and relevant local councils to understand and reduce the risks of increasing development or development impacts on the Murray floodplain.	M
Pest plants and animals: • Carp, redfin perch and Gambusia • Foxes, pigs and cats • Willows and other pest	Pest fish limit the availability of habitat for other species such as macroinvertebrates and small-bodied fish, decrease habitat quality, introduce diseases, and some species also predate on small native fish. This reduces the diversity and abundance of native species. Water dependent fauna are vulnerable to predation by foxes and cats.	Fauna Vegetation	Certain	Major	H	Improving habitat variability and refuge for small-bodied fish such as Southern pygmy perch will reduce the impacts of pest fish on this species. For example, Redfin is less tolerant of low flow levels in wetlands, and a range of control measures are being trialled in the Murray-Darling Basin including physical removal techniques such as nets and traps, as well as mid-water trawling and	M

Risk Category	Impact of the Risk Occurring	Water-Dependent Ecological Values Impacted	Likelihood (Unlikely / Possible / Certain)	Consequence (Minor / Moderate / Major)	R	Management Actions	RR
plant species	Willows and other pest plants clog waterways, out compete for habitat space with native plants, and decrease water quality, decreasing the abundance and diversity of native vegetation within the floodplain.					electrofishing at night. Fox and cat control programs may assist in reducing the likelihood of their predation, as may improving riparian vegetation cover and longitudinal connectivity along the floodplain. Pest plant removal programs will assist to reduce its impacts associated with colonisation on the floodplain. Residual risk is calculated based on the assumption that management interventions have reduced the likelihood to 'Possible'.	
Nutrient inputs to floodplain wetlands	Nutrient input is very likely to be affected by catchment land-use practices, with extensive land clearing (especially riparian areas) and agricultural practices increasing the run-off of nutrients into floodplain wetlands. The main impact of increased nutrient loads in wetlands is increased primary productivity, potentially resulting in blooms of algae (including toxic species). This issue will decrease habitat availability and quality for native plants and animals within the wetlands.	Fish Vegetation	Certain	Moderate	H	Catchment and river health programs delivered by NSW Department of Primary Industries , North East CMA, and other agencies will help to reduce the likelihood of this risk occurring. Residual risk is based on the assumption that likelihood is reduced following management interventions.	M

Risk Category	Impact of the Risk Occurring	Water-Dependent Ecological Values Impacted	Likelihood (Unlikely / Possible / Certain)	Consequence (Minor / Moderate / Major)	R	Management Actions	RR
Stock access and grazing pressure	Grazing by livestock in the riparian zones of the floodplain prevents establishment of native vegetation. Grazing also decreases water quality, by increasing water turbidity due to bank erosion and stock disturbance, and increasing nutrient concentrations from grazing runoff. Soil compaction and the destruction of seedlings also prevents the recolonisation of floodplain areas by native vegetation such as River Red Gum. These impacts reduce habitat availability and quality for native plants and animals.	Vegetation Fish Macroinvertebrates	Certain	Moderate	H	Catchment and river health programs delivered by NSW Department of Primary Industries, North East CMA, and other agencies will help to reduce the likelihood of this risk occurring. Encourage more landowners to remove cattle from the floodplain riparian zones. Residual risk is based on the assumption that management interventions reduce the likelihood of this risk occurring.	M
Climate Change	Climate change will reduce water availability within the Murray River catchment, and alter flow regimes through changes to the temporal and volumetric patterns of seasonal rainfall. Impacts on the floodplain include loss of habitat, loss of flow regime cues for breeding and migration, and a consequent reduction in biodiversity and ecosystem services.	All	Certain	Major	H	Management actions will focus on understanding the nature of the risks that climate change poses to the biodiversity and ecosystem services of the floodplain. Programs to improve the resilience of water-dependent environmental values will be implemented. Planning for environmental flow releases will take in to consideration the relative vulnerabilities and sensitivities of high value species to climate change stressors. Residual risk is based on the assumption that the consequences of climate change will be difficult to mitigate given there is currently no environmental entitlement for the floodplain.	H

Risk Category	Impact of the Risk Occurring	Water-Dependent Ecological Values Impacted	Likelihood (Unlikely / Possible / Certain)	Consequence (Minor / Moderate / Major)	R	Management Actions	RR
Threats related to the delivery of environmental water							
Flow releases greater than 25,000 ML/d. Flooding of private land caused by flow releases greater than 25,000 ML/d.	Environmental water releases cause flooding of private land, public infrastructure and/or Crown land along the floodplain, with subsequent impacts on the economic and social values of the floodplain.	Economic values / Social values	Certain	Major	H	Through its Constraints Management Strategy, MDBA is currently working with local landowners and business owners to understand and mitigate the risks of potentially releasing flows from Hume Dam at volumes greater than 25,000 ML/day. Residual risk is based on the assumption that the consequences of overbank flows for landowners and businesses will be able to be suitably minimised and/or appropriate compensatory actions implemented to minimise or remove the impacts of flooding.	M
Cultural values are not identified and documented	Opportunities to identify, document and protect indigenous cultural values may be missed, reducing the ability to combine ecological and cultural outcomes for high value sites along the floodplain	Heritage values	Possible	Moderate to High	M	Work with local indigenous representatives and other agencies such as MDBA to document the location and sensitivity of heritage values along the floodplain	L
Environmental releases cause personal injury to floodplain users	Personal injury may have serious consequences for those impacted.	N/A	Unlikely	Major	M	Detailed risk assessment will be undertaken in collaboration with MDBA prior to release events occurring. This risk assessment will consider catchment conditions, the seven day weather forecast and the level of communication required. Flow releases targeting the floodplain must	L

Risk Category	Impact of the Risk Occurring	Water-Dependent Ecological Values Impacted	Likelihood (Unlikely / Possible / Certain)	Consequence (Minor / Moderate / Major)	R	Management Actions	RR
						be adequately communicated. Delivered flows are low volume and velocity	
Release volume and/or timing is insufficient in meeting required flows for the floodplain	Environmental watering requirements are not able to be complied with.	All	Unlikely	Moderate	L	Releases from Hume Dam have generally been higher than required to ensure compliance. Close communication with storage operators and monitoring of losses will increase the required body of knowledge for the floodplain's management. A systematic review of flow releases will be conducted on a regular basis to ensure operational issues such as timing are appropriately managed.	L
The current recommendations regarding environmental watering require updating	The evidence base behind the environmental flow recommendations is inadequate to ensure ecological and management objectives are met for the floodplain. Flow releases as a consequence may not be able to meet these objectives.	All	Possible	Moderate	M	Environmental watering recommendations are based on the best possible science and a monitoring program will be put in place to identify if ecological objectives are not being achieved. A systematic review of environmental watering recommendations will be conducted on a regular basis.	L
Storage Operator maintenance works affects the ability to deliver water.	Flow releases are not able to be delivered and ecological objectives may not be met as a consequence.	All	Unlikely	Moderate	L	This risk is considered low because there is sufficient institutional experience in delivering passing flows when maintenance does occur	L

Risk Category	Impact of the Risk Occurring	Water-Dependent Ecological Values Impacted	Likelihood (Unlikely / Possible / Certain)	Consequence (Minor / Moderate / Major)	R	Management Actions	RR
Competing storage operator priorities do not allow for the delivery of some events	Flow releases are not able to be delivered and ecological objectives may not be met as a consequence.	All	Unlikely	Moderate	L	This risk is considered low because the outlet capacity at Hume Dam is sufficient to incorporate the delivery of all recommended flow volumes.	L
Releases cause water quality issues (e.g. blackwater, low DO)	Flow releases of poor water quality will detract from the ability of environmental watering program to meet ecological objectives due to secondary effects on ecosystem health.	All	Possible	Moderate	M	Water quality monitoring is in place to measure effects of releases. Monitoring, evaluation and reviewing (MER) processes will be designed and implemented to track the positive and negative impacts and outcomes of environmental flow releases.	L
Flow releases improve conditions for non-native species (e.g. Carp and Redfin)	Pest fish numbers and distribution increase, producing a deleterious effect on native fish health, abundance and distribution across the floodplain.	Fish	Possible	Moderate	M	No effective mitigation actions currently possible. A watching brief on advances in pest fish management should be undertaken to ensure the best available practices to manage this risk.	M
Public misperceptions of the objectives and benefits of floodplain environmental watering.	Public misperceptions regarding the nature and outcomes of the environmental watering program may reduce political and social support for the program.	All	Certain	Moderate	H	A communications and engagement strategy must be developed with the specific objective of improving understanding and acceptance of an environmental watering program for the floodplain. Existing groups such as the Murray River Action Group, and the Advisory Group on Hume to Yarrawonga Waterway Management will be important stakeholders for this engagement, as will the MDBA. Engagement should consider creating reach-	M

Risk Category	Impact of the Risk Occurring	Water-Dependent Ecological Values Impacted	Likelihood (Unlikely / Possible / Certain)	Consequence (Minor / Moderate / Major)	R	Management Actions	RR
						specific community advisory groups where pre-existing advisory groups may not be able to provide adequate representative coverage of issues in these reaches. Discussions with agencies, landowners, interest groups and public enquiries indicates a reasonably widespread level of community interest in the program.	

12. Environmental Water Delivery Infrastructure

12.1 Constraints

12.1.1 MDBA Constraints Management Strategy

12.1.1.1 Hume to Yarrawonga Constraints

A great deal of work has been undertaken by MDBA in recent years to understand the constraints to delivering appropriate environmental flow regimes for the reach of the River Murray between Hume Dam and Yarrawonga Weir (incorporating both the NSW and Victorian sides of the channel), which corresponds with the Victorian extent of the floodplain for the EWMP. This section provides a synopsis of this work.

The objective of the Constraints Management Strategy is to explore the potential additional environmental benefits that would result if major existing river operating constraints to the delivery of water were relaxed, as well as investigating how this can be done in ways that avoid or address impacts on third parties and optimise the environmental, social and economic benefits (MDBA 2013a).

Seven key focus areas in the Basin are identified where the relaxation of constraints needs detailed consideration, one of which includes the reach of river between Hume Dam and Yarrawonga Weir. The focus area includes both the River Murray channel and associated anabranches in this reach. Under the current situation, the regulated operation of Hume Dam provides flows within a range that is largely governed by irrigation requirements and minimum flow provisions. Irrigation requirements generally follow consumptive demand patterns and do not vary significantly during the summer irrigation season (MDBA 2014b). The river is operated to maximise water availability for consumptive use, to limit evaporation losses on the floodplain, and to limit inundation of low-lying land near the river channel used for business purposes such as cattle grazing. Because of this, overbank flows only occur as a consequence of managing Hume Dam when it is close to full or spilling over, rather than to meet environmental objectives (MDBA 2014b).

The major limiting constraint on the operation of the system between Hume to Yarrawonga is the requirement that flows not exceed 25,000 ML/d at Doctors Point. Under the Constraints Management Strategy, flows of 40,000 ML/day at Doctors Point are being considered for this reach of the River Murray. Table 35 shows a comparison of the modelled existing and relaxed constraints volumes for Hume to Yarrawonga and immediately downstream of Yarrawonga under the Constraints Management Strategy.

Table 35: Comparison of the modelled existing and relaxed constraints flows for the Murray region

Location	Existing constraint in model (ML/d)	Relaxed constraint in model (ML/d)
Murray region Hume to Yarrawonga	25,000	40,000 (only during winter/spring)
Downstream of Yarrawonga	10,600 during summer/autumn	10,600 during summer/autumn and 40,000 at other times

The proposed flow release volumes being assessed under the Constraints Management Strategy have been modelled for the technical investigations contributing to the development of this EWMP, and are discussed further in the Hydrology and Hydrological Objectives sections of this Plan.

As discussed previously in the EWMP, flows of 40,000 ML/day already happen naturally without regulated contributions every few years. The Constraints Management Strategy is proposing to deliver flows of 40,000 ML/day when it is seasonally appropriate (between June and November) and when it can be coordinated with other flows to get the greatest benefit from the water available, both for the river and the floodplain. Extensive modelling of flow footprints and community consultation has been undertaken by MDBA to explore the full extent of possible impacts of relaxing the 25,000 ML/d constraint (MDBA 2014b).

Creating a flow of 40,000 ML/day in the River Murray between Hume Dam and Yarrawonga Weir would typically be achieved by coinciding releases from Hume Dam with inflows from the Kiewa River. For example, if there was 15,000 ML/day coming in from the Kiewa River, then the release from Hume Dam may only be 25,000 ML/day. Topping-up unregulated inflows with environmental releases to generate a higher peak flow and/or longer event duration has proved successful and is a common tool for water managers in other areas of the State (MDBA 2014b).

Although flows of 40,000 ML/day are still considered too high by some landholders along the floodplain, landholders consider it is the most pragmatic level that can be implemented. Consultation by MDBA has shown that flows larger than 40,000 ML/day are likely to cause increasing and unacceptable impacts for a considerable number of landholders (MDBA 2014b).

A range of mitigation measures are being assessed for their feasibility. These include:

- Arranging for easements to allow flows on private land
- Infrastructure works — for example, upgrades to roads and bridges, including bridges and crossings on private properties.

The Constraints Management Strategy will identify the preferred options at the end of the feasibility phase, before moving into the planning and implementation phase between 2016 and 2024.

12.1.1.2 Barmah Choke

The Barmah Choke is a relatively narrow section of the River Murray through the Barmah-Millewa Forest downstream of Yarrawonga Weir. While Yarrawonga Weir itself does not represent a physical impediment to the delivery of environmental flows, the practices and policies governing the operation of the weir impose flow constraints on releases from Hume Dam as well as releases from the weir. These constraints are closely tied to the channel characteristics defining the Barmah Choke. The channel capacity immediately downstream of the weir is 62,000 ML/d, but this decreases significantly when approaching the Barmah Choke. Relative to other nearby sections of the River Murray system, the operating capacity (near bankfull) of the Choke is small - approximately 8,000 ML/day near the township of Barmah (at the downstream end of the Barmah-Millewa Forest). This limited capacity contributes to several operational and policy challenges related to releasing water from upstream at Hume Dam, storing water in Lake Mulwala, and releasing water from Yarrawonga Weir to areas downstream of the Choke (SKM 2011).

During the summer regulated periods, releases from Yarrawonga Weir are limited to 10,600 ML/d to minimise the incidence and magnitude of unseasonal flooding of Barmah–Millewa Forest, which can have a negative impact on the conditions required for the forest to remain ecologically healthy.

An investigation is currently being managed by MDBA to develop an understanding of current and potential future water supply and environmental risks associated with the Barmah Choke and other mid-river operational issues. The investigation is considering a range of options, with the aim of identifying a preferred option, or package of options, for reducing the impact of the constraint, while recognising that the Barmah Choke performs an important role in flooding the Barmah-Millewa Forest (SKM 2011).

One such option currently being trialled is the relaxation of the ‘Six-Inch Rule’. This rule limits the rate of fall of river level at Doctors Point downstream of Hume Dam to a maximum of 6-inches (150 mm) per day. This rule was adopted to provide adequate warning of river level changes and to minimise bank slumping (SKM 2011), and is the most conservative “rate of fall” rule being applied in the Murray-Darling Basin (Earth Tech (2007), in SKM (2011)).

Another option being investigated is lowering the minimum (and normal) operating level of Lake Mulwala over the unseasonal flooding period. This option would provide air space in the lake which can then be used to capture and reregulate rainfall rejections from Hume Dam and Yarrawonga Weir, reducing unseasonal flooding of the Barmah-Millewa Forest. The potential impact on recreational use of Lake Mulwala is likely to raise community concern, and extensive economic and social impact studies would need to be undertaken prior to any decisions being made on this option (SKM 2011). The environmental impacts to the Murray floodplain immediately surrounding and upstream of Lake Mulwala will also need to be considered.

Future work: Key stakeholders will continue to liaise with the MDBA to understand options for improving management of the Barmah Choke and any implications for environmental flow releases from Hume Dam and/or changes to the operational management of Lake Mulwala.

12.2 Infrastructure

There are a number of wetlands within the floodplain that currently have regulating structures, allowing for a controlled supply and/or drawdown of water to these sites. There are also a number of wetlands within the floodplain where it may be feasible to construct regulating structures to improve the delivery of environmental flows to them at seasonally appropriate times. Through its Riparian Program, MDBA has been mapping and recording the locations of current regulating structures, recording commence to fill data, as well as identifying potential future sites for additional works and measures, and has a significant database that documents this information (Damian Green and Sarah Commens MDBA, *Pers. Comm. 2015.).*

The nature of the work and measures implemented through this program will be largely driven by the availability of environmental water (i.e. if flows greater than 25,000 ML/d will be available) and budgetary considerations. It will do so by seeking to activate current infrastructure such as regulators and/or by constructing new works and measures at appropriate locations, to create more seasonally appropriate inundation regimes for these wetlands.

If flows between 25,000 ML/d and 40,000 ML/d are made available to the floodplain once the Constraints Management Strategy implementation phase has begun (sometime between June 2016 and 2024), North East CMA will look for opportunities to collaborate with MDBA regarding works and measures to allow for seasonally appropriate inundation regimes for those wetlands on the floodplain requiring these greater level of flows to be inundated.

Future work: NECMA will collaborate where appropriate with the MDBA Riparian Program team regarding works and measures feasibility assessments for:

- Wetlands currently connected to the River Murray at flows less than 25,000 ML/d (immediate program following implementation of the EWMP)
- Wetlands requiring flows between 25,000 ML/d and 40,000 ML/d (the longer term program if the MDBA Constraints Management Strategy is able to implement these flows).

12.3 Complementary Actions

The North East Waterway Strategy details a wide variety of complementary management actions which will help to improve environmental outcomes for the Murray floodplain. The Murray Plains management unit contains the most relevant complementary actions for the floodplain, and the strategic issues for management in this unit include:

- Management of the Murray River Floodplain for water conveyance, primary production and environmental values (e.g. floodplain wetlands)
- Urban and industrial growth around rivers and the associated community connection with waterways
- Building resistance into the Murray River Floodplain though a landscape scale connections program (e.g. vegetation and hydrology) (NECMA 2014).

Strategic actions under the Waterway Strategy include working with communities to maintain and improve waterway values along the floodplain, as well as protecting the River Murray and associated floodplain by undertaking targeted management activities.

Table 36 lists complementary management actions in the North East Waterway Strategy that target areas of the Murray floodplain.

Table 36: Murray Plains System - Management Outcomes and Activities Relevant to the Murray floodplain (Source: Adapted from NECMA 2014)

Priority Asset	Management Objective	Management Actions	Stakeholders
Murray River floodplain Complex (inc wetlands), Lake Moodemere	Murray floodplain maintained	Contribute to the Murray River floodplain Advisory Group to determine priories for management	CMA, Community, Community Groups, DELWP, EPA, Emergency Response Agencies, Government, Indigenous Peoples and Bodies, Industry, Land Managers, Local Councils, NRM Organisations, Peak Body Groups, PV, Research Organisations, VEWH, Water Corporations
		Establish pest animal controls (invasive terrestrial species) in Priority waterways	CMA, Community, Community Groups, DELWP, Land Managers, NRM Organisations, Peak Body Groups
	Improved waterways functions and values associated with growth in urban and lifestyle land uses around Wodonga	Further develop the Wodonga Urban Waterway Action Plan to incorporate the Murray River and floodplain (including wetlands)	CMA, Community, Community Groups, DELWP, Land Managers, Local Councils, NRM Organisations, Peak Body Groups, PV, Research Organisations, Water Corporations
		Implement programs to support the community and associated groups of Wodonga to build on existing community driven efforts	CMA, Community, Community Groups, DELWP, Government, Land Managers, Local Councils, Peak Body Groups
		Incorporate water sensitive urban design in all future urban development plans	CMA, DEPI, Government, Land Managers, Local Councils, Research Organisations, Water Corporations

Management actions are also described in the Risk Management section of this EWMP, such as controlling livestock access to wetlands within the floodplain, instigating fox and cat control programs, recreational fishing programs, and pest fish control actions such as carp screening. Refer to Section 11.1 for further details on these actions.

Management actions to improve environmental outcomes for the Murray floodplain are also incorporated in current and planned external strategic documents, such as the ‘Greening Wodonga Strategy’, slated for development in 2015 by the Wodonga City Council (City of Wodonga 2014). Under the Greening Wodonga Strategy, the Murray and Kiewa River floodplains will be regarded as significant natural landscapes for the regional cities of Albury and Wodonga (City of Wodonga 2013). The encroachment of urban areas onto the floodplains will be restricted, and Wodonga Council will work in partnership with North East CMA to reduce impacts of flooding and preserve the natural functions of the floodplain (City of Wodonga 2013).

13. Demonstrating Outcomes

Monitoring and research data is required to demonstrate that watering is achieving long term environmental outcomes for the Murray floodplain, and will be critical for a variety of agencies in reporting on the use of River Murray environmental holdings. This type of information is also an important component of the adaptive management of the floodplain.

A number of different types of information collation activities are needed:

- Baseline condition assessments, to firstly understand the current condition and ecological values present within the system, as well as probable trajectories under do-nothing scenarios;
- Short-term response monitoring, to understand ecological responses to specific watering events, such as waterbird breeding and/or fish breeding in response to seasonal inundation of floodplain depressions;
- Targeted research programs, to understand particular aspects of the floodplain's ecological dynamics; and
- Long-term condition monitoring to assess the effectiveness of the proposed water regime on environmental objectives.

13.1 Monitoring and Research

13.1.1 Baseline Condition and Longer Term Ecological Responses

Currently there is a paucity of data concerning the baseline condition of wetlands within the Murray floodplain, as well as the predicted longer term responses to environmental watering. A priority for the CMA is thus the collation of baseline data on the environmental values present within the different wetland types, their current ecological condition, and their trajectories under do-nothing scenarios. Long-term monitoring is also needed to assess the responses of key environmental values to the changes in the inundation regime recommended through this EWMP, as well as the achievement of ecological objectives e.g. increased diversity and abundance of small-bodied native fish.

Monitoring the responses to watering events will be particularly important to provide feedback on how the floodplain system is responding and if any amendments need to be made to its operational management, and to determine if any risk management actions need to be enacted. Ground-truthing the extent of wetlands inundated at the variety of flows recommended will also be particularly important to enable greater accuracy for any future hydraulic modelling undertaken for the floodplain. This will again assist in the adaptive management of the area.

It is also important to understand how confounding factors and legacy effects may impact on floodplain wetland responses to different water regimes. For legacy effects (i.e. those that relate to historical management practices), it may be important to see if their influence diminishes over successive wetting and drying cycles. Specific confounding factors and legacy effects include:

- The presence of introduced fish species that can physically disturb aquatic plants and increase turbidity and/or predate on native fish
- Water quality, in particular nutrients, turbidity and temperature
- Fire history (severity and time since last fire)
- History of artificial permanent inundation that may have compromised natural seedbanks
- History of grazing or current grazing
- Other land management practices.

13.1.2 Short-term Responses

While the full results of environmental watering activities can take years to emerge, short-term monitoring can providing good evidence that environmental water is providing a broad range of ecological benefits, including improved water quality and improved health of vegetation. It can also provide information on the reproduction and recruitment of native fish, waterbirds and reptiles in response to specific inundation events across the floodplain.

13.1.3 Research

Research is needed on a variety of topics associated with demonstrating outcomes for environmental watering of the Murray floodplain. The following questions provide a high level overview of the research topics needed:

- What are the specific water regime requirements of particular plant species and EVCs for the different wetland types of the floodplain?
- What plant assemblages are favoured by particular water regimes (i.e. inundation patterns) and what plant assemblages are disadvantaged by particular water regimes?
- How do plant assemblages respond year on year to water management in wetlands?
- How do wetlands respond to the first one or first few watering events after a very prolonged dry period? How do these responses differ from subsequent watering events?
- How does groundwater connection influence wetland responses to different water regimes?
- How do different inundation regimes affect introduced and pest species within wetlands, i.e. are they advantaged or disadvantaged?
- Does the application of environmental water allow waterbirds to successfully fledge their young?
- How does the duration of dry periods, and the timing, duration and frequency of re-wetting affect the biological productivity of wetlands along the floodplain?

Table 37 presents the proposed monitoring and research program that will be used to understand the ecological responses to environmental watering on the floodplain.