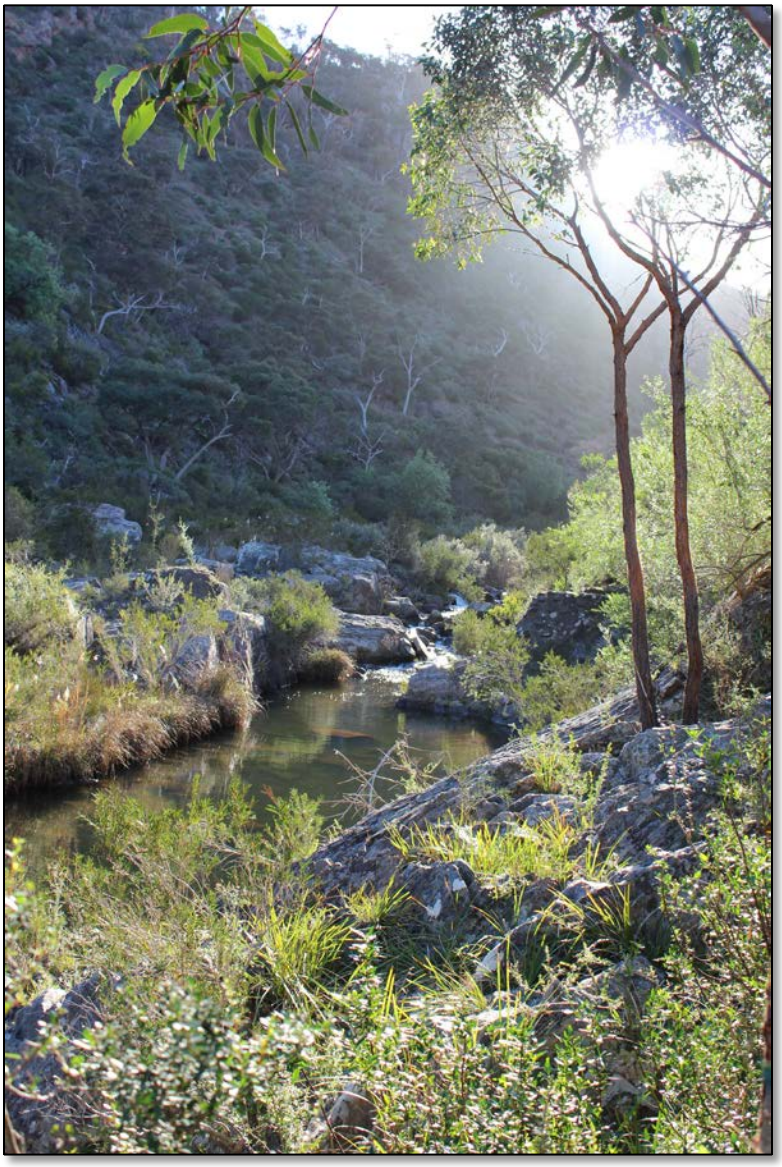
Werribee River
Environmental Water Management Plan



Collaborative NRM

Melbourne Water

Collaborative NRM

ABN: 50 575 776 286

PO Box 211 Brunswick VIC 3056 Australia

Tel: +61 412 796 770

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Acknowledgements

Acknowledgement of Country

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Contributions to the Werribee River EWMP

The information contained in the Werribee River Environmental Water Management Plan has been sourced from a variety of reports, studies and consultations. Melbourne Water acknowledges the contribution of the following people in preparing the EWMP:

- Suzanne Witteveen and Susan Watson, Department of Environment, Land, Water and Planning
- Mark Toomey and Chloe Wiesenfeld, Victorian Environmental Water Holder
- Marcus Cooling, Terry Hillman and Jane Roberts, Expert Review Panel
- Jeff Bonning, Southern Rural Water
- John Forrester, Werribee Riverkeeper
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Executive Summary

The Werribee River Environmental Water Management Plan (EWMP) sets out the long-term objectives for flow-dependent ecological values within and near the Werribee River and its estuary. The EWMP is an important planning tool for managers, describing the 5 to 10 year management objectives for the river. It has been developed using best available scientific information, evidence-based decision-making processes and stakeholder consultation. The Werribee River EWMP is intended for use by Melbourne Water, the Victorian Department of Environment, Land, Water and Planning (DELWP), and the Victorian Environmental Water Holder (VEWH) for both short term and long-term environmental water planning purposes.

Flowing through unique areas such as Victoria's Volcanic Plain outcrops and gorges, native grasslands, wetlands of international importance, and stands of mature River Red Gums, the community is increasingly valuing the Werribee River as an important waterway in a region slated for significant urban development over the next ten years. Providing water to protect and enhance the Werribee River's water-dependent values will help to ensure these values are not lost with the encroaching development of the area.

The river provides habitat for the iconic Platypus, now at a critical threshold in terms of its continuing population within the Werribee catchment. It also provides habitat for a wide variety of native fish, many of which rely on good longitudinal connectivity between the river, the estuary, and the marine environment to complete aspects of their life cycles. The endangered Growling Grass Frog is reliant on flows down the river to nourish its streamside habitat, while a vast population of birds, a number of whom are protected under international agreements and/or critically endangered, also rely on flows in the lower reaches and the estuary to supply water for their feeding and breeding habitats.

The vegetation communities along the river are some of the most endangered in the State, and provide a remnant record of ecological vegetation classes once common but now in danger of disappearing because of threats such as urban development, habitat fragmentation and altered flow regimes.

The river has highly variable natural flows, and its diverse biota reflects this variability in terms of their life history adaptations and survival mechanisms. During periods of drought, deeper pools provide refuge for many fauna and flora species in the river. In one of the driest Victorian catchments south of the Great Dividing Range, the Werribee River is critical to the survival of many of these species, providing an oasis of water in a challenging environment.

Water-dependent Values

Significant community consultation undertaken prior to the development of the EWMP determined the water dependent values of the Werribee River. These are:

- Platypus
- Fish
- Macroinvertebrates
- Frogs
- Birds
- Vegetation
- Amenity.

The long-term vision for the Werribee River and its estuary is:

> *To protect and where possible restore and enhance its ecological health, functioning, and biodiversity. Using robust, evidence-based science, as well as community input to inform decisions, environmental flows will be provided for the water-dependent values along the waterway so that the river and its values can continue to be enjoyed by future generations.*

Flow in the Werribee River is highly regulated. Three storages - Pykes Creek Reservoir, Melton Reservoir and Merrimu Reservoir - and a number of diversion weirs have changed the hydrology of the system dramatically. Flows are now significantly decreased over the winter-spring period as water is harvested and stored, and increased during the irrigation season as water is released from storages to supply irrigators. A high level of reservoir storage relative to annual flow also means that often the only flow in the lower reaches in drier than average years comes from regulated deliveries and passing flows. Significant changes to annual discharge and median flows are seen as a result of the regulation of the system.

Condition and Threats

Reflecting the impacts of regulation and catchment development, the condition of the Werribee River ranges from very good in the upper and less developed reaches, through to moderate to very poor in the lower and highly developed reaches. The Millennium Drought, which extended from 1997 to 2009, had significant impacts on ecological values in the river, from which the system is still recovering The condition of Platypus in the system is particularly concerning, and significant efforts targeting improved flows and habitat condition are required to ensure its continuing survival. The size and diversity of the diadromous fish population is also greatly diminished from natural.

Threats to the values of the Werribee River include: urbanisation and agricultural development; decreasing habitat complexity and availability; altered water regimes; introduced pests; and poor water quality. The loss of longitudinal and lateral connectivity is also a key threat, with floodplains and wetlands along the system now receiving significantly fewer inundation events than prior to river regulation, and barriers to fish movement impacting on migration and movement between habitats.

Ecological Objectives and Priority Watering Actions

The key values of amenity, fish, birds, frogs, macroinvertebrates, platypus and vegetation provide the basis of the EWMP's ecological objectives, and are supported by the findings of a number of environmental flows studies, reviews and surveys. The primary ecological objectives for the Environmental Entitlements are to enhance fish populations in the lower reaches and estuary and to enhance macroinvertebrate populations below Lake Merrimu. Secondary ecological objectives are to improve vegetation and platypus populations in the lower reaches and to improve frog populations below Lake Merrimu.

Specific ecological objectives related to certain flow events have been developed in the Environmental Flows Study and are summarised in this Plan. Some of these flow events are classified as Priority Watering Actions and will be delivered from the Environmental Entitlement. Priority Watering Actions were chosen based on the feasibility of delivery and the probability of achieving their objectives.

Ten per cent of flows into Lake Merrimu are reserved for the environment through the Werribee River Environmental Entitlement, and can be released to the Werribee system from Lake Merrimu and Melton Reservoir. The environment also has access to 730 ML of high reliability and 360 ML of low reliability water shares in the Werribee System.

To achieve the Environmental Entitlements' ecological objectives for the Werribee system, delivering Priority Watering Actions Priority Watering Actions to Reach 6, Reach 9 and the Estuary is of first priority. In wetter climatic scenarios Priority Watering Actions may be delivered to Reach 8. For each of these reaches there are several watering actions, as shown in Table 1.

Table 1: Priority watering actions

Reach	Flow component	Ecological objective
Reach 6	• Spring freshes • Winter and spring base flows	• Improving macroinvertebrate habitat, providing frog habitat • Providing macroinvertebrate and frog habitat
Reach 9	• Summer and autumn freshes	• Improving water quality, allowing fish migration

Reach	Flow component	Ecological objective
	• Winter and spring flows in addition to natural baseflow and freshes	• Improving aquatic habitat for fish an platypus
Estuary	• Spring, summer and autumn freshes • Winter and spring baseflow • Winter and spring freshes	• Promoting fish recruitment, allowing fish migration • Improving fish habitat • Improving vegetation
Reach 8	• Winter and spring flows in addition to natural baseflow and freshes	• Improving aquatic habitat for fish and platypus

Specific flow objectives identified in the Environmental Flows Study have been prioritised as follows:

1. Immediate priority - Currently a Priority Watering Action in the Seasonal Watering Plan
2. Medium-term priority - Will become a priority watering action if more environmental water becomes available
3. Long-term priority - Would require permanent wholesale changes to the Werribee catchment and water resource management in order to be delivered.

For example, bankfull and overbank flows are important to the health of freshwater reaches and the estuary. The current frequency of these flows is less than natural, but because of the very large volumes of water required to deliver these events and the risk of flooding private land and infrastructure, they are not an immediate priority.

Delivering immediate Priority Watering Actions will decrease the likelihood of further declines in fish populations in the lower reaches and is likely to improve the macroinvertebrate and frog population in Reach 6.

Meeting medium-term priority flow objectives will significantly decrease the risk of further decline in fish and platypus populations in the lower reaches. However, in order to realise an improvement in populations, long-term priority flow objectives would need to be met, including the removal of significant in-stream barriers.

Risks and Constraints

Risks assessment and mitigation planning for the Werribee River EWMP covers three 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 on the broader waterway 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
- The level of risk associated with climate variability and climate change for a number of water-dependent values, based on species vulnerability and a range of life history variables.

Risks include instream barriers preventing fish movement, pest plants and animals, and land use change. A number of taxa, including Platypus and some fish (Galaxias and Tupong), are particularly vulnerable to low flow availability although there remains considerable uncertainty around the predicted responses of these species to antecedent hydrological conditions.

In developing the EWMP, Melbourne Water used an Expert Panel to estimate the likelihood of fauna such as fish and platypus shifting between semi-quantitative states (poor, average, good, very good) under a range of different hydrologic scenarios defined for the Werribee River, based on their knowledge of these species’ life-history traits. The life history traits of the species assessed were particular to the populations and hydrological regimes within the Werribee catchment.

The risk assessment found that following periods of high flow stress, Platypus may remain in a poor state for a significant proportion of time despite improved water availability. This trajectory is concerning because a very long period of consistently above average rainfall may be required for the population to recover. To provide real opportunities for recovery through flow management under current river regulation, this will require that Melton and Werribee weirs spill consistently, which currently only happens in 40% of years. Another significant risk is that migratory fish such as Galaxias and Tupong will be in poor condition for much of the time because of extremely limited passage for migration during 'Maintain' and 'Protect' scenarios (approximately 60% of years). This suggests that environmental water management should be prioritised such that passage is provided for migratory fish at critical times.

There is a lot of uncertainty around the predicted responses of species to antecedent hydrological conditions, but the results of the assessment provide a useful guide for determining watering priorities each year through the Seasonal Watering Proposal.

There are a number of constraints to the delivery of flow recommendations for the Werribee River. These include operational constraints, such as the limited amount of water available under the environmental entitlement and the loss of any stored water once reservoirs spill, and the need to use the river to transfer water during the irrigation season. Melbourne Water also has little ability to adjust flows in most reaches of the Werribee River because of physical constraints in infrastructure. Reaches have been prioritised for receiving environmental water based on these constraints.

Demonstrating outcomes

Monitoring is essential to enable Melbourne Water to adaptively manage environmental flows for the Werribee River. The Werribee River 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 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
- Long-term condition/health monitoring – To measure any trends in environmental condition over time.

Knowledge Gaps

Management actions for the Werribee River EWMP are evidence-based and using the best available information, however a range of knowledge gaps and weaknesses were identified during the preparation of the EWMP. These include:

- The predicted responses to changing climate conditions for environmental values in the Werribee River system are not well known, and data to support the current hypotheses are minimal. In particular, the predicted response of platypus communities to varying water availability scenarios is poorly known
- Migratory fish such as Galaxias and Tupong may be particularly vulnerable to a sequence of years with low flow availability, but knowledge of their level of resistance and resilience to such challenges is currently poor.
- There are significant knowledge gaps regarding the dependency of the estuarine environment on groundwater, in particular the links between groundwater contributions and ecosystem health. There is also a significant knowledge gap regarding the occurrence of seepage from treatment lagoons at the WTP and any impacts on hydrogeological regime and water quality.
- Knowledge of Werribee River estuary hydrodynamics for the Werribee River is still in its infancy, with insufficient information about the relationship between salt wedge dynamics

and flow regimes. The flow recommendations for the estuary apply to the requirements for fish, Black Bream in particular, that were determined based on studies in other estuaries. Given the unique physical and hydrodynamic nature of individual estuaries, it is unclear how well the results of these other studies apply to the Werribee estuary.

- The diversity and abundance of the frog and macroinvertegrate communities within the seasonal headwaters of the catchment is poorly understood, as are their hydrological and climatic dependencies.

It is the intention of Melbourne Water to address these knowledge gaps, and a series of recommended actions have been provided and prioritised for completion.

Consultation

Consultation activities that have contributed to the preparation of the EWMP include extensive community engagement during the development of Melbourne Water's Healthy Waterway Strategy for the determination of ecological values and objectives. Consultation during the development of the EWMP included representatives from Southern Rural Water, the Victorian Department of Environment, Land, Water and Planning (DELWP), and the Victorian Environmental Water Holder (VEWH). Technical input was also provided by consulting and research groups such as Jacobs, Alluvium, and DELWP's Arthur Rylah Institute for Environmental Research (ARI), as well as technical experts such as Tim Doeg (Independent) and Dr Nick Bond (Griffith University), the Werribee River Association (Werribee River Keeper John Forrester), and representatives from local government agencies were also consulted.

INTRODUCTION

Purpose and Scope of the EWMP

The Werribee River Environmental Water Management Plan (EWMP) is a ten-year management plan for the river that describes the ecological values present, the long-term goals for its management, the priority ecological objectives, and the recommended flow regime to achieve the ecological objectives. It is based on both scientific information and community consultation and will be used by Melbourne Water when making annual environmental watering decisions, as well as the Victorian Department of Environment, Land, Water and Planning (DELWP) and the Victorian Environmental Water Holder (VEWH) for both short and longer-term environmental water planning (DEPI 2014).

The key purposes of the EWMP are to:

- Identify the long-term objectives and water requirements for the river
- Provide a vehicle for community consultation, including for the long-term objectives and water requirements of the river
- Inform the development of seasonal watering proposals and seasonal watering plans
- Inform long-term watering plans that are being developed by the State.

The scope of the EWMP is the nine freshwater reaches of the Werribee River and its estuary.

Development process

The Werribee River EWMP has been developed in collaboration with DELWP, VEWH and Southern Rural Water. A number of tasks were undertaken to prepare the EWMP, including:

- Conducting a detailed desktop review of technical reports, strategies and plans relevant to the management of the Werribee River. For example, a significant amount of consultation was undertaken for the preparation of the Melbourne Water Waterways Management Strategy, and this has informed much of the ecological objectives section of the EWMP
- Convening a Climatic Risk Assessment Technical Panel to determine risks to Werribee River ecological values under a variety of climate change scenarios
- Consultation with a number of key stakeholders to confirm aspects of the EWMP, including ecological objectives and risks, and infrastructure and operation of the system.

SITE OVERVIEW

Site Location

The Werribee River is located approximately 40 km south-west of Melbourne and drains the southern slopes of the Great Dividing Range. It originates in the Wombat State Forest, and it flows for about 110 km in a south-east direction until it discharges to Port Phillip Bay at Werribee. The Werribee catchment covers an area of 1,424 km^2.

The northern boundary of the catchment is formed by the western extremity of the Great Dividing Range. The Western Highway between Melbourne and Ballarat divides the catchment, passing through the towns of Melton, Bacchus Marsh and Ballan. North of the highway it is mostly steep terrain, with a maximum elevation of approximately 750 m between Daylesford and Trentham (Ecological Associates 2005a). Figure 1 illustrates the Werribee catchment.

Figure 1: The Werribee catchment (Source: VEWH (2015))

The lower Werribee Plain extends from Bacchus Marsh southwards to Port Phillip Bay. The Rowsley Fault at Bacchus Marsh, a long tectonic fault line between Bacchus Marsh and Anakie, forms a distinct geological boundary between the relatively steep and incised area to the north-west of the catchment and the low relief Werribee Plain to the south-east (Ecological Associates 2005a).

Catchment setting

The Werribee catchment has a diverse range of ecosystem types and is considered a nationally significant biodiversity hotspot. Most of the catchment is located in the Victorian Volcanic Plains bioregion, with a smaller section of the catchment just near the estuary located in the Otway Plains Bioregion.

Around 25% of the catchment retains natural vegetation, and over 65% is used for agricultural purposes, while 5% is urban (Ecological Associates 2005a). Extensive native grasslands were once a feature of the lowland plains, but now only scattered remnants remain. Forestry occurs in the upper areas of the catchment and most of the plains around Bacchus Marsh are reclaimed swampland developed for agriculture (Ecological Associates 2005a).

Several significant wetlands are found in the Werribee catchment, including internationally listed Ramsar sites at the Western Treatment Plant, Point Cook Coastal Park, Lodges Wetland (at Avalon Airport) and The Spit Wildlife Reserve, as well as Cheetham Wetlands, Heathdale Glen Orden Wetlands and Truganina Swamp. Melbourne Water's 10,500-hectare Western Treatment Plant (WTP) is recognised as one of the world's most significant wetlands, and forms part of the 'Port Phillip Bay (Western Shoreline) and Bellarine Peninsula' Ramsar site (Melbourne Water 2013).

The Werribee River estuary is 8.25 km long, with its upper limit located at a ford about 3.5 km downstream of Werribee. The estuary is adjacent to the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site (Lloyd et al., 2008). Land on the western side of the estuary is managed by Melbourne Water and is mostly used for stock grazing. On the eastern bank of the estuary the dominant land uses are a golf course (upper estuary) and market gardens (lower estuary) (SRW 2009).

Climate

The Werribee catchment has a temperate climate, with most rainfall occurring over the winter to spring period. Annual rainfall ranges from about 1100 mm/year at the headwaters to about 450 mm/year on the plains near Melton and Werribee. The plains form part of Victoria's western volcanic plains grassland ecosystem (now highly fragmented), and lie in the rain shadow of the Otway Ranges. The plains are in the driest area south of the Great Divide in Victoria and during the summer, many of the streams in the upper catchment cease to flow (SRW 2009). As a consequence, flow in the catchment is highly seasonal and varies widely from year to year in line with rainfall.

Hydrophysical characteristics

The Werribee River is a highly regulated river, dominated by the major water resource reservoirs of Pykes Creek Reservoir, Lake Merrimu and Melton Reservoir, as well as a number of weirs – Upper Werribee Diversion Weir, Bacchus Marsh Weir and Werribee Diversion Weir (Ecological Associates 2005a).

For management purposes, environmental flows studies of the Werribee River and its major contributing tributaries have delineated the waterway into reaches of similar characteristics. The reaches extend from the Upper Werribee Diversion Weir downstream to the estuary, and include the tributaries of the Lerderderg River, Coimadai Creek (more commonly known as Pyrites Creek), Pykes Creek and Djerriwarrh Creek. Reaches are based on stream size, stream morphology, hydrology, and stream operation. They include six in the main stem of the Werribee River from Ballan to the Werribee estuary, the estuary, and separate reaches in the main regulated tributaries of Pykes Creek, Coimadai Creek and Djerriwarrh Creek, and the Lerderderg River. The reaches are as follows:

- Reach 1: Ballan, upstream of the Upper Werribee Diversion Weir

- Reach 2: Pykes Creek downstream of Pykes Creek Reservoir
- Reach 3: Werribee River from the Upper Werribee Diversion Weir to Pykes Creek
- Reach 4: Werribee Gorge, which extends from the confluence with Pykes Creek to Bacchus Marsh Weir
- Reach 5: Werribee River from the Bacchus Marsh Weir to the confluence with Parwan Creek
- Reach 6: Coimadai Creek downstream of Merrimu Reservoir
- Reach 7: Djerriwarrh Creek downstream of Djerriwarrh Reservoir
- Reach 8: Werribee River below Melton Reservoir and upstream of the Werribee Weir
- Reach 9: Werribee Diversion Weir to the Estuary limit
- Estuary: Estuary between the bluestone ford and Port Phillip Bay.

Refer to Figure 1 for the location of each of these reaches.

The headwaters of the Werribee River drain forest in the Great Dividing Range. Towards Ballan in **Reach 1**, the river passes through upper basalt plain, forming broad valleys with less steep grades. In this reach, the river has a floodplain with deep basalt sediments, supporting predominantly exotic vegetation, but also some of the largest isolated patches of remnant forest in north central Victoria. Reach 1 is delineated by the Upper Werribee Diversion Weir, which diverts water from the Werribee River across to Pykes Creek Reservoir via the Werribee tunnel.

The upper reaches of the Werribee River lie upstream of the Pykes Creek confluence, between Ballan and Bacchus Marsh. Korweinguboora Creek, Dale Creek and Stony Hut Creek are also within this area although theses creeks do not join the Werribee River until its middle reaches.

Reach 2 incorporates the length of Pykes Creek downstream of Pykes Creek Reservoir to its confluence with the Werribee River. The creek flows through a narrow, gravely and cobbly floodplain. Prior to regulation it would have flowed intermittently in response to rainfall events, and may have had a sustained period of baseflow in winter and spring. The watercourse is now an integral part of the water management system of the Werribee catchment and it has been heavily impacted by irrigation releases from Pykes Creek Reservoir, which are the opposite of the natural seasonal flow pattern.

Between **Reach 3** and **Reach 4**, the river encounters a steep drop in the landscape associated with the Rowsley Fault at Bacchus Marsh, and the grade of the river increases dramatically, forming the steeply incised and spectacular Werribee Gorge (iReach 4). The Werribee Gorge is recognised as a site of geomorphological significance within Australia and internationally, and a significant section of the Gorge is protected in State Park and retains natural habitat features, with diverse riparian vegetation such as River Red Gum and Blackwood. The gorge has extensive riffles and deep pools which provide high quality habitat for native fish, platypus and invertebrates. The landscapes here have significant biodiversity values, providing protected breeding habitat for Peregrine Falcons (*Falco peregrinus*) and Wedge-tailed Eagles (*Aquila audax*), and also providing habitat for significant species such as the Powerful Owl (*Ninox strenua*), Common Bent-Wing Bat (*Miniopterus schreibersii*) and Brush-tailed Phascogale (*Phascogale tapoatafa*) (Melbourne Water 2013).

Other tributaries in the area include: Myrniong; Korkuperimmul; Djerriwarrh; and Toolern creeks, as well as the lower reach of the Lerderderg River.

Along **Reach 5**, the river travels through deep alluvial floodplain sediments in the outwash of Werribee Gorge at Bacchus Marsh. Originally a swamp, the floodplain has been drained and extensively modified through the clearance of native vegetation and the development of urban and horticultural areas. The Bacchus Marsh Irrigation District is located near this reach, and the Lerderderg River joins the Werribee River at the lower end of the reach. The Lerderderg has been proclaimed a Heritage River upstream of Goodman Creek (an area encompassing the Lerderderg Gorge), on the basis of its geological significance and also because it has high scenic, cultural and forest values, and provides significant good quality instream habitat

(LREFTP, 2002). The Lerderderg River joins the Werribee River just past the town of Bacchus Marsh, and it provides a significant contribution to flows from the upper catchment of the Werribee River. Almost 45% of the total annual flow downstream of the Lerderderg and Werribee confluence is supplied by the Lerderderg River (LREFTP 2002).

Coimadai Creek (**Reach 6)** and Djerriwarrh Creek (**Reach 7**) drain exposed bedrock and sandstone in sub-catchments to the north, and join the Werribee River downstream of Bacchus Marsh. Coimadai Creek flows through the Long Forest area, a large proportion of which is protected in the Long Forest Nature Conservation Reserve. The reserve protects the only occurrence of Bull Mallee south of the Great Dividing Range (Ecology Associates 2005). There are some permanent pools in Reach 6, which appear to be maintained by groundwater discharge. In Reach 7, Djerriwarrh Creek comprises sections of pools, exposed bedrock and alluvium comprising sand and gravel. Djerriwarrh Creek also passes through the Long Forest Nature Conservation Reserve. The lower reaches of both creeks have a relatively low rainfall and their ecology is distinctive; they would have flowed intermittently and supported plants and animals tolerant of dry periods and intermittent flow.

Reach 8, which begins downstream of Melton Reservoir, passes through the Werribee River Volcanic Gorge, and becomes progressively shallower as it flows across the basalt plain toward the pool of the Werribee Diversion Weir at Werribee. Heavily infested by woody weeds for much of its length, this reach retains natural vegetation in areas as well as gravel riffles and pools. Releases from Melton Reservoir for irrigation purposes have significantly altered the pattern of flows in this reach.

Consultation for the development of Melbourne Water's HWS highlighted several values in the catchment near Reach 8 that are considered special by communities. These included vegetation such as woodlands, saltmarsh, orchids and grasslands (Melbourne Water 2013).

Other waterways in the area include: Little River (lower reaches); Lollypop Creek; Cherry Creek; Eynesbury Creek; Davis Creek; and Arnolds Creek.

Reach 9 of the Werribee River flows for approximately 9 km from the Werribee Diversion Weir to the top of the estuary (nominally the ford immediately downstream of the Werribee Mansion) (Jacobs 2014). The reach has an extensive alluvial floodplain and the main channel is deeply incised (Ecological Associates, 2005b). Bungey's Hole, which is behind the recreation reserve at Chirnside Park and approximately half way along the reach, is estimated to be 30 m deep and is fed by a freshwater spring at its downstream end (Jacobs 2014). Flow in Reach 9 is highly modified due to diversion and capture for agricultural, urban and industrial demands at the Werribee Diversion Weir or further upstream. Significant native fauna in and near this unit include platypus, frogs, fish, and the critically endangered Orange-Bellied Parrot (*Neophema chrysogaster*).

The Werribee River **estuary** (Figure 2) is permanently open to Port Phillip Bay. The entrance is reasonably wide (60 – 100 m) and deep (1 – 3 m), providing permanent access to the estuary for marine species (Lloyd et al. 2008). Because the estuary is located within Port Phillip Bay, the wave energy is relatively low. The estuary channel is located within a confined gorge in the fluvial sediments of the relict Werribee delta. A low-lying floodplain, positioned slightly above the normal upper tidal level, is found in a sharp bend in the river at K Avenue. Set within the floodplain area are shallow tidal pools which support saltmarsh communities. A higher-level floodplain, inundated by flood flows, is located between K Avenue and the ford (Lloyd et al. 2008).

The coastal fringe area and estuary within this unit contain significant saltmarsh vegetation communities and play an important role in providing habitat for the migratory birds protected under international agreements (Melbourne Water 2013). The internationally renowned Ramsar-listed wetlands of the Western Treatment Plant provide habitat for tens of thousands of birds as well as populations of the endangered Growling Grass Frog (*Litoria raniformis*), which is one of Victoria's most endangered species.

Other significant water-dependent fauna and flora species that have been recorded within the estuary include:

- High value commercial and recreational fishing estuarine fish species such as Black Bream, King George Whiting and Estuary Perch

- A number of Ecological Vegetation Classes that are considered endangered in the region, such as Coastal Saltmarsh (EVC 09), Estuarine Wetland (EVC 010), Seagrass Meadow (EVC 845), and Floodplain Riparian Woodland (EVC 056)
- The recently recognised and endangered Werribee Blue-box (*Eucalyptus baueriana* subsp*. thalassina*) (Lloyd et al. 2008).

Figure 2: Werribee estuary (Source: DSE 2005)

Management Arrangements

As the caretaker of river health in the Port Phillip and Westernport region, Melbourne Water has responsibility for managing and improving the health of the Werribee River. The river flows through a number of broader catchment management units used by Melbourne Water for planning purposes:

- The Werribee and Little River Middle and Upper system - Comprising the middle and upper reaches of Werribee River, as well as Little River, Balliang, Djerriwarrh and Pykes creeks, and the Lerderderg River. This management unit will be referred to in the EWMP as the Middle and Upper Werribee management unit
- The Werribee and Little River Lowlands system - Comprising the lower Werribee River, lower Little River, Lollypop and Davis creeks. This management unit will be referred to in this EWMP as the Lower Werribee management unit.

Figure 3 illustrates these management units. Note that the Werribee River does not cross through the Cherry, Kororoit, Laverton and Skeleton Creeks management unit, and as such, this unit is not discussed further in the EWMP.

Figure 3: Management units of the Werribee catchment (Source: Melbourne Water (2014))

Cultural Heritage

Aboriginal Heritage

When Europeans first settled in the Port Phillip region, a single bloc of Aboriginal people consisting of five language groups owned the entire Port Phillip region as far north as Euroa. The five groups all spoke a related language and were said to form a confederacy or nation, which the people themselves called Kulin, from their common word for a human being (Ecology Partners, 2011). People from the Kulin nation have lived in the Werribee catchment for at least 25,000 years. At the time of European contact, the Werribee River lay between the traditional lands of three of the Kulin nation tribes; the western Wathaurong (also commonly referred to as Watha wurrung, or Wadawurrung): the eastern Woi wurrung (or Woiwurrung); and the eastern Bunerong (also called Boon wurrung).

European Heritage

Settlement of the Werribee catchment quickly followed the arrival of John Batman in 1835. By 1837, European settlers had reached the Bacchus Marsh area and by 1840 most of the plains and foothills within the catchment were occupied by squatters (Melbourne Water 2009). Evidence of early European settlement includes farm complexes and homestead ruins, old orchards, river crossings, weirs and bridges.

In the 1890s farmers from the Ballarat area began to move into the district, establishing dairying and agriculture. The production of vegetables began when an irrigation scheme was established around 1910. A state research farm (still in operation) was established in 1912 and ex-servicemen were granted land in the area after World War 1 (Melbourne Water 2009).

Aviation instruction began at Point Cook in 1913-14 and the RAAF's first base was established there in 1921. Still in operation, it is among the oldest continually operating military bases in the world. Werribee was declared a city in 1987 (Melbourne Water 2009).

Land Status and Management

The Werribee River flows through urban, rural and peri-urban areas as well as more natural and protected areas such as Werribee Gorge State Park and the Wombat State Forest. About 25% of the catchment retains natural vegetation, 67% is agricultural and 5% urban, although most of the urban area is in the Kororoit Creek catchment (Ecological Associates 2005a). Extensive grasslands were once a feature of the lowland plains, but now only scattered remnants remain (again, mostly located in the Kororoit Creek catchment).

Forestry occurs in the upper areas of the catchment, while most of the plains around Bacchus Marsh are reclaimed swampland developed for agriculture. Agriculture in the southern part of the basin is predominantly cropping and irrigated and dryland pastures. The Werribee Irrigation District near Werribee estuary is a key horticultural production area for Melbourne, producing a wide range of vegetables, notably cabbages, cauliflowers, lettuce and broccoli in the local market gardens. The Bacchus Marsh Irrigation District, located on the Werribee floodplain near the town of Bacchus Marsh, is a major producer of vegetables as well as stone fruits, pasture and plant nursery stock.

Due to its close proximity to Melbourne, the Werribee catchment contains some of the fastest growing municipalities in Australia, with the Melbourne Urban Growth Boundary recently being expanded by the State Government in recognition of this growth. The expanded urban growth areas include parts of the lower reaches of the Werribee River at Werribee, as well as upper reaches of the Werribee near Melton (DTPLI 2014).

Water supply in the Werribee catchment

Surface water is diverted by Central Highlands Water, Western Water and Southern Rural Water, as well as by licensed private diverters. Surface water is also harvested in small catchment dams. Major water storages in the Werribee catchment include Melton, Pykes Creek and Merrimu reservoirs, and total storage capacity for the system is 69,000 ML. Overall storage capacity is allocated approximately 60% to irrigation use, and 30% for urban use (with 10% unallocated) (SRW 2009).

There are two major irrigation districts in the Werribee catchment: the Werribee Irrigation District (WID); and the Bacchus Marsh Irrigation District (BMID).

Figure 4 provides a schematic of the Werribee catchment water supply system.

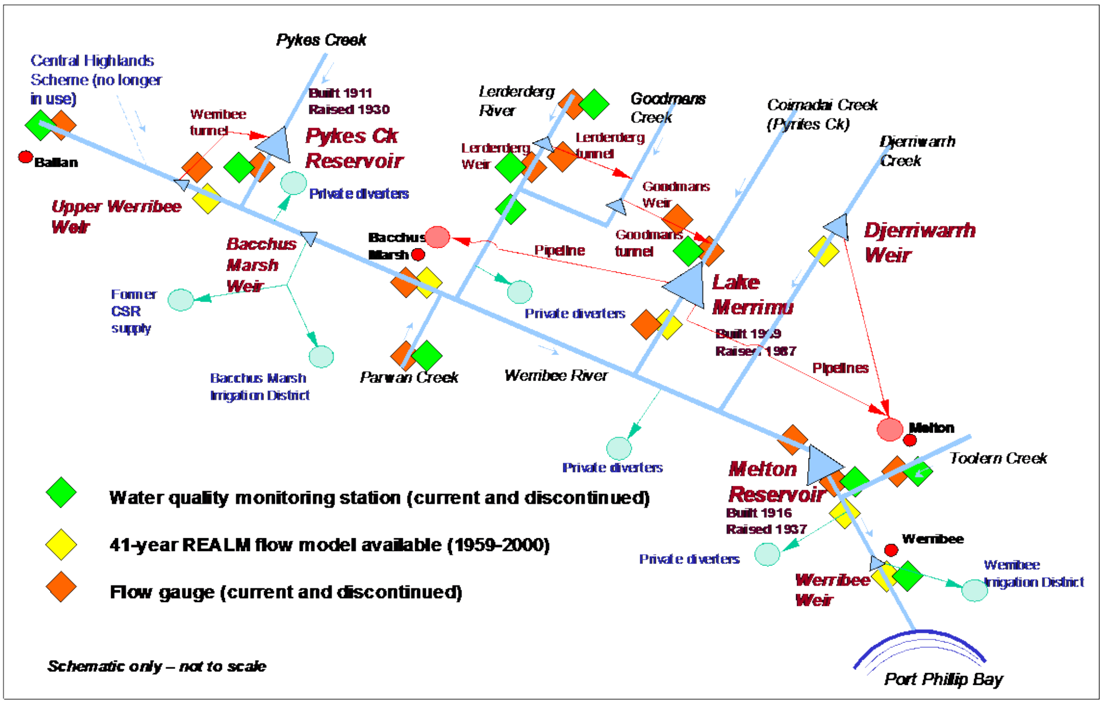

Figure 4: Schematic of the Werribee supply system and storages (Source: Ecological Associates 2005a)

Table 2 summarises the water resources management responsibilities for water authorities in the Werribee catchment, while Table 3 lists surface water entitlements to water in the catchment.

Table 2: Water resource management roles and responsibilities (Source: DEPI 2013c)

	Function			
Authority	**Irrigation and rural water supply**	**Licencing**	**Urban water supply**	**Management obligations**
Southern Rural Water	Manages Werribee and Bacchus Marsh irrigation districts	Manages groundwater and surface water licensed diversions	N/A	Operates Pykes Creek Reservoir, Melton Reservoir and Merrimu Reservoir Obliged to meet passing flow requirements
Western Water	N/A	N/A	Supplies towns in the north of the basin including Melton and Bacchus Marsh	Operates Djerriwarrh Reservoir Obliged to meet passing flow requirements
Melbourne Water	N/A	Manages surface water licensed diversions for lower reaches of Kororoit Creek	Provides bulk water to City West Water and Western Water from the Thomson–Yarra system Operates the Western	Manages waterways, drainage and floodplains in all of the Werribee catchment

	Function			
Authority	**Irrigation and rural water supply**	**Licencing**	**Urban water supply**	**Management obligations**
			Treatment Plant and supplies recycled water to Southern Rural Water	
City West Water	N/A	N/A	Supplies towns and manages wastewater in metropolitan Melbourne	N/A
Central Highlands Water	N/A	N/A	Supplies Blackwood and Ballan	Obliged to meet passing flow requirements

Table 3: Surface water entitlements in the Werribee catchment

Entitlement Holder	Bulk Entitlement	Purpose
Central Highlands Water	Bulk Entitlement (Ballan) Conversion Order 1998	Urban supply
	Bulk Entitlement (Blackwood and Barrys Reef) Conversion Order 1998	Urban supply
Western Water	Bulk Entitlement (Myrniong) Conversion Order 2004	Urban supply
	Bulk Entitlement (Werribee System - Western Water) Conversion Order 2004	
Victorian Environmental Water Holder	Werribee River Environmental Entitlement (2011)	Environment
Southern Rural Water	Bulk Entitlement (Werribee System - Irrigation) Conversion Order 1997	Services private irrigation licence / entitlement holders

Groundwater within the Werribee catchment is part of the West Port Phillip Bay Groundwater Catchment, and is managed by Southern Rural Water. The Werribee catchment contains two incorporated groundwater management areas:

- The Merrimu Groundwater Management Area (GMA), located near Bacchus Marsh with a maximum aquifer depth of 30 m;
- The Deutgam Water Supply Protection Area (WSPA), which is located at the southern end of the catchment near Werribee, also with a maximum aquifer depth of 30 m (DEPI 2013c).

There are also numerous domestic and stock bores in unincorporated areas of the catchment (DEPI 2013c). Groundwater is used in the catchment for licences and domestic and stock use, and is also an option for urban water supply for the township of Blackwood near the Lerderderg River.

Environmental Water Management and Sources

The Environmental Water Reserve (EWR) is water set aside through Victoria's water allocation framework to provide environmental benefits for waterways. For the Werribee River, the EWR comprises:

- The Werribee River Environmental Entitlement (2011), held by the Victorian Environmental Water Holder (VEWH)
- Water set aside for the environment through the operation of passing flows released as a condition of consumptive bulk entitlements held by Central Highlands Water, Western Water and Southern Rural Water
- Water set aside for the environment through the operation of passing flow conditions on licensed diversions (regulated and unregulated waterways)
- All other water in the basin not allocated for consumptive use.

Under the Environmental Entitlement, VEWH is entitled to 10 per cent of the flow into Merrimu Reservoir, after water has been set aside to meet passing flow requirements. The entitlement is not expressed volumetrically because it is not capped. Previous modelling has indicated that the maximum allocation VEWH could expect to receive from Lake Merrimu under historical conditions is 1,944 ML/year, assuming the environmental water is drawn out of storage as inflows occur, so that no environmental water is spilt (Victorian Government 2011c). Average inflow to the environmental entitlement is around 580 ML per year, based on a 1992-2012 climate scenario.

Melbourne Water purchased 730 ML of high and 360 ML of low reliability water share in the Werribee Irrigation District in 2013-14 to supplement the environmental entitlement for the river.

Table 4 outlines relevant agencies and advisory/interest groups, and their roles and responsibilities in managing environmental water in the Werribee catchment. Table 5 summarises the sources of environmental water in the Werribee catchment. Passing flows rules for the Werribee River are detailed in Appendix 5.

Table 4: Werribee catchment environmental water management roles and responsibilities

Authority / Agency	Roles and Responsibilities
Victorian Environmental Water Holder	Independent statutory body responsible for deciding the most effective and efficient use of Victorian environmental water entitlements. Holds the Werribee River Environmental Entitlement
Melbourne Water	Caretaker of river health. Manages rivers and creeks, regional drainage networks, drainage schemes, floodplains, the environmental water reserve and works on waterways. Manages the Werribee River Environmental Entitlement on behalf of VEWH.
Port Phillip and Westernport Catchment Management Authority	Co-ordinates natural resources and catchment management for Port Phillip and Westernport catchments, including the Werribee catchment. Identifies regional priorities for catchment management in the Port Phillip and Westernport region
EPA Victoria	Develops and oversees the implementation of State Environmental Protection Policy (SEPP) for the bays and catchments including water quality objectives. Regulates discharges and enforces environmental protection conditions.
Southern Rural Water	Releases environmental flows at dams and weirs and monitors water quality at specific sites as well as being the land manager

Authority / Agency	Roles and Responsibilities
	of reservoirs. Manages and controls the take and use of water from rivers and groundwater.
Victorian Department of Environment, Land, Water and Planning	Develops and oversees the implementation of policy focused on the management of the Environmental Water Reserve, as well as the Victorian Healthy Waterways Strategy
Parks Victoria	Land manager for Werribee Gorge State Park and Lerderderg State Park. Provides advice regarding water-dependent ecological values.
Moorabool, Melton and Wyndham councils	Management of local drainage networks, infrastructure and stormwater
Input and advice into Werribee River environmental water management	
LeadWest	Undertakes actions to support sustainable growth and regional development in Melbourne's west, including consideration of environmental and sustainability issues.
Werribee River Association (WRIVA)	Based in Werribee, WRIVA works locally with Wyndham City Council, Melbourne Water, and Parks Victoria, engaging in whole of catchment and wider initiatives.
Western Melbourne Catchments Network (WMCN)	WMCN is a not-for-profit association for individuals, groups and organisations with an interest in the environmental management of the wider Werribee catchment

Table 5: Sources of environmental water in the Werribee catchment

Water Source		Flexibility of management	Reaches	Conditions of availability	Conditions of use	Management responsibility	Compliance point
Nature of water source	**Volume or rate of water delivery (ML/d)**						
ENTITLEMENT							
Werribee Environmental Entitlement 2011 (Victorian)	10% of inflows The lesser of 15 ML/day and the natural flow at Melton Reservoir, less the Melton Target passing flow	Fully flexible management	Reach 6	Air space storage in Lake Merrimu or Melton Reservoir	EWR is first to spill	Entitlement is held by the VEWH and managed by Melbourne Water in accordance with seasonal watering statements	N/A
		Dependent on system storage and operation	Reaches 8, 9 and estuary				
PASSING FLOWS							
Passing flows for the Werribee River	*Refer to Appendix 5 for details of these rules.*	Fixed	Various	Based on inflows	Currently limited by valve capacity	SRW	Various
OTHER SOURCES							
Water shares in the Werribee Irrigation District	730 ML High Reliability Water Shares 360 ML Low Reliability Water Shares	Fully flexible management	Reaches 8, 9 and estuary	Dependent on allocation, No access to carryover	N/A	N/A	N/A
Operation transfer / Consumptive water en route such as	Variable – options to ‘piggy back’ environmental water	Limited / No ability to manage.	Various	Dependent on releases made	Any additional losses are deducted from environmental account.	SRW	NA

Water Source		Flexibility of management	Reaches	Conditions of availability	Conditions of use	Management responsibility	Compliance point
Nature of water source	**Volume or rate of water delivery (ML/d)**						
Irrigation Releases					Arrangements yet to be finalised.		
Unregulated flow	Variable	Limited / No ability to manage	All	Rainfall and catchment conditions	Available only in periods of unregulated flows	N/A	N/A

Related agreements, policy, plans and activities

A wide variety of legislation, as well as policies, strategies and plans are relevant to the management of environmental water for the Werribee River. These are listed in Table 6.

Table 6: Relevant management instruments for Werribee River environmental water

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 • Coastal Management Act (1995)
Commonwealth Legislation	• Water Act 2007 • Environment Protection and Biodiversity Conservation Act (1999)
International Agreements	• Ramsar Convention on Wetlands of International Importance • 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)
Plans and Strategies	• Victorian Waterway Management Strategy (2013) • Melbourne Water Healthy Waterways Strategy (2014) • A Cleaner Yarra River and Port Phillip Bay - A plan of action (2012) • Victorian Central Region Sustainable Water Strategy (2006) • Victorian Coastal Strategy (2014) • Port Phillip and Westernport Regional Catchment Strategy (2015) • Victorian Coastal Strategy (2008) • Melbourne's Water Future - Consultation Draft (2013) • Biodiversity Conservation Strategy for Melbourne's Growth Corridors (2013) • Plan Melbourne: Metropolitan Planning Strategy (2014)
Scientific Recommendations	• Victorian Environmental Flows Monitoring and Assessment Program (VEFMAP) • The Environmental Water Needs of the Werribee River: Final Report - Flow Recommendations (2005) • Environmental Flow Determination of the Lerderderg River Catchment (2003) • Environmental Water Requirements of the Werribee River Estuary - Estuary Environmental Flows Assessment Report (2009) • Werribee River Environmental Flows Review – Flow recommendations report (2014) • Victorian Environmental Flows Monitoring and Assessment Program (VEFMAP)

HYDROLOGY AND SYSTEM OPERATIONS

River Hydrology

A feature of the Werribee River is the rapidly changing flow and the variation between daily flows, particularly during the high-flow period between June to November, making this a very 'flashy' system. The runoff-generating parts of the upper catchment have a generally low water holding capacity, and generate little groundwater base flow in the area. The upper Werribee and Lerderderg rivers cease flowing in most summers and consequently, flow is highly seasonal and varies widely from year to year in line with rainfall. The flow regime within the regulated reaches of the Werribee River reflects the use of water in the system by consumers. Flows over the winter-spring period are reduced as water is being harvested, and are increased during the irrigation season, mainly between November and April, as water is released from storages to supply irrigators (Ecological Associates 2005a).

The high level of reservoir storage relative to annual flow also means that the only flow in the lower reaches in drier than average years comes from regulated deliveries and passing flows. This was particularly evident during the Millennium drought, when there were only 2 years in 13 where there was significant flow downstream of the Werribee Diversion Weir and through the mouth of the river (Figure 5). Diversions to the Werribee Irrigation District remained relatively stable for almost 9 years, but environmental flows were severely impacted even in the first year of the drought.

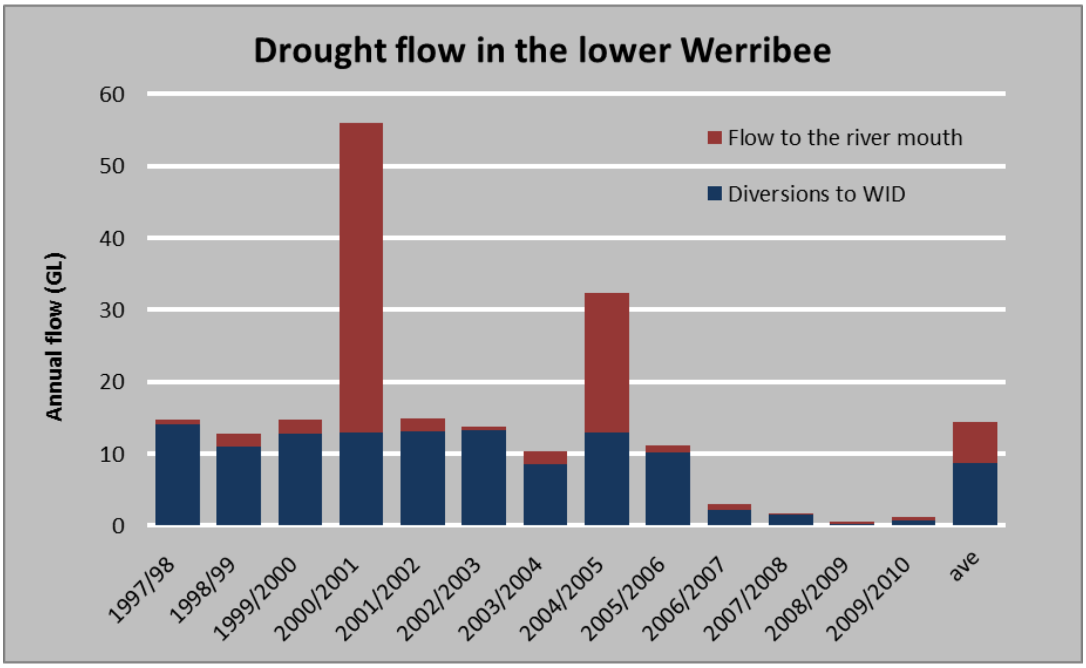

Figure 5: Flow in the lower Werribee during the Millennium Drought (Source: Melbourne Water)

The Werribee is a highly regulated catchment, with a mean annual flow of around 60-80 GL and storage of nearly 70 GL, with annual diversion of around 20-30 GL. The river was prioritised for receiving additional environmental flows through the Victorian Government's White Paper, Our Water Our Future in 2004 in recognition that existing environmental flow provisions were inadequate (DSE 2004), The Werribee River Environmental Entitlement (2011) was implemented to address some of this flow stress (Victorian Government 2011b, 2011c).

The third Victorian Index of Stream Condition assessment (ISC3), conducted in 2010, assessed the extent of flow regime modification across numerous reaches in the Werribee catchment. The scores for hydrology reflect the impacts of flow modification in the river, with the lower, more modified reaches of the river receiving poor scores, and the higher reaches in less modified areas receiving scores that reflect their more natural flow regimes (DSE 2010). Out of a possible score of ten (10 being most natural and 1 being the most modified flow regimes), assessment locations that corresponded most closely to Reach 8 and Reach 9 receive scores of only 1 and 2, reflecting their highly modified hydrology. Upper reaches of the river, near the Upper Werribee Diversion Weir, received scores of 9 out of 10, reflecting much more natural flows in this part of the system (DSE 2010).

Changes in Annual Discharge

Diversion of river water to supply both irrigation and urban demands has resulted in a reduction of the mean annual discharge to Port Phillip Bay to approximately 60% of what the natural annual flow would have been prior to regulation (Ecological Associates 2005a). The fraction of flow diverted is higher in dry years and it is not uncommon for there to be no unregulated flow to the bay during severe droughts. The reduction in flow is greatest immediately downstream of diversion weirs near Ballan (Reach 3) and Werribee (Reach 9) (Figure 6).

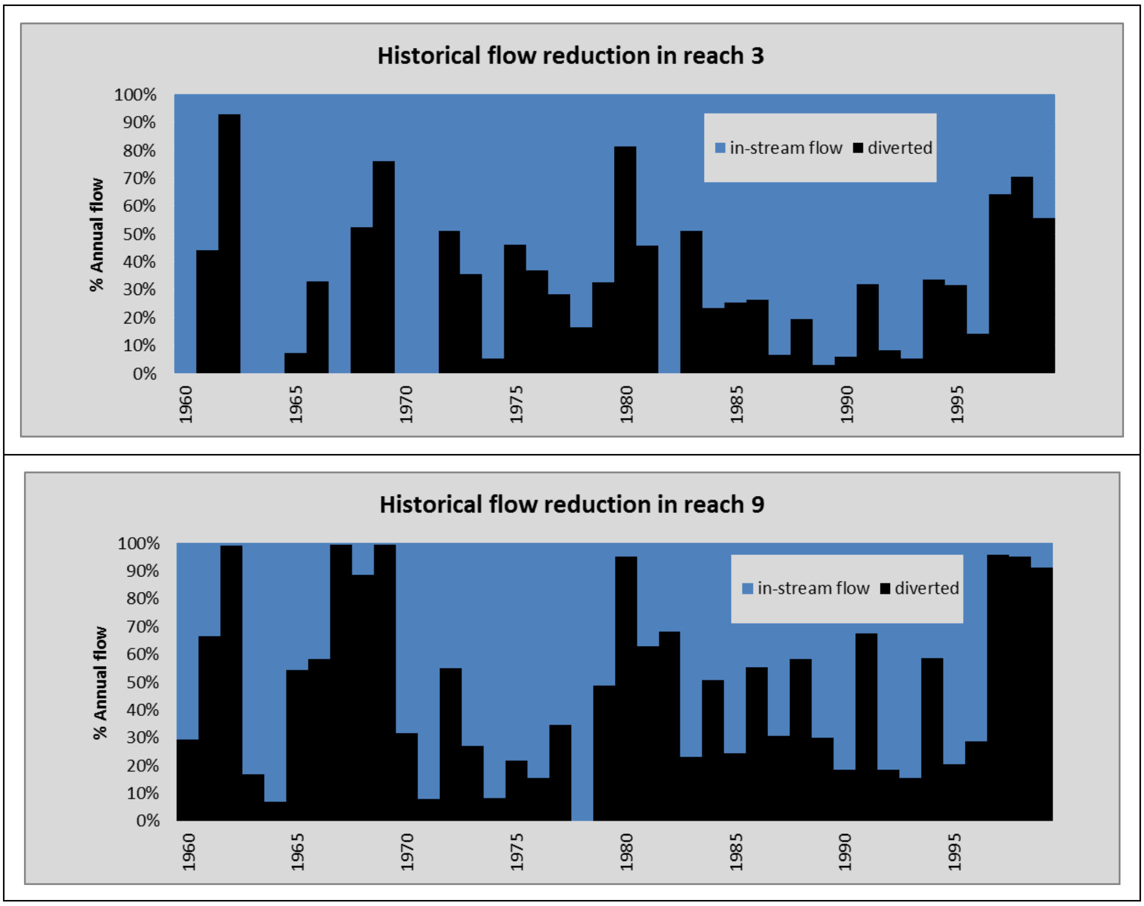

Figure 6: Percentage reductions in mean annual flow of the Werribee River downstream of diversion weirs

As seen in Figure 7, downstream of irrigation supply reservoirs at Pykes Creek (Reach 5) and Melton (Reach 8), some of the water captured in winter is subsequently released in summer, reducing the impact of the reservoir on mean annual flow, although significantly altering seasonality (see next section).

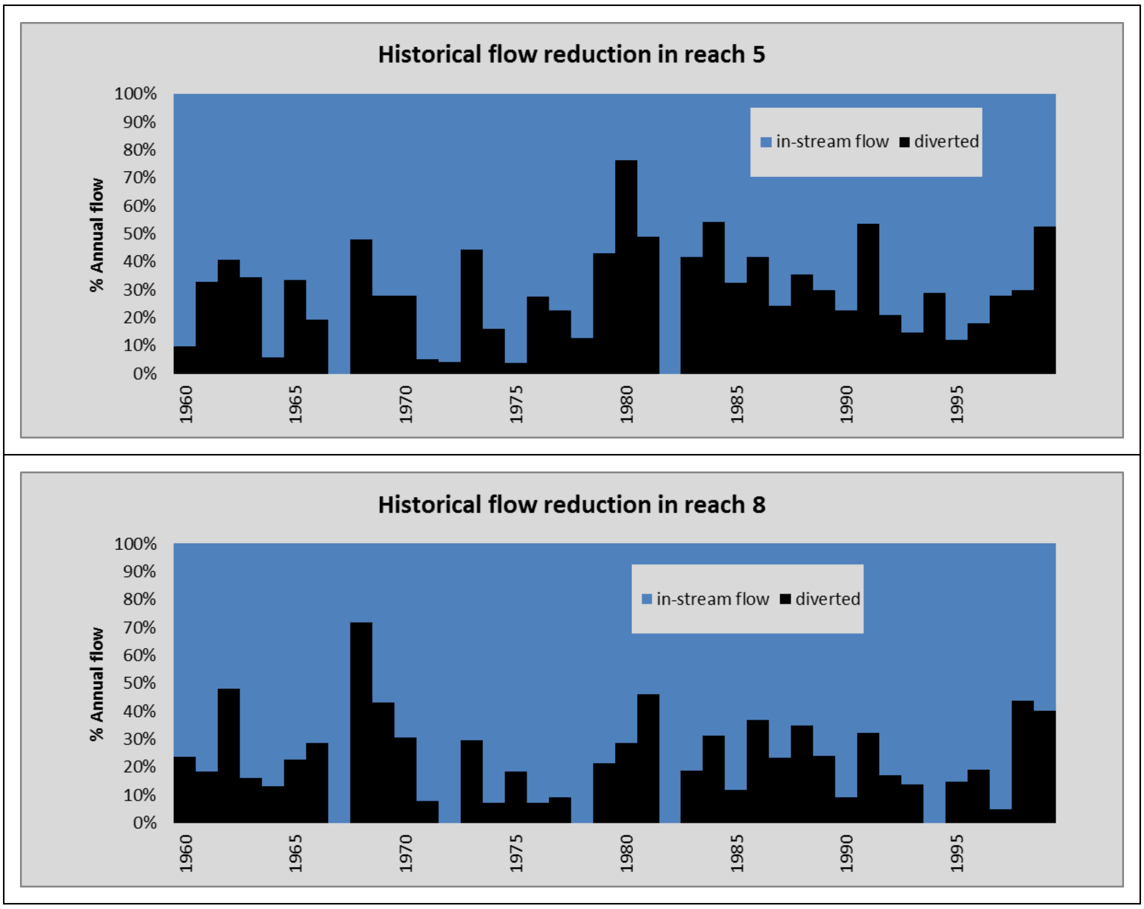

Figure 7: Percentage reduction in mean annual flow of the Werribee River downstream of irrigation supply reservoirs

Changes in Median Flows

Werribee River

Median flow gives a good representation of flows that occur often in a system (i.e. they are exceeded 50% of the time). Comparing gauged flow data against modelled natural flows, median daily flows for reaches along the river were assessed during the preparation of the 2005 environmental flow study. The assessment showed there have been significant impacts of regulation in the system. For example, downstream of Upper Werribee Diversion Weir in Reach 3 (Figure 8), diversions to Pykes Creek Reservoir have reduced median flows, and diversions from Bacchus Marsh Weir (Reach 5) have also reduced median flows downstream (Figure 9).

Melton Reservoir is operated to direct water downstream to Werribee Diversion Weir for diversion to Werribee Irrigation District, and the effect has been to increase median flows downstream of the Reservoir (Reach 8) during the irrigation season, and has also significantly reduced median daily flows during the winter fill period (Figure 10).

When looking at Reach 9, a high level of reservoir storage relative to annual flow means that the only flow in the lower reaches in drier than average years is regulated deliveries and passing flows (Figure 11). Flows in this reach, particularly during the wetter months, are now significantly less than what would have occurred naturally.

Median flows in Coimadai Creek and Djerriwarrh Creek were naturally zero (or close to zero), so regulation has not impacted this index in these tributaries (Ecological Associates 2005a).

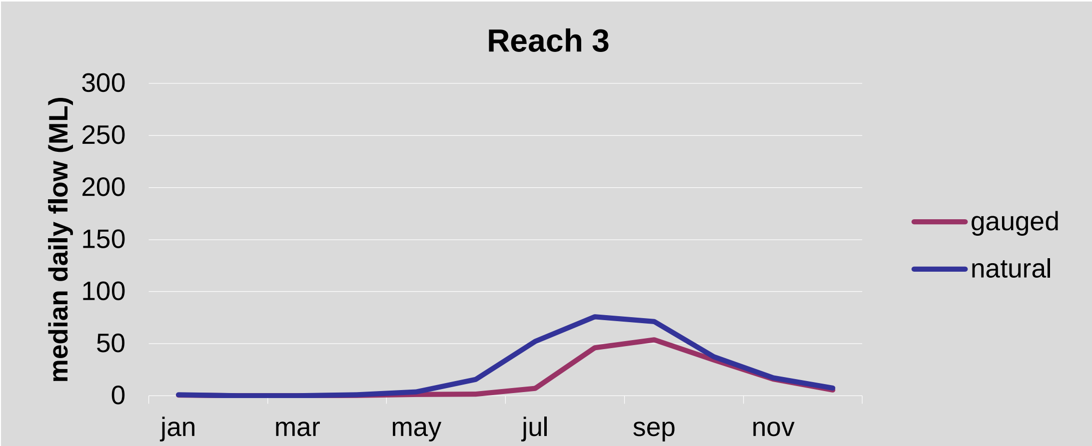

Figure 8: Median daily flows – Reach 3 (downstream of the Upper Werribee Diversion Weir)

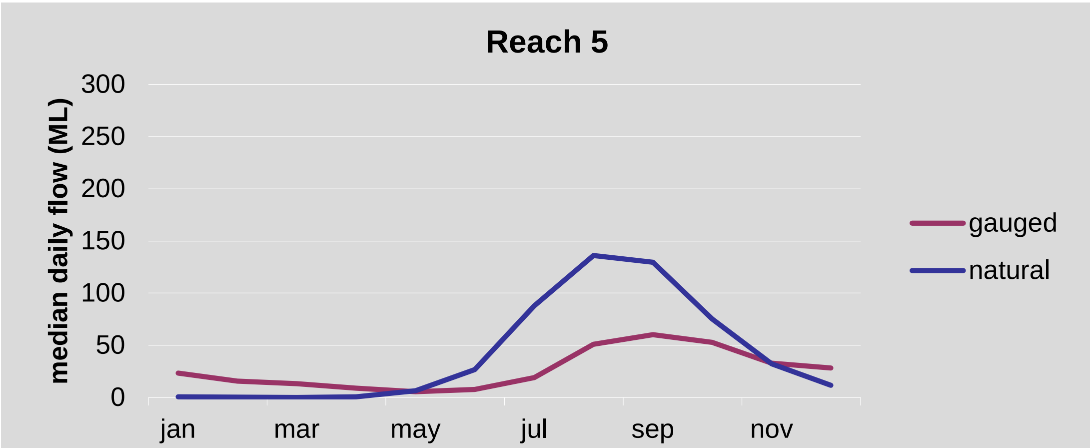

Figure 9: Median daily flows – Reach 5 (Werribee River from the Bacchus Marsh Weir to the confluence with Parwan Creek)

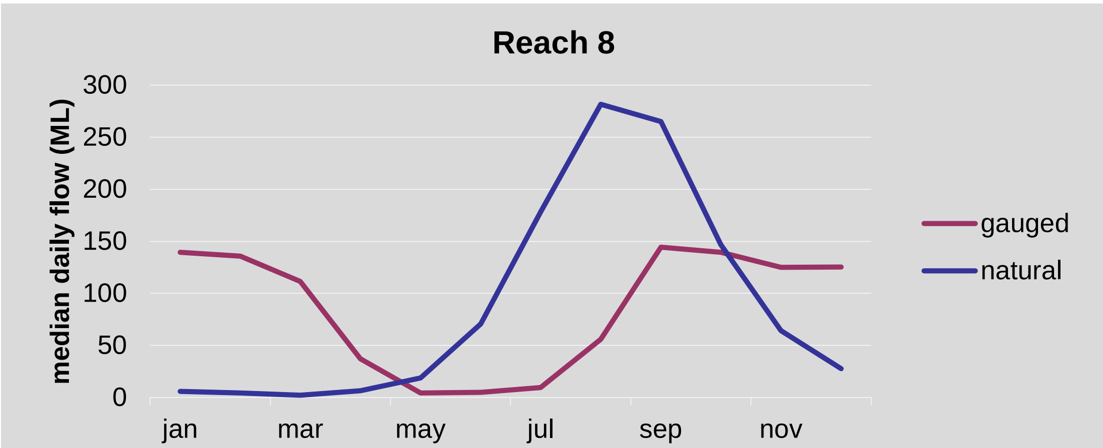

Figure 10: Median daily flows – Reach 8 (Werribee River below Melton Reservoir)

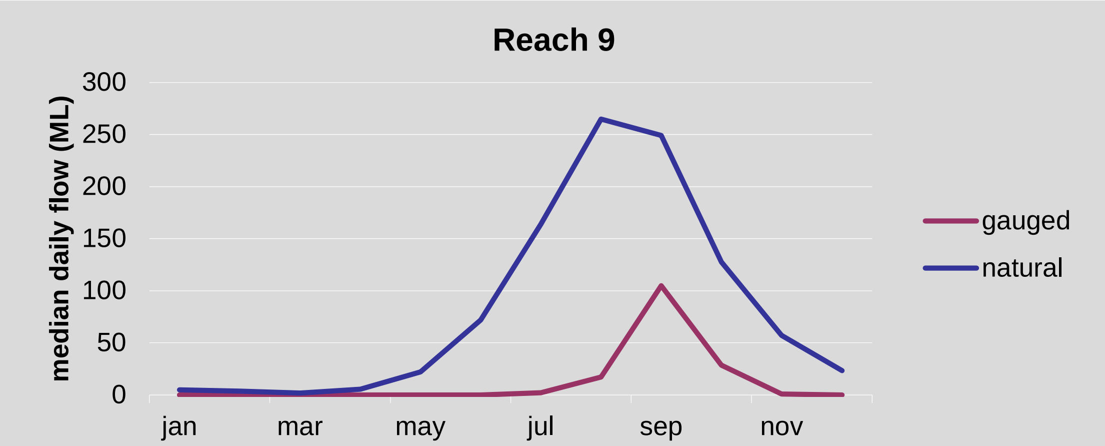

Figure 11: Median daily flows – Reach 9 (Werribee Diversion Weir to the Estuary limit)

Lerderderg River

When looking at the Lerderderg River, median flow assessments were conducted for the 2002 environmental flows study (LREFTP 2002). Modelling results for three of the river's reaches found that:

- At Reach 3 (Lerderderg River downstream of Lerderderg Weir), median flows are largely unchanged between October and June, but show reductions between July and September
- At Reach 5 (Goodman Creek downstream of Goodman Weir), there was little change in the median flow at any time of the year
- At Reach 7 (Lerderderg River from Darley to Bacchus Marsh), there was little or no change to the median flow in October to June, but reductions between July and September.

Changes to the seasonal distribution of flows

Regulation has also changed the seasonality of the flow regime in the Werribee River. The 2005 environmental flow study found that at Reach 3, regulation has decreased the median flows for each month, particularly between June and September, typically the wettest months of the year. At Bacchus Marsh and Werribee the study found the natural seasonal pattern of winter-spring dominance is retained, but median flows are much reduced. Median flow at these reaches in summer and early autumn (January to April) however, is now higher than it would be under natural conditions. The flow study found that the Werribee River downstream of Toolern Creek (Reach 8) is different to other reaches in that regulation has caused a marked seasonal reversal of median flows, reflecting releases from Melton Reservoir during the summer months for irrigation demand.

Pykes Creek under the current regime also shows a seasonal flow reversal typical of the creek being used to transfer irrigation water downstream (Ecological Associates 2005b).

Estuary Hydrology

Estuary hydrology is highly dynamic, and is best characterised by describing how freshwater flows change water levels and the location and amount of salinity stratification within the estuary (the salt wedge). This is because water levels and salinity levels in an estuary vary with freshwater inflow discharge as well as tidal fluctuations. (Sherwood et al. (2005) in Lloyd et al. (2008)) measured salinity profiles at six locations along the Werribee estuary at monthly intervals between August 2004 and May 2005. Based on these observations:

- The estuary has a strong marine (Port Phillip Bay) influence in the lower estuary (< 3.6 km upstream).

- A shallow (< 1 m) freshwater lens is common in the upper estuary and the maximum observed downstream extent of the freshwater lens is approximately 2.8 km downstream of the ford
- The estuary is highly stratified in its upper reaches with salinity increasing as water depth increases
- Water of intermediate salinity levels is generally confined to the middle section of the estuary (approximately 4-6 km) (Sherwood et al (2005) in Lloyd et al. (2008)).

For the Werribee estuary flows study, Lloyd et al. (2008) assessed the absolute length over which estuarine conditions are found, and determined the percentage of the estuary that this represents. Results of the assessment found that moderate freshwater inflow discharges (20 – 50 ML/day) maximised the length over which estuarine conditions prevail for the Werribee estuary. Table 7 shows the predicted length along the river that estuarine conditions can be found (expressed as a percentage of the total estuary length of 8,250 m).

Table 7: Predicted length along the river that estuarine conditions were found. Estuarine conditions are defined as: 5 > salinity > 30; somewhere in the vertical profile (Source: Lloyd Environmental, 2008)

	Predicted Estuarine Length (m)	
Inflow Discharge	**Ebb**	**Flood**
1 ML/day	3,000m (36%)	2,000m (24%)
20 ML/day	6,750m(82%)	6,250m (76%)
50 ML/day	6,250m (76%)	6,500m (79%)
100 ML/day	5,500m (67%)	5,500m (67%)

Note that at 100 ML/day, a strong freshwater surface flow is present, which traps salt water on the bottom layer of the estuary for extended periods. This trapping would likely decrease at flows greater than 100 ML/day as the freshwater layer thickens and flushes salt from the estuary entirely (Lloyd et al. 2008).

The impact of regulation is apparent for low flows and high flows reaching the estuary (Figure 12), with fewer of these flow components reaching the estuary in current conditions than when compared to natural conditions.

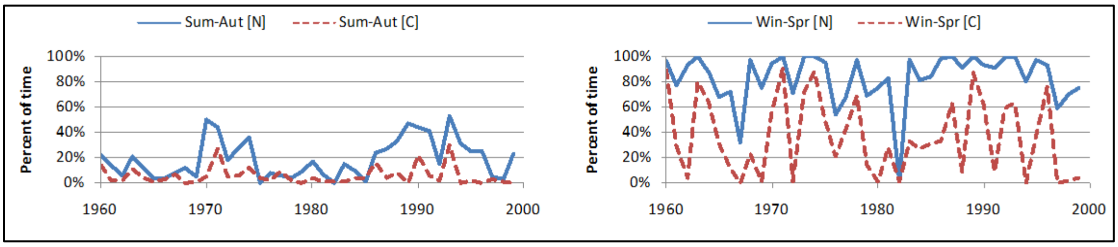

Figure 12: Hydrological distribution of hydraulically determined potential low flow and high flow components reaching the estuary in summer-autumn, and winter-spring. [N] is natural conditions and [C] is current flow conditions. (Source: Lloyd et al. 2008)

High flow freshes have also reduced since regulation. The impact of regulation on the duration and frequency of these components is significant, with fewer events occurring, and the duration of them reduced between the typically wetter months of July to October (Figure 13).

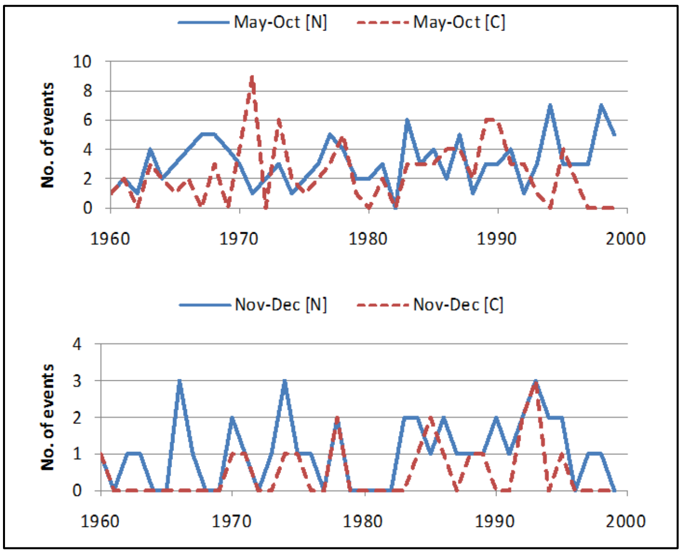

Figure 13: Hydrological distribution of high flow freshes. [N] is REALM natural series and [C] is REALM current series (Source: Lloyd et al. 2008)

Flood magnitudes of 6,000 ML/d are thought to fill the deeper holes and inundate the flatter bank areas of the estuary (equivalent to morphological bankfull), while flood magnitudes of 10,000 ML/d are thought to inundate approximately 50% of the estuary's floodplain area. Both of these flood events have been impacted since regulation (Figure 14), with a reduction in flood frequency occurring (Lloyd et al. 2008).

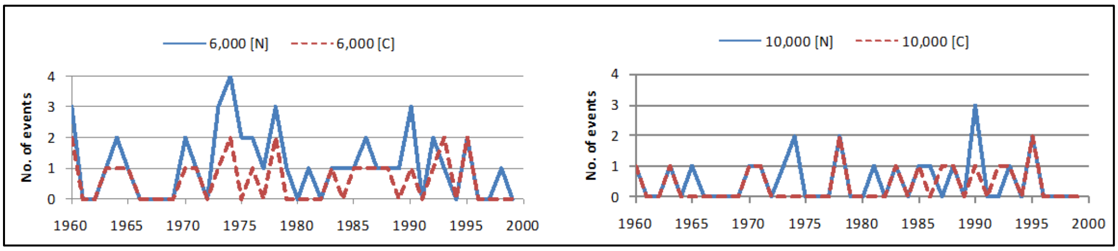

Figure 14: Hydrological distribution of overbank events. [N] is REALM natural series and [C] is REALM current series (Source: Lloyd et al. 2008)

Groundwater / surface water interactions

The groundwater resources of the Werribee catchment within the West Port Phillip Bay groundwater catchment area are shown in

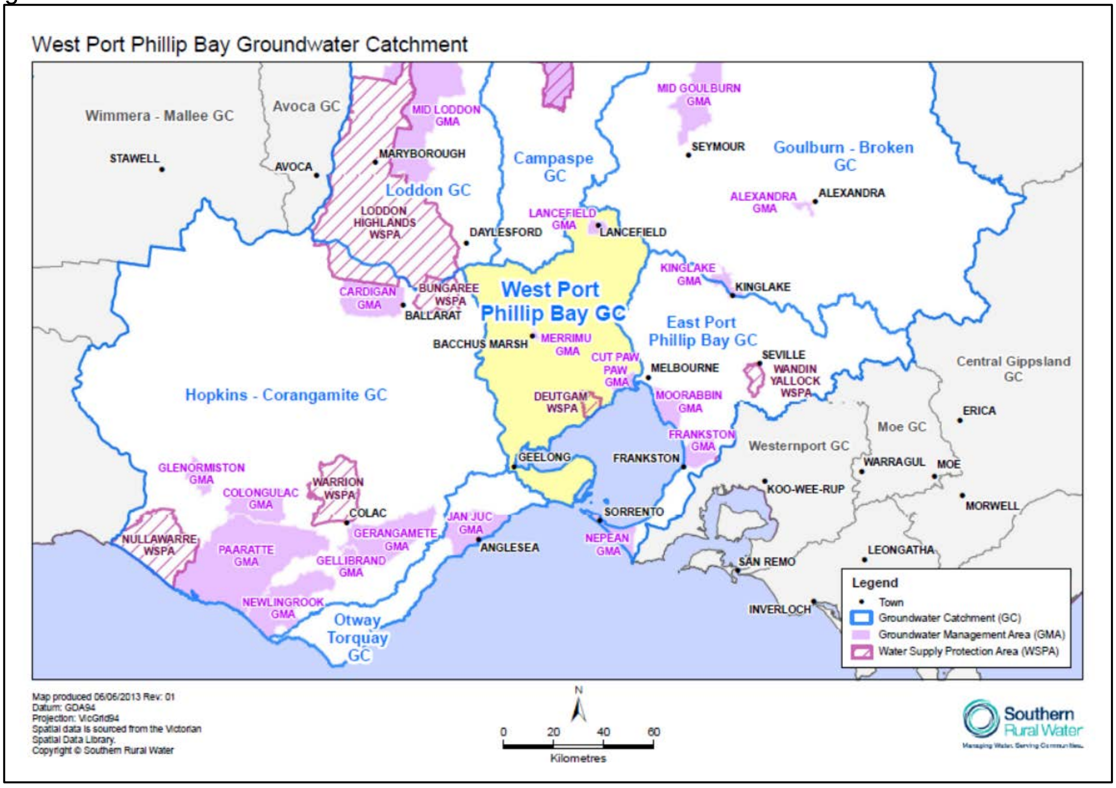

Figure 15). The relative importance of groundwater and surface water inputs is poorly understood for the majority of the Port Phillip and Westernport region, however it is considered likely that groundwater discharge may represent a significant component of the water balance at many locations.

The upland areas of the Port Phillip Basin, where the headwaters of the Werribee River are located, are dominated by bedrock outcropping to the surface. Rainfall in these areas is usually high, but the low permeability of the bedrock, significant depths to aquifers, and dense vegetation cover probably results in a low recharge to the underlying groundwater, and there is believed to be minimal groundwater/surface water interactions in this region (GHD 2010). No direct linkage between ecosystems, species and groundwater has yet been identified for the Werribee River, but groundwater flow dynamics indicate that in the lower reaches of the river, a component of the water budget is groundwater, with discharge to the river providing a freshwater baseflow (Jacobs 2014).

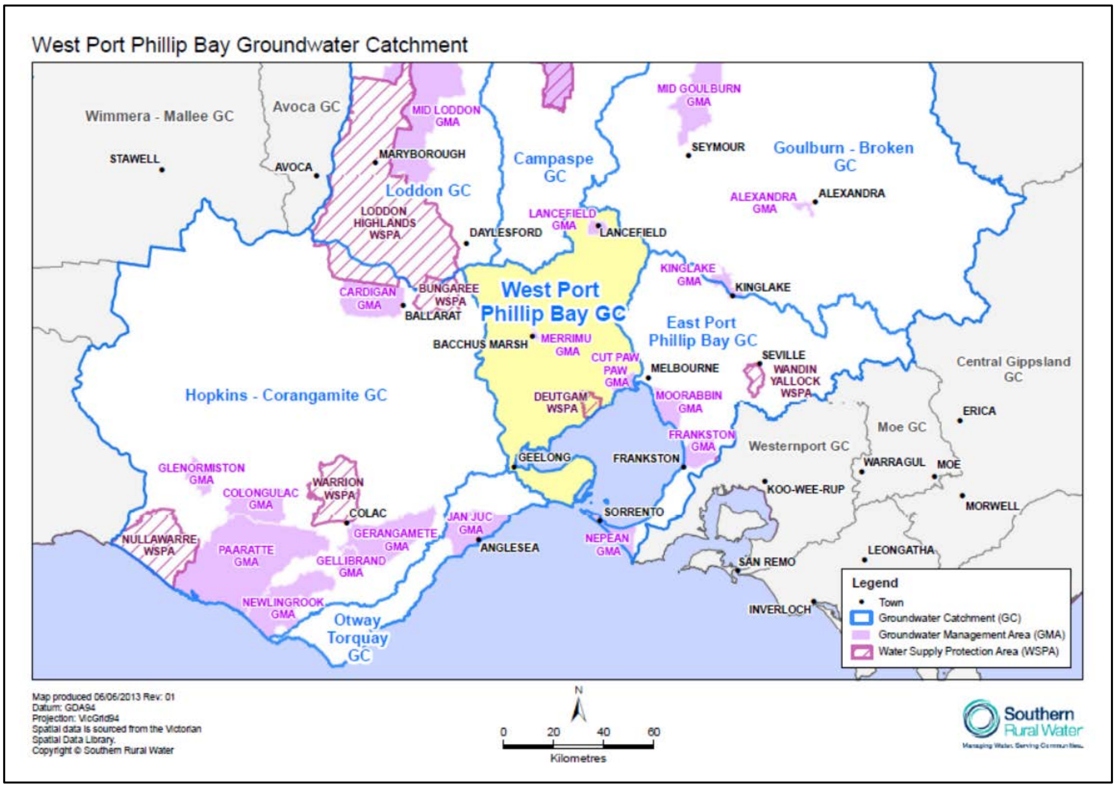

Figure 15: West Port Phillip Bay Groundwater Catchment (Source: Adapted from SRW 2013)

A number of areas within the Werribee catchment have been assessed to better understand their groundwater/surface water interactions. These are the Werribee Irrigation District and the Werribee estuary. Both of these areas are connected to the Werribee Delta, the main aquifer system below the lower reaches of the Werribee River. The groundwater gradient in the Werribee Delta aquifer means that water generally travels to the south towards Port Phillip Bay, however in some areas groundwater also flows upwards, discharging into the Werribee River (Jacobs 2014).

Local groundwater also flows within the estuarine sediments adjacent to the Werribee estuary, with localised discharge to the estuary during wet periods. It is likely that this groundwater contributes to both the baseflow of the lower Werribee River (gaining) and the Werribee estuary. Groundwater is also likely to support a number of permanent pools in Reach 9 in the vicinity of Werribee Zoo. The freshwater spring at the downstream end of Bungey's Hole is probably an example of such flow (Jacobs 2014).

It is thought that reduced groundwater contributions to the Werribee Estuary due to groundwater extraction can cause the salt-water wedge to move further upstream, potentially allowing salt water to extend into the downstream end of Reach 9, where it may influence aquatic and riparian vegetation and aquatic fauna.

A change in groundwater flow and flux within the Werribee Estuary is also thought to cause saline water to enter and contaminate the underlying aquifer (Jacobs 2014). Associated changes in water quality may lead to temporary or permanent loss of individual species that rely on the groundwater or the loss of some groundwater dependent ecosystems (Jacobs 2014).

Figure 16 shows where groundwater/surface water interactions are thought to occur near the Werribee River. It is estimated that about 1 to 50 mm of the Werribee River's baseflow each year is provided by groundwater (GHD 2010).

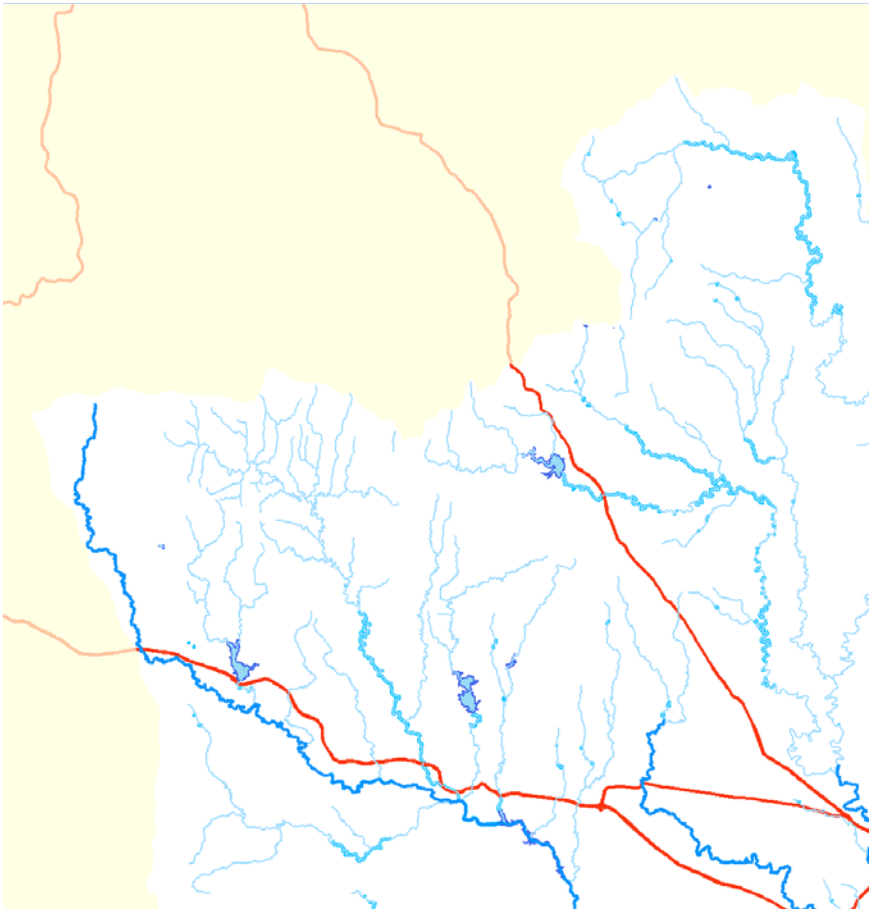

Figure 16: Groundwater contributions to the Werribee River (Source: Adapted from GHD (2010))

Water Management and Delivery

Storage in the Catchment

Management of flow in the Werribee River is achieved through the operation of a number of water reservoirs in the catchment - Pykes Creek, Lake Merrimu, Melton and Djerriwarrh. Of these, Pykes Creek, Lake Merrimu and Melton are the major storages in the Werribee catchment and their combined capacity is approximately 69,000 ML (Melton reservoir 14,400 ML, Pykes Creek reservoir 22,100 ML, Merrimu reservoir 32,500 ML). In addition, water is diverted to Lake Merrimu from Lerderderg Weir. The storages are used to support the irrigation areas and to supply domestic and industrial water consumers. The system also has three main weirs on the Werribee River – Upper Werribee Diversion Weir, Bacchus Marsh Weir and Werribee Diversion Weir, with a connected system of diversion tunnels and pipelines. Please refer back to Figure 4 for a schematic of the Werribee water supply system.

Merrimu Reservoir

Merrimu Reservoir, on Pyrites Creek, forms the largest water storage in the Werribee catchment. Constructed in 1970 and managed by SRW, the reservoir provides storage for the

Werribee Irrigation District and also supplies water for the towns of Melton, Bacchus Marsh, Rockbank, and Toolern Vale. Merrimu Reservoir is operated by SRW under the *Bulk Entitlement (Werribee System – Western Water) Conversion Order 2004.*

Water in Merrimu Reservoir (apart from what flows down Coimadai Creek), mainly comes from the Lerderderg River and Goodman Creek. At the Lerderderg Weir, water is diverted by gravity feed via the Lerderderg Tunnel through the hillside to Goodman Creek where it is released. The capacity of the tunnel is 1,000 ML/d and diversions from the Lerderderg River stop when Merrimu Reservoir is over 95% full. The diversion tunnel does not always operate at full capacity, but captures a variable amount of water when the natural streamflow is above the minimum passing flow. Downstream of the outlet of the Lerderderg Tunnel, water from the Lerderderg River and flows from Goodman Creek are diverted through the Goodman Tunnel to Lake Merrimu. The capacity of this tunnel is 920 ML/d.

Western Water has a bulk entitlement to 60% of the capacity and 70% of the inflows into Merrimu Reservoir. The remaining storage shares are held by Southern Rural Water (10%) and the Environment (10%), or are unallocated.

Lake Merrimu has 2 outlets, which are regulated manually:

- A main valve with a capacity of 550 ML/d. The value has a minimum opening 10% which is approximately 100 ML/d; and
- A riparian valve with a capacity of 25 ML/d – This is constrained due to concrete lined pipe velocities of 6m/s.

Melton Reservoir

Melton Reservoir is located on the Werribee River approximately 6kms south of Melton. It is operated by SRW under the *Bulk Entitlement (Werribee system – Irrigation) Conversion Order 1997* and is the main regulation storage for the Werribee Irrigation District. Water in the reservoir comes from the Wombat and Lerderderg Forests, Parwan Creek, the Werribee and Lerderderg rivers, as well as Pykes Creek and Merrimu reservoirs. Water is delivered downstream and diverted from the Werribee Diversion Weir to irrigate the market gardening area. The Reservoir has 2 outlets:

- A small riparian valve which passes 9 ML/day (up to 12 ML/day at Full Supply Level) and;
- A main conduit, which passes 70-270 ML/day.

Even though the main conduit valve on Melton Reservoir has a minimum capacity of 70 ML/day, SRW is able to run the valve for part of the day to supply smaller, pulsed releases of banked environmental water (e.g. 20 ML/day) (Melbourne Water 2014).

Pykes Creek Reservoir

Pykes Creek Reservoir is located on Pykes Creek, and is 72 km west of Melbourne on the Western Highway. Constructed between 1908 and 1911, the reservoir provides water for use within the Bacchus Marsh and Werribee Irrigation Districts. It also supplies a small amount of drinking water to the township of Myrniong and is a popular location for recreation. Dale Creek flows into the reservoir at the northeast corner. Supplementing the flows into the reservoir` are flows from the upper Werribee River, which are piped through a tunnel from a diversion weir on the Werribee River downstream of Ballan, into Myers Creek and then into the southwest corner of the reservoir. Flows from the reservoir are released to Pykes Creek downstream and then to the Werribee River during the November to April irrigation period. The maximum irrigation flow is 150 ML/d.

SRW harvests all flows into the reservoir other than that provided for passing flows.

Djerriwarrh Reservoir

Djerriwarrh Reservoir is located on Djerriwarrh Creek and supplies water for Melton. The allocation is 980 ML/yr, but this is not necessarily fully utilised (Ecological Associates, 2005). The reservoir captures most of the inflows of Djerriwarrh Creek and is managed by Western Water. Western Water's entitlement (*Bulk Entitlement (Werribee System - Western Water) Conversion Order 2004*), requires a minimum passing flow downstream of Djerriwarrh Reservoir of 1.5 ML/day or the natural flow at that point, whichever is the lesser flow rate.

Diversion Weirs

Upper Werribee Diversion Weir

The Upper Werribee Diversion Weir diverts water from the Werribee River, through Werribee tunnel, and then on to Pykes Creek Reservoir. The effective capacity of the offtake is 310 ML/d, but the volume actually diverted at any time depends on stream flow and demands. All floods larger than the diversion capacity overtop the weir, and smaller floods overtop the weir when diversions are not at full capacity. The weir has a low-flow bypass, which allows a minimum 5 ML/d flow down the main stem of the Werribee River before diversions to Pykes Creek Reservoir commence (Ecological Associates, 2005).

Bacchus Marsh Weir

Bacchus Marsh Weir diverts water from the Werribee River to the Bacchus Marsh Irrigation District. Floods larger than the capacity of the offtake overtop the weir, and the weir has only a very minor flood mitigation effect. A passing flow is released from the weir at the rate of at least 5 ML/d and the natural flow plus other intermittent flows resulting from deliberate releases (Ecological Associates 2005a).

Werribee Diversion Weir

The function of Werribee Weir is to divert water from the Werribee River to the Werribee Irrigation District. Like the other weirs in the system, floods larger than the capacity of the offtake will overtop the weir, which means that the weir only has a minor flood mitigation effect. The passing flow from the weir is 1 ML/day, averaged over any 30-day period, if the declared seasonal allocation for the Werribee Irrigation District is equal to or less than 130% of water right. Currently the passing flow is released as a 1 ML/d flow, but it has previously been released at 10 ML/d over 3 days (Ecological Associates 2005a).

Environmental Water Releases

The Werribee River Environmental Entitlement was granted in 2011, with an allocation of 3,000 ML in Lake Merrimu. Melbourne Water has been gradually drawing this 'windfall' allocation down for the first few years of managing the entitlement. Prior to granting the Environmental Entitlement, there was no separate entitlement for environmental purposes, with only passing flows specified in bulk entitlements in the catchment. Releases under the Environmental Entitlement began in 2012.

Since commencement of the Environmental Entitlement, rainfall in the Werribee catchment has been at or above average for most of the time but declined rapidly in the last 12 months (Melbourne Water 2015). In 2012, Melton reservoir spilled for the third consecutive year and Lake Merrimu reached restricted full supply level for the first time in over 15 years. 2013 was an average year for rainfall but below average for stream flow meaning neither the Melton nor Merrimu Reservoirs reached full supply level or spilled. Rainfall in 2014 was below average, particulary in spring, and catchment inflows were greatly reduced with an allocation against high reliability water shares of only 70% for the 2014-15 water year.

As the environmental entitlement does not include secure storage space in any reservoir and only allows storage in airspace not being used by other entitlements, there is risk in storing and carrying over a large volume of environmental water because this water is lost if the reservoir spills. For this reason, large volumes of environmental water are generally not able to be carried over from one season to the next.

The priority reaches for delivering flow have been Reach 6 and the estuary, with reaches 9 and 8 being important but of lower priority due to the very large quantity of water required to meet objectives in these reaches (Melbourne Water 2014). Although Reach 6 is a small, intermittently flowing creek, the potential to achieve ecological improvement in this reach is quite high. Reach 9 and the estuary are downstream of the Werribee Diversion Weir, which has limited ability to control passing flows, making it problematic to deliver environmental water. However, the ecological and social values of these reaches are very high, which makes them a priority for delivering environmental water.

Environmental water releases from Melton Reservoir target Reach 9, while water releases from Lake Merrimu target Coimadai Creek (Reach 6), and can also be re-harvested in Melton Reservoir and used for subsequent environmental water releases for the lower Werribee River.

Table 8 and Figure 17 show the priorities for environmental water use and the annual deliveries under the Environmental Entitlement since its inception.

Table 8: Environmental water delivery and priorities for the Werribee Environmental Entitlement

Watering Year	Environmental Water Delivery
2011-12	• Abundant unregulated flows and near-full storages. • Enhance scenario. • No water was delivered.
2012-13	• Enhance scenario to December 2012, Recover scenario to June 2013. • Water delivered to Reach 6 to scour fine sediment and algae, improve macroinvertebrate habitat and inundate fringing habitat for frogs. • Water delivered to the estuary to improve recruitment of Black Bream and allow migration of small-bodied fish downstream. • Water delivered to Reach 9 to improve water quality. • 1300 ML delivered from EE, 850 ML deliverd from water shares.
2013-14	• Recover scenario to May 2014, Maintain scenario to June 2014. • Water delivered to Reach 6 to scour fine sediment and algae and improve macroinvertebrate habitat. • Water delivered to the estuary to improve recruitment of Black Bream. • 460 ML delivered from EE, water shares not available.
2014-15	• Maintain scenario to August 2014, Protect scenario to June 2015. • Water deliverd to Reach 6 to provide macroinvertebrate and frog habitat, scour fine sediment and algae and improve macroinvertebrate habitat, and inundate fringing habitat for frogs • Water delivered to the estuary to improve recruitment of Black Bream and allow migration of small-bodied fish downstream. • Water delivered to Reach 9 to improve water quality. • 210 ML deliverd from EE, 500 ML delivered from water shares

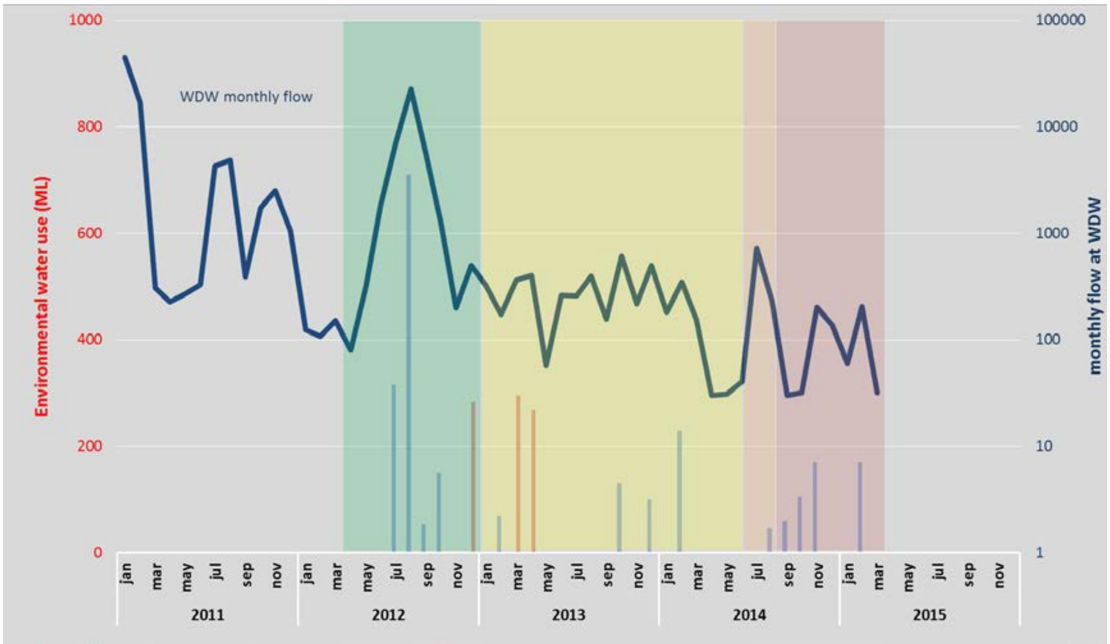

Figure 17: Monthly flow at the Werribee Diversion Weir and environmental deliveries. Climatic scenarios are indicated by coloured regions; Green = Enhance, Yellow = Recover, Orange = Maintain and Red = Protect.

WATER-DEPENDENT VALUES OF THE WERRIBEE RIVER

The Werribee River is highly valued by the community for its biodiversity and ecosystem services, its economic worth, its social and recreational opportunities, and the significant cultural heritage values associated with it. Sometimes maligned in the past because of its lower reaches being located near the Western Treatment Plant, the river now has a passionate collective of interest groups and agencies working to protect and improve its natural values.

The water-dependent values of the Werribee River its tributaries have been identified using a variety of mechanisms by Melbourne Water, including previous flows studies, scientific surveys, and consultation processes guided by Melbourne Water's Healthy Waterways Strategy and the Victorian Waterway Management Strategy.

Werribee River Water-Dependent Values

The water-dependent values for the Werribee River are classified under seven different categories:

- Platypus
- Fish
- Macroinvertebrates
- Frogs
- Birds
- Vegetation
- Amenity (Melbourne Water 2013).

Platypus

An iconic Australian native, the Platypus (*Ornithorhynchus anatinus*), is highly valued by communities. Melbourne Water is committed to protecting and improving habitat quality throughout the greater Melbourne area through the Melbourne Water Urban Platypus Program (MWUPP). Although not listed under legislation, the national conservation status of Platypus has recently been elevated to Near Threatened in the CSIRO's 'Action Plan for Australian Mammals' (Woinarski et al. 2012), in recognition that Platypus numbers have been declining in many areas over the past few decades and the species has already disappeared from some catchments.

Platypus require access to freshwater habitats to forage, and earth banks to dig their burrows, and their ideal habitat includes rivers or streams with earth banks consolidated by the roots of native vegetation, invertebrate food sources, cobbled or gravel substrates, overhanging shady vegetation, and a sequence of pools and riffles (DPIPWE, 2014). However they can also occupy lakes and farm dams, and can be found in some streams moderately degraded by human activities (DPIPWE, 2014). The species remains relatively common throughout most of its original range but due to difficulties in surveying it, it is hard to estimate current numbers living in the wild. Although it is thought that Platypus are present in a high proportion of river systems across Victoria, NSW and Qld, its population abundance is considered extremely low and at risk of disappearing from the Werribee catchment.

Platypus are known to inhabit the Werribee River from as low down as the estuary and upstream to the Werribee River Gorge, and although none have been captured through Melbourne Water's annual platypus surveys, they are also predicted to live further upstream where conditions are appropriate (Jacobs 2014). The lack of surface flow for extended periods along Coimadai and Djerriwarrh Creeks means that these tributaries are unsuited for permanent occupation by the species (cesar 2013).

The ideal foraging habitat for platypuses is pools that are at least 0.5m deep to provide them with cover. They generally prefer slow flowing sections of waterways, choosing submerged backwater habitats during high flow events (Gust & Handasyde, 1995). They also generally need continuous sections of aquatic habitat, to reduce the need to leave the protection of waterways and hence reduce the risk of predation (Serena et al., 2001 in Jacobs (2014)).

Platypus build burrows on steep or undercut banks that are usually at least 1m high with a dense cover of vegetation. Burrow openings are usually at least 0.5m above normal flow levels to reduce the risk of flooding, and breeding females will build their burrows at least 0.5m above the winter high water mark on a waterway to reduce the risk of their young drowning during high spring or summer flows (Serena et al. (2001) in Jacobs (2014).

Key flow requirements for platypus

Key flow-dependent factors for the Platypus include:

- The availability of adequate flows to provide a reliable source of food and cover
- The height of high flow events, which influence the platypus' choice of burrow location.

Fish

The Werribee River and its estuary provide a diverse range of fish habitats. While some of the migratory habitat components of the system have been lost, the system maintains the potential to support a large and diverse community of native fish. The HWS identified fish as a key value of the Werribee River because of their important role in waterways - they are usually near the top of the aquatic food chain - and because they provide food for people and some birds. Fish are also valued for recreational purposes, with the River Blackfish highly prized by the local fishing community for example.

Fish in the Werribee River are generally categorised according to whether they are freshwater or estuarine, and if they are marine or freshwater derived[1]. They are also categorised according to whether they are migratory or non-migratory[2].

Thirteen native freshwater species and seven exotic fish species have been recorded in the freshwater reaches of the Werribee River. Table 9 lists the freshwater fish species recorded in the Werribee River.

Key flow requirements for migratory fish

Migratory fish require a range of different flows for their general lifecycle requirements, and for movement within and between their habitats. Adult Common Galaxias, Tupong and Short-finned Eels live in freshwater and migrate downstream to estuaries or the sea to spawn, while Pouched Lamprey adults live in the sea and migrate upstream into freshwater to spawn. Spotted Galaxias live and spawn in freshwater and the larvae are washed downstream to the sea. Each of these species are highly dependent on different aspects of the flow regime for their lifecycles. For example, the Common Galaxias uses high flow freshes in autumn as a cue to migrate downstream to a waterway's estuary. The species then spawns on vegetation flooded by high water levels around the estuary. The eggs hatch upon being re-inundated, and the larvae migrate or are washed out to sea, returning to fresh water about five to six months later. Migration from the estuary upstream to freshwater by the returning juveniles is also thought to be influenced by flow cues, particularly low and high flow freshes discharging into the estuary (Lloyd et al., 2008).

In other examples:

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[1] Marine derived fish are estuarine dependent species that mostly live in the sea but migrate into the estuary to breed or recruit, while freshwater derived fish mostly live in freshwater, and migrate downstream to breed in the estuary or sea and then return upstream.

[2] Migratory fish have life stages in both freshwater, estuarine and/or marine environments, and non-migratory species spend their entire lifecycle in freshwater.

- Female Tupong migrate downstream to their estuarine or marine spawning grounds during high flows in late autumn and early winter. Without these cues, breeding can be severely interrupted.
- Pouched Lampreys, who migrate upstream to spawn during spring and summer, are also reliant on adequate freshes during this period to allow for their movement.
- Climbing Galaxias require a rise in water level to stimulate spawning. The fish lays eggs along the edges of the streams where they require a second high flow to cover the exposed eggs before they can hatch. If the second rise in water is not received the eggs will remain exposed and will not hatch.

Migratory fish species in the Werribee River also require enough flow depth within the waterway to facilitate their movement through and/or over natural and artificial barriers, such as riffles, rock bars and small weirs. They also require appropriate flow velocity variability; to ensure fast flowing sections of the river are interspersed with sections of slower flows, so they can rest as they migrate upstream. There is not enough scientific evidence yet to absolutely determine the minimum water depth and flow conditions needed by fish to assist their movement upstream in the Werribee River. Because of this uncertainty, the minimum depth of flow required for migratory fish in the Werribee River is conservatively based on assessments of waterway riffle morphology and the minimum depth required for each species based on their body size. This has been estimated at 0.1m for the Werribee River in the environmental flow studies conducted so far for the system (Jacobs, 2014).

Key flow requirements for non-migratory fish

Non-migratory fish are dependent on flows for the provision of habitat, food, breeding opportunities, and protection from predators. Flow may also provide cues for spawning for these species. For example the River Blackfish is highly reliant on flows for the provision of appropriate habitat and breeding opportunities. Although the species can be found in both slower and faster flowing waters, it prefers to stay in low-velocity, highly sheltered pools (Jacobs, 2014). River Blackfish rely on flows and freshes to inundate instream hard surfaces such as hollow logs to lay their eggs. High flows are risky for the reproductive success of the species as they can scour away eggs and wash larvae away.

As another example, the Southern Pygmy Perch is a relatively weak swimmer, and favours still or slow flowing habitats. It cannot disperse very far or very quickly, and as such is reliant on flows to maintain its habitat from year to year (Jacobs, 2014). It is also reliant on flows to make sure that water quality within its habitat is optimal (Jacobs, 2014).

Table 9: Freshwater fish species in the Werribee River

Common Name	Scientific Name	FFG Listed	DSE 2007 Advisory List	EPBC Listed	Recreation Value *C = Consumption* *B = Bait*	Culturally Significant Species
Migratory Species						
Short-finned Eel	*Anguilla australis**				C	✓
Common Galaxias	*Galaxias maculatus*				B	
Climbing Galaxias	*Galaxias brevipinnis**				B	
Tupong	*Pseudaphritis* urvillii**				C	
Short-headed Lamprey	*Mordacia mordax***					
Pouched Lamprey	*Geotria australis***					
Spotted Galaxias	*Galaxias truttaceus*					
Non-Migratory Species						
River Blackfish	*Gadopsis marmaratus*				C	✓
Mountain Galaxias	*Galaxias olidus*					
Southern Pygmy Perch	*Nannoperca australis*					
Flat Headed Gudgeon	*Philypnodon grandiceps*				B	
Australian Smelt	*Retropinna semoni*					
Introduced / Exotic Species						
Goldfish	*Carassius auratus*					
Carp	*Cyprinus carpio*					
Eastern Gambusia	*Gambusia holbrooki*					
Redfin	*Perca fluviatilis*					
Roach	*Rutilis rutilis*					

Common Name	**Scientific Name**	**FFG Listed**	**DSE 2007 Advisory List**	**EPBC Listed**	**Recreation Value** *C = Consumption* *B = Bait*	**Culturally Significant Species**
Brown Trout	*Salmo trutta*					
Tench	*Tinca tinca*					
Chinook Salmon	*Oncorhynchus tsawytscha*					
Macquarie Perch#	Macquaria australasica	Endangered	Endangered		C	

Notes:

- Migratory species marked with a '*' are freshwater derived, while species marked with '**' are marine derived
- The Short-headed Lamprey is only known from three fish recorded in 1995, while the Pouched Lamprey from one fish recorded in 1992 and two in 1995 (McGuckin 2006).
- #The Macquarie Perch is the only listed threatened fish species. It has been introduced outside of its natural range and as such is regarded as an introduced species
- Although no threatened freshwater fish species have been recorded in the Werribee River for a long period of time, two native species - River Blackfish and the Southern Pygmy Perch - are considered of regional significance (McGuckin 2010).

Estuarine species

The fish within the Werribee estuary can be divided into three groups according to their biology and distribution:

- Estuarine Residents - These specialised fish use the abundant resources of the estuary and complete their entire life cycle in the estuary complex
- Estuarine Dependent - Fish species that are dependent upon the estuary for spawning, as a nursery ground for their young, for shelter and/or for feeding
- Estuarine Opportunists – Fish species that live primarily in either marine or freshwater environments but which opportunistically exploit the resources of the estuary. (Lloyd et al., 2008).

A total of sixty-four species have been previously recorded within the Werribee estuary. While there are no locally native species of conservation value in the estuary, there are many species that are important either as a recreational or commercial fisheries species. A number of these fish species are either exotic or are not native to the catchment.

Table 10 lists the fish species recorded in the Werribee estuary. The species are grouped according to how they use the estuary.

Key flow requirements for estuary fish

The three types of estuary fish species in the Werribee estuary; estuarine residents, estuarine opportunists, or estuarine dependent, are either highly reliant on freshwater flows for aspects of their life cycle, and benefit from freshwater flows for shelter, growth and condition, or their persistence within the estuary is influenced by its salinity levels, which are modified by freshwater inflows.

For example Black Bream, an estuarine resident species, relies on freshwater flows to provide appropriate habitat as well as reproduction opportunities. This species will generally avoid low salinity conditions, and high flow events that reduce the salinity in the system may force it to retreat downstream until the flows subside (Lloyd et al., 2008). The salt wedge within the Werribee estuary is also likely to provide critical habitat for spawning and for encouraging recruitment success, with Black Bream preferring water between 15 and 30 g/L for spawning (Koster et. al, 2013).

Freshwater flow is also crucial in establishing the most suitable salinities and salt wedge dynamics for successful reproduction. The movement of the salt wedge up and down the Werribee estuary is likely to be critical in shaping the recruitment success for Black Bream as its eggs develop and hatch only within a particularly narrow range of salinities. As a consequence, the flow of freshwater into the estuary is important for both establishing salinities and influencing the salt wedge dynamics required for successful reproduction (Lloyd et al., 2008).

Table 10: Estuarine fish species

Common Name	Scientific Name	FFG Listed	DSE 2007 Advisory List	EPBC Listed	Values	Culturally Significant Species
Estuarine Residents						
Black Bream	*Acanthopagrus butcheri*				C, R	✓
Blue Spot Goby	*Pseudogobius sp.*					
Estuary Perch	*Macquaria colonorum*				C, R	✓
Glass Goby	*Gobiopterus semivestitus*					
Lagoon Goby	*Tasmanogobius lasti*					
Tamar Goby	*Afurcagobius tamarensis*					
Estuarine Dependent – Marine Derived						
Congolli (Tupong) (CR)	*Pseudapritis urvillii*				C, R	
Elongate Hardyhead	*Atherinosoma elongata*					✓
King George Whiting	*Sillaginodes punctata*				C, R	
Mulloway	*Argyrosomus japonicus*				C, R	
Pouched Lamprey	*Geotria australis*					
Short-headed Lamprey	*Mordacia mordax*					
Small-mouthed Hardyhead	*Atherinosoma microstoma*				B	
Estuarine Dependent – Freshwater Derived						
Common Jollytail	*Galaxias maculatus*					
Short-finned Eel	*Anguilla australis*				C, R	
Estuarine Opportunists – Marine Derived						

Common Name	Scientific Name	FFG Listed	DSE 2007 Advisory List	EPBC Listed	Values	Culturally Significant Species
Australian Anchovy	*Engraulis australis*				C, B	
Australian Herring (Tommy Rough)	*Arripis georgianus*				C, R	
Australian Salmon	*Arripis trutta*				C, R	✓
Blue Sprat	*Spratelloides robustus*				C, R	
Bridled Goby	*Arenigobius bifrenatus*					
Estuary Cobbler	*Cnidoglanis macrocephalus*					
Yank Flathead	*Platycephalus speculator*				C, R	
Greenback Flounder	*Rhombosolea tapirina*				C, R	
Half Bridled Goby	*Arenigobius frenatus*					
Little Rock Whiting	*Neoodax balteatus*					
Longfin Goby	*Favonigobius lateralis*				C, R	
Longsnout Flounder	*Ammotretis rostratus*					
Luderick	*Girella tricuspidata*				C, R	
Pike-head Hardyhead	*Kestratherina esox*					
Pilchard	*Sardinops neopilchardus*				C	
Prickly Toadfish	*Contusus brevicaudatus*					
Pygmy Leatherjacket	*Brachaluteres jacksonianus*					
Sandy Sprat	*Hyperlophus vittatus*				C, B	
Sea Mullet	*Mugil cephalus*				C, R	

Common Name	Scientific Name	FFG Listed	DSE 2007 Advisory List	EPBC Listed	Values	Culturally Significant Species
Silver Trevally	*Pseudocaranx dentex*				C, R	✓
Silver Fish	*Leptatherina presbyteroides*					
Six-spine Leatherjacket	*Meuschenia freycineti*				C, R	
Smooth Toadfish	*Tetractenos glaber*					
Snapper	*Chrysophrys auratus*				C, R	
Southern Fiddler Ray	*Trygonorrhina guanerius*				C, R	
Globefish	*Diodon nicthemerus*					
Spotted Pipefish	*Stigmatopora argus*					
Western Australian Salmon	*Arripis truttaceus*				C, R	✓
White Trevally	*Pseudocaranx georginanus*				C, R	
Wide-body Pipefish	*Stigmatopora nigra*					
Yellow-Eyed Mullet	*Aldrichetta forsteri*				C, R	
Yellowfin Goby*	*Acanthogobius flavimanus*					
Estuarine Opportunists – Freshwater Derived						
Australian Smelt	*Retropinna sp*					
Big-Headed Gudgeon / Flathead Gudgeon	*Philypnodon grandiceps*					
Brown Trout*	*Salmo trutta*					
Chinook Salmon*	*Oncorhynchus tsawytscha*					
Common Carp*	*Cyprinus carpio*					
Eastern Gambusia*	*Gambusia holbrooki*					

Common Name	Scientific Name	FFG Listed	DSE 2007 Advisory List	EPBC Listed	Values	Culturally Significant Species
Goldfish*	*Carassius auratus*					
Macquarie Perch#	Macquaria australasica	Endangered	Endangered			
Mountain Galaxias	*Galaxias olidus*					
Redfin Perch*	*Perca fluviatilis*					
Roach*	*Rutilis rutilis*					
Tench*	*Tinca tinca*					

Notes:

- For the Values column, C = Consumption/Commercial, B = Bait and R = Recreation
- # The Macquarie Perch is the only listed threatened fish species. It has been introduced outside of its natural range and is consequently regarded as an introduced species.

Aquatic Macroinvertebrates

Aquatic macroinvertebrates are a diverse group of animals found in river channels. The group includes insects (e.g. Mayflies, Caddisflies, and Beetles), Crustacea (Yabbies and Amphipods), aquatic snails, and aquatic worms. Macroinvertebrates form an important component of the Werribee River ecosystem, because they contribute to biodiversity, and they are a vital component of the food chain as they are a major component of the diets of platypus, fish and frogs.

Flow is a major determinant of the abundance and composition of macroinvertebrate fauna and many Australian aquatic macroinvertebrates have flexible life history patterns that are thought to be a direct response to highly variable and unpredictable flow regimes. For example, physical disturbance from floods (and droughts) is thought to be a major determinant of the spatial and temporal dynamics of macroinvertebrate communities in streams (Bunn & Arthington 2002). Rivers with unstable substrates tend to be characterised by low species diversity, and the communities present will often have the life history or behavioural characteristics of frequently disturbed environments (Bunn & Arthington 2002). Macroinvertebrates are also vulnerable to rapid diurnal changes in flow, with erratic flow patterns typically characterised by species-poor macroinvertebrate communities (Bunn & Arthington 2002).

Available habitat, sources of food, and water quality are also major determinants of the abundance and composition of macroinvertebrate fauna.

Key flow requirements for macroinvertebrates

Key flow-dependent factors that can influence macroinvertebrate condition include:

- The availability of adequate flows for habitat
- Indirect effects on habitat such as water quality, salinity and temperature.

Frogs

Being amphibians, most frog species require surface water for food and breeding habitat during their life cycles. The frogs that are known to occur in the Werribee River catchment include:

1. Those that use permanent pools and other in-stream habitats
2. Those that use off-stream habitats such as wetlands (Jacobs 2014).

Frogs in the first category include the endangered Growling Grass Frog (*Litoria raniformis*), the Pobblebonk Frog (*Limnodynastes dumerilii*), the Striped Marsh Frog (*Limnodynastes peronii*), the Spotted Marsh Frog (*Limnodynastes tasmaniensis*), and the Southern Brown Tree Frog (*Litoria ewingii*) (Jacobs 2014). These species use permanent pools or slow flowing channel habitats with good vegetation to provide cover. They also like to use backwaters and anabranch channels that are filled during high flow events and hold water for long periods of time. Critical to the survival of these species are flows that maintain fringing vegetation and water in these habitats, allowing individuals to move between habitats.

Species in the latter category include the endangered Bibrons Toadlet (*Pseudophryne bibronii*), as well as the Spadefoot Toad (*Neobatrachus sudelli*), and the Common Froglet (*Crinia signifera*). These species typically use off-stream habitats, and are more dependent on catchment rainfall than stream flows for their sources of water (Jacobs 2014).

Key flow requirements for frogs

The key flow-dependent factors that can influence frog species in the catchment include:

- The availability of surface water at the right time of year, as the majority of Victorian frog species mate in water and lay their eggs near, or attached to, fringing vegetation

- The duration that water bodies contain water (hydroperiod). For example, waterways need to hold water for long enough to allow tadpoles to develop and metamorphose into adult frogs
- The timing and velocity of flows. Still or slow flowing conditions can assist tadpoles as high flows and fast moving water occurring at the wrong time can wash tadpoles out of suitable habitat (Jacobs 2014).

Birds

Water-dependent bird species in the Werribee catchment are considered in two sub-sets: streamside birds and wetland birds (Melbourne Water 2013). Some 57 wetland bird species and 113 streamside bird species are expected in the catchment, having been regularly found at water habitats and occurring widely within the Port Phillip and Westernport region (Melbourne Water 2013). The Western Treatment Plant has an international reputation for providing habitat for many endangered and threatened migratory and non-migratory species, including the Brolga (*Grus rubicunda*), which is listed under Victoria's Flora and Fauna Guarantee Act, and the Orange-bellied Parrot (*Neophema chrysogaster*). Orange-bellied Parrots are listed as extremely rare and critically endangered species under the IUCN Red List. Once fairly common in coastal areas, their numbers have declined dramatically, with drainage, competition for food from introduced and native seed-eating birds, and predators such as foxes and cats responsible for a population today of only around 50 wild-living birds (Melbourne Water 2013). The Western Treatment Plant (WTP) and adjacent areas of coastal saltmarsh near the Werribee River estuary are some of the very few places where this species can be seen during winter (Melbourne Water 2013).

The WTP is designated a part of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site because of its values for waterbird habitat and is recognised as being of international importance for waders (based on supporting at least 1% of the flyway population) for species such as the Double-banded Plover (*Charadrius bicinctus*), Eastern Great Egret (*Ardea modesta*), Red-kneed Dotterel (*Erythrogonys cinctu*), Grey Plover (*Pluvialis squatarola*), Banded Stilt (*Cladorhynchus leucocephalus*), and Red-necked Avocet (*Recurvirostra novaehollandiae*).

Other bird species which can be seen in and around the reaches and estuary of the Werribee River include the Wedge-Tailed Eagle (*Aquila audax*), the Great Egret (*Ardea alba*), and the Crimson Rosella (*Platycercus elegans*).

Key flow requirements for birds

Streamside birds and wetland birds are dependent on flows for the provision of habitat, feeding opportunities, nesting locations, and cues for breeding and migration. For example, Egrets are thought to be dependent on a reliable food supply, natural seasonal flows of streams and the availability of suitable wetlands to trigger and sustain their breeding in riparian habitats (DSE 2001). The lack of major flooding in suitable wetlands can lead to abandonment of breeding sites.

The understanding of flow-ecology relationships for water-dependent birds in the Werribee River system is not well understood as there have been very few studies undertaken for these species. It has been assumed however that meeting the flow requirements for other biota, such as vegetation and fish, will also have valuable beneficial effects on the life cycle and habitat requirements of water-dependent birds.

Vegetation

The Werribee River flows through three different bioregions: the Victorian Volcanic Plains; Central Victorian Uplands; and the Otway Plain Bioregion. The Victorian Volcanic Plain is one of the state's largest and also one of the most cleared bioregions, with only 15.6% of native vegetation remaining, and fragmented landscapes dominating. The Otway Plain is also a highly cleared bioregion, with only one-third of the original extent of native vegetation remaining. Around Werribee, native vegetation for this bioregion has been heavily cleared and modified and what remains is associated with the river, particularly the estuary. The Central Victorian Uplands bioregion is a moderately cleared bioregion, with significant patches of remnant native vegetation of high quality and connectivity near the Wombat State Forest, at the headwaters of the Werribee River. Table 11 lists some key Ecological Vegetation Classes (EVCs) for each bioregion and provides their bioregional conservation status.

Table 11: EVCs of the Werribee River (Source: DEPI Biodiversity Interactive Map 2015)

Bioregion	EVC Name	EVC No.	Bioregional Conservation Status
Central Victorian Uplands	Grassy Woodland	175	Endangered
	Plains Grassy Woodland	55	Endangered
	Stream Bank Shrubland	851	Vulnerable
	Rocky Chenopod Woodland	64	Vulnerable
	Escarpment Shrubland	895	Endangered
	Shrubby Dry Forest	21	Least Concern
	Grassy Dry Forest	22	Depleted
	Riparian Woodland	641	Endangered
Victorian Volcanic Plains	Plains Grassy Woodland	125	Endangered
	Floodplain Riparian Woodland	56	Endangered
	Plains Grassland	132	Endangered
	Creekline Grassy Woodland	68	Endangered
	Escarpment Shrubland	895	Endangered
	Red Gum Swamp	292	Endangered
Otway Plains	Coastal Saltmarsh	9	Endangered
	Plains Grassy Woodland	55	Endangered
	Estuarine Wetland	10	Endangered
	Seagrass Meadow*	845	Endangered
	Floodplain Riparian Woodland	56	Endangered

Note:

- * Seagrass Meadow has not been mapped as an EVC in the Port Phillip Region (Lloyd et al. 2008)

Freshwater Vegetation

Vegetation within and along the riparian zones of the Werribee River typically comprises a common set of plant assemblages. These are:

- Aquatic macrophytes found in pools, such as Water Ribbons (*Tryglochin sp.*), Eel Weed (*Vallisneria americana*), and Milfoil (*Myriophyllum sp*.)
- Reeds that are found at the fringes of pools and riffles, such as Common Reed (*Phragmites australis*,) Cumbungi (*Typha sp.*), and Tall Spike-sedge (*Eleocharis sphacelata*)
- Riparian grasses, particularly Common Tussock Grass (*Poa labillardieri*) and Spiny-headed Mat-rush (*Lomandra longifolia*), which are found in a similar environment to reeds, but often extend into the terrestrial zone

- Riparian shrubs, such as River Bottlebrush (*Callistemon sieberi*) and Tea Tree (*Leptospermum sp.)* species but now also includes the exotic Gorse, Blackberry and others
- Riparian trees which naturally included River Red Gum (*Eucalpytus camaldulensis*), Blue Box (*Eucalyptus bauerana*) and Silver Wattle (*Acacia dealbata*), but now often includes the exotic Willow (*Salix sp.)* and Desert Ash (*Fraxinus rotundifolia*) (Ecological Associates 2005a).

The vegetation of the Werribee River system is unusual however in that it has a diverse and dense band of woody shrubs and trees growing along the channel margins, often interspersed with the beds of rushes, reeds and sedges. Many of these shrubs and trees are in the family Myrtaceae: examples include River Bottlebrush (*Callistemon sieberi*), Woolly Teatree and River Teatree (*Leptospermum lanigerum* and *L. obovatum,* respectively) (Jacobs 2014)

A number of reaches include the spatially limited and only recently discovered sub-species Werribee Blue Box (*Eucalyptus bauerianna subsp. Thalassina)*, which occurs in elevated areas and is thought to only occur in the Werribee catchment, with fewer than 1000 specimens. This species has recently been listed as endangered in the DEPI Advisory List of Rare and Threatened Plants in Victoria (DEPI 2014).

Coimadai Creek flows through the Long Forest area, a large proportion of which is protected in the Long Forest Nature Conservation Reserve. The reserve protects the only occurrence of Bull Mallee south of the Great Dividing Range (Ecological Associates 2005b). This community is believed to be a remnant of a more widespread community that existed in the region in drier conditions about 18,000 years ago. It is likely to have persisted at Long Forest as a result of the dry conditions created by the rain shadow in the local area. The Reserve provides habitat for a diverse range of native plants, many of which have particular conservation significance (Ecological Associates 2005b).

Vegetation in the sections of the Lerderderg River declared as a Heritage River (from just upstream of the Goodman Creek confluence to near the top of the catchment) varies substantially along its length, reflecting a north-south rainfall gradient (LREFTP 2002). The upstream sections (upstream of the gorge) are dominated by Messmate (*E. obliqua*), Broad-leaf peppermint (*E. dives*) and Brown Stringybark (*E. baxteri*), with Manna gum (*E. viminalis*) dominant on alluvial soils close to the river. Within the gorge, the vegetation of the lower slopes are primarily dominated by open forests of Red Stringybark (*E. macrorhyncha*), Blue Gum (*E. pseudoglobulus*) and Red Box (*E. polyanthemos*). Downstream of the gorge, the vegetation has been substantially altered, with degraded riparian zones and extensively cleared floodplains for agriculture (LREFTP 2002).

Key flow requirements for freshwater vegetation

The water-regime requirements are understood for only a few of the semi-aquatic and riparian plant groups found in the Werribee River catchment (VEAC, 2006). Submerged plants need annual inundation for up to 12 months, typically to a depth of 50-100 cm, but can survive periodic drying if the following wet period is long enough for them to complete their vegetative life cycle, for example by laying down desiccation-resistant organs or flowering and setting seed (Jacobs 2014). If the wet phase is too short, growth will occur but the ability to recolonise an area after a prolonged dry period will be compromised as the plants will not have had time to set seed (Jacobs 2014).

For rushes, reed and sedges, the water requirements are well understood (Jacobs 2014). They usually require an annual inundation to a depth of approximately 20 cm for some 2-4 months over spring or summer (Jacobs 2014). Fluctuating water levels can provide an advantage for some species over others (e.g. *Phragmites australis* over *Typha spp*.) and facilitate the development of different communities and different taxa along elevation gradients according to variations in their responses to wetting and drying (Jacobs 014)

The least well understood of all water-dependent plant taxa are the woody trees and shrubs. Good information is available only for a small number of species, including River Red Gum, Black Box (*Eucalyptus largiflorens*), Coolibah (*Eucalyptus coolabah*), and River Cooba (*Acacia stenophylla*) (VEAC 2006). The wetting and drying regimes needed to maintain adult bottlebrushes and teatrees are not well understood and scientists rely on the position of these plants in the landscape (e.g. occurring at high or low elevations along river banks) to infer their likely water-regime requirements (Jacobs 2014).

The wetting and drying regimes required by grasses are also poorly understood, with the exception of Cane Grass (*Eragrostis australasica*), Water Couch (*Paspalum distichlum*), Spiny Mud Grass (*Pseudorhapis spinescens*) and, Common Reed (*Phragmites australis*) (Roberts and Marston, 2011). The position of (*Poa labillardierei*) in the landscape informed the 2014 flows study prescriptions for its optimal wetting and drying cycles (Jacobs 2014).

Estuary vegetation

The Werribee estuary is located in the Werribee Zone of the Victorian Otway Plain Bioregion and has four key EVCs:

- Coastal Saltmarsh (EVC 9), which has an endangered conservation status in the Bioregion
- Estuarine Wetland (EVC 010), which has an Endangered conservation status in the Bioregion
- Floodplain Riparian Woodland (EVC 056), which has an endangered conservation status in the Bioregion
- Seagrass Meadow (EVC 845), which is not currently classified for its conservation status (Lloyd et al. 2008).

A brief description of these EVCs and their key flow requirements is provided below.

Coastal Saltmarsh

Coastal Saltmarsh occupies perennially waterlogged areas that are intermittently inundated. Very high salinities are likely to occur in these areas as saline surface water evaporates or shallow groundwater evaporates, depositing salts on and in the soil. Salinisation of these environments is moderated by intermittent high river flows and by the low salinity of the groundwater. Coastal Saltmarsh species are adapted to variable flooding depths and variable and potentially high salinity levels (Lloyd et al. 2008).

Estuarine Wetland

Estuarine Wetland grows on anaerobic peat-rich muds on the edges of estuaries with intermediate salinity conditions. The vegetation is determined by fluctuating salinity levels, which vary from occasionally fresh to brackish or saline depending on river flood and marine tide levels. Estuarine Wetland is found on the floodplain enclosed by the sharp bend in the river at K Avenue, between 4.5 and 6.5 km upstream of the estuary entrance (Lloyd et al. 2008). The area lies approximately 1 m above the level of the daily high tide, and is flooded only when estuary levels are particularly high. This community is likely to benefit from regular inundation, with freshwater recharge reduce accumulated salts and providing soil moisture to support growth of reeds and other aquatic plants.

Floodplain Riparian Wetland

Floodplain Riparian woodland grows on the banks and floodplains of rivers and creeks, and is found between the floodplain upstream of the reef at the K Avenue wetland to beyond the ford. Significant remnants occur between the golf course and Werribee Park and the river (Lloyd et al. 2008). A smaller area occurs on the opposite bank on the narrow floodplain. The soils here are fertile and subject to periodic flooding. The community is dominated by *Eucalyptus camaldulensis* but includes a number of other woodland trees and tall shrubs including *Acacia melanoxylon, Hymenanthera denticulata, Acacia dealbata, Solanum laciniatum* and *Callistemon brachyandrus*. The EVC benchmark indicates a recruitment interval (i.e. flood interval) of 10 years (Lloyd et al. 2008).

The state of the woodland community provides an indication of the adequacy of the current water regime (Lloyd et al. 2008). The Red Gum trees in this EVC are generally in good health, as are the other flood-dependent woodland species (Lloyd et al. 2008). The scarcity of young River Red Gum however is an indication of infrequent flooding and the absence of flood-dependent understorey species indicates that the current interval between floods is too long for these species to persist (Lloyd et al. 2008).

Seagrass Meadow

Seagrass Meadow has not been mapped as an EVC in the estuaries of the Port Phillip region. In the Werribee estuary it extends from the mouth to below the shallow reef area with more extensive beds in the lowest 2 km of the estuary. It was observed in shallow sandy areas (<2m depth) but may also occur in deeper waters.

In many locations light availability limits the deeper boundaries of seagrass beds and poor light conditions are thought to be a cause of seagrass decline (Lloyd et al. 2008). Light penetration may be reduced by high turbidity, smothering by sediment and an increase in epiphyte growth on seagrass leaves, and flushing flows are important to prevent sediment accumulation and decrease turbidity, having a positive influence on the amount of light available for seagrass growth (Lloyd et al. 2008).

Amenity

Amenity is the pleasantness, attractiveness or agreeable nature of a place. The HWS defines amenity as “the pleasantness of a waterway to visitors and the ability of the waterway to provide a restorative escape from the urban landscape” (Melboune Water 2013). Amenity attributes contribute to the way people appreciate and value the Werribee River and are both tangible, such as paths and natural vegetation, and intangible, such as vistas, links to places or people and the knowledge that wildlife is present.

The amenity values derived from the Werribee River are intrinsically linked to the quality and extent of its natural vistas, vegetation and natural surroundings. Physical aspects such as the sight and sound of running water, accessibility to the area, the ability to move along or around the waterway, and facilities that enable time to be spent beside the river are also important.

Amenity means different things to different people, but is the most commonly expressed reason for visiting waterways and is an important value that needs to be managed and protected (Melbourne Water 2013).

Key flow requirements for amenity

Flow requirements for amenity are difficult to define. Melbourne Water has assumed that by providing flows for the needs of biota within and surrounding the Werribee River, this will also support water-dependent amenity values.

Ecosystem Functions

Ecosystem functions are the biological, geochemical and physical processes and components that take place or occur within an ecosystem. They relate to the structural components of an ecosystem (e.g. vegetation, water, soil, atmosphere and biota) and how they interact with each other, within ecosystems and across ecosystems. Sometimes, ecosystem functions are called ecological processes. Table 12 provides a description of a number of key ecosystem functions that are critical in supporting the water-dependent environmental values of the Werribee River.

Table 12: Key ecosystem functions

Ecosystem Function	Description
Supports the creation and maintenance of vital habitats and populations	The Werribee River requires environmental water because it provides vital refuge areas for native water-dependent biota during dry periods and drought, as evidenced during the extended dry period of the Millennium Drought
	The Werribee River provides vital pathways for the dispersal, migration and movement of native water-dependent biota such as fish and platypus. A varied flow regime maximises these pathways to best meet the different

Ecosystem Function	Description
	flow requirements of the waterway's biota.
	The Werribee River provides a diversity of important feeding, breeding and nursery sites for native water-dependent biota. Providing alternative flows to different areas of the waterway, from the instream areas to the overbank and floodplain areas, supports and maintains these sites.
	The Werribee River provides a vital habitat that is essential for preventing the decline of native water-dependent biota such as the platypus, now considered to be declining and at risk in Victoria, and the Growling Grass Frog, a critically endangered species.
Provides connections along a watercourse (longitudinal connections)	The Werribee River requires environmental watering to sustain it because it provides longitudinal connections to the ocean for numerous migratory species that must fulfil stages of their life-history in the ocean and/or in the freshwater reaches of the river.

Social Values

The delivery of environmental water to the Werribee River supports a wide variety of social and cultural heritage values.

Cultural Values

People from the Kulin nation have lived in the Werribee catchment for at least 25,000 years. At the time of European contact, the Werribee River lay between the traditional lands of three of the Kulin nation tribes; the western Wathaurong (also commonly referred to as Watha wurrung, or Wadawurrung): the eastern Woi wurrung (or Woiwurrung); and the eastern Bunerong (also called Boon wurrung).

The Wathaurong peoples' territory included Ballarat, Geelong, the Bellarine Peninsula, extending into the Otway Ranges and reaching east to the Werribee River. The Wathaurong tribe was made up of 25 clans, and the Marpeang balung (or Marpeang balluk) clan was responsible for the area around the Werribee River (Ecology Partners 2011). Descendants from these clans call themselves the Wathaurong people. Today they are represented by the Wathaurong Aboriginal Co-operative.

The traditional lands of the Woi wurrung encompassed the catchments of the Yarra and Maribynong, was bounded to the north by the Dividing Range at Mount Baw Baw continuing westward to Mount William and Mount Macedon and was bounded in the west by the Werribee River (Ecology Partners 2011). Descendants of the Woi wurrung clans call themselves the Wurrundjeri people, and are represented by the Wurundjeri Tribe Land and Compensation Cultural Heritage Council Inc.

Bunurong territory extended along the northern, eastern and southern shorelines of Port Phillip, the Mornington Peninsula, Western Port and its two main islands, and land to the south-east down to Wilsons Promontory. The Bunurong Land Council Aboriginal Corporation and the Boon Wurrung Foundation Ltd. are recognised by the Aboriginal Heritage Council as traditional landowners of the region that includes the Werribee River (Ecology Partners 2011). Descendants of these clans call themselves the Bunerong

Registered Aboriginal Parties relevant to the Werribee catchment include: the Wathaurung Aboriginal Corporation, with country bordered on the east by the Werribee River; and the Wurundjeri Tribe Land and Compensation Cultural Heritage Council, with country bordered in the north-west by upper reaches of the river near Melton.

There are a large number of previously recorded Aboriginal archaeological sites located along the Werribee River and its tributaries. The majority of these comprise artefact scatters, scar trees, earth features, and burial sites. Due to the culturally sensitive nature of these sites, their specific locations along the Werribee River cannot be discussed for the EWMP.

Social values

Aside from the amenity values of the Werribee River, previously discussed in Section 6.7, other social values include camping, recreational fishing, bushwalking and boat sports such as canoeing. Recreational fishing brings many visitors to the area, and with its close location for Melbourne residents, is a popular weekend destination. The Lerderderg River is popular destination for bushwalkers and campers, while the wetlands and estuaries of the Western Treatment Plant in the lower reaches have worldwide renown for the vast array of bird species it supports and the local residents are justifiably proud of its international conservation status.

Economic Values

The Werribee River supports a diverse range of industries and businesses along its reaches. Many farming enterprises are highly dependent on its water, including the key agricultural areas of the Werribee Irrigation District and Bacchus Marsh Irrigation District. Some general economic values include the following:

- Water carrier for the irrigation districts, industrial and urban users
- Commercial fisheries and aquaculture in the estuary
- Water source for rural areas
- Tourism and recreation industries.

Conceptual Model

The conceptual illustrated in Figure 18 shows how different flow components and ecological processes interact for freshwater values in the Werribee River.

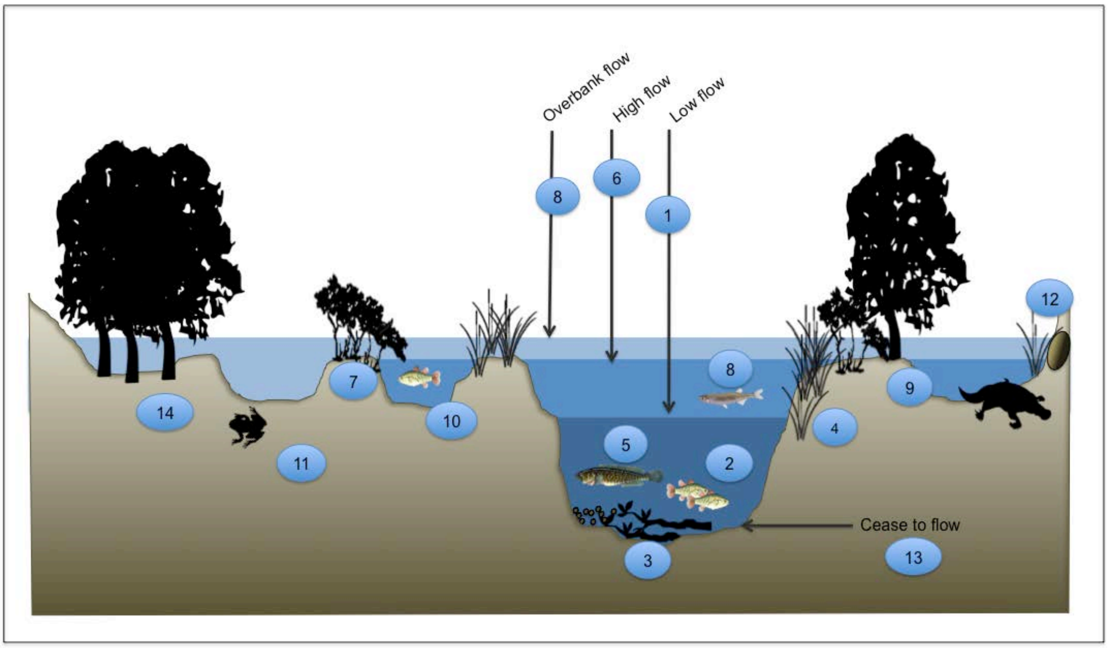

Figure 18: Conceptual model for freshwater reaches of Werribee River using a cross-section

In explanation:

- Low flows in summer (1) maintain habitat for fish, macroinvertebrates and platypus. Low flows also wet the width of the river channel, fill pools, and allow fish such as Southern Pygmy Perch (2) to move between pools.
- Summer freshes flush organic material and water that has accumulated in the channel during the dry phase and scour silt, biofilms and filamentous algae from substrata (3) and

semi-emergent vegetation at the margin of the low flow channel (4). Summer freshes also allow fish movement through a reach, such as the River Blackfish (5).

- High flows (6) help to maintain clear flow paths and control encroachment by terrestrial vegetation (7). They also assist fish movement throughout a reach (8).
- Overbank flows (8) promote growth and recruitment of native riparian vegetation (9), cue and facilitate fish movement (10), and connect wetlands at the margins of the channel for frog breeding (11). Overbank flows also provide essential watering events for riparian vegetation such as River Red Gums (14), which are dependent on flooding regimes for their recruitment and survival.
- Winter freshes provide important cues for where mother Platypus locate their burrows to ensure they are high enough up the bank to not be flooded when babies are present (12).
- Cease-to-flow periods (13) assist in maintaining a natural ephemeral flow regime and prevent further expansion of *Phragmites* and *Typha*.

The conceptual model illustrated in Figure 19 illustrates how key hydrology and ecological processes interact for estuarine values of the Werribee River.

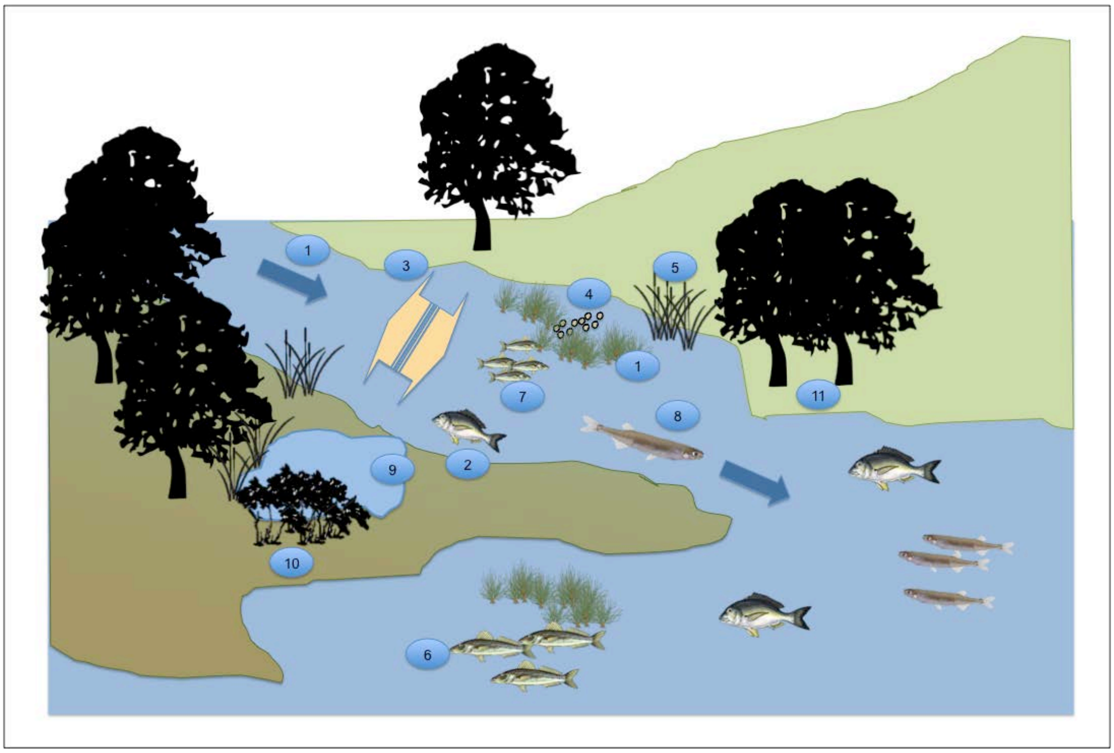

Figure 19: Estuary conceptual model for the Werribee River

In explanation:

- Freshwater flows (1) are important for estuarine dependent fish species such as Black Bream (2), who will move upstream in response to freshes for feeding and parasite removal, and back downstream if salinity levels become too low (i.e. too much freshwater entering the estuary).
- Mature Black Bream spawn in areas of the estuary that have certain salinity levels within the salt wedge (3). Once hatched, the juveniles will shelter in seagrass beds (4) or *Phragmites* stands until more mature (5).
- Some estuarine dependent and marine derived species, such as King George Whiting (6), breed in the marine environment, and their larvae move to seagrass areas in the estuary once hatched (7). Seagrass meadows are dependent on flows to maintain appropriate water conditions for their growth, such as low turbidity. Once King George Whiting are mature enough, they move into the more open areas of the estuary, but high freshwater flows prevent this species from travelling too far up the estuary. High flows are

needed however to make sure the estuary mouth remains open so fish can migrate into and out of the marine environment.

- The Common Galaxias (8) relies on freshwater flows to cue its movement from the upstream freshwater reaches down into the estuary. Common Galaxias lay their eggs on samphire and in the flooded wetlands of the estuary (9), and once the eggs hatch, juveniles are washed out to sea, to return once mature.
- Overbank flows support estuarine wetlands (9), coastal saltmarsh (10), and floodplain riparian woodlands (11), with these vegetation communities requiring regular inundation from overbank flows to maintain their ecological health.

Significance

The Werribee River has a rich history and it flows through unique areas such as Victoria's Volcanic Plain outcrops, bedrock and gorges, as well as beautiful areas of native grasslands, wetlands of international importance, and stands of mature River Red Gums. The community is increasingly recognising the Werribee River as an important natural resource in an area slated for significant urban development over the next ten years, and Melbourne Water is working with all levels of government and the community to develop an integrated approach to protecting and enhancing its values so that they are not lost with the encroaching development of the area.

The river provides habitat for the iconic Platypus, now at a critical threshold in terms of its continuing presence within the system and possibly more broadly. The river also provides habitat for a wide variety of native fish, a large number of which rely on good longitudinal connectivity between the river, its estuary and also the marine environment to complete aspects of their life cycles. The endangered Growling Grass Frog is reliant on flows down the river to nourish its streamside habitat, while a vast population of birds, many of whom are protected under international agreements and/or critically endangered, also rely on flows in the lower reaches and estuary to supply water for their feeding and breeding habitats.

The vegetation communities along the river are some of the most endangered in the State, and provide a remnant record of ecological vegetation classes once common but now in danger of disappearing because of threats such as urban development, habitat fragmentation and altered flow regimes.

The river has highly variable natural flows, and a diverse biota that reflects this variability in terms of their life history adaptations and survival mechanisms. During periods of drought, deeper pools provide refuge for many fauna and flora species in the river. In one of the driest Victorian catchments south of the Great Dividing Range, the Werribee River is critical to the survival of many of these species, providing an oasis of water in a challenging environment.

The river forms an important boundary between different clans of the Kulin nation, and with a continuous Aboriginal culture dating back at least 25,000 years in the region, the river has a vast record of the people, past and present, who have enjoyed its beauty, been spiritually connected to it, and lived off its offerings.

ECOLOGICAL CONDITION AND THREATS

Overall, the condition of the Werribee River system ranges from very good in the upper and less developed reaches, to moderate to very poor in the lower and highly developed reaches. The Millennium Drought, which extended from 1997 to 2009, had significant impacts on the condition of the Werribee River, the effects of which the system is still recovering from.

Waterway condition

Waterway condition for the Werribee River has been assessed using Victoria's Index of Stream Condition (ISC), which provides an overall measure of the relative environmental condition of rivers when compared to reference condition. The ISC combines information on hydrology, water quality, physical form, vegetation, and aquatic life, and provides an overall basin condition assessment as well as reach specific assessments. Using data collected between 2004 and 2010, the latest ISC assessment (DEPI 2010), found that about 10% of stream length in the Werribee Basin was in good condition, about half of the stream length (56%) was in moderate condition, 17% of stream length was in poor condition, with another 17% in very poor condition.

ISC assessment reaches are often different to the reaches used for environmental flow assessments. For the Werribee River, ISC reach numbering starts at 1 near the estuary (which corresponds with Reach 9 for environmental flows), and ends at 6 in the upper reaches (which corresponds with Reach 1 for environmental flows). There is also reach number 201, which is located within the estuary. Other ISC reaches include 9 and 10, which correspond to Reach 7 for environmental flows, and 11 and 12, which correspond to Reach 6 for environmental flows.

Table 13 shows the results of the 2010 ISC assessment for the Werribee River, and also shows results for Werribee River tributaries of the Lerderderg River, Djerriwarrh Creek, Pyrites Creek (Coimadai Creek) and Toolern Creek. Where there is an approximate correspondence with environmental flows reaches, this is indicated in the table.

Table 13: 2010 Index of Stream Condition sub-index scores for the Werribee River and tributaries

ISC Reach No.	Hydrology	Physical Form	Streamside Zone	Water Quality	Aquatic Life	ISC Score	Condition Rating
Werribee River – *ISC reaches approximately correspond to reaches 1, 3, 4, 5, 8 and 9 and the estuary for environmental flows*							
1	1	9	6	-	-	20	Poor
2	2	9	6	6	6	24	Moderate
4	9	5	7	7	-	32	Moderate
5	9	5	4	3	4	21	Poor
6	9	5	9	-	4	29	Moderate
201	1	9	3	-	-	15	Very Poor
Lerderderg River							
13	3	4	6	6	-	21	Poor
14	3	6	9	-	5	25	Moderate
15	7	7	10	7	5	33	Moderate
Djerriwarrh Creek – *ISC reach 9 approximately corresponds to Reach 7 for environmental flows*							
9	9	7	7	-	-	37	Good

ISC Reach No.	Hydrology	Physical Form	Streamside Zone	Water Quality	Aquatic Life	ISC Score	Condition Rating
10	10	6	9	-	-	39	Good
Pyrites Creek – *ISC Reach 11 approximately corresponds to Reach 6 for environmental flows*							
11	9	5	7	-	7	32	Moderate
12	10	6	9	-	-	39	Good
Toolern Creek							
7	1	9	4	4	-	17	Very Poor
8	1	7	4	-	7	19	Very Poor
Pykes Creek – *ISC reach 21 is upstream of Pykes Creek Reservoir and hence upstream of Reach 2 for environmental flows*							
21	9	6	7	5	-	31	Moderate

Condition, trend and predicted trajectories of focal values

Historic trends, current condition, and the expected outcomes for key focal values in the Werribee system are detailed in the HWS (Melbourne Water 2013) and have been examined during a number of trajectories assessments that provided essential data for the development of the HWS (Alluvium 2011a, 2011b and 2011c). The trajectories assessments involved forecasting the future condition of each of Werribee River's focal values, using all available information to understand historic trends, to see if condition has been declining, stable, or increasing, and predicting what impact management actions may have on this trajectory.

Platypus

Platypus data has been collected by the Centre for Environmental Stress and Adaptation Research (cesar) for Melbourne Water since 1995 through the Melbourne Water Urban Platypus Program. Across the entire Melbourne Water region, significant and widespread declines in platypus populations have been seen, with many surveyed locations reduced to low or very low abundance. The severe and prolonged Millennium Drought, experienced during much of the study period, is seen as a major contributing factor for this decline because of habitat fragmentation and degradation (cesar 2013). With the end of the drought in mid 2010, increased rainfall was predicted to improve conditions for platypuses and populations were expected to increase, but recent survey results continue to be low, although there are some localised increases in population.

For the Werribee River, platypus populations have declined significantly in the past 200 years. In 2012-13, the survey results for the capture of platypus in the catchment were the lowest of any of Melbourne Water's catchments for that year, and also the lowest ever recorded from previous surveys in the Werribee Catchment with only one platypus captured in the catchment (cesar 2013), indicating the platypus population is yet to recover from the impacts of the drought. The only confirmed platypus population occurs near Werribee, although there have been a number of sightings within Werribee Gorge and Ballan (cesar 2013). Upstream of Ballan, the Werribee River is seasonally dry and is unlikely to support a resident population (cesar 2013).

Lower Werribee Management Unit

Prior to the Millennium Drought, platypus capture data from the Lower Werribee Management Unit suggests that its abundance was relatively high between 1997 and 2000. This declined significantly during the drought and scientists believe the population has so far failed to recover in this part of the river. The HWS rates the condition of platypus in the Werribee and Little River lowlands system as very low and declining (Melbourne Water 2013).

Middle to Upper Werribee Management Units

In this management unit, sightings of platypus were relatively common around both the Werribee and Lerderderg Rivers near Bacchus Marsh prior to 1997. Since the Millennium Drought however, the population of platypus in the upper reaches is suspected to have been significantly impacted by the drought, although because there is no recent capture data, the population size and trend is currently unknown (Alluvium 2011b; cesar 2013). The HWS rates the condition of platypus in this management unit as very low and declining (Melbourne Water 2013).

Because of this decline in condition in both management units, there are major concerns for the long-term survival of platypus in the Werribee catchment, particularly in the lower reaches where the current population is considered critically low and likely to become locally extinct. Table 14 details platypus condition, trend and trajectories for the Upper, Middle and Lower Werribee management units.

Table 14: Werribee platypus condition, trend and predicted trajectories (Source: Adapted from Alluvium (2010b) and Melbourne Water (2013))

Management Unit	Condition	Trend	Predicted trajectory
Upper and Middle Werribee	Platypus have been sighted but not captured in surveys recently, and there is insufficient information to establish population size in this system.	There is insufficient information to establish trend in this management unit.	The current status of platypus in this management unit is unknown. The lack of capture data suggests a low population and works would need to be undertaken quickly to improve confidence in maintaining/improving the population. Trajectory is unknown, but there is the potential for a stable population and increased distribution.
Lower Werribee (Not including coastal fringe and estuary as no recorded populations)	There does not appear to be a stable population in the system and capture data suggests a decline since the Millennium Drought.	Capture data suggests a significantly declining Platypus population in the system.	Platypus population in this system is low and declining and despite proposed actions they are unlikely to persist in the medium term. A very small population size and declining trend means that the population is at a high risk of extinction and unlikely to be resilient to future pressures. Possible stabilisation of population numbers is possible if extensive actions are undertaken in the short term.

Key threats

Platypus need an abundant supply of macroinvertebrates as a food source, suitable foraging habitats with enough water cover to protect them from predators, and well vegetated banks where they can build and access burrows (Serena and Williams, 2008). Predation by foxes, dogs and cats when platypus travel over land or in shallow water, litter, poor water quality, and the degradation of riparian habitats through clearing, weed infestation or willows are considered the key threats to Platypus in the Werribee River (Serena & Williams (2008) in Jacobs (2014)). Very large flows during the breeding season (September to January), can also threaten the viability of platypus populations by flooding the burrows of nesting platypus, drowning the juveniles (Serena & Williams (2008) in Jacobs (2014)).

Key threats to platypus include:

- Small population sizes – Small populations are vulnerable to changes in the environment, disease, and catastrophic events such as fire
- Lack of in-stream habitat complexity, which decreases food and shelter availability
- Urbanisation - Which results in reduced water quality, natural vegetation and waterway form, all of which are important for platypus survival
- Agricultural development – This can include changes to waterways such as clearing of streamside vegetation, damage due to stock access, poor water quality influxes, and erosion
- Entanglement in litter and/or fishing equipment – This is a common problem for platypus and often results in severe injury or death (Melbourne Water 2013).

Frogs

Frog condition for the Werribee system is determined by measuring species richness, comparing species numbers determined through recent surveys to the number of species expected to have occurred historically. Frog data has been collected through a number of monitoring studies and programs, including Melbourne Water's Frog Census program, DELWP programs, university assessments, and consultants.

The diversity of frog species in the Werribee catchment has declined significantly since European settlement, and species richness is now considered moderate for the catchment (Melbourne Water 2013). Table 15 shows the current condition, trend and predicted trajectories for frogs in the Werribee system.

Table 15: Werribee frog condition, trend and predicted trajectories (Source: Adapted from Melbourne Water (2013))

Management Unit	Condition	Trend	Predicted trajectory
Upper and Middle Werribee	Frog species richness scores (ratio of observed to expected species) appear to be in poor condition in this management unit. 50% of species expected in the system have been observed in the Upper Werribee, while 44% have been observed in the Werribee Middle in recent surveys. This indicates that in some areas along the river, more than half of all	Where sufficient survey effort has occurred (in the Werribee Middle management unit only), there appears to be a general decline in species richness scores over time.	For the Middle to Upper reaches of the Werribee, trajectories are currently difficult to ascertain because of a paucity of data, although it is thought that species richness will probably remain stable, and improved riparian corridors may correlate with improved condition for frog populations.

Management Unit	Condition	Trend	Predicted trajectory
	expected native species have not been observed in recent surveys.		
Lower Werribee (Incorporating coastal fringe and estuary)	58% of species expected in the system have been observed in the Lower Werribee in recent surveys. Frog species richness appears to be in poor condition in both Lower Werrribee and coastal fringe/estuary areas	Where there is adequate data, the trend for frog species indicates a decline in condition.	Species richness is expected to remain stable. Improved riparian corridors may correlate with an improved condition for frog populations, including abundance and resilience.

Key threats

Key threats to frog species in the Werribee catchment include:

- A lack of native vegetation along and around wetlands - Native vegetation is necessary for providing food and shelter, and for supporting different stages of frog lifecycles such as breeding
- Diminishing wetland sizes – Where larger wetlands support a greater variety of frogs than smaller ones
- Altered water regimes in waterways - High flow rates can wash tadpoles out of wetlands, and reduce protection and habitat. Where water level variations are absent in wetlands, these conditions will favour fish over frogs
- Human disturbance - Noise and artificial light can disrupt the breeding behaviour of frogs.
- Introduced pests - Species such as introduced fish, foxes and cats can prey on eggs, larvae and adult frogs.
- Poor water quality - Frogs are sensitive to poor water quality and pollution.
- Loss of connectivity - Floodplains and wetlands that have wet and dry periods are critical for breeding for some frog species. When these areas are disconnected from waterways, frog populations tend to decline. Proximity and access to alternative wetlands is critical to healthy population and life cycle dynamics.
- Disease - A major threat to frog populations is the disease *Chytridiomycosis*. This infectious disease is caused by a fungus and is now found in frogs throughout much of the world, including Australia. The fungus attacks the skin of the frog and also damages its nervous system, resulting in death (Melbourne Water 2013).

Macroinvertebrates

The HWS uses SIGNAL scores (Stream Invertebrate Grade Number – Average Level) and AUSRIVAS to assess the condition of macroinvertebrates in the Werribee system. The two measures are combined to form an overall ISC sub-index – Aquatic Life (DEPI 2010).

Using the ISC data, macroinvertebrate condition in forested areas of the Werribee catchment was found to be fairly good in the 1999 ISC assessment, but by 2010, four reaches of the Werribee catchment showed a distinct downward trend in condition (in the upper Goodman, Toolern, Dale and Djerriwarh Forest sub-management units).

Table 16 shows the current condition, trend and predicted trajectories for macroinvertebrates in the Werribee system.

Table 16: Werribee macroinvertebrates condition, trend and predicted trajectories (Source: Adapted from Alluvium (2011c) and Melbourne Water (2013))

Management Unit	Condition	Trend	Predicted trajectory
Upper and Middle Werribee	This management unit contains the predominantly forested reaches and some rural areas in the lower reaches. Macroinvertebrate condition is variable through the system, but is generally rated between moderate to good. Out of a possible score of 10, ISC 2010 Aquatic Life scores were as follows: • Forested reaches: scores range from 4 to 9 • Rural reaches: scores range from 4 to 8	Based on ISC scores from the 1999 and 2010 ISC assessments, there is a declining trend in macroinvertebrate condition in some reaches across the system in both forested and rural waterways.	The trajectory for macroinvertebrate condition is considered stable for this management unit.
Lower Werribee (Incorporating the coastal fringe and estuary management units)	For the Lower Werribee, macroinvertebrate condition is considered moderate to good. Out of a possible score of 10, ISC 2010 Aquatic Life scores were as follows: • Forested reaches: scores of 5 • Rural reaches: Scores not rated for 2010, but 9 in 1999. • Urban reaches = 8 For the coastal fringe management unit, this area is predominantly in urban reaches and macroinvertebrate condition is generally poor. For urban reaches, a score of 8	It is difficult to determine the trend for macroinvertebrate condition in this system due to insufficient data.	The trajectory for macroinvertebrate condition is considered unknown, but possibly stable for this management unit

Key threats

Key threats to macroinvertebrate populations in the Werribee system include:

- Lack of in-stream habitat complexity - Waterways that have submerged wood, rocks and pebbles, and aquatic plants generally have higher numbers of macroinvertebrates

- Changes to the flow behaviour and quality of water from runoff due to urban and rural land practices
- Lack of streamside native vegetation - Streamside vegetation that has weeds and introduced trees (for example willows) will lead to altered leaf fall input, shading, water temperature, food sources and water quality
- Waterways that have significant amounts of aquatic weeds will reduce water and habitat quality for macroinvertebrates
- Very high and very low flows can lead to a reduction in habitat availability for macroinvertebrates
- A reduction in wetlands can results in a loss of habitat for macroinvertebrate species dependant on wetlands
- Removing the ability of floodplains to connect to waterways can also result in a loss of habitat for macroinvertebrates (Melbourne Water 2013).

Fish

Looking broadly across the Melbourne Water region, thirty-six species of freshwater fish (native and exotic) have been recorded in the rivers, lakes and wetlands of the region, with an additional thirty-nine species of estuarine fish recorded in the lower reaches (Alluvium 2011a).

For freshwater species, fish condition has been assessed by Melbourne Water at the catchment scale using species richness and nativeness indicators, as well as by metrics adapted from the Independent Sustainable Rivers Audit (SRA) conducted in 2006 (Alluvium 2011a). For species richness metrics, the expected lists were developed based on the species that have been recorded in the catchment since 1900 (Alluvium 2011a).

In the Middle and Upper management units of the Werribee River, the high variety and proportion of native fish species gives a high condition rating for fish in the HWS, with trajectories predicted to improve over the next ten years (Melbourne Water 2013). For the Upper Werribee management unit, eight of the expected 17 fish species have been recorded, five of which are native. For the Middle Werribee management unit, 15 of the expected 17 species of fish have been recorded in this management unit, seven of which are native.

Table 17 summarises condition, trend and predicted trajectories for fish in the Upper Werribee management unit, as assessed in Alluvium (2011a). The table is categorised into altitude zones of 0-200m, 200-400m, and 400+m above sea level.

Table 17: Native fish condition, trend and predicted trajectories in the Middle and Upper Werribee Management Unit (Source: Adapted from Alluvium (2011a) and Melbourne Water (2013))

Altitude zone	Condition	Trend	Predicted trajectory
0 – 200m	92% of expected species present (species richness) 66% of species present are native (nativeness)	No net change in species richness or nativeness over time.	An increase in species' distribution and resilience is expected with appropriate management actions. Species richness will remain stable or increase, and the proportion of native species will significantly increase if competition and predation by exotic fish species is reduced through management actions.
200 - 400m	44% of expected species present 62% of species present are native	There is insufficient data to determine the trend in condition	
400+ m	81% of expected species present 84% of species present are native	There appears to be a general decline in richness following 1995, but a return to a high rating in the 2005-2009 period. There is also an	

Altitude zone	Condition	Trend	Predicted trajectory
		apparent overall increase in nativeness.	

Table 18 summarises the condition, trend and predicted trajectories for fish in the Lower Werribee management unit.

Table 18: Condition, trend and predicted trajectories for fish in the Lower Werribee Management Unit (Sources: Adapted from Alluvium (2011a) and Melbourne Water (2013))

Altitude Zone	Condition	Trend	Predicted trajectory
0 - 200m (Incorporating coastal fringe and estuary)	92% of expected species present 66% of species present are native	No net change in species richness or nativeness has been seen over time.	Appropriate management actions are likely to increase species distribution and resilience. Species richness is likely to remain stable, and nativeness is likely to remain stable or increase. For the coastal fringe and estuary, there is scope to better understand the estuary fish population through further study. Also, a possible improvement in wetland dependent species distribution and abundance may occur with appropriate management actions

Key threats

Key threats to native fish in the Werribee system include:

- Reduced connectivity of waterways - Removing the ability of waterways to connect (through the introduction of weirs or channelling of rivers and streams), results in barriers to fish movement, which is especially important to migratory fish that need to move up and down waterways throughout their lifecycle. For example, it was found that no fewer than 10 instream barriers exist in the Werribee River between the Werribee River estuary and the Werribee Diversion weir. A ford at Werribee Mansion, six rock bars and three weirs all restrict fish passage. Currently few migratory fish are being attracted into the freshwater reaches of the Werribee River and even fewer can make passage to the Werribee Diversion weir (McGuckin & Borg 2013).
- Altered flow regimes - Many fish require ecological triggers such as changes in the timing, duration and volume of water flows for natural processes such as mating, migration and spawning to occur (Poff & Zimmerman 2010)
- Barriers to fish movement from river regulation infrastructure such as dams and weirs, restricting fish from suitable habitat – Currently few diadromous fish are being attracted into the freshwater reaches of the Werribee River and even fewer can make passage all the way through to the Werribee Diversion weir, which is still in the lower reaches of the system (Poff & Zimmerman 2010)

- Urban and rural catchment run-off leading to changed hydrology and/or water quality – This can reduce fish population sizes and diversity through mortality, reduced fitness, reduced breeding opportunities and reduced recruitment
- Degraded riparian vegetation condition caused by an influx of non-native plants – Non-native plants (for example willows), can lead to altered leaf fall input, reduced food sources, shading and water temperature changes, as well as degraded water quality for aquatic animals
- Degraded water quality - Includes the introduction of aquatic weeds, changes in the type and quality of vegetation, and physical changes to the form of waterways.
- Physical changes to the form of waterways such as channelling, the removal of water through diversion and changes in the flow of water, leading to a loss of habitat in the waterway and increased pollutant levels.
- Land practices such as urbanisation, vegetation clearing, loss of floodplain, the use of herbicides and pesticides and increased nutrient levels, and stock access to waterways.
- Introduced plants and animals such as aquatic weeds, land weeds, introduced fish and rabbits.
- Directly Connected Imperviousness (DCI), causing increased stormwater influxes to the river - These increase the inputs of polluted water into waterways and reduce water quality, and can significantly change the flow regime of the system.
- Blue-Green algal blooms reducing water quality and habitat availability for fish
- Recreational fishing reducing native fish population numbers
- Cold water pollution from releases of water below the reservoirs, affecting native fish that are particularly sensitive to changes in water temperature (Rowe et al. 2008).

Vegetation

Vegetation in the upper reaches of the Werribee River catchment is relatively intact and in moderate condition, with a trend for moderately improving condition over time. However, vegetation quality declines in the lower reaches of this management unit, and overall, the vegetation is rated as being in moderate condition in the HWS (Melbourne Water 2013).

Upper and Middle Werribee Management Unit

Table 19 summarises condition, trend and predicted trajectories for vegetation in the Upper and Middle Werribee and Lower Werribee management units.

Table 19: Condition, trend and predicted trajectories for vegetation in the Upper, Middle and Lower Werribee Management Units (Source: Adapted from Melbourne Water (2013) and Alluvium (2010)

Management Unit	Condition	Trend	Predicted trajectory
Lower Werribee (Incorporating coastal fringe and estuary)	Vegetation quality in this management unit ranges from very low to high and is predominantly of medium quality.	Although minimal data is available, the trend for vegetation in this management unit is thought to be improving for both the condition and extent of riparian vegetation.	Actions focused on improving riverine connectivity (fragmented riparian vegetation) and riverine quality (the impacted flow regime due to upstream diversions), are expected to help continue to improve the condition and extent of vegetation. For the coastal fringe area, it is thought that the condition and extent

Management Unit	Condition	Trend	Predicted trajectory
			of floodplain vegetation will improve.
Middle and Upper Werribee	Parts of the waterway in the Middle and Upper Werribee River (as well as the Lerderderg River), contain some of the only significant lengths of waterway in the catchment that have a relatively intact structural vegetation. The lower reaches of waterways in the unit contain riparian vegetation quality rated as medium to very low condition.	There is little specific information to establish trend for vegetation in the management unit. However, trend is assumed to have been improving for both condition and extent of riparian vegetation.	Actions focused on improving riverine connectivity (especially fragmented and weed infested riparian vegetation) will provide the most effective outcomes for condition of waterway values in this system. Increases in the condition and extent of riparian vegetation are expected with implementation of these management actions.

Key threats

When considering threats to vegetation in the Werribee system, the HWS lists threats to vegetation as the following:

- Poor water quality – Where constant high levels of suspended solids in waterways can reduce the availability of light to aquatic plants, resulting in a decrease in health and species diversity
- Stock damage such as by cattle grazing can kill plants, prevent the natural regeneration of most native plant species, and lead to soil compaction and the destruction of sensitive vegetation environments through trampling. Stock can also spread weed seeds.
- Grazing damage by introduced and native animals (in unsustainable populations) can result in species loss and prevent natural regeneration of most native vegetation species.
- The clearance of native vegetation, resulting in the destruction of plants.
- Fragmentation – Where the health of native vegetation deteriorates when it is broken up or isolated into smaller or single stands.
- Rising saline water tables, which can kill susceptible native vegetation.
- Structural changes to waterways and floodplains, resulting in significant changes to water flow regimes and hence resulting in unfavourable conditions for native vegetation.
- Weed invasion reduces species diversity and may impact on regeneration of native species.
- Fire can kill some native vegetation species and increase the ability of weeds to invade.
- Stormwater inputs to waterways can increase the amount and strength of water flow, damaging in-stream vegetation.
- Drought can kill off some native vegetation species (Melbourne Water 2013).

Birds

When assessing the condition of bird communities in the Werribee system, rather than looking at only one or a few selected species, the assessment considers measures of:

- Species richness – the number of expected bird species observed in an area (the number of different types of species recorded)
- Nativeness, the proportion of all observed species that are native.

Table 20 summarises condition, trend and predicted trajectories for birds in the Upper and Middle Werribee and Lower Werribee management units.

Table 20: Condition, trend and predicted trajectories for birds in the Upper, Middle and Lower Werribee Management Units (Source: Adapted from Melbourne Water (2013) and Alluvium (2010b))

Management Unit	Condition	Trend	Predicted trajectory
Lower Werribee (Incorporating the coastal fringe, estuary and wetlands)	Bird condition (in terms of species richness and nativeness) appears to be excellent in this management unit Measurements indicate 84% species richness, with 96% of these species being native.	Trends in bird species richness appears to be increasing over time in this system. Nativeness appears to remain stable.	Trajectories are predicted to remain stable for both species richness and nativeness (both are currently high). For the coastal fringe and estuary, the system already is considered of high species richness in a regional context. Species richness is expected to increase and nativeness to remain stable.
Middle and Upper Werribee	Bird condition appears to range from moderate to good in this unit. Measurements of species richness indicate: • Werribee Middle: 69% species richness, with 95% of species being native • Werribee Upper: 54% species richness, with 92% of species being native	There is insufficient data to establish trends in bird condition in the Upper Werribee, while bird species richness appears to decline post-2004 in the Middle Werribee (current score equal to pre-95). Trends in nativeness have remained stable over time.	A local increase in bird species richness and abundance is predicted with appropriate management actions, but this is unlikely to be reflected in change in species richness at a management unit level. Nativeness is expected to remain at a stable high level.

Key threats

- Lack of native streamside and landscape vegetation - Vegetation provides the essential habitat framework for streamside and wetland birds; for their feeding, roosting, moulting and breeding. Vegetation clearing reduces habitat extent and tends to degrade remaining habitat quality, limiting the variety of bird species found.
- Introduced pests - Species such as foxes, dogs and cats prey directly on eggs, chicks and adult birds. The presence of introduced predators can deter birds from frequenting an area, and may prevent breeding attempts.
- Reduction in size and amount of wetland habitat - This results in a direct loss of habitat extent but often also a loss of habitat variety and complexity, and consequently some bird species.
- Lack of wetland vegetation diversity - Many wetland birds are herbivorous and rely on wetland plants for food. Urban water management often leads to a simplification of wetland structure and hydrology that limits wetland plant diversity and can reduce the number of bird species that can feed, roost or nest in an area.
- Poor water quality - Water that contains pollutants such as pesticides and heavy metals poses a threat to birds' health.

- Altered water regimes in wetlands - When the amount of water is reduced or the natural wetting and drying patterns are changed, bird species richness can decline
- Flow conditions - Some birds require ecological triggers (such as changes in water height) and seasonal changes for natural processes such as breeding (Melbourne Water 2013).

Amenity

It is relatively difficult to measure the condition of amenity for waterways. In putting together the HWS, a tailored social research program survey was used by Melbourne Water to assess how the community values and relates to waterways in the region. This survey collects information on community knowledge, behaviour and attitude across several issues related to waterways. To develop condition ratings, data from community perceptions of waterways research on 'satisfaction with waterways' and 'rating waterways as an escape from urban areas' was used.

Table 21 summarises amenity condition, trends and predicted trajectories for the Werribee River. Note that only the Healthy Waterways Strategy (Melbourne Water 2013) provides data for this table.

Table 21: Condition, trend and predicted trajectories for amenity in the Upper, Middle and Lower Werribee Management Units (Source: Adapted from Melbourne Water (2013))

Management Unit	Condition	Trend	Predicted trajectory
Lower Werribee	Condition in this unit is considered moderate	The trend for amenity values is considered stable	A high condition is expected in the next 20 years as urban development occurs – increasing the opportunities for access – and vegetation condition is improved.
Middle and Upper Werribee	In the Middle and Upper Werribee management units, amenity is rated as moderate.	The trend for amenity values is considered stable	Improvement is expected as actions targeted at improving amenity – including improving vegetation – are implemented.

Key threats

- Poor access to waterways – Difficult public access to waterways can decrease the value of the waterway for people.
- Litter - The presence of litter in and around waterways reduces amenity values.
- Environmental condition - Poor quality and amount of vegetation in and around waterways also reduces amenity values.
- Quality of physical assets - Poor quality or a lack of infrastructure such as barbecues, tables and car parks makes an area less attractive for some people.
- Precinct and urban design - Poor integration of waterways into new and existing suburbs can detract from amenity values.
- Alternative local choices for amenity - Competition between waterways and other areas such as shopping centres and parks may detract amenity value.
- Extent of community knowledge – A lack of awareness and understanding of the role and location of waterways can reduce their value for people (Melbourne Water 2013).

Do Nothing Condition Trajectories

Without the implementation of management options to improve flow conditions for the focal values of the Werribee River, there is a very real risk that these values will continue to downgrade in condition. Table 22 describes some of these risks.

Table 22: Do nothing trajectories for key values

Focal Value	Predicted Do Nothing Trajectory	Description
Platypus	Platypus is at risk of extinction in the system	The two biggest flow related threats to platypus are: • Low flows which limit the amount of available food and force animals to move overland where they are susceptible to predators • High flows that flood burrows and drown juvenile animals. Researchers have a high level of confidence that improving low flows will increase the amount of available habitat (and food supply) for platypus, leading to increases in range and hopefully helping to stabilise the population (Alluvium 2011b; Jacobs 2014) Protecting juvenile platypus by ensuring burrows are not flooded may also increase their chances of survival to adulthood (Jacobs 2014).
Fish	Even though there is a dedicated Environmental Entitlement for the Werribee River, native fish populations will continue to decline as the system remains in flow stress	Fish populations may continue to decline due to: • Fish barriers preventing successful migration of fish to their breeding and spawning habitats • Seasonal reversal of flows due to continuing irrigation releases from storages, which alters breeding and migration cues • Lower volumes in the winter/spring months as water is harvested in the catchment by storages • Melbourne Water not being able to deliver bankfull and overbank flow events from the environmental water holding due to the very large volumes of water required, as well as the risk of flooding private land and infrastructure • Melbourne Water having little ability to adjust flows in reaches other than 6 and 9 • Inadequate flows reaching the estuary, changing salinity conditions and impacting on spawning and egg survival of estuary fish.
Frogs	Frog populations may continue to decline	Loss of bankfull and overbank flows to floodplains may limit habitat availability for flow-dependent species.
Macro-invertebrates	The condition of macroinvertebrates is expected to remain moderate	Macroinvertebrate communities are affected more by the indirect effects of flow reduction, such as increased electrical conductivity and increased water temperature, than they are by direct effects, such as reductions in water depth, water velocity, and wetted channel width (Jacobs 2014).
Vegetation	Vegetation condition will continue to decline in some reaches, particularly for flood dependent trees such as River Red Gum	Floodplain vegetation will continue to decline and recruitment for River Red Gum may be halted due to the lack of overbank flows to the floodplain and wetlands in the lower reaches and estuary zone.
Birds	Insufficient data	Climate change impacts may decrease flows and as a consequence habitat availability for water-dependent birds.
Amenity	Insufficient data, but possibility improving in condition	Amenity is likely to improve in condition as the urban areas of the catchment expand.

ECOLOGICAL OBJECTIVES

Vision

It is important that ecological objectives for the Werribee River and its estuary are guided by a vision for the system. The vision must reflect what is valued in the system by people and how these values are to be protected and managed into the future. The vision must also be consistent with current policy and legislation.

The vision for Victoria's waterways in the VWMS, one of the primary determinants for how waterways are managed in Victoria, is: "*Victoria's rivers, estuaries and wetlands are valued and well-managed, so that communities can enjoy the current and future benefits that healthy waterways provide*" (DSE 2012b). Through the guidance of the VWMS, the management objectives for the Werribee River and estuary 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.

The HWS states its high-level vision for waterways within the Port Phillip and Westernport region as:

"Healthy and valued waterways are integrated with the broader landscape and enhance life and liveability.

They:

- *Connect diverse and thriving communities of native plants and animals.*
- *Provide amenity to urban and rural areas and engage communities with their environment.*
- *Are managed sustainably to balance environmental, economic and social values."*

The vision for the Werribee River and its flow dependent values articulates not only what ecological objectives are aiming to achieve overall, but also the way in which these ecological objectives are set.

Werribee River Vision
To protect and where possible restore and enhance its ecological health, functioning, and biodiversity. Using robust, evidence-based science, as well as community input to inform decisions, environmental flows will be provided for the water-dependent values along the waterway so that the river and its values can continue to be enjoyed by future generations

Ecological Objectives

The key values of amenity, fish, birds, frogs, macroinvertebrates, platypus and vegetation in the HWS provide the basis of the ecological objectives for the Werribee River, and have been endorsed through extensive community consultation.

A summary of the ecological objectives and expected outcomes for the flow-dependent values identified in the HWS is provided in Table 23.

Table 23: Ecological objectives and expected 20-year outcomes in the Healthy Waterways Strategy

Value	Ecological Objectives	Expected Outcomes and Management Units
Fish	Maintain high species richness and abundance of fish populations in the upper reaches Maintain nativeness and abundance through improved fish passage	• Management interventions aim to improve the condition of native fish populations from high to very high over the next 20 years • Applies to Werribee Upper, Middle and Lowlands Systems

Value	Ecological Objectives	Expected Outcomes and Management Units
Platypus	Prevent further declines and stabilise the population	• Works aim to stabilise the very low condition of Platypus over the next 20 years • Applies to Werribee Upper, Middle and Lowlands Systems
Vegetation	Maintain and improve vegetation condition Maintain vegetation at high quality	• Interventions aim to improve the condition of vegetation from moderate to high within the next 20 years (Werribee Middle and Upper System) • Interventions aim to improve vegetation condition from low/moderate up to moderate over the next 20 years (Werribee Lowlands System)
Macroinvertebrates	Maintain macroinvertebrate diversity Maintain the number of macroinvertebrate families present in the upper reaches	• Interventions aim to improve the condition of macroinvertebrates from moderate to high over the next 20 years (Werribee Middle and Upper System) • Interventions aim to maintain condition at moderate (Werribee Lowlands System)
Birds	Improve species richness and abundance of streamside and wetland native bird populations	• Interventions aim to improve the condition of water-dependent native birds from low and downward trending, to moderate over the next 20 years (Werribee Middle and Upper System) • Interventions aim to improve the condition of native birds, particularly at Western Treatment Plan, from high to very high over the next 20 years
Amenity	Improve amenity	• Actions targeted at amenity aim to improve its condition from moderate to high over the next 20 years • Applies to Werribee Upper, Middle and Lowlands Systems
Frogs	Improve species richness, maintain distribution of expected species and overall abundance of frogs	• Interventions aim to improve the condition of frog populations from moderate and downward trending, to high (Werribee Upper and Middle System) • Interventions aim to improve frog population condition from moderate to high over the next 20 years (Werribee Lowlands System)

The priority flow-dependent values and locations along the Werribee River as specified in the HWS are:

- Platypus in the upper reaches between Ballan and Bacchus Marsh, and in the lower freshwater reaches above and below the Werribee Diversion Weir
- Fish in the lower reaches upstream to the Werribee Diversion Weir. Common species here include Gudgeon and Smelt in the freshwater reaches, Black Bream in the estuary and Eels, Galaxids and Tupong moving between the two

- Vegetation in the lower reaches, including riparian River Red Gum woodland and salt marsh vegetation around the estuary, and in Coimadai Creek (Reach 6).
- The lower reaches have high social value, which will be maintained to some degree by enhancing in-stream biodiversity and the flow regime
- Coimadai Creek downstream of Merrimu reservoir (Reach 6), which flows through the Long Forest Nature Reserve, an important regional hotspot of plant and bird biodiversity. Evidence from monitoring suggests that macroinvertebrate and frog populations in this reach may be enhanced by environmental flow (Melbourne Water 2013).

Environmental Flows Study Ecological Objectives

Environmental flows studies for the Werribee River and estuary provide the more detailed and reach-specific set of ecological objectives for water-dependent values in the waterway. In 2005, environmental flow recommendations were developed for the freshwater reaches (Ecological Associates 2005). In 2008, flow recommendations were developed for the estuary (Lloyd et al. 2008), and in preparation for the development of the Werribee River EWMP, the 2005 flows study was reviewed in mid-2014 (Jacobs 2014). The flows studies have focused on providing ecological objectives and flow recommendations for geomorphology, vegetation, fish, platypus, macroinvertebrates and frogs. The flow requirements of water-dependent birds have not been considered in the flows studies for the Werribee River due to insufficient knowledge of their flow regime requirements. As a consequence, although they are a high priority value within the HWS, they are not discussed in this section of the EWMP.

A collated summary of the water-dependent ecological objectives recommended through these flow studies is provided in Table 24 through to Table 35. In each table, a justification for each objective is provided, and objectives are categorised and described as:

- Primary – Where overarching objectives are provided for both the freshwater river and estuary sections of the system
- Secondary – Where the water-dependent functional aspects of the ecological values that flows are targeting are described, again for the freshwater reaches and the estuary.
- Reach specific – Where flow specific objectives are provided, including the reaches targeted for these objectives.

It should be noted that not all of the recommendations in these tables are of equal priority for delivery by Melbourne Water. Factors such as the feasibility of delivering environmental water, infrastructure constraints, and water availability have a significant influence on which ecological objectives and reaches are targeted for the annual use of the Werribee River Environmental Entitlement. Priorities are thus provided for each specific ecological objective, and are as follows:

- **Priority 1** = Currently a priority watering action in the Seasonal Watering Plan
- **Priority 2** = Will become a priority watering action if more environmental water becomes available
- **Priority 3** = Would require permanent wholesale changes to Werribee catchment and water resource management.

Geomorphology Objectives

Justification

- The geomorphic structure and stability of the freshwater reaches of a waterway has a significant influence on its ecological functioning and biodiversity, and supports all of the ecological values present in the system.
- Salt wedge dynamics within the estuary play an important role in providing a diversity of habitat for estuarine fish and vegetation. Baseflows to an estuary maintain the position of the salt wedge. If the position of a salt wedge migrates upstream due to reduced flows, then salt intolerant bank vegetation can become salt affected and bank erosion is likely to follow. Summer baseflows are important for maintaining the mouth in an open state.

Table 24: Primary and secondary ecological objectives for geomorphology

Objective Level	Freshwater reaches	Estuary
Primary	• Ensure that major natural habitat features are represented and are maintained over time, and that linkages between river and floodplain and associated wetlands are maintained to protect vital ecological processes.	• Maintain salt wedge and sediment dynamics in the estuary.
Secondary	• Maintain capacity to mobilise sediment and shape channel and habitat features	• Maintain sediment processes through maintaining baseflows and high flows, as both of these have been implicated in maintenance of estuaries in an open state.

Table 25: Reach specific ecological objectives for geomorphology

Specific Geomorphology Objectives	Reach	Priority
Mobilise gravels and sands on bed of river	3, 4, 5, 8,	3
Maintain channel dimensions and form through sediment reworking	3, 5, 6, 7, 8, 9, Estuary	3
Disturb woody vegetation and benches approximately every 10 years	3	3
Mobilise gravels in rifles and pools	4	3
Maintain / mimic natural hydrologic variability of baseflows – Avoid long periods of high regulated flows in summer	4, 5, 8	3
Maintain channel dimensions and form through sediment reworking	5, 6, 7, 8,	3
Clean substrate on streambed - Flush silt and scour algae and biofilms from substrates on the streambed	6	1
	9	2
Flush organic material from low lying benches	6	1

Specific Geomorphology Objectives	Reach	Priority
Maintain secondary flow paths and billabongs - Inundate secondary flow paths and billabongs within the main channel	9	3
Maintain channel dimensions - Mobilise and re-work sand and gravel on streambed to maintain pools and channel dimensions	9	3
Estuary: • Maintain bank stability in the upper estuary • Maintain suspended sediment dynamics in the middle estuary • Maintain the channel and floodplain morphology of all parts of the estuary • Scour sands at the entrance	Estuary	N/A

Fish Objectives

Justification

- Native fish play an important role in freshwater ecosystems.
- There are no locally native species of conservation value in the Werribee River and estuary, but there are numerous species that are important for their recreational or commercial fisheries values.

Table 26: Primary and secondary ecological objectives for fish

Objective Level	Freshwater reaches	Estuary
Primary	• Maintain existing populations of migratory fish • Provide passage to allow migratory species to move between the estuary and freshwater reaches • Maintain existing populations of non-migratory fish	• Sustain and protect a diversity of habitat types to maintain current estuary fish biodiversity
Secondary	• Maintain existing populations of migratory fish • Allow Common Galaxias, Tupong and other species to migrate to and from the freshwater reaches, estuary and the sea • Maintain any existing populations of small-bodied native fish species such as Southern Pygmy Perch, Flathead Gudgeon, Mountain Galaxias, Short-finned Eel.	• Provide suitable habitat for the estuarine resident fish species Black Bream • Provide suitable habitat for the estuarine dependent (marine derived) fish species King George Whiting • Provide suitable habitat for the estuarine dependent (freshwater derived) fish species Common Galaxias

Objective Level	Freshwater reaches	Estuary
	• Provide suitable habitat for River Blackfish • Control Brown Trout • Provide and maintain suitable habitat conditions for Southern Pygmy Perch • Maintain suitable habitat for Tupong	

Table 27: Reach specific ecological objectives for fish

Reach Specific Objectives for Fish	Reach	Priority
Control Brown Trout numbers	3	3
Provide suitable water quality for the entire reach	3	3
Maintain pool refuge habitat (persistence)	3, 4, 5	3 Met naturally and/or via passing flow requirements
	6, 8, 9	1 Usually met naturally or through passing flow requirements
Provide passage (dispersal) for River Blackfish fry and adults between pools	4, 5	2
	8, 9	3
Avoid flushing of fish from the reach	3, 4, 5	2
Provide deep spawning habitat in pools or submerged rocks and snags for River Blackfish	3, 4, 5	2
	8, 9	3
Maintain pool water quality during low flows	4, 5	2
	8, 9	1
Maintain pools for Southern Pygmy Perch	6, 7,	3
Provide access to emergent vegetation in the stream bed for Southern Pygmy Perch	6, 7	3
Maintain any existing populations of small-bodied native fish species in addition to Southern Pygmy Perch, such as Flathead Gudgeon, Mountain Galaxias, and Short-finned Eel*	6,	1
Provide access to other channel habitats and dispersal opportunities during the wet period*	6	1
Migratory fish:	9	1

Reach Specific Objectives for Fish	Reach	Priority
• Maintain existing populations of migratory fish • Allow Common Galaxias, Tupong and other species to migrate to estuary or sea in autumn • Allow juvenile Common Galaxias, Tupong and other diadromous species to migrate into freshwater reaches		
Black Bream (Estuarine Resident): 1. Maintain suitable estuarine salinities 2. Maintain conditions for spawning / survival 3. Provide refuge/feeding for settlement and post-settlement for juveniles 4. Provide opportunities for migration in to the estuary from the sea 5. Provide habitat for larval Black Bream to survive and grow	Estuary	Priority 1 for objectives 2, 3 & 5 Priority 2 for objectives 1 and 4
Common Galaxias (Estuarine Dependent – Freshwater Derived): • Provide cues for migration downstream to the estuary • Maintain appropriate inundation levels for spawning, egg survival and marine migration • Support migration to the estuary from the sea	Estuary	1
King George Whiting (Estuarine Dependent – Marine Derived): • Provide habitat for larval King George Whiting to survive and grow • Support migration to the estuary from the sea	Estuary	1

Vegetation Objectives

Justification

- Vegetation is an important component of waterway ecosystems. It provides food, shelter and water quality parameters for both in-stream, riparian and floodplain biodiversity
- Instream plants provide food and shelter for small fish and support the food web
- Riparian vegetation provides food, shelter, and bed and bank stability
- Estuarine vegetation provides food, shelter and substrate for fish and other species

Table 28: Primary and secondary ecological objectives for vegetation

Objective Level	Freshwater reaches	Estuary
Primary	• Improve the cover of aquatic and riparian vegetation to stabilise banks, promote plant and animal diversity and provide a wider range of habitats for aquatic fauna • Protect and enhance existing remnant riparian and aquatic vegetation and functional wildlife corridors along the waterway	• Maintain and improve the representative EVCs of Coastal Salt Marsh (EVC 09), Estuarine Wetland (EVC 010), Floodplain Riparian Woodland (EVC 056), and Seagrass Meadow (EVC 845)
Secondary	• Maintain and restore semi-emergent, emergent and shrub assemblages • Maintain a mosaic of plant assemblages	• Maintain a mosaic of plant assemblages appropriate to the variety of representative EVCs present at the estuary • Connect the estuarine wetland to its surrounding floodplain to promote growth and recruitment of River Red Gum and prevent terrestrialisation across the Riparian Woodland Zone • Provide appropriate habitat conditions (i.e. salinity and turbidity) for seagrass to extend its range up the estuary to Red Cliffs

Table 29: Reach specific ecological objectives for vegetation

Reach Specific Objectives for Vegetation	Reach	Priority
Maintain pools to support aquatic vegetation	3, 4, 5, 8, 9	2
	6	1
	7	3
Maintain in-stream bench soil moisture to support emergent vegetation	3, 4, 5, 8, 9	2
	6	1
	7	3
Create disturbance and patches in emergent vegetation to promote vegetation diversity	3, 5, 8, 9	3
Replenish floodplain soil moisture and trigger recruitment of floodplain vegetation	4, 5, 8	3
Create a broad riparian zone of aquatic macrophytes by gradually exposing banks over spring and summer	3, 4, 5,7, 8, 9	3
	6	1
Inundate in-stream benches to promote riparian plant growth and submerged plants in pools and backwaters	3, 5, 8,	2
	6	1
	7	3
Promote open, diverse vegetation structure in stream bed	3, 4, 5, 6, 7, 8, 9	2

Reach Specific Objectives for Vegetation	Reach	Priority
Coastal Salt Marsh: • Promote salt-tolerant herbs, grasses and forbs • Exclude emergent macrophytes • Promote salt-tolerant charophytes and submerged vascular macrophytes • Provide habitat for salt-tolerant grasses, sedges, herbs and forbs • Encourage salts to accumulate in summer to exclude salt intolerant sedges. Maintain *Sarcocornia quinqueflora* • Support moderately salt tolerant *Juncus kraussii* at and below the high tide level	Estuary	N/A
Estuarine Wetland: • Promote and maintain the growth and density of *Phragmites australis*, and the growth and recruitment of *Eucalyptus camaldulensis*	Estuary	1
Floodplain Riparian Woodland: • Maintain and promote growth and recruitment of *Eucalytpus camaldulensis* and other flood-dependent trees and shrubs • Promote growth of aquatic understorey plants. • Maintain aquatic plant communities in the riparian zone.	Estuary	3
Seagrass Meadow: • Promote salinity levels between a median of 0.5 to 1.0 times sea water to promote best conditions for growth and photosynthesis of seagrass meadows • Provide freshwater pulses as a trigger for seagrass meadow germination • Prevent excessive accumulation of sediment and reduce turbidity downstream of Red Cliffs bend • Maintain well-lit conditions from the estuary mouth up to Red Cliffs bend to support seagrass growth	Estuary	N/A

Macroinvertebrate Objectives

Justification

- Macroinvertebrates play a highly critical role in waterways biodiversity, and are a food source for fish, frogs and platypus.

Table 30: Primary and secondary ecological objectives for macroinvertebrates

Objective Level	Freshwater reaches	Estuary
Primary	• Maintain and improve the condition of the existing macroinvertebrate community	• Not included as an objective
Secondary	• Maintain appropriate water quality parameters • Replenish food sources such as biofilms • Keep surfaces relatively free of fine silt and filamentous algae • Prevent excessive increases in electrical conductivity	• Maintain habitats and suitable flow conditions for tolerant macroinvertebrate fauna in Coimadai Creek • Maintaining permanent flow in some riffle habitats • Maintain permanent pools in ephemeral reaches such as Lerderderg River and Coimadai Creek • Ensure flowing water available to encourage riverine fauna colonisation • Remove fines from under cobbles and also remove filamentous algae

Table 31: Reach specific ecological objectives for macroinvertebrates

Reach Specific Objectives for Macroinvertebrates	Reach	Priority
Scour silt, biofilms and filamentous algae from substrate to maintain quality and quantity of food and habitat*	3, 4, 5	2
	6	1
	7	3
	8	2
Maintain pools for drought intolerant macroinvertebrate fauna	5	2 Usually met naturally or through passing flow requirements. Requires additional environmental water to increase persistence through possible future droughts
	6	1
	7	3
Provide access to riffle and run habitats*	6	1

Reach Specific Objectives for Macroinvertebrates	Reach	Priority
	9	2
No macroinvertebrate objectives for the Estuary	N/A	N/A

Frog Objectives

Justification

- Frogs are an integral part of waterway ecology
- Most Victorian frog species require surface water for foraging and/or breeding habitat at some stage during their life cycle. The flow requirements of the frogs of the Werribee River and Coimadai Creek are designed primarily to trigger and promote successful breeding.
- The Growling Grass Frog is considered vulnerable in Australia and endangered in Victoria

Table 32: Primary and secondary ecological objectives for frogs

Objective Level	Freshwater reaches	Estuary
Primary	• Maintain populations of Growling Grass Frog, Pobblebonk, Striped Marsh Frog, Spotted Marsh Frog and the Southern Brown Tree Frog	• Not included as an objective
Secondary	• Provide appropriate habitat conditions for frog species to trigger and promote successful breeding	• Not included as an objective

Table 33: Reach specific ecological objectives for frogs

Reach Specific Objectives for Frogs	Reach	Priority
No flow specific objectives for frogs provided	3, 4, 5, 7, 8, Estuary	N/A
Maintain permanent pools with fringing vegetation	6	1
	9	2 Usually met naturally or through passing flow requirements, requires additional environmental water to increase persistence

Reach Specific Objectives for Frogs	Reach	Priority
		through possible future droughts
Provide connecting flows to allow frogs to use channel habitats and allow Growling Grass Frog to move and mix with other metapopulations	6	1
Inundate depressions adjacent to the waterway that frogs can use for breeding*	6	1
	9	2
Inundate secondary channels and billabongs	9	3 Partially achieved currently, requires catchment-scale change to restore to natural frequency.
Provide inundation to fill billabongs, promote vegetation growth and provide aquatic habitat for a range of floodplain fauna including frogs	Estuary	3 Partially achieved currently, requires catchment-scale change to restore to natural frequency

Platypus Objectives

Justification

- The Platypus is an iconic species in Australia, highly valued by communities for its uniqueness.
- Platypus numbers in the lower reaches of the Werribee River are now critically low.

Table 34: Primary and secondary ecological objectives for Platypus

Objective Level	Freshwater reaches	Estuary
Primary	• Prevent further decline of Platypus numbers and increase their abundance in the system	• Not included as an objective
Secondary	• Provide appropriate habitat for Platypus	• Not included as an objective

Table 35: Reach specific ecological objectives for Platypus

Reach Specific Objectives for Platypus	Reach	Priority
Maintain refuge pools in summer and autumn	4, 5	2 Usually met naturally or through passing flow requirements, requires additional environmental water to increase persistence through possible future droughts
Maintain water quality in permanent pools	4	2
	8, 9	1 May require additional environmental water
Scour sediments from base of pools and silt from riffles to maintain quantity and quality of feeding habitat	4, 8	2
Maintain and regenerate stable undercut banks for burrows and feeding habitat	4, 5	2
Provide feeding habitat in backwaters and in-channel benches	5, 8, 9	2
Avoid flooding burrows during the breeding and rearing seasons by controlling summer floods	9	3
Avoid flooding burrows during the breeding and rearing seasons by providing extended high flows during winter	9	2 Requires additional environmental water, possibly requires catchment-scale change
Provide feeding habitat in riffle sections	9	2 Requires additional environmental water, (see macroinvertebrate habitat objective for reach 9)

Watering Objectives

The priority flow recommendations to address the ecological objectives of the Werribee River and its estuary are provided in Table 36. The frequency, duration and timing for each of the recommended flow components is included in the table. The recommendations have been presented according to winter or summer flows, with spring flows included within the winter season, and autumn flows included within the summer season recommendations. Flows have also been prioritised according to their ease of delivery under current entitlement and water shares.

Priority watering actions

To achieve the environmental objectives, delivering water to Reach 6 and the estuary are the first priorities. In wetter climatic scenarios, water deliveries will be targeted to Reach 9 and possibly Reach 8. For each reach, there are several watering actions, listed below in order of priority:

- Reach 6
    - Spring freshes of 30 ML/d for 2 days, up to 3 times between September and December
    - Winter and spring base flow of 2 ML/d between July and December
- Estuary
    - Spring and summer freshes of 50 to 80 ML/d for 2 days, twice per season between November and January
    - Winter and spring baseflow of 15 ML/d between June and November
    - Autumn freshes of 89 ML/d for 2 days, 2-4 times per season
    - Winter and spring freshes of 100 ML/d for 1 day 8 times between June and November
- Reach 9
    - Summer freshes of 137 ML/d for 1 day, three times per season between January and April
    - Winter flows in addition to natural baseflow and freshes between May to December
- Reach 8
    - Winter flows in addition to natural baseflow and freshes between June to December.

Although Reach 6 is a small and intermittently flowing creek, it is in good condition and drains the intact ecosystem of the Long Forest Nature Conservation Reserve. The potential to achieve ecological improvement in this reach is therefore quite high. There has been minimal historical clearing or disturbance of the channel and the riparian area is largely free of introduced weeds.

Reach 9 and the estuary are downstream of the Werribee Diversion Weir, which has limited ability to control passing flows, making it challenging to deliver environmental water. However, as the ecological and social values of these reaches are very high, Melbourne Water rates them a priority for delivering environmental water. Southern Rural Water has been proactive in finding ways to deliver water to these reaches and has received strong community support to do so.

Bankfull and overbank flows are important to the health of all freshwater reaches as well as the estuary, and the current frequency of these flows is less than natural. However, due to the very large volumes of water required to deliver these events, as well as the risk of flooding private land and infrastructure, they will not be delivered from the environmental water holdings.

Table 36: Priority watering actions

Flow component	Reach	Timing	Priority*	Objective	Recommendation	Comments
Winter /Spring base flow	6	June – December	H	Maintain habitat for macroinvertebrates and frogs	2 ML/d or natural	Mostly provided by BE passing flows. Duration may be extended by releases from the environmental reserve
Winter /Spring base flow	8	June - December	M	Provide passage and spawning habitat for fish, promote macrophytic vegetation and provide platypus habitat	36 ML/d continuously or natural	Delivery from environmental reserve would only occur in Enhance or Recover scenarios and would represent a small fraction of total flow
Winter /Spring base flow	9	May - December	M	Provide passage and pool habitat for fish and inundate in-stream macrophytes	81 ML/d or natural, continuously	Delivery from environmental reserve would only occur in Enhance or Recover scenarios and would represent a small fraction of total flow
Winter /Spring base flow	E	June - December	H	Provide Black Bream habitat	15 ML/d continuously, 5 years in 10	-
Winter / Spring fresh	6	September - December	H	Scour silt and algae from riffles, promote vegetation growth	30 ML/d for 2 days, up to 3 times per season	-
Winter / Spring fresh	8	June- December	L	Promote hydrophilic shrubs and disturb macrophytes	350ML/d or natural for 3 days. Four events per year	Insufficient volume of water available for reliable delivery
Winter / Spring fresh	9	July- December	L	Provide fish passage, maintain macrophytic and shrub vegetation mosaic and mobilise sand from riffles	350ML/d or natural for 3 days. Four events per year	Insufficient volume of water available for reliable delivery
Spring / Summer fresh	E(1)	November - January	H	Promote recruitment of juvenile Black Bream	50-80 ML/d for 2 days, twice per year, 5 years in 10.	-
Winter / Spring fresh	E(2)	June - December	M	Inundate salt marsh with brackish water	100 ML/d for 1 day, 8 times per year, 5 years in ten	-
Spring high	6	September - December	M	Promote growth of riparian vegetation	130 ML/d for 2 days, once every three years	-
Summer / Autumn base	8	January -	L	Maintain pool and riffle habitat for fish,	10 ML/d or natural in all years	Currently achieved by high flow

Flow component	Reach	Timing	Priority*	Objective	Recommendation	Comments
flow		May		macroinvertebrates and Platypus	except drought	releases for irrigation
Summer / Autumn base flow	9	January - April	L	Maintain pool habitat for fish, macroinvertebrates and Platypus and riffle habitat for macroinvertebrates	6 ML/d or natural, continuously	Difficult to achieve given infrastructure constraints at the Werribee Diversion Weir
Summer / Autumn base flow	E	December - May	L	Maintain freshwater macrophytes in upper estuary	9 ML/d, 30% of the time, 5 years in ten	Currently achieved naturally
Summer / Autumn Fresh	8	January - May	L	Improve riffle habitat for macroinvertebrates and Platypus, maintain pool water quality for fish and platypus and allow for dispersal of fish fry	167 ML/d or natural for 1 day, three times per year	Currently achieved by high flow releases for irrigation
Summer / Autumn Fresh	9	January – April	M	Maintain pool water quality for fish and platypus, allow for fry dispersal and mobilise silt from riffles	137 ML/d or natural for 1 day, three times per year	
Autumn fresh	E	Mar-May	H	Provide fish passage between estuary and freshwater reaches	89 ML/d for 2 days, 2-4 times per year on average	May be achievable with lower flow rates due to new fishway

Adaptive management

The level of the catchment's storages, the level of risk faced by particular species as they cope with climate variability, and recent inflows to the Environmental Entitlement all influence the adaptive management of the Werribee River environmental entitlement, and change the priority ecological objectives that are targeted for flow releases. Triggers for action have been determined based on climate scenarios, of which there are four: 'Recover', Enhance', 'Protect' and 'Maintain'. The priority watering actions and expected water use under these scenarios are detailed in Table 37.

Table 37 Planning scenarios under a range of climatic conditions

Scenario	Estimated volume available	Environmental objectives	Priority flow components	Possible volume required	Estimated carryover
Very dry year (Protect scenario)	Up to 1200 ML total	Macroinvertebrate and frog habitat, Black Bream recruitment and habitat and fish migration	Winter freshes and baseflow in reach 6 and summer freshes in the estuary	Up to 900 ML total	300 ML
Dry year (Maintain scenario)	Up to 1700 ML total	Macroinvertebrate and frog habitat, Black Bream recruitment and habitat, and fish migration	Winter freshes and baseflow in reach 6 and winter and summer freshes in the estuary and reach 9	Up to 1500 ML total	200 ML
Average year (Recover scenario)	2000- 2500 ML total	Macroinvertebrate and frog habitat, Black Bream recruitment and habitat, and fish migration	Winter freshes in reach 6 and the estuary. Winter baseflow in the estuary, summer freshes in reaches 6, 9 and the estuary and winter flows in reach 8	Up to 1500 ML total	500-1000 ML
Wet year (Enhance scenario)	Greater than 2500 ML total	Macroinvertebrate and frog habitat, Black Bream recruitment and habitat, and fish migration	Winter freshes in reach 6 and the estuary. Winter baseflow in the estuary, summer freshes in reaches 6, 9 and the estuary and winter flows in reach 8	Up to 1500 ML total	> 1000 ML

The scenarios are based upon conditions that will influence the operation of entitlements and water shares such as spills, likely spills and amounts of water required for certain actions. The volumes of water required are rough estimates and will be refined by Melbourne Water to account for losses as experience is gained in operating during dry and wet conditions.

The scenarios are also based on storage and flow records for the period 1992-2012, the only period for which reliable gauged records are available. During this period, the Werribee catchment was in a ‘Protect’ or ‘Maintain’ scenario for approximately 60% of the time and a ‘Recover’ or ‘Enhance’ scenario for approximately 40% of the time.

In dry scenarios, when Melton is not spilling in winter, water released from the Environmental Entitlement in Lake Merrimu in winter can be stored and then released to achieve high priority actions in the estuary. In wet scenarios, the water will spill over Melton and add marginally to winter baseflow and freshes in reaches 8, 9 and the estuary.

As the Environmental Entitlement has no provision for storage, more water will generally be released from Lake Merrimu in Enhance and Recover scenarios than Maintain and Protect scenarios. The main ecological objectives of these releases will be in Reach 6 because Melton is likely to be spilling in the wetter scenarios, limiting the opportunity to achieve ecological objectives in the estuary.

The way in which climate variability and species’ vulnerability alters priority flow releases is discussed further in the ‘Managing Risks’ section of the EWMP.

MANAGING RISKS

Risk Assessment Methodology

When assessing risk to the water-dependent ecological values of the Werribee River, Melbourne Water has sought to understand the following:

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

Because climate variability and climate change pose a significant challenge for the Werribee River, Melbourne Water has undertaken an additional risk assessment process which seeks to quantify the magnitude of climatic risk for the river’s water-dependent ecological values.

Risk Matrix

When assessing the risks to water-dependent ecological values for the Werribee River, the relationship between the likelihood (probability of occurrence) and the consequences of a risk occurring have provided the basis for evaluating the level of risk (Table 38).

Table 38: Risk matrix

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

A summary of the results from the Werribee River qualitative risk assessment is shown inTable 39, containing risk ratings and estimated residual risks following the implementation of successful management actions. More detailed risk assessment findings and the management actions to address these risks are provided in Appendix 3.

Table 39: Risk assessment and management actions

Risk Category	Water-Dependent Ecological Values Impacted	Likelihood	Consequence	Risk Rating	Residual Risk
Threats to achieving ecological objectives					
Further consumptive extraction of surface water, causes additional alteration of natural flow regimes	All	Possible	Major	H	M
Groundwater extractions causing shifts in the seawater/freshwater interface	Fish, Vegetation, Macroinvertebrates	Possible	Moderate	M	L
Construction of additional artificial instream structures (e.g. dams, weirs, gauging stations)	Fish, Platypus, Geomorphology, Amenity	Unlikely	Major	M	M
Recreational fishing decreasing native fish abundance	Fish	Certain	Moderate	H	M
Urban development altering catchment and urban stream hydrology and reducing habitat availability	All	Certain	High	H	M
Land clearing for agricultural and residential purposes, and the associated increases in numbers of licenced and unlicenced farm dams	Fish	Certain	Major	H	M
Pest plants and animals, for example Carp, Brown Trout, Gambusia, Redfin, foxes, dogs and cats.	Fish, Platypus	Certain	Major	H	M
Illegal fishing nets causing preventable platypus mortality	Platypus, Fish	Certain	Major	H	M
Catchment land use practices increasing sediment and nutrient inputs to the estuary	Fish, Vegetation, Amenity	Certain	Moderate	H	B
Further expansion of irrigation areas within the catchment increasing demands for surface water and groundwater	All	Unlikely	Major	M	L
Stock access and grazing pressure in the riparian zone	Vegetation, Fish, Platypus, Amenity	Certain	Moderate	H	M
Climate change reducing water availability and altering flow regimes	All	Certain	Major	H	H
Threats related to the delivery of environmental water					

Risk Category	Water-Dependent Ecological Values Impacted	Likelihood	Consequence	Risk Rating	Residual Risk
High flow releases drowning juvenile Platypus	Platypus	Possible	High	M	L
Flow releases causing personal injury to river users	N/A	Unlikely	Major	M	L
Release volume is insufficient in meeting required flow at target point	All	Unlikely	Moderate	L	L
Current recommendations on environmental flow are inaccurate	All	Possible	Moderate	M	L
Storage Operator maintenance works affect ability to deliver water	All	Unlikely	Moderate	L	L
Resource Manager cannot deliver required volume or flow rate (outlet/capacity constraints, insufficient storage volume)	All	Unlikely	Moderate	L	L
Competing storage operator priorities do not allow delivery of some events (fire, flood etc)	All	Possible	Moderate	M	M
Releases cause water quality issues (e.g. blackwater, low DO, mobilisation of saline pools, acid-sulphate soils, etc)	All	Possible	Moderate	M	L
Releases improve habitat conditions for non-native species (e.g. carp)	Fish	Possible	Moderate	M	M
Unable to provide evidence that hydrological targets have been met	All	Possible	Minor	L	L
Irrigators divert environmental releases from the system leading so the target is not reached.	All	Possible	Moderate	M	L
Environmental releases cause flooding of private land, public infrastructure or Crown land	All	Unlikely	Moderate	L	L
Environmental releases interfere with essential Melbourne Water services	N/A	Unlikely	Moderate	L	L
Public misperceptions regarding the purpose of releases	All	Possible	Moderate	M	L

Climatic Risk

Climate variability and climate change pose a significant challenge for environmental water managers, particularly in areas with low and variable runoff, such as those across much of southern Australia. Quantifying the magnitude of risk posed by drought cycles is made more difficult by the variable resistance and resilience traits of individual species as they resopnde to hydrologic stress (Crook et al. 2010).

For example, whether a population of a particular animal species declines during periods of drought will depend on the resistance of that species to harsh environmental conditions (e.g. low DO, high temperature), coupled with traits such as longevity and its ability to breed under those conditions (Bond et al. 2008). For species that do undergo declines, their rate of recovery (their resilience) will be influenced by factors such as fecundity and their minimum age at maturity. Collectively these traits can give rise to varied, and sometimes lagged patterns of decline and recovery in response to hydrologic variability, which ultimately can affect population viability in drought prone environments (Bond et al. 2008).

For the EWMP, Melbourne Water used an Expert Panel to estimate the likelihood of fauna such as fish and platypus shifting between semi-quantitative states[3] (poor, average, good, very good) under the different hydrologic scenarios defined for the Werribee River, based on their knowledge of these species' life-history traits. The life history traits of the species assessed were particular to the populations and hydrological regimes within the Werribee catchment.

The hydrologic scenarios are the 'Protect', 'Maintain', 'Recover' and 'Enhance'[4] scenarios previously discussed. The Expert Panel comprised ecologists with strong knowledge of platypus, fish and macroinvertebrates within the Werribee River, as well as consultants and Melbourne Water managers with a strong knowledge of the system. The probability of each hydrological scenario was determined from the 1992-2012 hydroclimatic period, the longest period of reliable gauged data relavent to environmental flow objectives.

The 1992-2012 period was drier than the long-term average (about 60th percentile for rainfall and stream flow in the upper Lerderderg catchment). The climate of the period was highly variable, encompassing an exceptionally long and intense drought from 1997 to 2009 and several exceptionally wet years in the early 90s and from 2010-2012. The dry and variable climate of the period makes it representative of future climate predictions for the region and the hydrological conditions likely to be experienced by aquatic biota.

For the purposes of simplicity, the Expert Panel did not determine exactly what the population 'state' refers to, but abundance was thought likely to be a relatively straight forward metric for monitoring purposes and this concept will be further developed as part of Melbourne Water's work to improve its knowledge and understanding of the Werribee system. The average health of individuals or their genetic diversity could also be used as indicators of state, and these will also be explored as options over time as Melbourne Water further develops this risk assessment methodology.

Appendix 4 provides a summary of the life history traits of a number of key species in the Werribee River and estuary.

Using the life history traits data, the Expert Panel assessed the probability that key species would shift from one particular condition to another under a variety of hydrological scenarios and a first-order markov chain model was then used to assess the likely population condition of species against these scenarios. Figure 20 and Figure 21 illustrate the results of the modelling, which uses the following flow data:

- Historic Werribee catchment flow data from 1992 to 2012 (incorporating the Millennium Drought) (Figure 20)

[3]Ultimately, the indicator(s) used to represent population 'state' will be developed to have a strong conceptual link to flow (as outlined in the flow objectives) and will be used to determine the state and/or trajectory of population abundance. For some species, appropriate indicators of population 'state' will need to be determined and these will guide the design of future monitoring programs. Age-structure, measurements of breeding and/or recruitment, and genetic structure could all be considered (P. Reich pers. comm.)

- A hypothetical and random 100-year flow sequence, based on probabilities derived from the 1992-2012 flow sequence (Figure 21).

To interpret the assessment results; red bars indicate poor condition, green is moderate, blue is good and and purple bars indicate excellent condition. In any given year, the probability that the population is in one of the four conditions is illustrated by the proportion of the bar in each colour.

The black line indicates the climatic scenarios, with 1 representing a wet 'Enhance' scenario, 0.75 representing a 'Recover' scenario, 0.5 representing a 'Maintain' scenario, and 0.25 representing a dry 'Protect' scenario. It's important to note that these sequences do not consider the influence of other changes in the system that might occur during this period e.g. land use change, pollution, sea level rise etc.

For example, when looking at the condition of Platypus, it can be seen that in Figure 19 its condition remains relatively good (i.e. purple bars) when experiencing a run of years of the 'Enhance' and 'Recover' water availability scenarios. As the black line drops down towards the drier 'Protect' scenario however, Platypus condition drops (as evidenced by red bars), and even as water availability improves, its condition remains poor for some time afterwards, indicating a lag in its recovery.

When looking at Figure 20, it can be seen that following periods of high flow stress, Platypus may remain in a poor state for a significant proportion of time despite improved water availability. This trajectory is concerning because a very long period of consistently above average rainfall may be required for the population to recover. To provide real opportunities for recovery through flow management under current river regulation, this will require that Melton and Werribee weirs spill consistently (in 'Enhance' and 'Recover' scenarios), which currently only happens in 40% of years.

This contrasts markedly when comparing to the estuarine fish species Bream. Based on life history traits, Bream are remarkably resilient to changes in flow availability, with a much greater likelihood that they will stay in excellent to good condition for longer when water availability drops, and a much faster recovery of condition once water availability in the system improves.

A significant risk that can be confidently predicted by the model is that migratory fish such as Galaxias and Tupong will be in poor condition for much of the time. This is due to there being extremely limited passage for their migration during 'Maintain' and 'Protect' scenarios, which occur in approximately 60% of years.

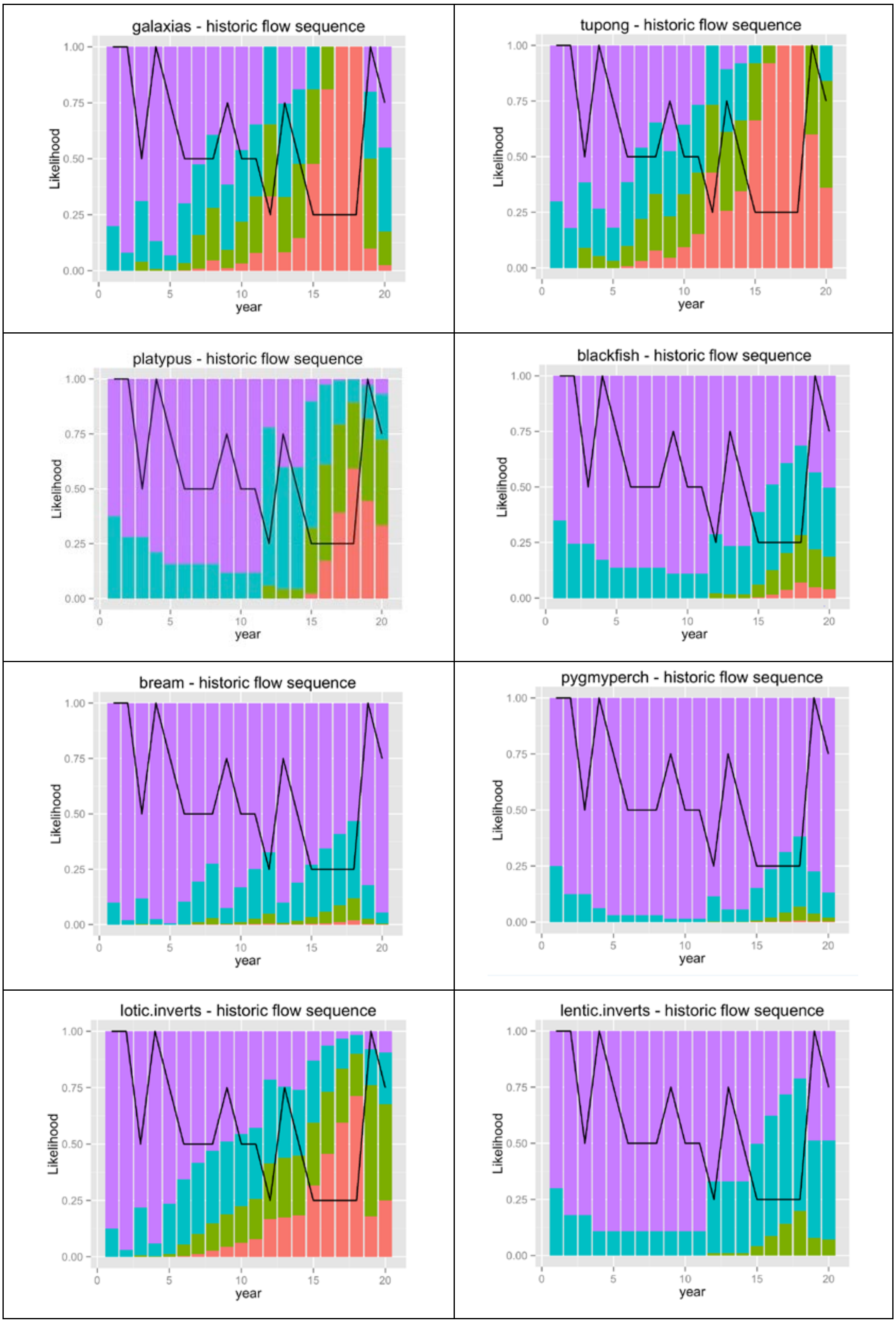

Figure 20: Likely population condition of priority fauna values using historical flow sequences (1992 to 2012)

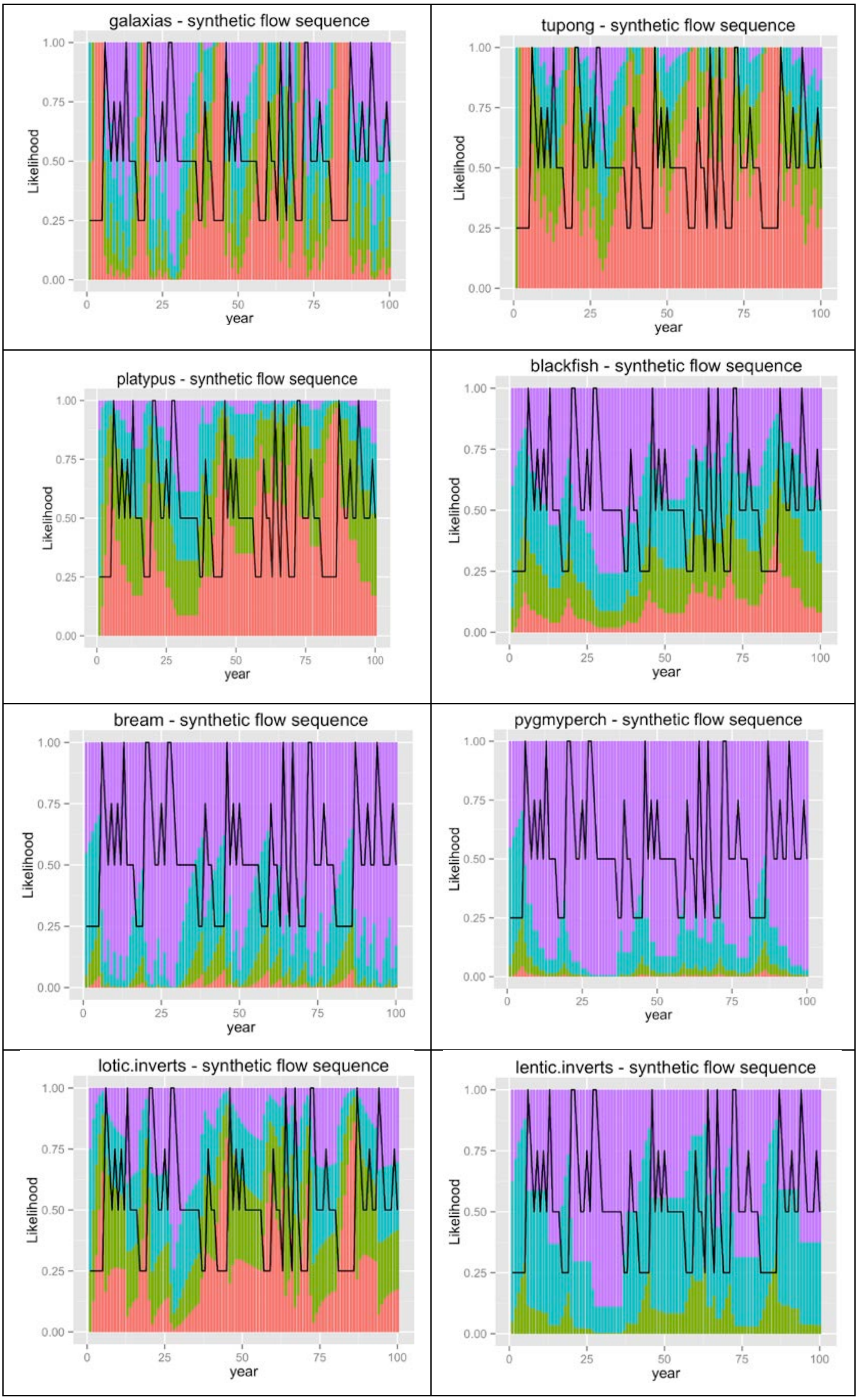

Figure 21: Likely trajectories in population condition of ecological values using a hypothetical 100 year flow sequence

Model predictions and looking forward

The modelling results will be used by Melbourne Water to assess the risks posed to priority ecological values under a range of different climate conditions. Table 40 summarises the key findings of the assessment.

Table 40: Key findings of climate risk assessment

Ecological Value	Key findings
All species	There is a lot of uncertainty around the predicted responses of species to antecedent hydrological conditions. **Conclusion:** • The modelling results provide a useful guide for Melbourne Water in determining its watering priorities each year through its Seasonal Watering Proposal, but given the uncertainty in the predicted responses of species, will not be the only decision-making tool used for this process **Future Actions:** • Continue to develop knowledge of key species and their vulnerabilities, responses and tolerances to a range of flow conditions within the Werribee River and estuary. • Continue to use adaptive management to ensure monitoring data and other information is effectively used in informing environmental watering priorities for the system.
Platypus	Following periods of high flow stress, Platypus may remain in a poor state for a significant proportion of time despite improved water availability. This trajectory is concerning because a very long period of consistently above average rainfall may be required for the population to recover. To provide real opportunities for recovery through flow management under current river regulation, this will require that Melton and Werribee weirs spill consistently, which currently only happens in 40% of years. **Conclusion:** • The long-term viability of Platypus in the Werribee River will require the recovery of significant volumes of environmental water **Future Actions:** • Investigate options for the recovery of significant volumes of environmental water or share in storage • Complementary activities – vegetation establishment and maintenance as well as predator management • Monitoring data – improve understanding of the existing population, including understanding of the condition / response assumptions used for this assessment.
Fish	**Migratory fish (Galaxias and Tupong)** The most significant risk that can be confidently predicted by the model is that migratory fish will be in poor condition for much of the time because of extremely limited passage for migration during 'Maintain' and 'Protect' scenarios (approximately 60% of years). This suggests that environmental water management should be prioritised such that passage is provided for migratory fish at critical times. A new fishway that will reduce the flow rate required for fish passage between the estuary and freshwater reaches will complement environmental water management for this purpose. ***Galaxias*** The model predicts that Galaxias are able to rapidly recover from extended drought once fish passage is re-established (less so for Tupong), maintaining the long-term viability of the population.

<table>
<tr><th>Ecological Value</th><th>Key findings</th></tr>
<tr><td></td><td>There is currently not enough data to support this hypothesis. This is a priority to be addressed through monitoring and research.

Bream

Bream are predicted to be in good or excellent condition in the Werribee for much of the time, and this is supported by data. Only periodically favourable conditions are required to promote successful recruitment in the population. Provided these conditions are met frequently enough to maintain cohort strength (i.e. minimal intervals of every 8-12 years), then the population should remain in an excellent state (P. Reich pers comm).

The models suggest that current environmental flow management can change the priority focus away from this species in many years, instead focusing environmental flow releases to target more vulnerable species such as Galaxias and Tupong.

Conclusion:

• Environmental water delivery should be prioritised to meet life cycle requirements of migratory fish in Reaches 8 and 9.

Future Actions:

• Monitor condition of Galaxias populations and update the ecological response model as appropriate.</td></tr>
<tr><td>Macroinvertebrates</td><td>Flowing water (lotic) invertebrates

Lotic invertebrates may be in poor condition for much of the time in Reach 6. However, there is considerable flexibility in the way that water can be delivered through this reach so as to maximize habitat availability and mitigate the impacts of dry years, which would naturally impact these taxa significantly.

Still water (lentic) invertebrates

Populations of lentic invertebrates are expected to remain relatively healthy, regardless of hydrological condition as they are confined to refuge environments that retain water through drought.

Conclusion:

• No changes to the priorities for environmental water delivery for macroinvertebrates are currently required.

Future Actions:

• Continue to monitor macroinvertebrate condition in all reaches.</td></tr>
</table>

ENVIRONMENTAL WATER DELIVERY INFRASTRUCTURE

There are a number of constraints to the delivery of flow recommendations for the Werribee River. These include physical constraints such as water management structures (weirs and reservoirs), and operational constraints such as the amount of water available to use for the environmental entitlement, and the need to use the river to transfer water during the irrigation season.

Physical constraints

Melbourne Water has little ability to adjust flows in most reaches of the Werribee River because of physical constraints in the existing infrastructure. Diversion weirs in the system are able to provide passing flows, but are unable to provide for flow components such as spring and winter freshes. There are also difficulties in providing bankfull and overbank flows, because of the very large volumes of water required to deliver these events, as well as the risk of flooding private land and infrastructure.

Because of these reasons, delivering water to Reach 6 and the estuary is Melbourne Water's first priority. In wetter climatic scenarios, water deliveries will be targeted to Reach 9 and possibly reach 8.

Getting water to Reach 9 and the estuary

Reach 9 and the estuary are downstream of the Werribee Diversion Weir, which has limited ability to control passing flows, making it problematic to deliver environmental water to these reaches. Flow rates up to 20 ML/d can be passed through valves, although operational control is crude and measurement is difficult. Higher flow rates must be delivered via spills over the crest of the weir. Achieving a spill with a consistent flow rate is extremely difficult due to operation of the main offtake to the Werribee Irrigation District immediately upstream of the weir. Total volume requiremens can be achieved over the course of one or two days, but instantaneous flow rate can vary by as much as 100% within that time frame.

Operational Constraints

As the environmental entitlement does not include secure storage space in any reservoir and only allows storage in airspace not being used by other entitlements, there is risk in storing and carrying over a large volume of environmental water because this water is lost if the reservoir spills. For this reason, large volumes of environmental water are generally not able to be carried over from one season to the next.

Some of the storage and inflows to Lake Merrimu are currently unallocated. Melbourne Water may make a case for allocating at least some storage to the environment. Should storage be secured, there will be opportunities for storing entitlement inflow in wetter scenarios and releasing it in drier scenarios, when it can achieve ecological objectives in the high priority estuary as well as Reach 6 (Alluvium 2013).

DEMONSTRATING OUTCOMES

Robust and carefully designed monitoring helps to judge the strength of the Werribee River environmental watering program, improve work planning, and generate new knowledge. For the Werribee River, the monitoring covers a range of activities, and falls into the following categories:

- Compliance monitoring (such as hydrological monitoring) - Were the environmental flow release targets met?
- Administrative compliance - Were the management arrangements implemented as intended?
- Short-term event monitoring – How did the environmental values respond in the short-term to watering events?
- Long-term ecological response monitoring - Do short-term environmental responses lead to long-term change?
- Long-term condition/Health Monitoring - What is the trend in environmental condition over time?

Compliance monitoring

Compliance with environmental flow provisions is monitored using a series of flow gauges throughout the Werribee catchment as outlined in Table 41.

Table 41: Reaches and their streamflow gauges for monitoring purposes

Reach	Extent	Streamflow Gauge
Reach 1	Ballan (Upstream of Upper Werribee Diversion Weir);	231225 – Werribee River at Ballan
Reach 2	Pykes Creek (Pykes Creek from Pykes Creek Reservoir to the Werribee River);	231203 – Pykes Creek at Pykes Creek reservoir
Reach 3	Upper Werribee Diversion Weir to Pykes Creek;	N/A
Reach 4	Werribee Gorge (Werribee River from Pykes Creek to Bacchus Marsh Weir);	231200 - Werribee river at Bacchus Marsh
Reach 5	Bacchus Marsh (Bacchus Marsh Weir to the confluence with the Lerderderg River);	N/A
Melton Reach 6	Coimadai Creek (Coimadai Creek below Lake Merrimu to Melton Reservoir);	231223 – Pyrites Creek at Merrimu reservoir
Reach 7	Djerriwarrh Creek (Djerriwarrh Creek below Djerriwarrh Weir to Reservoir);	231212 - Djerriwarrh Creek downstream of Djerriwarrh reservoir.
Reach 8	Werribee River below Melton Reservoir (Melton Reservoir to Lower Werribee Diversion Weir); and	Werribee river downstream Toolern Creek
Reach 9	Lower Werribee Diversion Weir to estuary limit at the bluestone ford (downstream of the Maltby bypass).	231204 – Werribee River downstream of Werribee Diversion Weir
Estuary	Estuary between the bluestone ford and Port Phillip Bay	231204 – Werribee River downstream of Werribee Diversion Weir

These gauges along the river allow monitoring and reporting on the achievement of flow components through releases. It is important to note that the ecological objectives that the environmental releases are aiming to achieve can be difficult to monitor in the short term, so monitoring is also progressive over time.

As the resource manager, Southern Rural Water is required to keep account of the volume of water released from the Environmental Water Account, which is in accordance with the accounting principles outlined in the Werribee River Environmental Entitlement Operating Arrangements.

Long term condition monitoring

Long-running ecological monitoring programs include a platypus program and Waterwatch (water quality and macroinvertebrates). The fish fauna of the Werribee catchment were surveyed in 2012 and are scheduled for survey again in 2017. Water quality in the lower reaches and estuary is tested relatively frequently but irregularly, often in response to regulated flow events, and community interest in water quality issues is high.

For Reach 6, monitoring is focused on learning more about the flow-dependent ecological processes in this reach through delivering and monitoring environmental releases as well as comparative studies of similar nearby reaches with more ‘natural’ flow regimes. Returning the reach to a natural flow regime with long periods of no flow and periodic very high flows to maintain natural vegetation and geomorphology is unfeasible, but data and observations suggest that increasing the annual duration of low flows beyond natural and providing periodic freshes may increase the abundance and diversity of frogs and macroinvertebrates.

For the Estuary, flow and salinity were monitored extensively in 2012/13 (McGuckin 2013). Results indicated that the flow recommendations for freshes are adequate to move the salt wedge to its recommended location above the seagrass beds. Monitoring in 2013/14 focused on whether this has moved juvenile fish into the seagrass beds, although this has so far been inconclusive. There is currently little evidence to support the recommendation for winter low flows to extend spawning habitat. Salinity sensors have been installed however to measure the extent of the salt wedge under low flow conditions, and a three year ARC research project is underway to determine biological responses to freshwater flow inputs.

Melbourne Water also extensively uses information from the Victorian Index of Stream Condition benchmarking program, which has assessed the environmental condition of Victoria’s major rivers and streams in 1999, 2004 and 2010.

Intervention monitoring

Intervention monitoring is assessing the responses of Werribee River system ecological values to the changes in the flow regime (i.e. the intervention). A number of intervention monitoring programs have already been conducted since environmental flows have been released from the Environmental Entitlement. These include:

- A monitoring program to assess the effect of environmental flow releases from Merrimu Reservoir on Coimadai Creek (SKM 2012). The study examined the effect of two flow releases and periods of stable low flow on the amount of fine sediment, biofilm and filamentous algae on cobble riffle/run substrates in Pyrites Creek (SKM 2012).
- A five-year monitoring program for a number of the ephemeral tributaries of the Werribee River (Goodman Creek, Pyrites Creek and Djerriwarrh Creek) was designed by SKM in 2013 (SKM 2013). The monitoring program focuses on the effects of flow regime on macroinvertebrates and in-stream vegetation. It also investigates how the composition and density of instream vegetation communities affects nutrient processing with the intention of determining a target type of vegetation community for these naturally ephemeral streams.

Current research programs through Melbourne Water’s Environmental Flows Knowledge and Innovation Program include:

- Optimisation of environmental flows investigation with Associate Professor Mike Stewardson at Melbourne University.
- Participation in the Victorian Environmental Flows Monitoring and Assessment Program (VEFMAP), run through DELWP
- An ARC linkage project with multiple partners focusing partly on the response of Black Bream to freshwater flows into the estuary.
- An ongoing macroinvertebrate and frog monitoring program in reach 6 and other seasonal tributaries.

KNOWLEDGE GAPS AND OPPORTUNITIES / RECOMMENDATIONS

Continuing to improve knowledge about the Werribee River, its water-dependent ecological values and most appropriate flow regimes is imperative. A number of knowledge gaps exist, and will be targeted for future work by Melbourne Water. These are summarised in Table 42.

Table 42: Knowledge gaps and recommended actions

Knowledge Gap	Recommended Action	Who	Priority
Adaptive management for climate change The conditional responses to changing climate conditions for environmental values in the Werribee River system are not well known, and data to support the current hypotheses are minimal.	Continue to develop knowledge of key species and their resilience, threshold responses and tolerances to a range of flow conditions within the Werribee River and estuary Continue to use adaptive management to ensure monitoring data and other information is effectively used in informing environmental watering priorities for the system.	Melbourne Water / Research Body	High
Platypus The predicted responses of platypus communities to varying water availability scenarios is currently poorly known	Improve understanding of the existing Platypus population, including its resilience and appropriate condition / response assumptions for different water availability scenarios. Monitoring the condition of Platypus populations and updating the ecological response model as appropriate will be essential given their poor recovery from the Millennium drought so far.	Melbourne Water / Research Body	High
Migratory fish Migratory fish such as Galaxias and Tupong may be particularly vulnerable to a sequence of years with low flow availability. Knowledge of their level of resistance and resilience to such challenges is currently poor.	Environmental water delivery may need to be prioritised to meet life cycle requirements of migratory fish in Reaches 8 and 9. Monitoring the condition of migratory fish populations and updating their ecological response models as appropriate will be undertaken	Melbourne Water	High
Groundwater Dependent Ecosystems Very little is known about the dependency of the estuarine environment on groundwater, in particular links between groundwater contributions and ecosystem health. A significant knowledge gap exists around the occurrence of seepage	Conduct an intensive study of groundwater dependent ecosystems in the Werribee River system	Melbourne Water / Research Body	Moderate

Knowledge Gap	Recommended Action	Who	Priority
from treatment lagoons at the WTP and its impact on hydrogeological regime and water quality.			
Estuary hydrodynamics Knowledge of Werribee River estuary hydrodynamics for the Werribee River is still in its infancy, with insufficient information about the relationship between salt wedge dynamics and flow regimes	Conduct a study of flow regime influence on estuary salinity and hydrodynamics	Melbourne Water / Research Body	Medium
Estuary fish The flow recommendations for the estuary apply to the requirements for fish, Black Bream in particular, that were determined based on studies in other estuaries. Given the unique physical and hydrodynamic nature of individual estuaries, it is unclear how well the results of other studies apply to the Werribee estuary.	Further study of fish in the estuary will be required to determine freshwater requirements and the efficacy of flow releases in achieving ecological objectives	Melbourne Water / Research Body	Moderate
Frogs The diversity and abundance of the frog community within the seasonal headwaters of the catchment is poorly understood, as is its hydrological and climatic dependence..	Implement a medium to long term study of the frog community in the regulated and unregulated seasonal headwaters	Melbourne Water / Research Body	Moderate
Macroinvertebrates The diversity and abundance of the macroinvertbrate community within the seasonal headwaters of the catchment is poorly understood, as is its hydrological and climatic dependence.	Implement a medium to long term study of the frog community in the regulated and unregulated seasonal headwaters	Melbourne Water / Research Body	Moderate
Community Engagement There are opportunities to improve community knowledge regarding the management of the Werribee River for its water-dependent values.	Assess, develop and implement a communications, education and education strategy specific to the management of the Werribee River environmental entitlement.	Melbourne Water / VEWH	High

CONSULTATION

The majority of the consultation and stakeholder engagement activities contributing to the development of the EWMP occurred prior to beginning its preparation. During the development of Melbourne Water's Healthy Waterway Strategy, extensive consultation was conducted to determine the priority environmental values for the Werribee River system and the management objectives for these values. In starting the development process for the EWMP, Melbourne Water consulted with DELWP to ensure that leveraging from previous recently conducted consultation exercises would be acceptable.

For a description of the consultation process undertaken by Melbourne Water for the development of the HWS, please refer to Melbourne Water (2013).

Additional consultation events during the development of the EWMP included:

- Convening a Werribee River flows review workshop in June of 2014 with the following attendees:
  - Dr Andrew Sharpe (Aquatic Ecologist – Jacobs)
  - Dr Simon Treadwell (Aquatic Ecologist – Jacobs)
  - Dr Peter Sandercock (Geomorpology – Jacobs)
  - Amanda Woodman (Hydrologist – Jacobs)
  - Dr Paul Boon (Vegetation – Dodo Environmental)
  - Bill Moulden (Environmental Flows – Melbourne Water)
  - Jodi Braszell (Natural Resources Management – Collaborative NRM)
- Convening a Climate Change Risk Assessment Technical Panel workshop in October 2014, with the following attendees:
  - Mark Toomey (VEWH)
  - Simon Treadwell (Jacobs)
  - Edward Tsyrlin (Melbourne Water)
  - Amanda Wealands (Alluvium)
  - Nick Bond (Griffith University)
  - Tim Doeg (Independent Consultant)
  - Paul Reich (DELWP),
  - Wayne Koster (DELWP)
  - Jodi Braszell (Collaborative NRM).
- Consulting with members of the DELWP funded Technical Review Panel (Terry Hillman) regarding appropriate climate change risk assessment methodologies

Representatives from the following agencies and groups also provided input into aspects of the development of the EWMP:

- Wyndham, Melton and Moorabool Councils
- DELWP
- LeadWest
- Werribee Riverkeeper
- Southern Rural Water
- Victorian Environmental Water Holder

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APPENDIX 1 – FAUNA SPECIES LIST

Conservation Status Codes

EPBC
CR = Critically Endangered
EN = Endangered
VU = Vulnerable

Victorian Advisory List
cr = critically endangered
en = endangered
vu = vulnerable
nt = near threatened
k = poorly known
dd = data deficient
wx = extinct in the wild

FFG
L = Listed
X = Rejected

Introduced
***** = Introduced

Table A 1: Fish

Conservation Status	Scientific Name	Common Name
	Engraulis australis	Australian Anchovy
	Retropinna semoni	Australian Smelt
	Acanthopagrus butcheri	Black Bream
	Spratelloides robustus	Blue Sprat
EN cr L	*Maccullochella macquariensis*	Bluenose Cod (Trout Cod)
	Arenigobius bifrenatus	Bridled Goby
*	*Salmo trutta*	Brown Trout
*	*Cyprinus carpio*	Carp
*	*Oncorhynchus tshawytscha*	Chinook Salmon
	Galaxias maculatus	Common Galaxias
	Misc Dry	Dry waterbody
	Arripis trutta	Eastern Australian Salmon
	Pseudogobius sp. 9	Eastern Blue-spot Goby
*	*Gambusia holbrooki*	Eastern Gambusia
	Macquaria colonorum	Estuary Perch
vu X	*Galaxias rostratus*	Flat-headed Galaxias
	Philypnodon grandiceps	Flat-headed Gudgeon
en L	*Tandanus tandanus*	Freshwater Catfish
	Gobiopterus semivestitus	Glass Goby
*	*Carassius auratus*	Goldfish
	Rhombosolea tapirina	Greenback Flounder
	Girella tricuspidata	Luderick
EN en L	*Macquaria australasica*	Macquarie Perch
	Galaxias olidus	Mountain Galaxias
	Kestratherina esox	Pikehead Hardyhead
	Sardinops sagax	Pilchard
	Geotria australis	Pouched Lamprey
	Contusus brevicaudas	Prickly Toadfish

Conservation Status	Scientific Name	Common Name
*	*Perca fluviatilis*	Redfin
	Gadopsis marmoratus	River Blackfish
*	*Rutilus rutilus*	Roach
	Hyperlophus vittatus	Sandy Sprat
	Mugil cephalus	Sea Mullet
	Anguilla australis	Short-finned Eel
	Mordacia mordax	Short-headed Lamprey
	Leptatherina presbyteroides	Silver Fish
	Pseudocaranx georgianus	Silver Trevally
	Atherinosoma microstoma	Smallmouthed Hardyhead
	Pseudogobius olorum	Southern Blue-spotted Goby
	Favonigobius lateralis	Southern Longfin Goby
	Nannoperca australis	Southern Pygmy Perch
	Galaxias truttaceus	Spotted Galaxias
	Afurcagobius tamarensis	Tamar River Goby
	Pseudaphritis urvillii	Tupong
	Aldrichetta forsteri	Yellow-eye Mullet
*	*Acanthogobius flavimanus*	Yellowfin Goby

Table A 2: Reptiles

Conservation Status	Scientific Name	Common Name
-	*Egernia saxatilis intermedia*	Black Rock Skink
-	*Tiliqua nigrolutea*	Blotched Blue-tongued Lizard
-	*Lerista bougainvillii*	Bougainville's Skink
-	*Tiliqua scincoides*	Common Blue-tongued Lizard
dd	*Chelodina longicollis*	Common Long-necked Turtle
-	*Egernia cunninghami*	Cunningham's Skink
-	*Pseudonaja textilis*	Eastern Brown Snake
-	*Rhinoplocephalus nigrescens*	Eastern Small-eyed Snake
-	*Acritoscincus duperreyi*	Eastern Three-lined Skink
-	*Lampropholis guichenoti*	Garden Skink
-	*Pseudemoia form cryodoma/pagenstecheri*	Grass skink FORM (P.pag/cry)
-	*Ctenotus robustus*	Large Striped Skink
-	*Parasuta flagellum*	Little Whip Snake
-	*Austrelaps superbus*	Lowland Copperhead
-	*Christinus marmoratus*	Marbled Gecko
-	*Anepischtos maccoyi*	McCoy's Skink
vu	*Emydura macquarii*	Murray River Turtle
-	*Pseudechis porphyriacus*	Red-bellied Black Snake
-	*Pseudemoia entrecasteauxii*	Southern Grass Skink
-	*Eulamprus tympanum tympanum*	Southern Water Skink

Conservation Status	Scientific Name	Common Name
-	*Tiliqua rugosa*	Stumpy-tailed Lizard
-	*Notechis scutatus*	Tiger Snake
-	*Amphibolurus muricatus*	Tree Dragon
vu	*Pseudemoia pagenstecheri*	Tussock Skink
-	*Saproscincus mustelinus*	Weasel Skink
-	*Liopholis whitii GROUP*	White's Skink

Table A 3: Frogs

Conservation Status	Scientific Name	Common Name
	Crinia signifera	Common Froglet
	Neobatrachus sudellae	Common Spadefoot Toad
VU en L	*Litoria raniformis*	Growling Grass Frog
	Litoria lesueuri	Lesueur's Frog
	Limnodynastes dumerilii dumerilii	Pobblebonk Frog
	Litoria ewingii	Southern Brown Tree Frog
	Litoria ewingii SOUTHERN	Southern Brown Tree Frog SOUTHERN
	Limnodynastes dumerilii	Southern Bullfrog (ssp. unknown)
	Limnodynastes tasmaniensis	Spotted Marsh Frog (race unknown)
	Limnodynastes tasmaniensis SCR	Spotted Marsh Frog SCR
	Limnodynastes peronii	Striped Marsh Frog
	Litoria verreauxii verreauxii	Verreaux's Tree Frog
	Geocrinia victoriana	Victorian Smooth Froglet

Table A 4: Mammals

Conservation Status	Scientific Name	Common Name
	Antechinus agilis	Agile Antechinus
*	*Rattus rattus*	Black Rat
*	*Rattus norvegicus*	Brown Rat
vu L	*Phascogale tapoatafa*	Brush-tailed Phascogale
	Rattus fuscipes	Bush Rat
*	*Felis catus*	Cat
	Trichosurus vulpecula	Common Brushtail Possum
	Pseudocheirus peregrinus	Common Ringtail Possum 30 11129
	Canis lupus	Dingo & Dog (feral
EN wx L	*Perameles gunnii*	Eastern Barred Bandicoot
	Macropus giganteus	Eastern Grey Kangaroo
*	*Lepus europeaus*	European Hare

Conservation Status	Scientific Name	Common Name
*	*Oryctolagus cuniculus*	European Rabbit
nt	*Sminthopsis crassicaudata*	Fat-tailed Dunnart
	Acrobates pygmaeus	Feathertail Glider
*	*Mustela furo*	Ferret
vu	*Petauroides volans*	Greater Glider
*	*Mus musculus*	House Mouse
	Phascolarctos cinereus	Koala
	Trichosurus cunninghami	Mountain Brushtail Possum
	Ornithorhynchus anatinus	Platypus
	Tachyglossus aculeatus	Short-beaked Echidna
EN nt L	*Isoodon obesulus obesulus*	Southern Brown Bandicoot
	Petaurus breviceps	Sugar Glider
	Hydromys chrysogaster	Water Rat

Table A 5: Bats

Conservation Status	Scientific Name	Common Name
	Chalinolobus morio	Chocolate Wattled Bat
	Falsistrellus tasmaniensis	Eastern False Pipistrelle
	Nyctophilus gouldi	Gould's Long-eared Bat
	Chalinolobus gouldii	Gould's Wattled Bat
VU vu L	*Pteropus poliocephalus*	Grey-headed Flying-fox
	Vespadelus darlingtoni	Large Forest Bat
	Nyctophilus geoffroyi	Lesser Long-eared Bat
	Vespadelus vulturnus	Little Forest Bat
	Vespadelus regulus	Southern Forest Bat
	Tadarida australis	White-striped Freetail Bat

Table A 6: Invertebrates

Conservation Status	Scientific Name	Common Name
dd L	*Archaeophylax canarus*	Caddisfly
CR cr L	*Synemon plana*	Golden Sun Moth
	Amarinus lacustris	Freshwater Spider Crab
	Cherax destructor destructor	Common Yabby
	Euastacus yarraensis	Southern Victorian Spiny Crayfish
	Paratya australiensis	Freshwater Shrimp

Table A 7: Birds

Conservation Status	Scientific Name	Common Name
Wader Birds		
	Vanellus tricolor	Banded Lapwing
	Cladorhynchus leucocephalus	Banded Stilt
	Elseyornis melanops	Black-fronted Dotterel
	Himantopus himantopus	Black-winged Stilt
nt L	*Hydroprogne caspia*	Caspian Tern
vu	*Tringa nebularia*	Common Greenshank
vu	*Actitis hypoleucos*	Common Sandpiper
	Calidris melanotus X ferruginea	Cox's Sandpiper
	Thalasseus bergii	Crested Tern
en	*Calidris ferruginea*	Curlew Sandpiper
	Charadrius bicinctus	Double-banded Plover
en L	*Calidris tenuirostris*	Great Knot
en L	*Gelochelidon nilotica macrotarsa*	Gull-billed Tern
	Numenius minutus	Little Curlew
nt	*Calidris subminuta*	Long-toed Stint
vu	*Tringa stagnatilis*	Marsh Sandpiper
	Vanellus miles	Masked Lapwing
vu	*Pluvialis fulva*	Pacific Golden Plover
nt	*Larus pacificus pacificus*	Pacific Gull
nt	*Calidris melanotos*	Pectoral Sandpiper
	Haematopus longirostris	Pied Oystercatcher
en	*Calidris canutus*	Red Knot
	Charadrius ruficapillus	Red-capped Plover
	Erythrogonys cinctus	Red-kneed Dotterel
	Recurvirostra novaehollandiae	Red-necked Avocet
	Calidris ruficollis	Red-necked Stint
	Philomachus pugnax	Ruff
	Calidris acuminata	Sharp-tailed Sandpiper
	Chroicocephalus novaehollandiae	Silver Gull
nt	*Haematopus fuliginosus*	Sooty Oystercatcher
nt	*Chlidonias hybridus javanicus*	Whiskered Tern
nt	*Chlidonias leucopterus*	White-winged Black Tern

Conservation Status	Scientific Name	Common Name
vu	*Tringa glareola*	Wood Sandpiper
Passerine Birds		
	Anthus novaeseelandiae	Australasian Pipit
	Gymnorhina tibicen	Australian Magpie
	Corvus coronoides	Australian Raven
	Zoothera lunulata	Bassian Thrush
	Manorina melanophrys	Bell Miner
	Melithreptus gularis	Black-chinned Honeyeater
	Coracina novaehollandiae	Black-faced Cuckoo-shrike
	Cincloramphus cruralis	Brown Songlark
	Acanthiza pusilla	Brown Thornbill
nt	*Climacteris picumnus victoriae*	Brown Treecreeper (south-eastern ssp.)
	Melithreptus brevirostris	Brown-headed Honeyeater
	Acanthiza reguloides	Buff-rumped Thornbill
	Acrocephalus stentoreus	Clamorous Reed Warbler
*	*Turdus merula*	Common Blackbird
*	*Acridotheres tristis*	Common Myna
*	*Sturnus vulgaris*	Common Starling
	Phylidonyris pyrrhoptera	Crescent Honeyeater
nt L	*Oreoica gutturalis gutturalis*	Crested Bellbird
	Falcunculus frontatus	Crested Shrike-tit
nt L	*Stagonopleura guttata*	Diamond Firetail
	Artamus cyanopterus	Dusky Woodswallow
	Acanthorhynchus tenuirostris	Eastern Spinebill
	Eopsaltria australis	Eastern Yellow Robin
*	*Passer montanus*	Eurasian Tree Sparrow
	Carduelis carduelis	European Goldfinch
*	*Carduelis chloris*	European Greenfinch
*	*Alauda arvensis*	European Skylark
	Petrochelidon ariel	Fairy Martin
	Petroica phoenicea	Flame Robin
	Lichenostomus fuscus	Fuscous Honeyeater
	Pachycephala pectoralis	Golden Whistler
	Cisticola exilis	Golden-headed Cisticola
	Cracticus torquatus	Grey Butcherbird
	Strepera versicolor	Grey Currawong
	Rhipidura albiscarpa	Grey Fantail
	Colluricincla harmonica	Grey Shrike-thrush
en L	*Pomatostomus temporalis temporalis*	Grey-crowned Babbler
nt L	*Melanodryas cucullata cucullata*	Hooded Robin
	Mirafra javanica	Horsfield's Bushlark
*	*Passer domesticus*	House Sparrow

Conservation Status	Scientific Name	Common Name
	Microeca fascinans	Jacky Winter
	Megalurus gramineus	Little Grassbird
	Corvus mellori	Little Raven
	Anthochaera chrysoptera	Little Wattlebird
	Grallina cyanoleuca	Magpie-lark
	Dicaeum hirundinaceum	Mistletoebird
	Phylidonyris novaehollandiae	New Holland Honeyeater
	Manorina melanocephala	Noisy Miner
	Pachycephala olivacea	Olive Whistler
	Oriolus sagittatus	Olive-backed Oriole
	Strepera graculina	Pied Currawong
	Anthochaera carunculata	Red Wattlebird
	Neochmia temporalis	Red-browed Finch
	Climacteris erythrops	Red-browed Treecreeper
	Petroica goodenovii	Red-capped Robin
	Myiagra inquieta	Restless Flycatcher
	Petroica rosea	Rose Robin
	Rhipidura rufifrons	Rufous Fantail
	Cincloramphus mathewsi	Rufous Songlark
	Pachycephala rufiventris	Rufous Whistler
	Myiagra cyanoleuca	Satin Flycatcher
	Petroica boodang	Scarlet Robin
	Zosterops lateralis	Silvereye
	Lichenostomus virescens	Singing Honeyeater
*	*Turdus philomelos*	Song Thrush
	Aphelocephala leucopsis	Southern Whiteface
	Dicrurus bracteatus	Spangled Drongo
vu L	*Chthonicola sagittatus*	Speckled Warbler
	Acanthagenys rufogularis	Spiny-cheeked Honeyeater
	Pardalotus punctatus	Spotted Pardalote
nt	*Cinclosoma punctatum*	Spotted Quail-thrush
	Calamanthus fuliginosus	Striated Fieldwren
	Pardalotus striatus	Striated Pardalote
	Acanthiza lineata	Striated Thornbill
	Malurus cyaneus	Superb Fairy-wren
	Petrochelidon nigricans	Tree Martin
	Daphoenositta chrysoptera	Varied Sittella
	Smicrornis brevirostris	Weebill
	Petrochelidon neoxena	Welcome Swallow
	Sericornis frontalis	White-browed Scrubwren
	Artamus superciliosus	White-browed Woodswallow
	Lichenostomus leucotis	White-eared Honeyeater

Conservation Status	Scientific Name	Common Name
	Epthianura albifrons	White-fronted Chat
	Melithreptus lunatus	White-naped Honeyeater
	Lichenostomus penicillatus	White-plumed Honeyeater
	Cormobates leucophaeus	White-throated Treecreeper
	Corcorax melanorhamphos	White-winged Chough
	Lalage sueurii	White-winged Triller
	Rhipidura leucophrys	Willie Wagtail
	Acanthiza nana	Yellow Thornbill
	Lichenostomus chrysops	Yellow-faced Honeyeater
	Acanthiza chrysorrhoa	Yellow-rumped Thornbill
	Lichenostomus melanops	Yellow-tufted Honeyeater
	Taeniopygia guttata	Zebra Finch
Non-Passerine Birds		
EN en L	*Botaurus poiciloptilus*	*Australasian Bittern*
	Tachybaptus novaehollandiae	*Australasian Grebe*
vu	*Anas rhynchotis*	*Australasian Shoveler*
	Falco longipennis	*Australian Hobby*
	Alisterus scapularis	*Australian King-Parrot*
	Aegotheles cristatus	*Australian Owlet-nightjar*
	Pelecanus conspicillatus	*Australian Pelican*
	Tadorna tadornoides	*Australian Shelduck*
	Porzana fluminea	*Australian Spotted Crake*
	Threskiornis molucca	*Australian White Ibis*
	Chenonetta jubata	*Australian Wood Duck*
nt	*Alcedo azurea*	*Azure Kingfisher*
vu L	*Porzana pusilla palustris*	*Baillon's Crake*
en L	*Ninox connivens connivens*	*Barking Owl*
vu	*Falco subniger*	*Black Falcon*
	Milvus migrans	*Black Kite*
	Cygnus atratus	*Black Swan*
	Hamirostra melanosternon	*Black-breasted Buzzard*
nt	*Chrysococcyx osculans*	*Black-eared Cuckoo*
	Elanus axillaris	*Black-shouldered Kite*
	Gallinula ventralis	*Black-tailed Native-hen*
en L	*Oxyura australis*	*Blue-billed Duck*
	Neophema chrysostoma	*Blue-winged Parrot*
vu L	*Grus rubicunda*	*Brolga*
	Falco berigora	*Brown Falcon*
	Accipiter fasciatus	*Brown Goshawk*
	Coturnix ypsilophora australis	*Brown Quail*
	Phaps elegans	*Brush Bronzewing*
	Cacomantis variolosus	*Brush Cuckoo*
	Gallirallus philippensis	*Buff-banded Rail*

Conservation Status	Scientific Name	Common Name
	Cereopsis novaehollandiae	*Cape Barren Goose*
	Ardea ibis	*Cattle Egret*
	Anas castanea	*Chestnut Teal*
	Accipiter cirrhocephalus	*Collared Sparrowhawk*
	Phaps chalcoptera	*Common Bronzewing*
	Ocyphaps lophotes	*Crested Pigeon*
	Platycercus elegans	*Crimson Rosella*
	Anhinga novaehollandiae	*Darter*
	Anser anser	*Domestic Goose*
	Gallinula tenebrosa	*Dusky Moorhen*
	Tyto longimembris	*Eastern Grass Owl*
vu L	*Ardea modesta*	*Eastern Great Egret*
	Platycercus eximius	*Eastern Rosella*
	Fulica atra	*Eurasian Coot*
	Cacomantis flabelliformis	*Fan-tailed Cuckoo*
en L	*Stictonetta naevosa*	*Freckled Duck*
	Eolophus roseicapilla	*Galah*
	Callocephalon fimbriatum	*Gang-gang Cockatoo*
nt	*Plegadis falcinellus*	*Glossy Ibis*
	Phalacrocorax carbo	*Great Cormorant*
	Podiceps cristatus	*Great Crested Grebe*
vu L	*Accipiter novaehollandiae novaehollandiae*	*Grey Goshawk*
	Anas gracilis	*Grey Teal*
vu	*Aythya australis*	*Hardhead*
	Poliocephalus poliocephalus	*Hoary-headed Grebe*
	Chrysococcyx basalis	*Horsfield's Bronze-Cuckoo*
en L	*Ardea intermedia*	*Intermediate Egret*
nt	*Gallinago hardwickii*	*Latham's Snipe*
	Dacelo novaeguineae	*Laughing Kookaburra*
vu L	*Lewinia pectoralis pectoralis*	*Lewin's Rail*
	Phalacrocorax sulcirostris	*Little Black Cormorant*
	Cacatua sanguinea	*Little Corella*
	Hieraaetus morphnoides	*Little Eagle*
en L	*Egretta garzetta nigripes*	*Little Egret*
	Glossopsitta pusilla	*Little Lorikeet*
	Microcarbo melanoleucos	*Little Pied Cormorant*
	Cacatua tenuirostris	*Long-billed Corella*
nt L	*Anseranas semipalmata*	*Magpie Goose*
vu	*Biziura lobata*	*Musk Duck*
	Glossopsitta concinna	*Musk Lorikeet*
	Falco cenchroides	*Nankeen Kestrel*

Conservation Status	Scientific Name	Common Name
nt	*Nycticorax caledonicus hillii*	*Nankeen Night Heron*
*	*Anas platyrhynchos*	*Northern Mallard*
CR cr L	*Neophema chrysogaster*	*Orange-bellied Parrot*
	Pandion cristatus	*Osprey*
	Tyto javanica	*Pacific Barn Owl*
	Anas superciliosa	*Pacific Black Duck*
	Turnix varia	*Painted Button-quail*
	Cuculus pallidus	*Pallid Cuckoo*
	Geopelia striata	*Peaceful Dove*
	Falco peregrinus	*Peregrine Falcon*
nt	*Phalacrocorax varius*	*Pied Cormorant*
	Malacorhynchus membranaceus	*Pink-eared Duck*
VU cr L	*Pedionomus torquatus*	*Plains-wanderer*
vu L	*Ninox strenua*	*Powerful Owl*
	Porphyrio porphyrio	*Purple Swamphen*
	Glossopsitta porphyrocephala	*Purple-crowned Lorikeet*
	Merops ornatus	*Rainbow Bee-eater*
	Trichoglossus haematodus	*Rainbow Lorikeet*
	Phalaropus lobatus	*Red-necked Phalarope*
	Psephotus haematonotus	*Red-rumped Parrot*
*	*Columba livia*	*Rock Dove*
nt	*Platalea regia*	*Royal Spoonbill*
	Todiramphus sanctus	*Sacred Kingfisher*
	Chrysococcyx lucidus	*Shining Bronze-Cuckoo*
	Ninox novaeseelandiae	*Southern Boobook*
	Porzana tabuensis	*Spotless Crake*
nt	*Circus assimilis*	*Spotted Harrier*
*	*Streptopelia chinensis*	*Spotted Turtle-Dove*
	Threskiornis spinicollis	*Straw-necked Ibis*
	Coturnix pectoralis	*Stubble Quail*
	Cacatua galerita	*Sulphur-crested Cockatoo*
	Circus approximans	*Swamp Harrier*
EN en L	*Lathamus discolor*	*Swift Parrot*
	Podargus strigoides	*Tawny Frogmouth*
	Anas spp.	*Unidentified Ducks*
	Platelea sp.	*Unidentified Spoonbill*
	Aquila audax	*Wedge-tailed Eagle*
	Haliastur sphenurus	*Whistling Kite*
vu L	*Haliaeetus leucogaster*	*White-bellied Sea-Eagle*
	Egretta novaehollandiae	*White-faced Heron*
	Ardea pacifica	*White-necked Heron*
vu	*Hirundapus caudacutus*	*White-throated Needletail*
	Platalea flavipes	*Yellow-billed Spoonbill*

Conservation Status	Scientific Name	Common Name
	Calyptorhynchus funereus	*Yellow-tailed Black-Cockatoo*

APPENDIX 2 – FLORA SPECIES LIST

Conservation Status Codes

EPBC
CR = Critically Endangered
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cr = critically endangered
en = endangered
vu = vulnerable
nt = near threatened
k = poorly known
dd = data deficient
wx = extinct in the wild

FFG
L = Listed
X = Rejected

Introduced
***** = Introduced

Table A 8: Plants

Conservation Status	Scientific Name	Common Name
Dicotyledons (0.1km buffer)		
*	*Lycium ferocissimum*	African Box-thorn
*	*Anagallis spp.*	Anagallis
	Lobelia anceps	Angled Lobelia
	Ranunculus sessiliflorus	Annual Buttercup
	Apium annuum	Annual Celery
	Euchiton sphaericus	Annual Cudweed
	Senecio glomeratus	Annual Fireweed
*	*Malus pumila*	Apple
*	*Aster subulatus*	Aster-weed
	Cymbonotus preissianus	Austral Bear's-ear
	Geranium solanderi s.l.	Austral Crane's-bill
	Myosotis australis	Austral Forget-me-not
	Indigofera australis	Austral Indigo
	Suaeda australis	Austral Seablite
	Pelargonium australe	Austral Stork's-bill
r	*Nicotiana suaveolens*	Austral Tobacco
	Lycopus australis	Australian Gipsywort
	Sarcocornia quinqueflora	Beaded Glasswort
	Atriplex semibaccata	Berry Saltbush
	Acaena novae-zelandiae	Bidgee-widgee

Conservation Status	Scientific Name	Common Name
	Maireana decalvans s.l.	Black Cotton-bush
*	*Solanum nigrum s.l.*	Black Nightshade
*	*Solanum nigrum s.s.*	Black Nightshade
	Acacia mearnsii	Black Wattle
*	*Rubus fruticosus spp. agg.*	Blackberry
	Tecticornia pergranulata	Blackseed Glasswort
	Acacia melanoxylon	Blackwood
*	*Opuntia puberula*	Blind Prickly-pear
	Eucalyptus baueriana	Blue Box
*	*Vinca major*	Blue Periwinkle
	Wahlenbergia spp.	Bluebell
	Amyema miquelii	Box Mistletoe
r	*Senecio cunninghamii var. cunninghamii*	Branching Groundsel
r	*Grevillea steiglitziana*	Brisbane Range Grevillea
	Eucalyptus dives	Broad-leaf Peppermint
	Opercularia ovata	Broad-leaf Stinkweed
	Wahlenbergia luteola	Bronze Bluebell
*	*Plantago coronopus*	Buck's-horn Plantain
en L	*Allocasuarina luehmannii*	Buloke
	Eucalyptus goniocalyx s.l.	Bundy
*	*Medicago polymorpha*	Burr Medic
*	*Arctotheca calendula*	Cape weed
*	*Euphorbia lathyris*	Caper Spurge
	Exocarpos cupressiformis	Cherry Ballart
*	*Stellaria media*	Chickweed
*	*Petrorhagia nanteuilii*	Childling Pink
#	*Dysphania pumilio*	Clammy Goosefoot
*	*Galium aparine*	Cleavers
*	*Trifolium glomeratum*	Cluster Clover
*	*Rumex conglomeratus*	Clustered Dock
	Chrysocephalum semipapposum	Clustered Everlasting
	Cassytha melantha	Coarse Dodder-laurel
	Craspedia glauca spp. agg.	Common Billy-buttons

Conservation Status	Scientific Name	Common Name
*	*Rubus anglocandicans*	Common Blackberry
*	*Centaurium erythraea*	Common Centaury
	Cotula australis	Common Cotula
	Euchiton involucratus s.l.	Common Cudweed
	Eutaxia microphylla	Common Eutaxia
*	*Heliotropium europaeum*	Common Heliotrope
*	*Erodium cicutarium*	Common Heron's-bill
*	*Cerastium glomeratum s.l.*	Common Mouse-ear Chickweed
*	*Lepidium africanum*	Common Peppercress
	Gonocarpus tetragynus	Common Raspwort
	Pimelea humilis	Common Rice-flower
	Centipeda cunninghamii	Common Sneezeweed
*	*Sonchus oleraceus*	Common Sow-thistle
	Triptilodiscus pygmaeus	Common Sunray
*	*Datura stramonium*	Common Thorn-apple
*	*Vicia sativa*	Common Vetch
*	*Callitriche stagnalis*	Common Water-starwort
	Asperula conferta	Common Woodruff
	Senecio quadridentatus	Cotton Fireweed
	Astroloma humifusum	Cranberry Heath
	Stackhousia monogyna s.l.	Creamy Stackhousia
	Euchiton japonicus s.s.	Creeping Cudweed
	Persicaria prostrata	Creeping Knotweed
	Brassicaceae spp.	Crucifer
*	*Rumex crispus*	Curled Dock
	Taraxacum spp.	Dandelion
	Brachyloma daphnoides	Daphne Heath
r	*Prostanthera decussata*	Dense Mint-bush
	Veronica derwentiana	Derwent Speedwell
	Senna artemisioides spp. agg.	Desert Cassia
	Cassytha pubescens s.s.	Downy Dodder-laurel
	Amyema pendula	Drooping Mistletoe
	Allocasuarina verticillata	Drooping Sheoak

Conservation Status	Scientific Name	Common Name
*	*Trifolium cernuum*	Drooping-flower Clover
	Scutellaria humilis	Dwarf Skullcap
*	*Chenopodium album*	Fat Hen
*	*Foeniculum vulgare*	Fennel
*	*Rumex pulcher subsp. pulcher*	Fiddle Dock
*	*Sherardia arvensis*	Field Madder
	Senecio linearifolius	Fireweed Groundsel
*	*Hypochaeris radicata*	Flatweed
*	*Conyza bonariensis*	Flaxleaf Fleabane
*	*Polycarpon tetraphyllum*	Four-leaved Allseed
r #	*Rhagodia parabolica*	Fragrant Saltbush
*	*Silene gallica*	French Catchfly
	Vittadinia cuneata	Fuzzy New Holland Daisy
*	*Galenia pubescens var. pubescens*	Galenia
	Acacia acinacea s.l.	Gold-dust Wattle
	Acacia pycnantha	Golden Wattle
r	*Boronia anemonifolia subsp. aurifodina*	Goldfield Boronia
*	*Ulex europaeus*	Gorse
	Geranium retrorsum s.l.	Grassland Crane's-bill
	Oxalis perennans	Grassland Wood-sorrel
*	*Plantago major*	Greater Plantain
	Eucalyptus microcarpa	Grey Box
	Sclerolaena diacantha	Grey Copperburr
	Ozothamnus obcordatus	Grey Everlasting
	Epilobium billardierianum subsp. cinereum	Grey Willow-herb
	Senecio spp.	Groundsel
*	*Leontodon taraxacoides subsp. taraxacoides*	Hairy Hawkbit
	Acaena agnipila	Hairy Sheep's Burr
	Epilobium hirtigerum	Hairy Willow-herb
*	*Trifolium arvense var. arvense*	Hare's-foot Clover
	Lysiana exocarpi	Harlequin Mistletoe
*	*Atriplex prostrata*	Hastate Orache
*	*Crataegus monogyna*	Hawthorn

Conservation Status	Scientific Name	Common Name
	Acacia paradoxa	Hedge Wattle
*	*Conium maculatum*	Hemlock
	Gynatrix pulchella s.l.	Hemp Bush
*	*Lepidium draba*	Hoary Cress
*	*Polygonum aviculare s.s.*	Hogweed
	Acrotriche serrulata	Honey-pots
*	*Trifolium campestre var. campestre*	Hop Clover
	Goodenia ovata	Hop Goodenia
*	*Marrubium vulgare*	Horehound
k	*Ceratophyllum demersum*	Hornwort
*	*Opuntia ficus-indica*	Indian Fig
	Carpobrotus modestus	Inland Pigface
*	*Valerianella eriocarpa*	Italian Corn-salad
	Viola hederacea sensu Willis (1972)	Ivy-leaf Violet
	Dichondra repens	Kidney-weed
	Solanum laciniatum	Large Kangaroo Apple
	Pultenaea daphnoides	Large-leaf Bush-pea
k	*Maireana aphylla*	Leafless Bluebush
	Alternanthera denticulata s.l.	Lesser Joyweed
	Acacia implexa	Lightwood
*	*Papaver dubium*	Long-headed Poppy
*	*Medicago sativa subsp. sativa*	Lucerne
*	*Solanum pseudocapsicum*	Madeira Winter-cherry
	Pelargonium rodneyanum	Magenta Stork's-bill
*	*Malva nicaeensis*	Mallow of Nice
*	*Centaurea melitensis*	Malta Thistle
	Eucalyptus viminalis	Manna Gum
	Galium leiocarpum	Maori Bedstraw
r	*Atriplex paludosa subsp. paludosa*	Marsh Saltbush
*	*Medicago spp.*	Medic
*	*Silene nocturna*	Mediterranean Catchfly
*	*Melilotus siculus*	Mediterranean Melilot
vu X	*Eucalyptus leucoxylon subsp. connata*	Melbourne Yellow-gum

Conservation Status	Scientific Name	Common Name
	Eucalyptus obliqua	Messmate Stringybark
	Calocephalus lacteus	Milky Beauty-heads
	Daviesia leptophylla	Narrow-leaf Bitter-pea
*	*Trifolium angustifolium var. angustifolium*	Narrow-leaf Clover
	Einadia nutans	Nodding Saltbush
*	*Helminthotheca echioides*	Ox-tongue
*	*Cucumis myriocarpus subsp. leptodermis*	Paddy Melon
	Drosera peltata s.l.	Pale Sundew
	Drosera peltata subsp. peltata spp. agg.	Pale Sundew
*	*Echium plantagineum*	Paterson's Curse
	Lissanthe strigosa subsp. subulata	Peach Heath
*	*Linaria pelisseriana*	Pelisser's Toad-flax
*	*Schinus molle*	Pepper Tree
*	*Mentha X piperita*	Peppermint
*	*Cirsium arvense*	Perennial Thistle
*	*Euphorbia peplus*	Petty Spurge
*	*Lysimachia arvensis*	Pimpernel
	Convolvulus erubescens s.l.	Pink Bindweed
	Calandrinia calyptrata	Pink Purslane
*	*Opuntia spp.*	Prickly pear
	Stellaria pungens	Prickly Starwort
*	*Polygonum aviculare s.l.*	Prostrate Knotweed
	Hardenbergia violacea	Purple Coral-pea
	Lythrum salicaria	Purple Loosestrife
	Ptilotus spathulatus	Pussy Tails
	Brachyscome perpusilla	Rayless Daisy
*	*Parentucellia latifolia*	Red Bartsia
	Eucalyptus polyanthemos	Red Box
	Eucalyptus tricarpa	Red Ironbark
*	*Spergularia rubra s.l.*	Red Sand-spurrey
	Eucalyptus macrorhyncha	Red Stringybark
*	*Modiola caroliniana*	Red-flower Mallow
*	*Phytolacca octandra*	Red-ink Weed

Conservation Status	Scientific Name	Common Name
*	*Plantago lanceolata*	Ribwort
	Callistemon sieberi	River Bottlebrush
	Mentha australis	River Mint
X	*Eucalyptus camaldulensis*	River Red-gum
	Leptospermum obovatum	River Tea-tree
*	*Opuntia elata*	Riverina Pear
	Correa glabra var. glabra	Rock Correa
	Galium gaudichaudii	Rough Bedstraw
*	*Trifolium scabrum*	Rough Clover
	Senecio hispidulus s.l.	Rough Fireweed
*	*Sonchus asper s.l.*	Rough Sow-thistle
*	*Sonchus asper s.s.*	Rough Sow-thistle
	Acacia aspera	Rough Wattle
	Disphyma crassifolium subsp. clavellatum	Rounded Noon-flower
	Enchylaena tomentosa var. tomentosa	Ruby Saltbush
	Pomaderris ferruginea	Rusty Pomaderris
#	*Acacia longifolia*	Sallow Wattle
	Einadia hastata	Saloop
	Leptorhynchos squamatus	Scaly Buttons
	Senecio odoratus	Scented Groundsel
	Urtica incisa	Scrub Nettle
	Apium prostratum subsp. prostratum	Sea Celery
	Rhagodia candolleana subsp. candolleana	Seaberry Saltbush
*	*Prunella vulgaris*	Self-heal
	Parietaria debilis s.l.	Shade Pellitory
*	*Acetosella vulgaris*	Sheep Sorrel
	Acaena echinata	Sheep's Burr
*	*Capsella bursa-pastoris*	Shepherd's Purse
	Cassinia longifolia	Shiny Cassinia
P	*Leionema lamprophyllum*	Shiny Leionema
	Maireana brevifolia	Short-leaf Bluebush
	Dillwynia sericea	Showy Parrot-pea
	Senecio minimus	Shrubby Fireweed

Conservation Status	Scientific Name	Common Name
	Platysace lanceolata	Shrubby Platysace
	Crassula sieberiana s.l.	Sieber Crassula
*	*Chondrilla juncea*	Skeleton Weed
*	*Centaurium tenuiflorum*	Slender Centaury
	Rumex brownii	Slender Dock
	Senecio tenuiflorus spp. agg.	Slender Fireweed
	Persicaria decipiens	Slender Knotweed
	Crassula colligata subsp. colligata	Slender Stonecrop
*	*Carduus pycnocephalus*	Slender Thistle
*	*Galium murale*	Small Goosegrass
	Lythrum hyssopifolia	Small Loosestrife
	Calandrinia eremaea	Small Purslane
en L	*Cullen parvum*	Small Scurf-pea
	Hypericum gramineum spp. agg.	Small St John's Wort
*	*Malva parviflora*	Small-flower Mallow
	Rubus parvifolius	Small-leaf Bramble
	Chenopodium desertorum subsp. microphyllum	Small-leaf Goosefoot
	Clematis microphylla s.l.	Small-leaved Clematis
*	*Hypochaeris glabra*	Smooth Cat's-ear
	Dillwynia glaberrima	Smooth Parrot-pea
r #	*Prostanthera nivea var. nivea*	Snowy Mint-bush
	Pultenaea mollis	Soft Bush-pea
*	*Oxalis pes-caprae*	Soursob
	Frankenia pauciflora var. gunnii	Southern Sea-heath
*	*Chenopodium murale*	Sowbane
*	*Cirsium vulgare*	Spear Thistle
	Schenkia australis	Spiked Centaury
	Hibbertia exutiacies	Spiky Guinea-flower
	Stuartina muelleri	Spoon Cudweed
*	*Medicago arabica*	Spotted Medic
	Wahlenbergia gracilis	Sprawling Bluebell
	Myoporum petiolatum	Sticky Boobialla
*	*Amaranthus albus*	Stiff Tumbleweed

Conservation Status	Scientific Name	Common Name
	Hydrocotyle laxiflora	Stinking Pennywort
*	*Dittrichia graveolens*	Stinkwort
*	*Trifolium fragiferum var. fragiferum*	Strawberry Clover
*	*Trifolium subterraneum*	Subterranean Clover
*	*Trifolium dubium*	Suckling Clover
*	*Eucalyptus cladocalyx*	Sugar Gum
	Crassula helmsii	Swamp Crassula
*	*Rosa rubiginosa*	Sweet Briar
	Bursaria spinosa	Sweet Bursaria
	Bursaria spinosa subsp. spinosa	Sweet Bursaria
	Cynoglossum suaveolens	Sweet Hound's-tongue
	Wahlenbergia stricta subsp. stricta	Tall Bluebell
	Gonocarpus elatus	Tall Raspwort
r	*Pseudanthus orbicularis*	Tangled Pseudanthus
	Acacia aculeatissima	Thin-leaf Wattle
	Veronica plebeia	Trailing Speedwell
	Melicytus dentatus s.l.	Tree Violet
	Melicytus dentatus s.s.	Tree Violet
	Wahlenbergia communis s.l.	Tufted Bluebell
	Eremophila deserti	Turkey Bush
*	*Verbascum virgatum*	Twiggy Mullein
*	*Brassica fruticulosa*	Twiggy Turnip
	Glycine clandestina	Twining Glycine
	Glycine tabacina s.s.	Variable Glycine
	Senecio pinnatifolius	Variable Groundsel
	Plantago varia	Variable Plantain
	Opercularia varia	Variable Stinkweed
	Epilobium billardierianum	Variable Willow-herb
*	*Silybum marianum*	Variegated Thistle
	Acacia verniciflua s.l.	Varnish Wattle
r	*Westringia glabra*	Violet Westringia
	Galium migrans spp. agg.	Wandering Bedstraw
*	*Cotula coronopifolia*	Water Buttons

Conservation Status	Scientific Name	Common Name
	Batrachium trichophyllum	Water Fennel
*	*Nasturtium officinale*	Watercress
	Dodonaea viscosa subsp. cuneata	Wedge-leaf Hop-bush
*	*Reseda luteola*	Weld
en	*Eucalyptus baueriana subsp. thalassina*	Werribee Blue-box
*	*Trifolium repens var. repens*	White Clover
	Sambucus gaudichaudiana	White Elderberry
*	*Salix alba*	White Willow
*	*Dipsacus fullonum subsp. fullonum*	Wild Teasel
*	*Salix spp.*	Willow
*	*Carduus tenuiflorus*	Winged Slender-thistle
	Maireana enchylaenoides	Wingless Bluebush
	Leptospermum lanigerum	Woolly Tea-tree
#	*Eucalyptus leucoxylon*	Yellow Gum
	Hydrocotyle foveolata	Yellow Pennywort
	Oxalis corniculata s.l.	Yellow Wood-sorrel
*	*Myosotis discolor*	Yellow-and-blue Forget-me-not
Monocotyledons (0.1km buffer)		
*	Polypogon monspeliensis	Annual Beard-grass
*	Rostraria cristata	Annual Cat's-tail
*	Poa annua	Annual Meadow-grass
*	Ehrharta longiflora	Annual Veldt-grass
	Puccinellia stricta s.l.	Australian Saltmarsh-grass
	Glyceria australis	Australian Sweet-grass
*	Hordeum spp.	Barley Grass
*	Hordeum leporinum	Barley-grass
	Juncus usitatus	Billabong Rush
	Dianella revoluta s.l.	Black-anther Flax-lily
k	Pterostylis bicolor	Black-tip Greenhood
	Cyanicula caerulea	Blue Fairy
	Pterostylis curta	Blunt Greenhood
	Potamogeton ochreatus	Blunt Pondweed
*	Asparagus asparagoides	Bridal Creeper

Conservation Status	Scientific Name	Common Name
	Typha orientalis	Broad-leaf Cumbungi
	Juncus planifolius	Broad-leaf Rush
	Juncus sarophorus	Broom Rush
*	Agrostis capillaris	Brown-top Bent
	Bulbine bulbosa	Bulbine Lily
*	Elodea canadensis	Canadian Pondweed
*	Nassella hyalina	Cane Needle-grass
*	Nassella neesiana	Chilean Needle-grass
	Arthropodium strictum s.l.	Chocolate Lily
*	Parapholis incurva	Coast Barb-grass
*	Dactylis glomerata	Cocksfoot
	Lachnagrostis filiformis s.l.	Common Blown-grass
	Schoenus apogon	Common Bog-sedge
	Lemna disperma	Common Duckweed
	Lemna minor s.l.	Common Duckweed
	Echinopogon ovatus	Common Hedgehog-grass
	Eragrostis brownii	Common Love-grass
	Phragmites australis	Common Reed
	Eleocharis acuta	Common Spike-sedge
	Poa labillardierei	Common Tussock-grass
	Poa labillardierei var. labillardierei	Common Tussock-grass
	Rytidosperma caespitosum	Common Wallaby-grass
	Anthosachne scabra s.l.	Common Wheat-grass
	Luzula meridionalis var. flaccida	Common Woodrush
	Rytidosperma fulvum	Copper-awned Wallaby-grass
	Cynodon dactylon	Couch
*	Cynodon dactylon var. dactylon	Couch
*	Agrostis stolonifera	Creeping Bent
	Enneapogon nigricans	Dark Bottle-washers
*	Lolium temulentum	Darnel
*	Lolium temulentum var. arvense	Darnel
*	Tribolium acutiflorum s.l.	Desmazeria
*	Cyperus eragrostis	Drain Flat-sedge

Conservation Status	Scientific Name	Common Name
	Caladenia fuscata	Dusky Fingers
	Pterostylis nana	Dwarf Greenhood
*	Aira praecox	Early Hair-grass
	Austrostipa semibarbata	Fibrous Spear-grass
	Juncus subsecundus	Finger Rush
*	Iris germanica	German Iris
*	Gladiolus X colvillii	Gladiolus
	Juncus caespiticius	Grassy Rush
*	Bromus diandrus	Great Brome
	Juncus gregiflorus	Green Rush
	Caladenia dilatata s.l.	Green-comb Spider-orchid
	Poa sieberiana	Grey Tussock-grass
*	Aira spp.	Hair Grass
	Rytidosperma erianthum	Hill Wallaby-grass
	Juncus amabilis	Hollow Rush
	Dipodium punctatum s.l.	Hyacinth Orchid
*	Sorghum halepense	Johnson Grass
	Juncus holoschoenus	Joint-leaf Rush
*	Juncus articulatus subsp. articulatus	Jointed Rush
	Themeda triandra	Kangaroo Grass
*	Cenchrus clandestinus	Kikuyu
	Austrostipa bigeniculata	Kneed Spear-grass
	Rytidosperma geniculatum	Kneed Wallaby-grass
	Carex inversa	Knob Sedge
	Ficinia nodosa	Knobby Club-sedge
*	Briza maxima	Large Quaking-grass
	Cyperus lucidus	Leafy Flat-sedge
*	Phalaris minor	Lesser Canary-grass
*	Briza minor	Lesser Quaking-grass
	Lepilaena cylindrocarpa	Long-fruit Water-mat
	Juncus pauciflorus	Loose-flower Rush
*	Bromus madritensis	Madrid Brome
	Bolboschoenus medianus	Marsh Club-sedge

Conservation Status	Scientific Name	Common Name
	Hemarthria uncinata var. uncinata	Mat Grass
	Caladenia moschata	Musk Hood-orchid
	Typha domingensis	Narrow-leaf Cumbungi
*	Gastridium phleoides	Nit-grass
	Isolepis cernua var. cernua	Nodding Club-sedge
*	Avena spp.	Oat
*	Romulea rosea	Onion Grass
	Juncus pallidus	Pale Rush
*	Ehrharta erecta var. erecta	Panic Veldt-grass
*	Paspalum dilatatum	Paspalum
*	Lolium perenne	Perennial Rye-grass
	Caladenia carnea sensu Willis (1970)	Pink Fingers
*	Bromus catharticus	Prairie Grass
*	Aira cupaniana	Quicksilver Grass
*	Vulpia myuros	Rat's-tail Fescue
*	Bromus rubens	Red Brome
	Schoenoplectus tabernaemontani	River Club-sedge
	Carex polyantha	River Sedge
*	Cynosurus echinatus	Rough Dog's-tail
	Austrostipa scabra subsp. falcata	Rough Spear-grass
	Juncus kraussii subsp. australiensis	Sea Rush
*	Nassella trichotoma	Serrated Tussock
	Rytidosperma pallidum	Silvertop Wallaby-grass
*	Aira caryophyllea subsp. caryophyllea	Silvery Hair-grass
*	Parapholis strigosa	Slender Barb-grass
	Thelymitra pauciflora s.l.	Slender Sun-orchid
	Poa tenera	Slender Tussock-grass
	Rytidosperma racemosum var. racemosum	Slender Wallaby-grass
	Cyrtostylis reniformis	Small Gnat-orchid
EN en L	Diuris basaltica	Small Golden Moths
	Austrostipa spp.	Spear Grass
*	Juncus acutus subsp. acutus	Spiny Rush
	Lomandra longifolia	Spiny-headed Mat-rush

Conservation Status	Scientific Name	Common Name
	Lomandra longifolia subsp. longifolia	Spiny-headed Mat-rush
*	Vulpia bromoides	Squirrel-tail Fescue
	Damasonium minus	Star Fruit
	Triglochin striata	Streaked Arrowgrass
	Austrostipa mollis	Supple Spear-grass
	Isolepis inundata	Swamp Club-sedge
*	Anthoxanthum odoratum	Sweet Vernal-grass
	Pterostylis longifolia s.l.	Tall Greenhood
	Carex appressa	Tall Sedge
	Diuris sulphurea	Tiger Orchid
	Wolffia australiana	Tiny Duckweed
	Juncus bufonius	Toad Rush
*	Phalaris aquatica	Toowoomba Canary-grass
	Thysanotus patersonii	Twining Fringe-lily
	Lepidosperma laterale	Variable Sword-sedge
	Corybas diemenicus s.l.	Veined Helmet-orchid
	Rytidosperma pilosum	Velvet Wallaby-grass
	Danthonia s.l. spp.	Wallaby Grass
*	Paspalum distichum	Water Couch
	Cycnogeton spp.	Water Ribbons
	Lomandra filiformis	Wattle Mat-rush
	Microlaena stipoides var. stipoides	Weeping Grass
	Rytidosperma penicillatum	Weeping Wallaby-grass
*	Avena fatua	Wild Oat
*	Lolium rigidum	Wimmera Rye-grass
	Chloris truncata	Windmill Grass
*	Holcus lanatus	Yorkshire Fog

APPENDIX 3 – 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	The ecological character of a river is dependent on the frequency, timing and duration of water flowing into and out of the system. Alteration to the River's natural flow regimes can occur through reducing or increasing flows, altering seasonality of flows, changing the frequency, duration, magnitude, timing, predictability and variability of flow events, altering surface and groundwater levels and changing the rate of rise or fall of water levels. Alteration of the natural flow regime of the Werribee River and its floodplains and wetlands is recognised as a major factor contributing to loss of biological diversity and ecological function in the system. Impacts include: • Reduction of 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 • Riparian zone and floodplain degradation through altered flow	All	Possible	Major	H	A cap has been placed on surface water extractions in the Werribee catchment, preventing extraction over and above limits set through water entitlements. The total volume of water entitlements is currently 38,656 ML/year (DEPI 2013c). Government regularly reviews surface water sustainable diversion limits in Victoria in light of antecedent catchment and climate conditions, additional environmental flows knowledge, and water demand. Residual risk is calculated based on the assumption that likelihood is reduced to 'Unlikely' following intervention actions.	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
	patterns • Increased habitat for invasive species • Loss or disruption of ecological functions • Increased bank erosion and changes to channel geomorphology.						
Increased groundwater extractions	Groundwater extraction can cause shifts in the seawater / fresh water interface near the Werribee estuary and Werribee Irrigation District, with a reverse flux of salty water from the Bay entering in to the aquifer as groundwater levels reduce, increasing salinity levels for local groundwater sources. Groundwater extraction may also reduce habitat availability for groundwater dependent ecosystems	Fish, Vegetation, Macroinvertebrates	Possible	Moderate	M	Southern Rural Water bans groundwater extractions when aquifer levels drop and salinity levels increase in some river and coastal bores. The ban is necessary to minimise the risk of seawater intrusion into the aquifer. A cap on the volume of groundwater extractions also exists in the catchment through licenced groundwater entitlements, which limit the amount of groundwater that can be taken each year. These extraction limits are reviewed regularly to ensure their continuing effectiveness and sustainability. Residual risk is calculated based on assumption that the likelihood is reduced to 'Unlikely' following intervention actions.	L
Construction of additional artificial instream structures (e.g. dams, weirs, gauging stations)	The construction of water storage and conveyance infrastructure and management activities can result in: • A loss of longitudinal and lateral connectivity in waterways, blocking passage for fish and movement of plant	Fish Platypus Geomorphology	Unlikely	Major	M	The construction of fishways, providing higher flows that directly link upstream and downstream environments, as well as modifying the operation of structures, will increasingly allow for better passage of organisms.	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
	propagules. Impacts often increase cumulatively downstream. Connectivity between the river and Port Phillip Bay allows the movement of aquatic animals (particularly fish, some of which need to move between fresh water and salt water to survive) • 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 • Increased risk to platypus being preyed on if they are required to travel overland to move between reaches. • Alter the geomorphology of waterways downstream, including deepening of channels and bed and bank erosion. Loss of connectivity is identified as a critical priority threat to significant flora and fauna, and EVC values in the Werribee catchment.					Melbourne Water will work with SRW and State Government to influence the design of any potential new water storage and conveyance infrastructure such that it is sensitive to habitat connectivity needs (e.g. fish passage) and is able to be managed for environmental flow regime requirements. 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. Melbourne Water is also investigating options to improve environmental flows in the Werribee River through an Integrated Whole of Water Cycle Management Plan. This identifies alternative sources of water that may reduce reliance on the strategy of constructing additional infrastructure on the Werribee River. Residual risk calculations assume that the consequences are reduced to 'Moderate' following intervention actions.	
Recreational fishing	Recreational fishing can negatively impact the abundance of native fish species. This is particularly a problem during periods of drought when the habitat availability for fish	Fish	Certain	Moderate	**H**	In partnership with DELWP fisheries, Melbourne Water to develop and implement an education and involvement program with recreational fishing groups to ensure native fish are released but	**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
	can already be considerably reduced.					introduced fish are not released back in to the river. Targeted particularly during drought periods. Residual risk has assumed that the likelihood is reduced to 'possible' following intervention actions.	
Land use change: Urban development	Different land uses have different impacts on environmental flows and the stream health of the Werribee River. A significant impact associated with urban development is stormwater influxes coming from increased areas of impervious surfaces. These influxes can change the hydrology of urban streams by increasing the frequency and magnitude of storm flow events, reducing the duration of storm flow events, and by reducing low flows through poor groundwater infiltration. Both high and low flow events in urban areas are also associated with increased pollutant concentrations, for example in the Estuary where stormwater drains enter. 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	Vegetation Geomorphology Fish Platypus	Certain	High	H	Under its Waterways Operating Charter, Melbourne Water is obligated to ensure urban development achieves appropriate standards of flood protection, protects waterway health and is sensitive to other environmental and social values of waterways. Local government is a key player in the success of managing the impacts of urban development because of its role and responsibilities in land use planning, drainage management, management of development, rates, and a variety of services including road infrastructure development and maintenance, water supply and the disposal of wastewater. Melbourne Water will work in collaboration with DELWP, relevant Local Councils and the Metropolitan Planning Authority to understand and reduce the risks of increasing urban development on the Werribee river and estuary. Melbourne Water is also investigating options for stormwater harvesting and reuse for environmental flows through	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
	discharges affecting water quality • Industrial discharges decreasing water quality and increasing toxicant loads within the waterway and estuary • Exposure of acid-sulphate soils leading to the acidification of the waterway and estuary • Increasing capture of rainfall and stormwater runoff, reducing inflows to the Werribee River and Estuary • Increasing salinity downstream (Note: this is also associated with soil erosion and irrigation drainage flows (Ecological Associates 2005a)					Water Sensitive Urban Design and integrated water cycle management programs. Residual risk is assessed assuming that that	
Land use change: Farm dams	Land clearing for agricultural and residential purposes, and the associated increases in numbers of licenced and unlicenced farm dams, can have a significant effect on environmental flows in a catchment. Farm dams capture runoff when it is available and store it for later use, with demands generally highest between the months of December to March in Australia; the months where temperatures are usually the highest and rainfall and streamflows are at their lowest.	Fish	Certain	Major	**H**	Melbourne water is improving its knowledge of the impacts of farm dams with hydrological analysis. Melbourne Water is also looking at options to cap farm dams through collaborative work with DELWP. This additional knowledge will assist in including farm dams as a clear part of catchment water resources, so that they can be closely monitored (for storage volume, losses and consumptive use over set timeframes) and used to calculate sustainable water allocations for the catchment. Residual risk is calculated based on 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
						assumption that interventions reduce the consequences of farms dams to 'Moderate' based on improvements to manage catchment water allocation processes.	
Pest plants and animals: • Carp • Brown Trout • Gambusia • Redfin • Foxes, dogs and cats	Carp limit the availability of habitat for other species such as macroinvertebrates and small-bodied fish, and increase sedimentation within waterways due to their feeding behaviours. Brown Trout out compete and prey on smaller native fish species such as Galaxids and the Southern Pygmy Perch Gambusia are linked with the decline in distribution and/or abundance of small-bodied fish through competition for food and habitat. They are also known to feed on amphibian eggs and tadpoles, dragonfly larvae and may also impact negatively on water quality Redfin are a host for diseases that are highly pathogenic to some native fish species. They also compete for food and habitat and prey on smaller fish Platypus are vulnerable to predation by foxes, dogs and cats when travelling through very shallow water or across dry land (Jacobs 2014)	Fish Platypus	Certain	Major	H	Actions for the broad scale control of carp are yet to prove successful. The proposed flow regime for the river may indeed provide favourable conditions for Carp. Physical removal of Gambusia before the species' spawning season can result in major reductions in its abundance, even resulting in complete eradication at some sites. The degree of success depends on site hydrology and hydrological connectivity, ecological value, habitat complexity, habitat size and climate. Fox control programs may assist in reducing the likelihood of fox predation, as may improving riparian vegetation cover and longitudinal connectivity along the river. Residual risk is calculated based on the assumption that management interventions have reduced the likelihood to 'Possible'.	M
Illegal fishing nets	Illegal fishing nets cause preventable platypus mortality.	Platypus	Certain	Major	H	A vigorous community education campaign, particularly targeting school	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
		Fish				groups, is the most effective method to address these issues using resources such as platypusSPOT, media, community talks and signage around waterways. Residual risk is based on the assumption that the likelihood of the risk occurring is reduced.	
Sediment inputs to the estuary	Sediment is very likely to be affected by catchment land-use practices, with extensive land clearing (especially riparian areas) increasing the run-off of sediment into rivers or directly into estuaries. Reduced flows are also likely to reduce channel scouring and increase sediment deposition with estuaries. Changes in the type and supply of sediment can markedly alter water depths and affect the distribution of biota relying on particular combinations of depth and substratum type. Sediments can also be sinks for various chemicals (including toxicants) altering water quality parameters such as chemical loads within sediments. Nutrient loads in estuaries are also considered to have increased due to extensive agriculture in most coastal catchments and increased run-off (with less filtering) into rivers as a result of land and riparian clearing. The main impact of increased nutrient loads is increased primary productivity, potentially resulting in blooms of	Fish Vegetation	Certain	Moderate	**H**	Working in collaboration with Local Councils and Port Phillip and Westernport CMA for catchment wide erosion control and mitigation programs will assist in ameliorating this risk. Stormwater capture and treatment options through Water Sensitive Urban Design projects and Integrated Water Cycle Management Plans and programs will also help to reduce sedimentation issues within the waterway and estuary. Residual risk is based on the assumption that likelihood is reduced following management interventions.	**B**

Risk Category	Impact of the Risk Occurring	Water-Dependent Ecological Values Impacted	Likelihood (Unlikely / Possible / Certain)	Consequence (Minor / Moderate / Major)	R	Management Actions	RR
	algae (including toxic species). Algal blooms are now thought to be a common occurrence in Victorian estuaries and recreational activities in some estuaries have to be restricted during such blooms (Drew et al 2008)						
Further expansion of irrigation areas within the catchment	The expansion of irrigated agriculture within the Werribee catchment may increase consumptive surface water and groundwater demands on the system, reducing the availability of water for environmental flows.	All	Unlikely	Major	M	Caps on extractions reduce the likelihood of irrigation expansion occurring within the catchment. Adaptive management, sourcing alternative supplies of water through Integrated Water Cycle Management plans, and monitoring of current water availability, will assist in understanding water availability and Sustainable Diversion Limits. Residual risk is based on the assumption that the consequences of irrigation expansion can be reduced.	L
Stock access and grazing pressure	Grazing by cattle in the riparian zone prevents establishment of native vegetation within the river and along its banks. Grazing also decreases water quality, by increasing water turbidity due to bank erosion and stock disturbance, and increasing nutrient concentrations from grazing runoff.	Vegetation Fish Platypus	Certain	Moderate	H	Catchment and river health programs through the Melbourne Water Healthy Waterways Strategy will help to reduce the likelihood of this risk occurring. Removing stock access to waterways within the catchment is a strategic priority for the HWS. 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	All	Certain	Major	H	Management actions will focus on	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
	within the Werribee catchment, and alter flow regimes through changes to the temporal and volumetric patterns of seasonal rainfall. Impacts on the Werribee River and estuary include loss of habitat, loss of flow regime cues for breeding and migration, and a consequent reduction in biodiversity and ecosystem services.					understanding the nature of the risks that climate change poses to the biodiversity and ecosystem services of the Werribee River and its catchment. 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 the volumetric limitations of the current Werribee River Environmental Entitlement.	
Threats related to the delivery of environmental water							
High flow releases	Winter high fresh drowns juvenile Platypus	Platypus	Possible	High	M	Deliver winter high fresh in August to trigger females to select or construct nursery burrows higher up the river bank	L
All releases	Environmental release cause personal injury to river user	N/A	Unlikely	Major	M	Detailed risk assessment undertaken prior to each release event. This risk assessment will consider catchment conditions, the seven day weather forecast and the level of communication required. Delivered flows are low volume and velocity	L
All releases	Release volume is insufficient in meeting	All	Unlikely	Moderate	L	To date, orders have generally been	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
	required flow at target point					slightly higher than required to ensure compliance. Close communication with storage operators and monitoring of losses is increasing the required body of knowledge	
Evidence base	Current recommendations on environmental flow inaccurate	All	Possible	Moderate	M	Flow recommendations are based on the best possible science and a monitoring program is in place to identify if ecological objectives are not being achieved. A systematic review of recommendations was conducted in 2014.	L
Operational	Storage Operator maintenance works affect ability to deliver water	All	Unlikely	Moderate	L	This risk is considered low because there is sufficient institutional experience in delivering passing flows when maintenance does occur	L
Operational	Resource Manager cannot deliver required volume or flow rate (outlet/capacity constraints, insufficient storage volume)	All	Unlikely	Moderate	L	Seasonally adaptive management approach allows watering actions to be tailored to the volume of water available in the entitlement	L
Operational	Competing storage operator priorities do not allow delivery of some events (fire, flood etc)	All	Possible	Moderate	M	Summer freshes can compete with irrigation deliveries for a share of valve capacity under certain circumstances Coordination with storage manager has avoided this in the past by changed scheduling of delivery. Upgrade of the valve at Melton has increased capacity	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
Impact of releases	Releases cause water quality issues (e.g. blackwater, low DO, mobilisation of saline pools, acid-sulphate soils, etc)	All	Possible	Moderate	M	Water quality monitoring is in place to measure effects of releases. Preliminary results suggest that water quality impacts are generally beneficial and that black water effects are transient and localised to small sections of the estuary that are frequently flushed by tidal action.	L
Impact of releases	Improved conditions for non-native species (e.g. carp)	Fish	Possible	Moderate	M	No effective mitigation actions currently possible	M
Operational	Unable to provide evidence that hydrological target has been met	All	Possible	Minor	L	Stream flow gauging is adequate. Access to SRW's flow gauging has been negotiated.	L
Operational	Irrigators divert environmental releases from the system leading so the target is not reached.	All	Possible	Moderate	M	Irrigators must order water releases before they can extract. Resource manager field staff routinely check compliance.	L
Operational	Environmental releases cause flooding of private land, public infrastructure or Crown land	Amenity	Unlikely	Moderate	L	Overbank and bankfull releases have not been selected as priority watering actions to reduce risk of flooding.	L
Operational	Environmental release interferes with essential MW service	N/A	Unlikely	Moderate	L	Regular communication has been established with MW River Health and Maintenance teams and potential risk to delivery of works has been rated as low at a general level. Teams are notified prior to all releases.	L
Evidence base	Public misperception of the purpose of releases	All	Possible	Moderate	M	An email list of interested parties has been created and updates on planned watering occur regularly.	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
						Interest from agencies and public enquiries indicates a reasonably widespread level of community interest and support.	

APPENDIX 4– LIFE HISTORY TRAITS

		Life-cycle Trait						
Environmental Value	**Relevant Reaches**	**Longevity**	**Resistance of adults to poor environmental conditions**	**Fecundity**	**Ability to breed in a wide range of conditions**	**Recruitment success**	**Dispersal ability**	**Time to maturity**
Platypus	**8, 9**	High (10-15 yrs)	Medium[1]	Low	Medium	Low-medium	Low-medium [2]	2-3 years
Galaxids	**9**	Low 3-4 years	High	High	Low	Medium [3]	Medium [3]	1 year
Bream	**Estuary**	High 30+ years	High	High	Medium-high	Medium-high	High	2-3 years
Pygmy Perch	**6**	Low (3-4 years)	High	Medium	Medium[4]	Medium	Low	1 year
Blackfish	**Potentially 8 and 9**	Medium (5-8 years)	Medium[6]	Low	Medium[5]	Medium	Medium	2-3 years
Tupong	**9**	Medium (5-8 years)	High	Medium?	Low	Medium [3]	Medium [3]	N/A
Frogs	**6**	N/A [6]	N/A	N/A	N/A	N/A	N/A	N/A
Still water insects	**6**	Low	High[8]	High	High	High	High	Less than one year
Non-insects	**6**	Low	High[8]	High	High	High	Low	Less than one year
Flowing water insects	**6**	Low	Medium[9]	High	N/A	High	High	Less than one year

Notes:

1. Platypus is limited by the amount of habitat available. It is resistant to poor water quality, but is exposed to predation at extended low flows. The species is also sensitive to fragmentation of populations.
2. Platypus has good dispersal ability, but is exposed to predation issues in the lower Werribee catchment
3. The recruitment success of Galaxids and Tupong is impacted by barriers to their movement up and down the system
4. Pygmy Perch requires suitable vegetated still water habitat
5. Blackfish are also dependent on structural features, and require freshes to stimulate breeding
6. **6.** Melbourne Water's HWS objective for frogs is to improve conditions for the whole community rather than individual species, so determining climatic and hydrological response was not appliacable in this instance

7. Blackfish are susceptible to poor water quality and high temperatures
8. Refers to the larvae of these species
9. Flowing water insects are vulnerable to siltation and poor water quality

APPENDIX 5 – PASSING FLOWS RULES

Passing flows for the Werribee River, as specified in the Bulk Entitlement (Werribee system – Irrigation) Conversion order 1997 – Consolidated version as at 30 May 2011.

Location of Passing Flows	Volume or rate of water delivery (ML/d)
Lerderderg Weir	a) Low flow in the Lerderderg River below the Lerderderg Weir equal to the lesser of the natural flow at this location and 30 ML/day; and b) Fresh flow in the Lerderderg River below the Lerderderg Weir during the period June to December inclusive, of (i.) 150 ML/day, up to five times per year, in accordance with the rules set out in Schedule 8 of the ; and (ii.) 1500 ML/day for 24 hours, in three out of four years, if the instantaneous natural flow at this location exceeds 1500 ML/day.
Goodman Creek	A minimum passing flow in Goodman Creek below Goodman Creek diversion weir of the lesser of 2.5 ML/day or the natural flow at this location.
Coimadai Creek	A minimum passing flow in Coimadai Creek downstream of Lake Merrimu of the lesser of 2 ML/day or the natural flow at this location.
Upper Werribee Diversion Weir	A minimum passing flow in the Werribee River below Upper Werribee diversion weir of the lesser of 5 ML/day and the natural flow at this location
Bacchus Marsh Diversion Weir	A minimum passing flow in the Werribee River below Bacchus Marsh diversion weir measured at the Bacchus Marsh gauging station, of the lesser of 12 ML/day averaged over any 7 day period and the natural flow at this location, consisting of (i.) The lesser of 12 ML/day continuous flow and the natural flow at this location; or (ii.) The sum of- (A) The lesser of a continuous flow of at least 5 ML/d and the natural flow at this location; and (B) Other intermittent flows resulting from deliberate releases by the Authority from, or spill over, the Bacchus Marsh diversion weir
Melton Reservoir	A minimum passing flow in the Werribee River below Melton Reservoir during the period from May to August (inclusive) of – (i.) The lesser of 9 ML/day and the natural flow at this location, if the level of Melton Reservoir is above the target for that month as specified in Schedule 6; or (ii.) The lesser of 9 ML/day averaged over any 7 day period and the natural flow at this location averaged over the same period, if the level of Melton Reservoir is at or below the target for the month as specified in Schedule 6
Werribee Diversion	Within the operational tolerances specified in the BE (Schedule 7), an average minimum passing flow in the Werribee River below Werribee

Location of Passing Flows	Volume or rate of water delivery (ML/d)
Weir	diversion weir of (i.) 10 ML/day, if the seasonal determination for low reliability water shares exceeds 60%; (ii.) 1 ML/day averaged over any 30 day period, if the seasonal determination for low reliability water shares is equal to or less than 60%.
Lerderderg River (Schedule 8 of BE)	(a) A fresh flow must have a duration of at least 132 hours (b) A fresh flow is triggered when the flow at O'Brien's Crossing gauging station is equal to, or exceeds an instantaneous flow of 150 ML/day. (c) Within 24 hours of a fresh flow being triggered, the Storage Operator must set the Lerderderg Weir structure to pass a minimum flow of 150 ML/day. (d) The fresh flow is defined as having commenced at the time the Lerderderg Weir Structure is set to pass 150 ML/day. (e) Once the valve is set it shall remain open for a minimum of 132 hours. (f) After 132 hours, the valve shall be set to provide the greater of - (i.) Half the flow measured through the valve, or (ii.) The low flow in accordance with paragraph (a) of sub-clause 12.2 of the bulk entitlement