Yarra River Environmental Water Management Plan

Melbourne Water

Final Report

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Yarra River Environmental Water Management Plan

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4.0	10th February, 2017	Final report	Jodi Braszell	Simon Treadwell	Simon Treadwell Cheryl Edwards

Contents

Important note about this report

The sole purpose of this report and the associated services performed by Jacobs is to prepare an Environmental Water Management Plan for the Yarra River in accordance with the scope of services set out in the contract between Jacobs and Melbourne Water. That scope of services, as described in this report, was developed with Melbourne Water.

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Acknowledgements

Acknowledgement of Country

Melbourne Water and Jacobs proudly acknowledge Aboriginal people as Australia's first peoples and as the Traditional Owners and custodians of the land and water on which we rely. We pay our respect to their Elders past and present.

We recognise and value the strong contribution and interest of Aboriginal people and organisations in waterways and catchment management and how this enriches us. In particular, we acknowledge the Ancestors, Elders and families of the Wurundjeri people of the Kulin Nation, who are the Traditional Owners of much of the Country through which the Yarra River flows.

We pay respect to the deep traditional knowledge and their custodianship of Country, and acknowledge that the Yarra catchment is a place of age old ceremonies of celebration, initiation and renewal and that the Kulin people's living culture has a unique role in the life of this region.

Contributions

The information contained in the Yarra River Environmental Water Management Plan has been sourced from a large number of reports, plans and strategies, as well as valuable contributions of knowledge and ideas from many people. We acknowledge the engagement and contributions of the following stakeholders in preparing this EWMP:

- The Yarra River Flows Advisory Group, consisting of representatives from:
  - Victorian Environmental Water Holder (VEWH)
  - Victorian Department of Environment Land, Water and Planning (DELWP)
  - Local government, including:
    - Yarra Ranges Council
    - Nillumbik Shire Council
    - Banyule City Council
    - Manningham City Council
    - City of Stonnington
    - City of Yarra
    - City of Boroondara
  - Local irrigators and landholders
  - Yarra Valley Water
  - Environment Protection Authority (EPA)
  - Environment Victoria
  - Yarra Riverkeeper and Yarra Riverkeeper Association
  - Native Fish Australia
  - VR Fish (Victorian Recreational Fishing Peak Body)
  - Kew Golf Club
- Melbourne Water Retailers:
  - Yarra Valley Water

  - City West Water
  - South East Water
- Parks Victoria
- Wurundjeri Tribe Land Compensation and Cultural Heritage Council
- Port Phillip and Westernport Catchment Management Authority
- City of Melbourne
- Yarra River Protection Ministerial Advisory Committee (MAC)

How to read this Environmental Water Management Plan

The Yarra River Environmental Water Management Plan (EWMP) provides the overarching strategy for the management of environmental water and protection of water-dependant values in the Yarra River for the next five to ten years. The EWMP is presented in three sections:

- **Part One** - An Executive Summary, which provides an overview of the contents of the EWMP and its key themes
- **Part Two** - A Technical Synthesis, which consolidates the evidence base used for the management of the Yarra River environmental watering program and discusses emerging issues and next steps, providing reference to primary sources of information and research where relevant and for further reading. The Technical Synthesis also provides more detailed information in a series of Appendices, to support the discussion of the EWMP
- **Part Three** - A series of seven fact sheets which summarise the condition, threats, flow requirements and emerging issues for each of the key values present within the waterway.

The values of the Yarra River are managed through a comprehensive and holistic program of catchment-wide actions, both flow and non-flow related. The EWMP seeks to answer a series of questions regarding the water-dependent values of the Yarra River and how these values can best be managed with the provision of flow-related actions. The Technical Synthesis section of the EWMP is organised into themes to help answer these questions, which explore:

- The context behind the Yarra River EWMP and a broad overview of the Yarra River catchment (Context and Catchment)
- Why the Yarra River is important for people and the environment, and what issues the river currently faces (Values, Condition and Threats)
- How we want to manage these values and threats by the provision of environmental flows (Management Objectives)
- The risks and challenges that may impact on our ability to achieve these management objectives (Risks, Challenges and Demonstrating Outcomes)
- Our knowledge gaps, stakeholder engagement and complementary management actions (Engagement, Knowledge and Next Steps) (Figure 1).

Context and Catchment

- Where is the river, and what is its catchment setting?
- What are Environmental Water Management Plans?
- Where does environmental water come from for the Yarra River?

EWMP Sections Covered

- Catchment overview
- Environmental water overview

Values, Condition and Threats

- Why is the river important for people?
  - What values does it support with its flows?
  - What do we know about the flow requirements of these values?
- What kind of condition is the river currently in, and does its condition seem to be improving or getting worse over time?
- How has the river's hydrological condition changed over time?
- What threats and issues are influencing the condition of the river?

EWMP Sections Covered

- Water dependent values
- Ecological condition and threats
- Hydrology

Management Objectives

- Using what we know about the river's values, condition and threats, what is our vision for the river, and what management objectives should we be implementing?
- How do environmental flows support these management objectives?

EWMP Sections Covered

- Strategic management objectives, including hydrological objectives

Risks, Challenges and Demonstrating Outcomes

- How do we physically provide environmental flows, and what arrangements are in place to help us do so?
- What could stop us from achieving our management objectives, and how do we propose to address these issues?
  - Risks
  - Climate change
  - Constraints
- How do we know and show that we're achieving our objectives?

EWMP Sections Covered

- Environmental water delivery infrastructure
- Managing risks to achieving objectives
- Emerging issues
- Demonstrating outcomes

Engagement, Knowledge and Next Steps

- Have we spoken to the right people?
- What other recommendations do we need to make to ensure the environmental watering program is successful?
- What do we still not know and/or understand about the waterway, and how do we propose to improve our knowledge?
- How do we secure the ecological heath of the river's flow-dependent values?
- What is the evidence base for this EWMP?

EWMP Sections Covered

- Knowledge gaps and recommendations
- Consultation
- Next steps
- References and Appendices

Figure 1 : Structure and contents of the Technical Synthesis section of the EWMP, organised by its key themes

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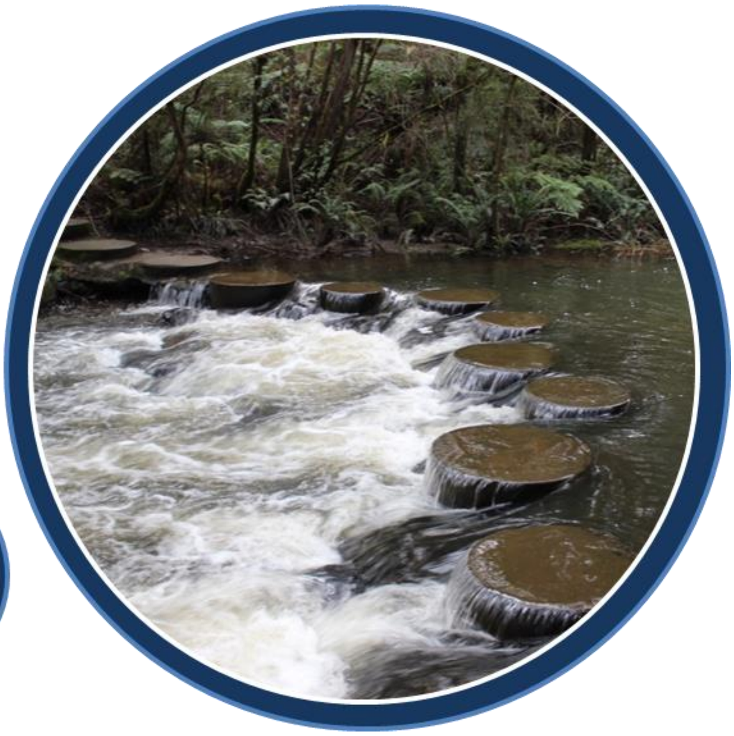
PART ONE – EXECUTIVE SUMMARY



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PART ONE - EXECUTIVE SUMMARY

The Yarra River is one of Victoria's most loved and iconic waterways. From the first members of the Kulin Nation to feed their children on its banks, to the diverse range of cultures and communities who now live, work and play in the Yarra catchment, people have highly valued and depended on the Yarra River for thousands of years.

The Wurundjeri people, members of the Kulin Nation and the Traditional Custodians of the Yarra River, have long known that the health of the Yarra and the Country that it waters are central to their cultural identity, their health, and their aspirations. The Yarra River is connected to their totem species and important cultural places, and its water is intrinsically part of their creation stories, the resources that they use and life itself, carrying with it a very long tradition of cultural practice and history. People depend on the Yarra River for their spiritual, cultural, emotional, physical and economic sustenance, and the tangible and intangible impacts on community wellbeing when its environmental health is compromised are only just beginning to be explored by scientists.

Sometimes affectionately known as 'the river that flows upside down' because of its muddy brown colour, the Yarra River is very important for the Melbourne community for the significant environmental values present within its system, including its estuary and Port Phillip Bay, the use of its water for drinking water supply and industry needs, and the wide range of benefits that people derive from visiting and accessing its reaches. Some of the ecological values in the Yarra River system include threatened fish species such as Australian Grayling, Macquarie Perch and Murray Cod; threatened frog species such as the Growling Grass Frog; and a wide range of vegetation species and communities that are now highly fragmented across the Yarra catchment and endangered as a consequence. Other species of value include the iconic platypus, as well as fish dependent on the estuary for food resources and/or habitat, such as Snapper and Sand Flathead, both of which have high recreational value for many fishers.

The health of these values is strongly linked to the Yarra River's flow regime, including the range of low flows, high flows and floods experienced by the river. However, changes to the natural flow regime as a result of extraction for potable water supply (via Upper Yarra and Maroondah Reservoirs, and pumps on the Yarra River at Yering Gorge), irrigation in the Yarra Valley, and increased stormwater inputs in urban areas, has significantly impacted on the health of values dependant on the Yarra's flow regime for survival. The condition of many of these values is considered poor to very poor, with concerning downwards trends for some such as the platypus. The river itself is also classified as flow stressed, meaning it does not receive enough flows, and that the flows it does receive have a significantly altered flow regime from natural, making it difficult to sustain its ecological health.

Although the river has largely retained its natural seasonality of flows, water harvesting, storage and diversions have altered the river's streamflow such that when compared to natural, much less water now flows down to Port Phillip Bay, and the frequency and volume of events such as floods is significantly reduced. For example, water harvesting has reduced the mean annual flow in the Yarra River at Chandler Highway (the most downstream freshwater gauging point) by over 50%, decreasing flow from 2,505 ML/day to 1,408 ML/day (SKM 2012a). In very dry years, this impact is even more noticeable. At the end of the Millennium Drought, only 33% of the total inflows to the Yarra basin actually flowed out into Port Phillip Bay (DSE 2011).

In recognition of the importance of delivering a flow regime that protects and enhances the river's important values, an environmental flows study was undertaken in 2005 (SKM 2005a) and a large volume of water (17 GL) was reserved for environmental purposes. The *Yarra River Environmental Entitlement 2006* is the instrument through which this water was reserved. It is protected from consumptive use and is intended specifically for addressing water-dependent environmental needs along the river.

The program to manage the delivery of environmental water from the Yarra Environmental Entitlement is under the joint responsibility of Melbourne Water in its role as a caretaker of river health and day-to-day manager of flow releases in the Yarra River system, and the Victorian Environmental Water Holder through its role as the independent statutory body responsible for making decisions on the most efficient and effective use of Victoria's environmental water entitlements. Both agencies have the ability to collaboratively address a range of waterway health needs along the Yarra River by actively providing and then managing environmental flows.

This EWMP plays an important role in maintaining and enhancing the values of the Yarra River by describing how the Environmental Entitlement will be effectively managed, to help address flow stress issues and ensure that the health and functioning of water-dependent flora and fauna reliant on the Yarra River is maintained or improved.

What is the scope of the area covered by the Yarra River EWMP?

The Yarra River environmental water management program is primarily defined by the extent of the system that can be actively watered via releases from the *Yarra River Environmental Entitlement 2006*, which includes:

- The main freshwater reaches of the Yarra River from the Upper Yarra Reservoir downstream to Dights Falls
- The Watts River, from Maroondah Reservoir to its confluence with the Yarra River
- The Yarra estuary, from Dights Falls and travelling 22 km downstream to the mouth of the river in Port Phillip Bay
- Floodplain billabongs still connected and receiving flows from the Yarra River or which can be watered from the Yarra River through works and measures, such as at Yering Backswamp (about 5 km southwest of Yarra Glen).

The volume of water in the Environmental Entitlement used to water these areas consists of:

- The first 17,000 ML of net inflow into the Yarra headworks system reservoirs in any watering year. This can be saved and carried over from year to year, building up a larger volume in storage
- Minimum environmental flows (also called passing flows), which are specified for 22 sites along the waterway
- A 55 ML per year allocation for use downstream of the Olinda Creek and Yarra River confluence (DEPI 2014c).

What are the values of the Yarra River and what is their condition?

The Yarra River provides habitat for a diverse set of values. The river extends for approximately 242 km, beginning in the upper forested headwaters, flowing through the mostly cleared agricultural Yarra Valley in its middle reaches, and finally flowing through highly urbanised suburbs and the central business district of Melbourne before discharging into Port Phillip Bay. A significant proportion of the river is fresh water, while the saline estuary reach extends from Dights Falls, located in the inner city suburb of Collingwood, for 22km downstream to Port Phillip Bay. Connected via the river's floodplain are a large number of billabongs, which are wetlands that rely on overbank (flood) flows from the Yarra River for their inundation.

The EWMP represents a synthesis of mostly pre-existing information, and is based on the Melbourne Water Healthy Waterways Strategy (Melbourne Water 2013a), stakeholder consultation, environmental flows studies and other scientific research. The seven values that provide the focus for this EWMP are:

- Fish
- Frogs

- Platypus
- Macroinvertebrates
- Vegetation
- Birds
- Amenity.

These values closely align with the Melbourne community's expectations and aspirations for waterways, and have been selected because of their importance to the community, the availability of data to assess their condition and their ability to appropriately represent the range of values found in Melbourne's waterways (Melbourne Water 2013a). Extensive community consultation was undertaken during the development of the Healthy Waterways Strategy to determine these values, and they were re-confirmed through the consultation process for the development of this EWMP.

Water-dependent cultural values are an important emerging issue for the Yarra River, and the Victorian Environmental Water Holder (VEWH) and Melbourne Water have committed to improve the indigenous collaborative management of waterways within the Melbourne region, a policy that is notably also being applied more broadly across Victoria through State Government initiatives. Water-dependent cultural values include tangible elements such as particular animals or plants, but also include less tangible elements such as the spirituality of a place, or the history of use and occupation of particular locations along the river. This knowledge has recently begun being explored by Melbourne Water and the VEWH with the Wurundjeri people, the Traditional Custodians of the Yarra River. As values are documented through this separate process and management objectives and watering needs are defined and documented, the knowledge will be incorporated into future revisions of the EWMP.

Flow requirements for the Yarra River's values

Streamflow in many Australian rivers is naturally highly variable, and this variation is apparent over multiple timescales, including daily and weekly, monthly and seasonally, and yearly and inter-decadal. Flow variability is made up of a range of different flow components, each of which provides water to the structural areas of a waterway, for example riffles, pools, benches or the floodplain, which makes these areas suitable habitat for a range of organisms. When they are determining a flow regime, scientists are seeking to understand the implications, benefits or otherwise, for habitat for a range of biota.

The first environmental flows study for the Yarra River defined the preferred minimum flow regime for the Yarra River, and was then reviewed in 2012 to incorporate new knowledge. A range of billabong studies have also identified general inundation requirements for these wetlands, documenting the need for periods of wet and periods of dry.

The flows studies for the Yarra River have considered the following flow components: Winter/Spring and Summer/Autumn low flows, freshes and high flows; and Winter/Spring bankfull flows and overbank flows, where:

- Low flows generally provide a continuous flow through the channel. This may either maintain the flow above a 'cease to flow', or provide habitat as a change from 'high flows'
- Freshes are small or short duration peak flow events. These flows exceed the base flow and last for at least several days. Freshes are a key contributor to the variability of flow regimes, providing short pulses in flow, increasing access to habitat and freshening water quality.
- High flows are persistent increases in the seasonal base flows that remain within the channel. They do not fill the channel to 'bankfull'. High flows help water vegetation on the banks, trigger fish spawning and flush accumulated sediment from riffles, hence improving habitat quality for macroinvertebrates.
- Bankfull flows are flows of sufficient size to reach the top of the river bank with little flow spilling onto the floodplain. Bankfull flows are important for maintaining natural rates of erosion and sedimentation, which collectively help maintain the physical structure (geomorphology) of the river channel.
- Overbank flows are flows that result in inundation of adjacent floodplain habitats. These flows are critical for a range of ecological factors, including floodplain productivity and wetland inundation (Figure 2).

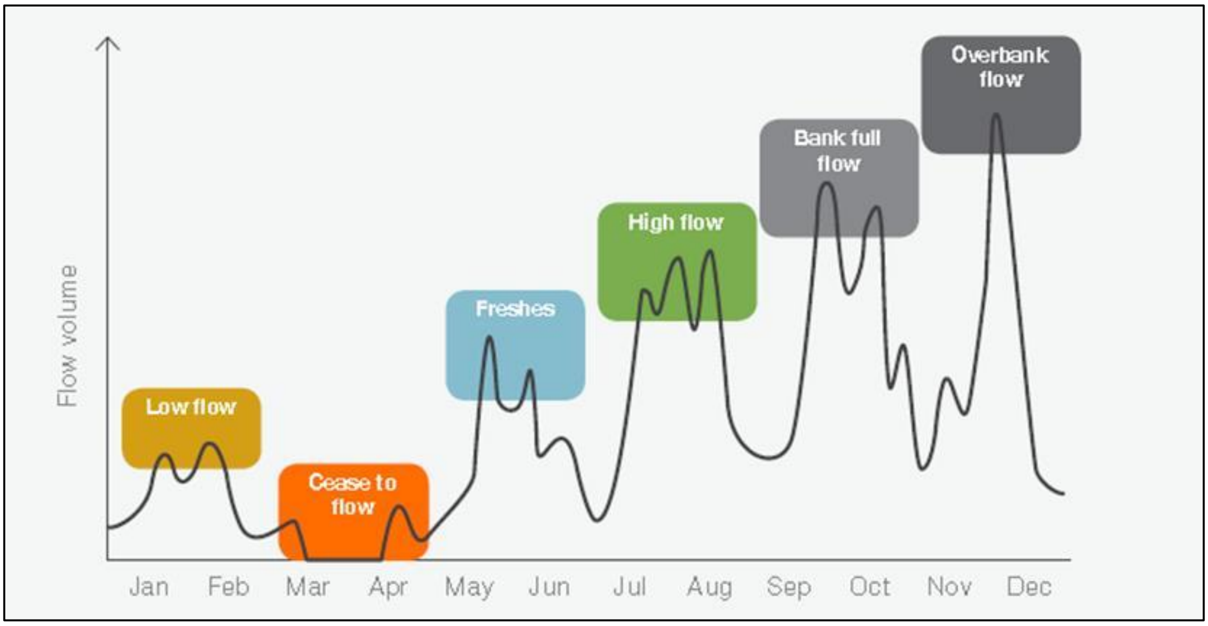


Figure 2 : Typical natural flow pattern of a Victorian river before construction of dams, weirs and channels (Source: (VEWH 2016)

The EWMP describes the flow regime and flow components that are critical for the Yarra River's values. There are a number of objectives for each flow-related event, for example providing high flows to trigger fish spawning and to provide physical habitat for riparian vegetation. In another example, low flows help to maintain critical wetted habitat for macroinvertebrates, help to maintain connectivity for resident fish, and also help to maintain habitat for submerged vegetation. Overbank flows, when they occur, are very important for maintaining wetland habitats for vegetation, birds and frogs.

Ecological condition

The condition of the water-dependent values in the Yarra River is mixed; sometimes poor, sometimes moderate, sometimes good, and reflects widespread changes to the availability, extent and quality of their preferred habitats and food resources. The upper sections of the Yarra River are in forested and generally less developed parts of the catchment, and the condition of values such as fish, macroinvertebrates and vegetation reflects the better quality and extent of the habitat available here. As the river flows through more urbanised and agricultural land in the middle reaches of the river, the condition ratings for these species and communities drops. Significant reductions in population abundance and distribution are in evidence for species such as the nationally endangered fish the Australian Grayling, and the Growling Grass Frog, and many vegetation communities are severely fragmented, to the point of being endangered in the catchment. Billabongs have reduced in number and size, and many have been drained or filled in since European occupation. The lower reaches of the Yarra River, in the highly urbanised suburbs of Melbourne, exhibit a poor condition for values such as vegetation, birds, platypus and macroinvertebrates. Although not yet considered endangered, the platypus has suffered a very large drop in its abundance and extent throughout the Yarra River catchment in the past decade, and scientists are very concerned about its vulnerability to natural events such as long-term droughts, bushfire and floods.

Hydrological condition

Flow variability is important for both ecological and geomorphological processes and many plants and animals are wholly or partly dependent on aspects of river flow to maintain critical life cycle requirements. Hence, the condition of key values in the Yarra River is closely linked to the river's hydrology. Releases of water from the Yarra Environmental Entitlement aim to partially offset the impacts of river regulation and contribute to meeting environmental flows recommendations, which are the minimum flows required to maintain water-dependant values. However, it is important to note that the volume of the current Environmental Entitlement is not sufficient to fully restore the rivers flow regime to natural conditions. Moreover, it is not even sufficient to enable all environmental flows recommendations to be achieved in all years. Although with careful planning and management, informed by scientific evidence and monitoring, and documented in the Seasonal Watering Plans prepared by Melbourne Water, the Environmental Entitlement can be effectively used to maximise the likelihood of achieving positive environmental outcomes for the river.

Further information

The Technical Synthesis section of the EWMP provides the more detailed discussion of best available knowledge for each value, and refers readers on to the contributing information sources such as the environmental flows studies where greater detail is available. Section 5 of the Technical Synthesis explores the hydrological changes that have happened to the Yarra River since river regulation began.

What threats are faced by the Yarra River's values?

Although river regulation and altered hydrology are a major threat to the Yarra River's values, there are many other threats that contribute to the general degradation in condition of the river, its catchment and the values contain therein. These include:

- Barriers to fish movement, reducing upstream and downstream connectivity, as well as to the floodplain and billabongs
- Foxes, dogs, cats and introduced fish preying on native animal species
- Urbanisation in the mid and lower reaches, as well as on major tributaries such as Merri Creek, Plenty River and Darebin Creek,, reducing habitat availability and quality and further altering the flow regime
- Introduced plants, which outcompete native vegetation for habitat space and also reduce habitat quality
- Desnagging of the river channel, which removes important habitat for fish and macroinvertebrates
- The degradation or loss of riparian vegetation
- Domestic stock access and grazing, which impacts on habitat availability and reduces water quality.

Further information

The Executive Summary Fact Sheets provide an overview summary of the main threats to values in the Yarra River. The Technical Synthesis provides a more detailed discussion of these threats in Section 4.

What are the flow-related management objectives for the Yarra River?

The flow-related management objectives for the Yarra River have been developed so that they take into account the current condition and trajectory of values, their threats, and their flow driven life-cycle requirements. Management objectives determined by Melbourne Water's Healthy Waterways Strategy provide the primary guidance for the management objectives of the EWMP, but a range of other strategic documents, such as the Victorian Waterways Management Strategy, are also highly influential. The Yarra River environmental flows studies have provided the more specific ecological objectives.

The management objectives within the Healthy Waterways Strategy were endorsed through extensive community consultation, and the EWMP acknowledges the important feedback provided by the community in developing these objectives. The management objectives for the EWMP aim to strengthen these objectives through placing them in the context of environmental flow requirements.

The objectives for the Yarra River environmental watering program focus on the provision of a range of flow components that help to maintain a more natural pattern of flow variability - low flows, freshes, high flows, bankfull and overbank flows - to create and/or support ecological functions that are then likely to lead to achieving specific ecological objectives. The logic that supports the environmental watering actions is based on an assumption that particular flow components provide an ecological function (such as inundating billabongs), which in turn help to support ecological objectives (such as the provision of appropriate habitat for riparian vegetation), which in turn support ecological outcomes (such as increasing the extent of riparian vegetation across the catchment) (Figure 3).

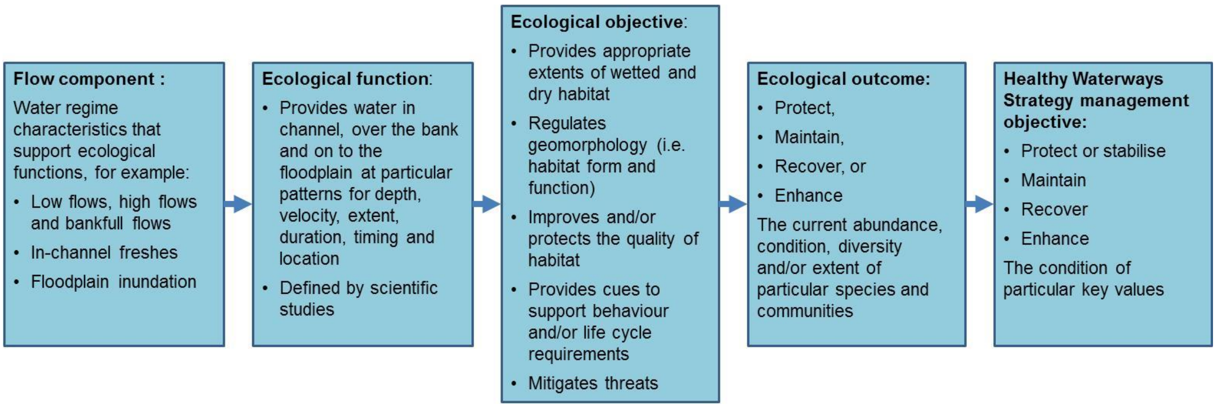


Figure 3 : Logic and assumptions that support the Yarra River environmental watering actions

The objectives also reflect a shared Vision for the Yarra River, which was developed in close consultation with key stakeholders during the production of the EWMP.

The Vision Statement is as follows:

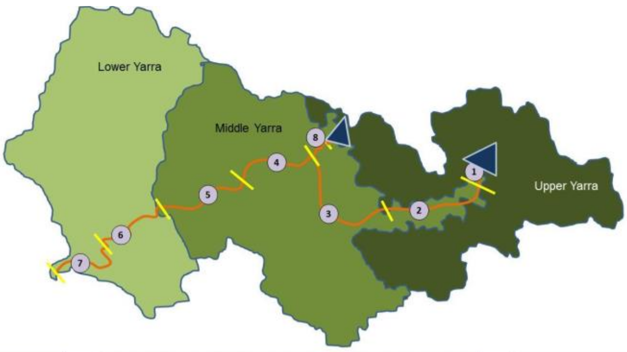
Vision Statement

The Yarra River is a unique, iconic and valuable waterway that is much loved by our community. We will work to protect and where possible restore and enhance its ecological health and functioning, so that it continues to contain a rich diversity of self-sustaining indigenous plants and animals. Using a catchment-wide approach, our work will apply from the river's headwaters to the Bay, and will target the water-dependent values our community sees as important. The environmental flows we provide to these values will be determined using robust and evidence-based science and strong community input, so that the Yarra River can continue to be enjoyed by future generations.

The watering actions as described in this EWMP are intended to support the broader Healthy Waterways Strategy management objectives (Figure 4), while the more specific ecological objectives for environmental water management focus on:

- Maintaining channel geomorphology and rehabilitating instream habitat
- Rehabilitating the macroinvertebrate community
- Rehabilitating populations of non-migratory and migratory native fish
- Maintaining in-channel and riparian vegetation extent, structure and composition
- Engaging low level floodplains in the upper catchment
- Maintaining water quality (to benefit aquatic species)
- Minimising the risk of stratification and low dissolved oxygen in pools on aquatic biota
- Rehabilitating lateral connectivity with billabongs

These objectives have been used to determine the appropriate flow recommendations for each reach of the Yarra system by linking the target ecological communities with their flow requirements.



Key to condition:
VL = Very Low
L = Low
M = Moderate
H = High
VH = Very High

Lower Yarra Management Unit

Relevant Reaches - 6 & 7

Value	Overall HWS Objective	Yarra Priority?	Condition Rating Current	Condition Rating Expected in 20 years
	Maintain the species richness, nativeness and abundance of fish populations	★	M	H
	Stabilise the relative abundance of the Platypus population		VL	VL
	Maintain diversity and improve the overall abundance and distribution of expected species of frog populations		H	H
	Maintain the number of macroinvertebrate families present		H	VH
	Maintain or improve the species richness and abundance of streamside and wetland bird populations		L	L
	Maintain and improve vegetation condition Maintain vegetation at high quality	★	VL	M
	Maintain and/or improve amenity	★	M	H

Middle Yarra Management Unit

Relevant Reaches - 2, 3, 4, 5 & 8

Value	Overall HWS Objective	Yarra Priority?	Condition Rating Current	Condition Rating Expected in 20 years
	Maintain the species richness, nativeness and abundance of fish populations	★	M	H
	Stabilise the relative abundance of the Platypus population		VL	VL
	Maintain diversity and improve the overall abundance and distribution of expected species of frog populations	★	H	H
	Maintain the number of macroinvertebrate families present	★	L	M
	Maintain or improve the species richness and abundance of streamside and wetland bird populations	★	L	L
	Maintain and improve vegetation condition Maintain vegetation at high quality	★	M	H
	Maintain and/or improve amenity	★	L/M	H

Upper Yarra Management Unit

Relevant Reaches - 1

Value	Overall HWS Objective	Yarra Priority?	Condition Rating Current	Condition Rating Expected in 20 years
	Maintain the species richness, nativeness and abundance of fish populations		M	H
	Stabilise the relative abundance of the Platypus population		VL	M
	Maintain diversity and improve the overall abundance and distribution of expected species of frog populations	★	M	H
	Maintain the number of macroinvertebrate families present	★	H	VH
	Maintain or improve the species richness and abundance of streamside and wetland bird populations		VH	VH
	Maintain and improve vegetation condition Maintain vegetation at high quality	★	H	VH
	Maintain and/or improve amenity		H	H

Figure 4 : Management objectives for the Yarra River from the Healthy Waterways Strategy

Further information

The management and ecological objectives for each key value are summarised in the Executive Summary Fact Sheets, and discussed in greater detail in the Technical Synthesis section of the EWMP (Section 6.1).

What are the constraints and risks to achieving management objectives?

It is important to remember that the 17,000 ML Environmental Entitlement is based on environmental flows studies that recommend the ***minimum*** volumes required to achieve ecological objectives for the system, and flows greater than these are preferable if they occur naturally in response to climatic conditions. Furthermore, the Entitlement is constrained in its ability to address all of the flow-dependent ecological objectives for the Yarra River, because the volumes that are needed are greater than what is available under the Entitlement and because the volumes able to be released at any one time are also limited by a range of delivery, ecological and infrastructure constraints.

Constraints

Delivery constraints

Delivery constraints can create a situation where there is enough water available in the Environmental entitlement to achieve a particular event, but it is not actually possible to get all of this water to where it is needed in the waterway. The impacts of delivery constraints are greatest in dry years, where unregulated flows in the river are lower, and larger volumes of water need to be released to achieve environmental flow targets. This impact can be made worse if there is insufficient water available in some of the smaller storages during dry years. The ability to overcome these constrains is an important issue to address in the future.

The Melbourne Water supply system needs to deliver water to a diverse range of entitlement holders, including consumptive, irrigation and environmental, and to provide public safety services such as firefighting reserves. This can result in conflicting pressures being placed on the system at the same time, resulting in delivery constraints that will impact different entitlement holders at different times.

Delivery constraints are particularly noticeable for the estuary. Environmental flow requirements for the estuary are currently not well understood. The initial environmental flow study for the Yarra (SKM 2005a) studied the estuary but did not make specific flow recommendations. The highly modified nature of the estuary and the volumes of water required to achieve a specific objective are likely to be very large in comparison to the requirements of the freshwater sections of the river. For this reason, the estuary has not yet been specifically targeted by the Yarra Environmental Entitlement. Delivery of specific flow events to the Yarra estuary will require further study to better understand the water requirements of the estuary. The outcomes of this study would then need to be prioritised for delivery each year as part of the Seasonal Watering Plan process.

Melbourne Water is also constrained in its ability to water billabongs along the river using water from the Environmental Entitlement. Delivering bankfull or overbank flow events that allow water to run onto the floodplain and fill wetlands poses a potential risk of flooding private land in some parts of the catchment, and therefore these events are not actively delivered along the Yarra River. Melbourne Water is pursuing other methods to water these billabongs, such as installing pumps and other works and measures. Although efforts to water billabongs are needed, it is also critical that bankfull and overbank flows are not prevented from naturally occurring as they remain important components of the overall flow regime for a range of reasons, not just for inundating billabongs.

Ecological constraints

Melbourne Water needs to be able to make releases from storages such as Upper Yarra Reservoir and Maroondah Reservoir to meet environmental flow objectives in the downstream reaches. The main flow components that these releases target are freshes and high flows. Bankfull and overbank flows have been recommended through the environmental flows studies, but Melbourne Water currently does not deliver those flows because of the delivery constraints and risks previously discussed.

The maximum flow recommendations for the Yarra River immediately below the Upper Yarra Reservoir (Reach 1) and the Watts River below Maroondah Reservoir (Reach 7) have created an ecological conflict for Melbourne Water. This is because these flows need to be lower during fish breeding season to prevent damage to and/or sweeping away of eggs and to protect habitat availability, but must at the same time be large enough to meet high priority flow objectives in reaches further downstream. Melbourne Water has acknowledged and assessed these conflicts and is implementing a program of flow release testing and monitoring to determine the maximum amount of flows that can be released while minimising ecological risk where potential conflicts occur.

Infrastructure constraints and flexibility

The Melbourne Water supply system is a complex network of storages, aqueducts, pipelines and pumps. The types of infrastructure represent both constraints to and flexibility in the delivery of environmental water. Maroondah Reservoir, a key delivery point for environmental water that can only be filled by natural inflows, and O'Shannassy Reservoir, have low volumes, which means there may be times when they may not be available to assist with the delivery of environmental flow events. There may also be capacity constraints on the amount of water that can be released from particular storages. Furthermore, environmental flows released from upstream storages may experience long travel times and losses during transfer to downstream reaches, which may reduce the effectiveness of the flow delivery. Conversely, the water supply network provides a level of flexibility through the ability to deliver some environmental water to targeted locations, for example via releases from the Maroondah Aqueduct, or by manipulating pumping infrastructure at Yering Gorge to bypass the needed to deliver water from upstream storages.

Understanding infrastructure constraints and opportunities is an important facet in being able to deliver environmental water in the most efficient and effective way possible.

Risks

Melbourne Water and the VEWH manage the Yarra River's environmental water with diligence and caution, and must continually appraise any risks, being careful to avoid any possible negative impacts while delivering water. This means that the environmental flow managers work with Storage Operators in real time to vary delivery to avoid third party impacts while still striving for the best possible environmental outcomes. Risks have been assessed for the Yarra River environmental watering program using a risk management framework developed by the VEWH.

Risks can be categorised as either related to achieving ecological objectives, or risks related to the delivery of the Entitlement water. The risks include:

- Further consumptive extraction of water, causing an alteration of natural flow regimes
- Land use change – Such as urban development, farm dams, and the further expansion of irrigation areas
- Foxes, dogs and cats preying on native animals
- Sediment inputs to the estuary
- Stock access and grazing pressures.

Risks are also associated with the release of water through the environmental watering program, including:

- Poorly timed high flows drowning juvenile Platypus
- Release volumes being insufficient in meeting required flows at target points
- Current recommendations on environmental flow are inaccurate, or there is difficulty in demonstrating outcomes are being achieved through environmental watering, leading to a loss of public/political support
- Environmental releases causing unintended inundation of private land, resulting in impacts on landowner activities and assets
- Public misperceptions of the purpose of releases, for example community concern over environmental releases under dry seasonal conditions may lead to a loss of support for environmental watering activities.

Further information

Constraints are discussed in greater detail in the Technical Synthesis section of the EWMP (Section 9).

Risks are summarised in the Technical Synthesis section of the EWMP (Section 7), and mitigation options are discussed in the Appendices.

What are the threats and emerging issues faced by the river?

A range of emerging issues and threats will also influence the condition of values in the Yarra River. These include urbanisation in the upper catchment, inconsistent planning controls for the Yarra River Corridor, and climate change.

Urbanisation and Yarra River corridor development

Melbourne's continuing population growth means that large sections of the Yarra catchment, particularly in tributary streams like the Plenty River and Darebin and Merri Creeks, will be urbanised over the coming years. Urban development presents a threat to waterways such as the Yarra River, particularly because of changes to flow regimes and water quality.

In recent years, an emerging issue for the Yarra River has also been the need to protect it from the impacts of development, particularly encroachments into its open space and poor compliance with building setback limits and height limits, and the overshadowing of lengths of the river. The impacts of development on riparian vegetation are also of concern as more of these areas are cleared.

Climate change

The implications of climate change for the environmental health of the Yarra River are particularly profound, and it is likely that there will not be enough water under the Environmental Entitlement to maintain the current condition of its values, let alone improve them. Full compliance with flow recommendations does not guarantee that the Yarra River will cease being flow stressed, and it is likely that as threats associated with climate change are realised, the river's flow stress will get worse.

Reductions in water availability, increasing temperatures, and changes in rainfall patterns will all significantly affect the pattern and volume of flows experienced by the river, further decreasing the quality of the water it receives and the quality of the habitat that it is able to provide. This in turn will significantly change the structure and ecosystem functioning of the waterway, which is likely to cause widespread negative impacts to the river's biodiversity.

For the development of the EWMP, an initial broad scale analysis of the possible implications of climate change on a range of key values within the Yarra River was undertaken. The results of this analysis are highly dependent on a range of assumptions made about possible changes to streamflow in the catchment, and Melbourne Water is currently conducting a number of studies using differing methodologies and tools to try to understand in greater detail the likely impact of climate change on Yarra River streamflows.

The analysis shows that climate change impacts are likely to result in a further decline in abundance of flow sensitive taxa, including fish, macroinvertebrates, platypus and frogs. Some of these taxa could eventually become locally extinct, and the impacts of climate change are particularly concerning for platypus, whose current condition is already very low in the catchment as well as more broadly.

A range of priority flow components will need to be delivered with a high degree of compliance to help maintain the current condition of Yarra River values. The analysis predicts that in the short term (i.e. the next 10 to 15 years), the condition of key values in the Yarra River is likely to remain similar to current, but in the longer term, especially in dry climate years, condition is expected to deteriorate significantly. In order to meet the current management and environmental flow objectives under a climate change outlook (i.e. maintain the current level of achievement with environmental flow recommendations) an increase in the volume of the Environmental Entitlement will be required.

The analysis shows that under current climate conditions, the existing Environmental Entitlement is sufficient to deliver all fresh and high flow recommendations in about 40% of years. There is very little difference in the shortfall volumes needed to deliver fresh and high flow recommendations under short term and medium level climate scenarios, but under a long term worst case scenario, there is a significant increase in the volume of water required to deliver fresh and high flow recommendations. If it is assumed that the Environmental Entitlement is not required to deliver low flow recommendations (i.e. passing flow requirements), then under the worst case scenario, an increase in the Environmental Entitlement from 17 GL to 25-30 GL/annum is required in order to achieve the same level of compliance with flow recommendations as is currently achievable. Other studies recently completed by Melbourne Water, using different assumptions and methodologies, have estimated that the Yarra Environmental Entitlement may need to be expanded from 17 GL to 40 GL over the same time period (GHD 2016). These findings indicate the importance of continuing to refine the methodologies, tools and assumptions used to estimate climate change impacts.

Climate change impacts that result in a reduction in the frequency of fresh flows and an increase in the duration of low flows and cease to flows will over time result in the steady decline in abundance of flow sensitive taxa, including fish, macroinvertebrates, platypus and frogs. Some of these taxa could eventually become locally extinct. For species that are endangered or vulnerable on a regional and/or national basis, this may have serious implications for our ability to protect them from total extinction.

Further information

The Executive Summary Fact Sheets provide a summary of emerging issues for key values in the Yarra River. The Technical Synthesis provides the more detailed analysis of these issues in Section 4.1 (Urban Development) and Section 8 (Climate Change).

How do we demonstrate outcomes for the environmental watering program?

A wide range of short-term, long-term and event-related monitoring actions are undertaken by Melbourne Water to help understand and demonstrate the outcomes of the environmental watering program. These include ongoing water quality monitoring and compliance monitoring, and more targeted monitoring programs such as tracking the response of Australian Grayling to specific flow releases.

Melbourne Water will work with key stakeholders to develop and implement an effective evaluation and review process to ensure that monitoring data and other knowledge is able to contribute towards the adaptive management of the Yarra River environmental watering program.

What are our knowledge gaps?

A considerable amount of knowledge has assisted in the determination of the environmental flow regime for the Yarra River. However, because the science of environmental flows is relatively new, this knowledge base is incomplete. The 2005 and 2012 environmental flows studies recommended minimum flow requirements for the Yarra and while these studies have advanced our scientific knowledge of the Yarra, there remain large gaps in our understanding of the river's species and their flow requirements, as well as the associated ecological processes. These knowledge gaps include:

- The flow requirements of values that are within and/or dependent on the estuary
- The likely impacts of climate change on streamflows within the Yarra catchment, and the likely impacts on the values of the Yarra River as a consequence
- The impact of climate change on Environmental Entitlement shortfalls, and the ability of Melbourne Water and VEWH to comply with the flow recommendations for Yarra River values
- The contribution of Yarra River flows to the environmental health and functioning of Port Phillip Bay
- The likely impacts of urbanisation on the flow regime and ecological health of the Yarra River and its receiving waters, particularly from development in the headwaters of tributary streams
- The flow requirements of platypus, birds and frogs, including their likely responses to drought and climate change
- The flow requirements of water-dependent indigenous cultural values
- Drought risk, and its implications for environmental water planning and management
- Billabong watering, including defining what the management objectives should be for these wetlands, their flow dependent values, their hydrology and hydraulics, and their ideal inundation regimes.

Further information

The Technical Synthesis provides a high level overview of monitoring and research actions in Section 10.2 and a summary of knowledge gaps in Section 0.

Consultation

An internal Yarra River Communications and Engagement Strategy has been developed to support the implementation of the EWMP and the ongoing management of the Yarra River Environmental Entitlement by Melbourne Water. This Strategy will be treated as a 'live' document by Melbourne Water, updated when and as needed to ensure that two-way communications and engagement remains appropriate, tailored and effective. As emerging issues become known, the Strategy will also be reviewed to ensure that key stakeholders with influence on and/or interest in these issues are appropriately engaged with

Further information

The Technical Synthesis provides an overview of the consultation and engagement actions undertaken to develop the EWMP in Section 11.

The Yarra River provides vital habitat for a wide range of values, and it is these values that people enjoy for both their simple existence as well as the ecosystem services they provide. The EWMP defines the medium term strategy for the management of these values by the provision of environmental flows. Complementary actions are important to support environmental watering actions, and emerging issues such as climate change will make it more challenging to achieve environmental outcomes for the system.

The community is increasingly recognising and appreciating the Yarra River as an important natural resource in a highly urbanised environment. The challenges and risks of climate change and continuing urbanisation will make the waterway even more important over time, as it provides refuge for species under threat and a highly valued green oasis for the Melbourne community.

Securing the ecological health of flow-dependent values in the Yarra River

The delivery of appropriate environmental flows is just one aspect of securing the health of flow-dependent values in the Yarra River. In addition to delivering environmental flows, a range of complementary actions are needed to assist in achieving the objectives of the EWMP. In some cases, failure to deliver complementary actions will limit the benefits of delivering environmental flows. Complementary actions include riparian vegetation rehabilitation, addressing catchment sources of sediment and pollution, and undertaking pest plant and animal eradication/control programs.

Melbourne Water is also working with key stakeholders to address the emerging issue of urbanisation. 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. Melbourne Water is working in collaboration with land developers and State and Local government agencies to understand and reduce the risks of increasing urban development within the Yarra catchment. For example, Melbourne Water is working with key agencies in the Northern Growth Corridor to develop stormwater capture and treatment options, which will to help reduce the impact of flow regime alterations and sedimentation issues within the catchment.

Melbourne Water is also working with the Department of Environment, Land, Water and Planning (DELWP) to help implement reformed planning controls for the Yarra River. This includes a revised State Planning Policy, which relates to the entire Yarra River corridor, and updated overlay controls within six metropolitan municipalities to manage development along the river between Punt Road, Richmond and Warrandyte. The overlays will be comprised primarily of a Yarra River focused Design and Development Overlay (DDO) to manage built form outcomes, and the use of a 'whole of river' corridor Environmental Significance Overlay (ESO) to manage vegetation and environmental outcomes.

Melbourne Water is directing significant effort towards better managing the risks that climate change poses to the Yarra River and its catchment. Programs to understand and improve the resilience of water-dependent environmental values are being implemented, with the aim of improving the ability of Melbourne Water to protect the Yarra River's values, particularly during times of drought. Melbourne Water's seasonal watering plans for the Yarra River will take in to consideration monitoring data and the relative vulnerabilities and sensitivities of high value species to climate change stressors, and will adapt flow releases accordingly.

A key threat is that climate change will significantly reduce the flows available for the river. Adaptive management, sourcing alternative supplies of water, and monitoring of current water availability will assist Melbourne Water in further understanding water availability and sustainable diversion limits for the Yarra catchment. While a cap has been placed on extractions in the Yarra catchment, Melbourne Water will actively seek opportunities to participate in reviews of the sustainability of this cap, and to improve its effectiveness under the impacts of climate change in particular. Melbourne Water is also investigating options to improve environmental flows for the Yarra River through Integrated Water Cycle Management Plans, and is working to identify alternative sources of water that may reduce our reliance on extractions from the Yarra River for consumptive purposes. Water Sensitive Urban Design programs will also explore options for harvesting stormwater to augment environmental flows.

While a great deal has been learned about the relationship between flows and the condition of water-dependent values within the Yarra River, there remains many knowledge gaps and uncertainties. It will take a concerted and collaborative effort to protect these values, particularly because we know already that there is not enough water to provide for all of the flow components that are important to maintain their ecological functioning and health. Melbourne Water will continue to work with key stakeholders to determine how the 17GL Environmental Entitlement can best be delivered to the Yarra River. In light of the current poor condition and flow stress of the river, it is also an imperative for Melbourne Water to identify and implement options to address these issues, to protect and restore the values of the river that people love and appreciate.

Next Steps

This EWMP provides the overarching strategy for the management of environmental water and protection of water-dependent values in the Yarra for the next ten years. It provides the basis of annual planning for the management of the entitlement, most notably providing the direction for future Seasonal Watering Proposals and the development of Melbourne Water's environmental water annual work program. Figure 5 shows the contribution of EWMP information towards the annual seasonal planning processes for both Melbourne Water and VEWH. The numbers in brackets associated with each of the EWMP topics correspond to key seasonal watering proposal considerations.

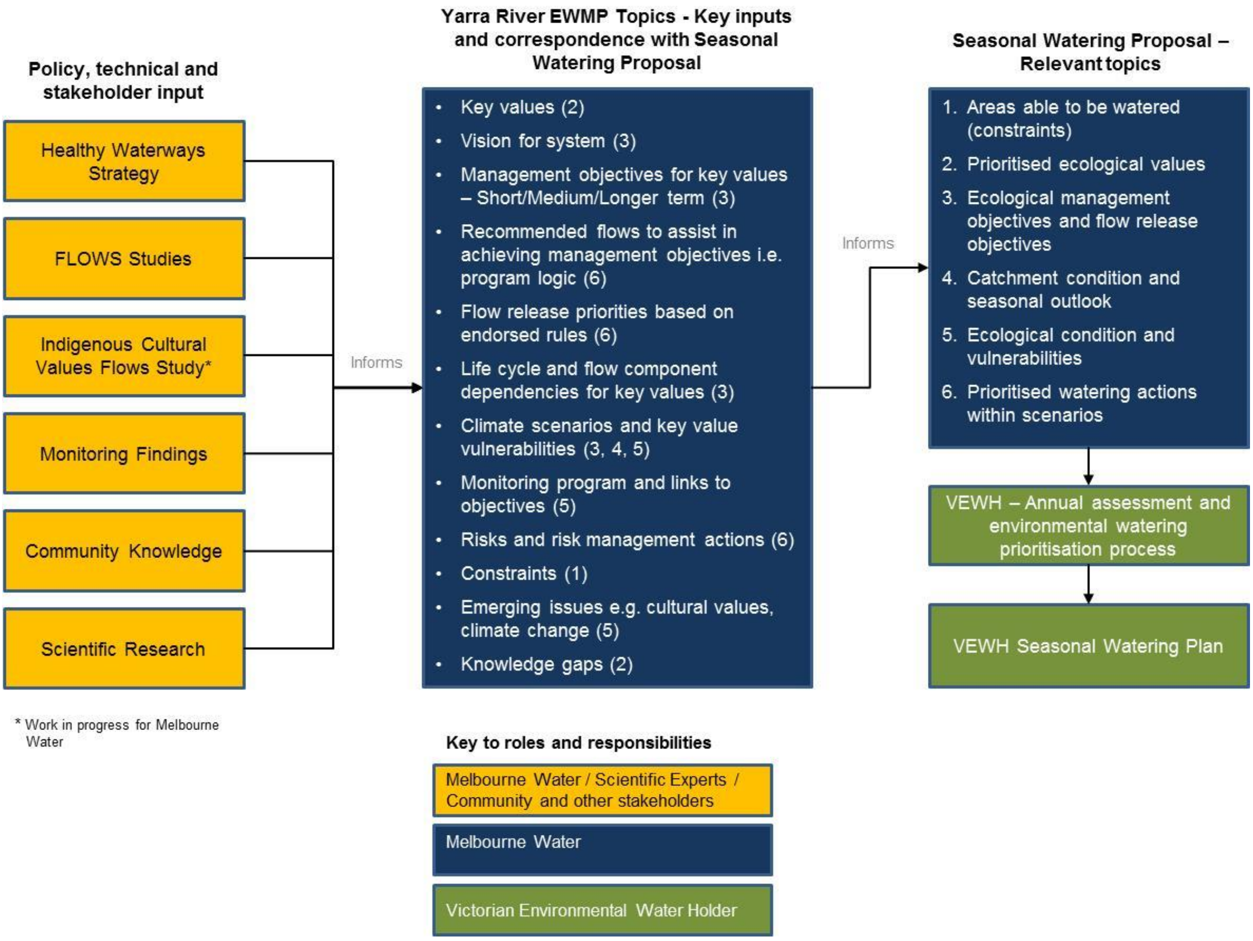


Figure 5 : The contribution of EWMP information to Seasonal Watering Proposal content

The EWMP will also be used to inform the review of technical information underpinning the Yarra Environmental Entitlement, including the upcoming review of the environmental flows study.

The EWMP will also provide the basis of future inputs to Melbourne Water strategic documents, including the review of the current Healthy Waterways Strategy, which is due for completion in 2017/18. In addition to internal strategies, the EWMP will allow Melbourne Water to advocate for improved outcomes for water dependent values in the Yarra through State Government policy reviews and strategies, such as the Yarra River Protection Ministerial Advisory Committee review of opportunities to improve the oversight and management of the Yarra River, and possible future reviews of the Central Region Sustainable Water Strategy.

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PART TWO – TECHNICAL SYNTHESIS

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CONTEXT AND CATCHMENT

1. Introduction

The Yarra River is one of Victoria's most loved and iconic waterways. From the first members of the Kulin Nation to feed their children on its banks, to the diverse range of cultures and communities who now live, work and play in the Yarra catchment, people have highly valued and depended on the Yarra River for thousands of years.

The Wurundjeri people, members of the Kulin Nation and the Traditional Custodians of the Yarra River, have long known that the health of the Yarra and the Country that it waters are central to their cultural identity, their health, and their aspirations. The Yarra River is connected to their totem species and important cultural places, and its water is intrinsically part of their creation stories, the resources that they use and life itself, carrying with it a very long tradition of cultural practice and history. People depend on the Yarra River for their spiritual, cultural, emotional, physical and economic sustenance, and the tangible and intangible impacts on community wellbeing when its environmental health is compromised are only just beginning to be explored by scientists.

Sometimes affectionately known as 'the river that flows upside down' because of its muddy brown colour[1], the Yarra River is very important for the Melbourne community for the significant environmental values present within its system, the use of its water for drinking water supply and industry needs, and the wide range of benefits that people derive from visiting and accessing its reaches. These values all contribute strongly towards making Melbourne the world's most liveable city (EIU 2016). This Environmental Water Management Plan (EWMP) plays an important role in maintaining Melbourne's liveability rating by supporting management objectives to maintain and improve the health and functioning of water-dependent flora and fauna within Melbourne's waterways.

Under natural conditions in Victoria, seasonal rains cause a cycle of high winter and spring river flows and low summer and autumn river flows, the pattern of which is often referred to as a flow regime. Industrial, agricultural and domestic users need a steady supply of water throughout the year, and the generally dry climate and variable streamflows have resulted in the need for a high degree of river regulation on the Yarra River to provide supply with appropriate security at different times of the year. Due to extraction and regulation, the Yarra River is considered flow stressed; its current flow regime is significantly altered from what would have been its natural flow regime, and too much water is now extracted from the system to sustain its ecological health, and many water-dependent values associated with the river are now in poor to very poor condition. The effects of regulating and extracting water from the Yarra River have also had a long-term ecological impact on its associated estuary, billabongs and floodplains. These ecological impacts are described in later sections of this EWMP.

To help address flow stress issues in priority river systems around the State, the Victorian Government implemented legislation to set aside an amount of water that is protected from consumptive use, called the Environmental Water Reserve (EWR). The EWR can include water provided through:

[1] The muddy brown colour is caused by turbidity in the Yarra River, caused by suspended solid loads. The lower section of the Yarra River has some of the highest turbidities of any waterway in Victoria (SKM 2012c).

- Statutory environmental water entitlements, such as a volume of water held in storage – these are the components of the EWR that can be actively managed. For the Yarra River, this is achieved through a management instrument called the *Yarra Environmental Entitlement 2006 (DEPI 2014b)*
- Water set aside for the environment as obligations on consumptive water entitlements held by urban and rural water corporations – these are usually called 'passing flows' that must be released from storages or provided at a particular point of a river
- Unregulated flows and spills from storages, usually created by heavy rainfall.

The active component of the EWR for the Yarra River, and the water for which this EWMP is focused on managing, is the Yarra Environmental Entitlement. The program to manage the delivery of the Environmental Entitlement is under the joint responsibility of the Victorian Environmental Water Holder as the independent statutory body responsible for making decisions on the use of Victoria's environmental water entitlements, and Melbourne Water in its role as a caretaker of river health and day-to-day manager of flow releases in the Yarra River system. Both agencies have the ability to collaboratively address a range of waterway health needs along the Yarra River by actively providing and managing the environmental flows. The Environmental Entitlement is important for the Yarra River because it is protected from consumptive use and is intended specifically for providing environmental benefits along the river.

The Environmental Entitlement for the Yarra River is used to protect and manage its water-dependent values, from the upper reaches in the forested catchments, to the middle reaches and billabongs and wetlands connected by its floodplains, and to the estuary with its connection and strong influence on the ecological health of Port Phillip Bay. The primary focus is on environmental values, but where there are opportunities to provide shared benefits, such as supporting indigenous cultural values and recreational opportunities, the watering program will also consider these.

1.1 What are Environmental Water Management Plans?

Environmental Water Management Plans (EWMPs) are evidence-based plans for waterways that describe their water-dependent environmental values, the risks and threats faced by these values, and how these values should be managed in terms of objectives and ecological outcomes. Importantly, EWMPs are developed for waterways that are considered flow stressed, where river regulation and the extraction of water for consumptive purposes has left too little water in these systems to sustain their ecological health.

Management actions focus on the provision of water to address the flow needs of the ecological values. EWMP's synthesise a large variety of evidence-based scientific reports, research and flows studies, community feedback, and monitoring data to present a range of flows provisions to address these objectives, specifying watering requirements for a five to ten year cycle (DEPI 2014a). Knowledge gaps, monitoring and evaluation processes, and stakeholder engagement are also described.

EWMPs are typically focused on waterways, floodplains and wetlands within a region that can be targeted for management through environmental water management interventions. Although only broadly defined within the State EWMP Guidelines (DEPI 2014a), the scope of an individual EWMP generally includes those reaches, wetlands and/or floodplains where environmental flows can be actively managed, while still remaining as a single Environmental Water Management Unit (EWMU). 'Actively managed' in this case means where a Manager is able to flexibly manage or modify the volume and/or flow patterns of water to a waterway without requiring a formal review and/or gazetting of a management instrument by State Government.

1.2 What is included in the scope of the Yarra River EWMP?

A range of waterway assets are included within the scope of the EWMP for the Yarra River; i.e. the reaches, wetlands and tributaries that can be actively provided with water from the Environmental Entitlement. These are:

- The main freshwater reaches of the Yarra River from the Upper Yarra Reservoir downstream to Dights Falls. These reaches have been the subject of an environmental flows study in 2005 (SKM 2005a) and a review of this first flows study in 2012 (SKM 2012d)

- The Watts River, from Maroondah Reservoir to its confluence with the Yarra River. This reach has also been the subject of environmental flows studies
- The Yarra estuary, from Dights Falls and travelling 22 km downstream to the mouth of the river in Port Phillip Bay
- Floodplain billabongs connected to the Yarra River.

Note that Melbourne Water is working with a range of stakeholders to prioritise a number of billabongs that will be watered using the Yarra River Environmental Entitlement or other suitable water sources. This work is ongoing and separate to the EWMP. For the purposes of the EWMP and given the potentially large number of billabongs that may be prioritised though this process, Yering Backswamp will be used as a case study where relevant to highlight billabong values, management objectives and watering requirements.

1.3 Catchment setting

The catchment of the Yarra River lies north and east of Melbourne, beginning on the southern slopes of the Great Dividing Range in the forested Yarra Ranges National Park. It covers an area of about 4046 square kilometres, and the length of the river, including its estuary, is 242 km. Over one-third of Victoria’s population lives in the catchment. the river flows in a general westerly direction through a confined valley and upper floodplain to Woori Yallock and then heads north towards the town of Healesville. At Healesville the river turns to the west, and passes through a constriction known as Healesville Gorge, emerging onto another broad floodplain area known as Yering Floodplain (Brizga and Craigie 1998, SKM 2005c). At the downstream end of Yering floodplain, the river then turns to the south near Christmas Hills. The river then emerges from Warrandyte Gorge and enters a broad valley at Templestowe, following it to Chandler Highway where it enters Fairfield Gorge. Fairfield Gorge extends downstream to Dights Falls, in Collingwood. Downstream of Dights Falls the river is considered estuarine, being affected by tidal incursion from Port Phillip Bay. The estuary flows for 22.5 km from Dights Falls through the inner suburbs of Hawthorn and Richmond, Melbourne's Central Business District, and the Docklands region, discharging into Port Phillip Bay at Williamstown (SKM 2005c, Cooling *et al.* 2013).

Major tributaries flowing from the north side of the river are the O’Shannassy, Watts and Plenty Rivers, and Diamond, Steels and Merri Creeks. Tributaries from the south side of the river include the Little Yarra River, Woori Yallock, Olinda, Mullum Mullum, Koonung and Gardiners Creeks (SKM 2005c). A 103 km stretch of the Yarra River from Warburton to Warrandyte is listed as a ‘Heritage River’ in order to provide for the protection of public land which has significant natural conservation, recreation, scenic and cultural heritage attributes.

The catchment lies within the Gippsland Plains and Highlands-Southern Fall bioregions. The Gippsland Plains bioregion includes flat low lying coastal and alluvial plains with a gently undulating terrain dominated by barrier dunes and floodplains and swampy flats (DELWP 2016). The Highlands-Southern Fall is the southerly aspect of the Great Dividing Range and has moderate to steep slopes, high plateaus and alluvial flats along the main valleys (DELWP 2016).

The climate of the Yarra catchment follows an east-west gradient, reflecting variations in altitude and relief (Brizga and Craigie 1998). The mountainous eastern end of the Yarra catchment receives much higher rainfalls than the lower western end, and temperatures are slightly lower in the highlands (Finlayson 1991). The catchment is located to the north east of Melbourne and encompasses an area of some 4000 km^2. The average annual rainfall across the catchment is variable, but usually ranges from 680mm in Burnley to 1080mm in the river headwaters around the Upper Yarra Reservoir (Carty and Pierott 2010). A map of average annual rainfall across greater Melbourne is shown in Figure 6, with the approximate location of the Yarra catchment indicated by the red circle. This map shows that the highest rainfall occurs in the upper Yarra catchment, dropping off in the lower reaches of the catchment.

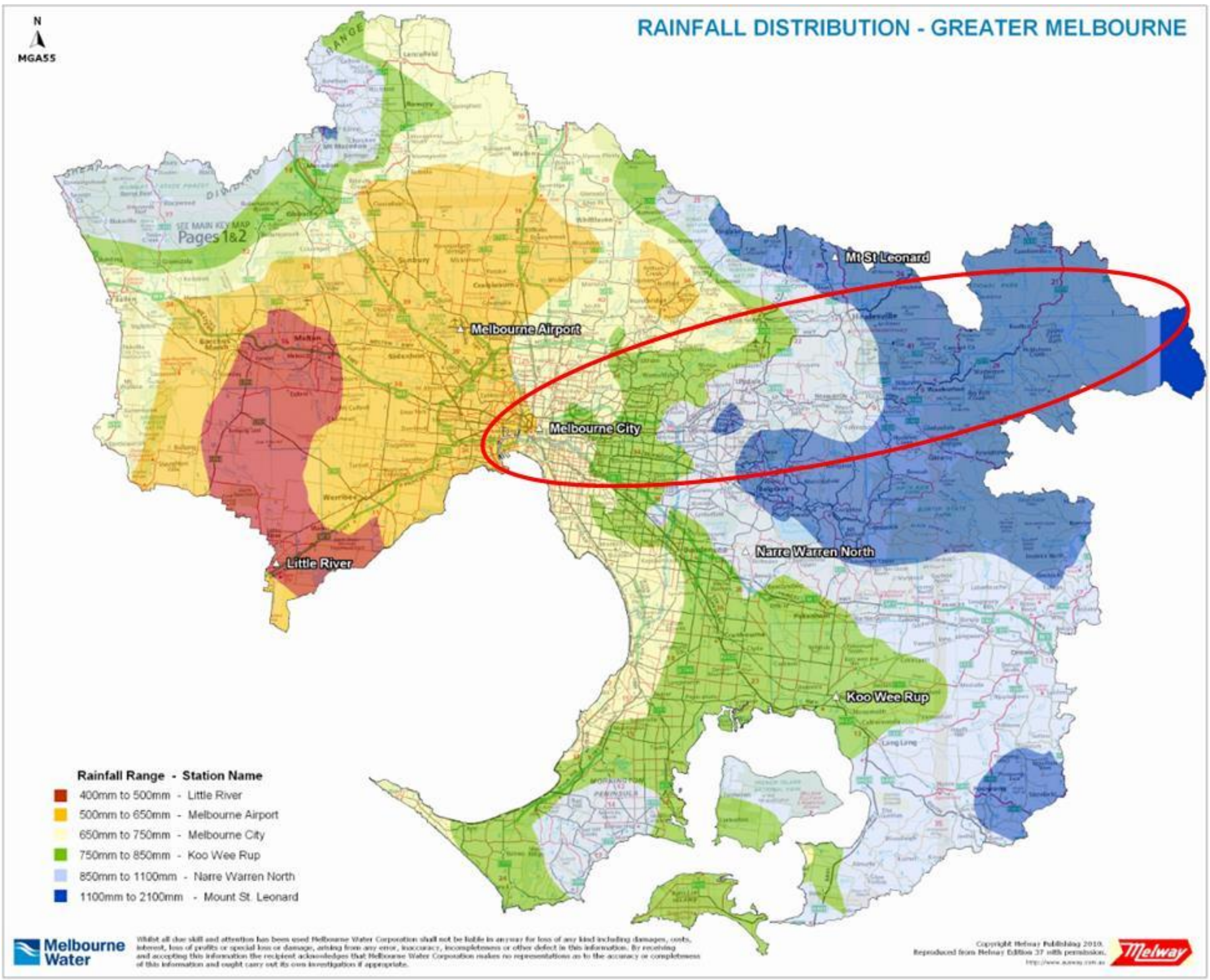

Figure 6: Average annual rainfall across the Greater Melbourne area, roughly showing the location of the Yarra River (circled) (Source: (Melbourne Water 2015a))

Watts River

The Watts River rises to the east of Healesville in the Yarra Ranges. The stream flows northwest for approximately 15 km, and then turns south west, flowing through Maroondah Reservoir and Healesville township. The Watts River joins the Yarra River approximately 3 km downstream of Healesville, near Tarrawarra (SKM 2005c). The Watts River catchment comprises an area of just over 100 km^2 upstream of the Maroondah Reservoir spillway, and an area of about 125 km^2 downstream of the spillway (Coleman and Pettigrove 1998). The main tributaries downstream of Maroondah include Chum Creek, Myers Creek, and Donnellys Creek, which enter from the north, and Grace Burn Creek which enters from the south. These combined tributary contribute approximately 50% of the total catchment area (SKM 2005c).

The climate is typically cool and wet in the catchment, with an average annual rainfall of over 1600 mm at Black Spur, and over 1100 mm at Maroondah Reservoir. The current mean annual streamflow at the catchment outlet is around 116,000 ML (SKM 2005c).

Much of the upstream parts of the catchment are heavily forested and there is restricted access, with logging occurring in some areas. Along Chum and Myers Creeks, there are areas of cleared land, used predominantly for horticulture and cattle grazing (SKM 2005c). The lower reaches of Grace Burn Creek have been extensively cleared for agriculture and urban development, with vegetable crops, viticulture and cattle grazing occurring in the area (SKM 2005c). Some irrigation of recreational facilities occurs near Healesville, including several ovals on Grace Burn Creek, and the Healesville Racecourse on Watts River (SKM 2005c).

1.4 Water Storages

Most of Melbourne's water for consumptive purposes comes from the Yarra catchment, and Melbourne Water operates seven major storages within the catchment (Figure 7):

- Upper Yarra Reservoir – A 200,579 ML on-stream storage located in the headwaters of the Yarra River. The dam was completed in 1957.
- O'Shannassy Reservoir – A 3,123 ML on-stream storage located on the O'Shannassy River. The dam was completed in 1928.
- Maroondah Reservoir – A 22,179 ML on-stream storage located on the Watts River. The dam was completed in 1927.
- The off-stream Sugarloaf Reservoir (96,253 ML) built in 1981, and the off-stream Yan Yean Reservoir[2] which was built in 1857 (30,266 ML) – Which have dual roles to harvest water and act as seasonal balancing reservoirs
- Silvan Reservoir (40,445 ML) and Greenvale Reservoir (26,839 ML) – Which are off-stream storages and act as seasonal balancing reservoirs. Silvan was completed in 1932, and Greenvale in 1971.
- Cardinia Reservoir (286,911 ML) - An off-stream storage located within the Bunyip basin but storing water harvested from the Yarra basin. The storage was completed in 1973.

There is also Toorourrong Reservoir, located on the Plenty River East Branch, which is currently offline due to water quality issues. The reservoir was constructed in 1883–1885, and is linked by the Clearwater Channel aqueduct to Yan Yean Reservoir.

A major extraction site along the Yarra River is the Yering Gorge pumping station. Four (250ML/day maximum) variable pumps extract water from the main stem of the Yarra River into Sugarloaf Reservoir. Two 70 ML/day low flow pumps can also extract water. Operators use their discretion as to when they operate these pumps depending on environmental flow constraints downstream of the pumps, the level of storage in Sugarloaf Reservoir, and demands in the system.

[2] Yan Yean was Melbourne's first constructed water storage.

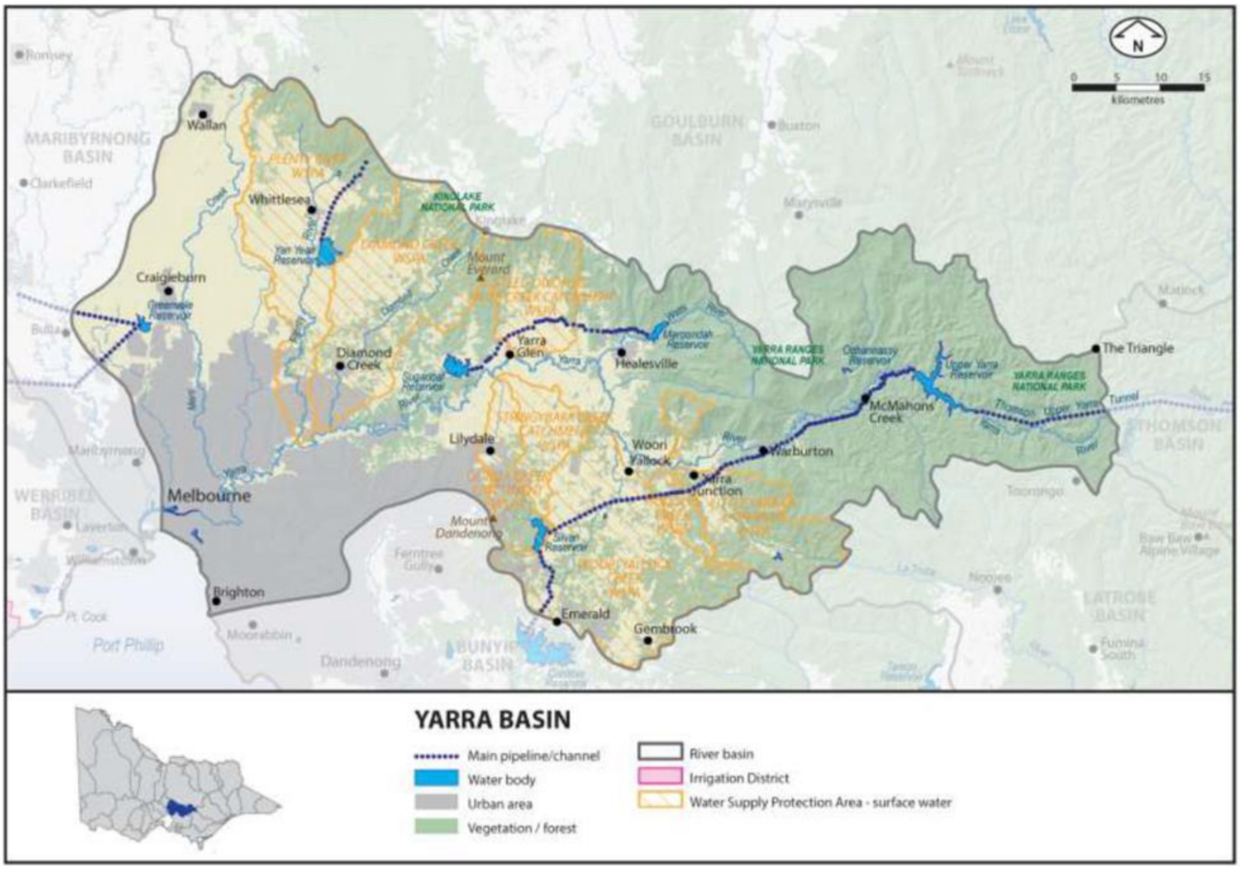

Figure 7 : Yarra Basin surface water supply and distribution network (Source: DELWP (2015e))

1.5 Land use and management

Over two million people live within the boundaries of the Yarra catchment (Yarra MAC 2016), and land uses are highly varied – from protected forests and rural areas, through to urban development and established industry in one of Australia's largest cities. The diverse land uses in the Yarra catchment can currently be divided into three major zones (Bessell-Browne 2000). The upper catchment is in near-pristine condition, having been managed as a closed and forested water supply catchment since the turn of the century and gazetted as the Yarra Ranges National Park in 1995. The mid catchment, through the foothills and the floodplains, has been cleared for agricultural production including grazing and intensive horticultural enterprises such as strawberry farming. The main Yarra floodplain has experienced a significant conversion from grazing to viticulture in the past twenty to thirty years (Davis et al. 1998, Bessell-Browne 2000). The lower catchment, from Warrandyte downstream is heavily urbanised, although the Yarra floodplain through Melbourne's north eastern suburbs forms a popular and extensive linear park, linking central Melbourne to Warrandyte with parklands, open space and trails (SKM 2005c).

The Yarra catchment is typically broken up into three sub-catchments for management by Melbourne Water: the Upper, Middle and Lower Yarra systems (Figure 8), and for the purposes of environmental flows management, the Yarra River is further broken up into nine reaches (Figure 9). Reaches 1 to 3 can be considered the Upper Yarra system, and Reaches 4 to 9 can be considered the Mid to Lower Yarra system. This division of reaches also reflects the options for releasing water, with Reach 2 representing the upper system, and Reach 5 representing the lower system. Achieving target flows in these reaches will also achieve flow events in the remaining reaches of each section. Table 1 provides a summarised description of each of the nine reaches in terms of their location and broad characteristics. Please refer to SKM (2005c) and SKM (2005b) for a more detailed description of each reach.

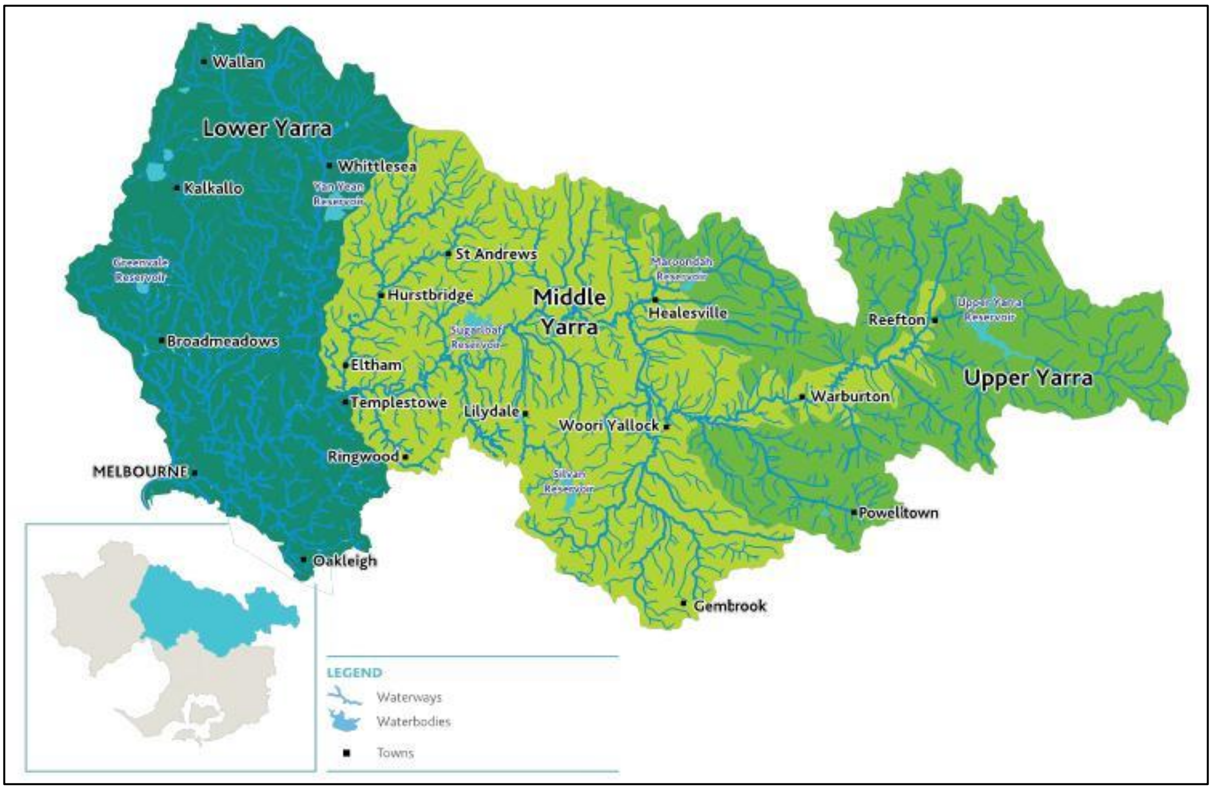

Figure 8: Yarra catchment and management units (Source: Melbourne Water (2013a))

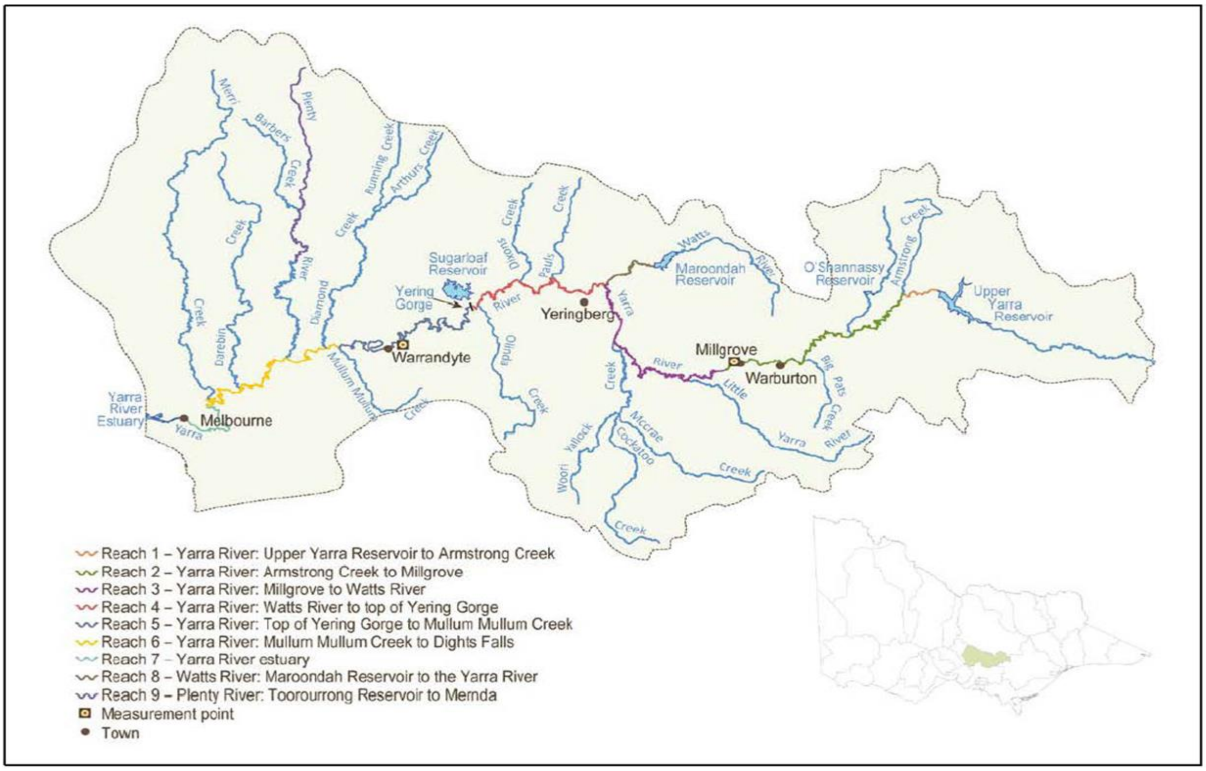

Figure 9 : Yarra catchment showing the environmental water management reaches (Source: Melbourne Water (2016b))

Table 1: Yarra River reaches, locations and characteristics

Reach	Location	Characteristics	
1	Upper Yarra Reservoir to Armstrong Creek junction	Reach 1 is relatively short (~5 km long) extending from the Upper Yarra Reservoir to Armstrong Creek, which is the first major tributary input to the Yarra River downstream of the Reservoir. The current minimum flow in this reach is 10 ML/day with some minor variability provided by inflow from Doctors Creek, a small tributary that enters just downstream of the dam wall.	 *Upper Yarra Reservoir Spillway*
2	Armstrong Creek to Millgrove	Armstrong Creek is the first major tributary input to the Yarra River downstream of Upper Yarra Dam, and from this point onwards the channel dimensions increase significantly as tributary inflows increase. The channel is confined in a narrow bedrock-controlled valley with a few small alluvial flats and is characterised by fast flowing water over predominantly pool-riffle structure with cobbled bed. The upper parts of the reach are in National Park with dense riparian forest. Alluvial flats have been cleared for grazing in the mid and lower reaches and township development occurs around Warburton.	 *Yarra River at Warburton East*

Reach	Location	Characteristics	
3	Millgrove to Watts River junction	The reach encompasses the upper floodplain of the Yarra River between Millgrove and a narrow constriction called Healesville Gorge, near the confluence with the Watts River. Several large tributaries enter this reach including the Little Yarra River and Woori Yallock Creek. Smaller tributaries include Don River, Hoddles Creek, Badger Creek and Coranderrk Creek. A proportion of flow in Badger Creek is diverted for water supply purposes and diversions for agricultural development occur from Woori Yallock Creek and the Yarra River main channel. The floodplain from Millgrove to Yering Gorge has been cleared for agricultural production and the channel has been de-snagged over time. A number of billabongs are still found along this reach.	 *Yarra River at Everard Park*
4	Watts River junction to top of Yering Gorge	This reach is characterised by a broad alluvial floodplain between Healesville Gorge and Yering Gorge. The Watts River enters at the upstream end and several tributaries enter towards the lower end including Pauls, Steels, Dixon, Stringybark and Olinda Creeks. A number of billabongs and wetlands exist on both sides of the river, including Yering Backswamp. Many billabongs have been cleared and converted to pasture. Levee banks are present along some sections of river bank and can restrict overbank flows across the floodplain.	 *Yarra River at Warrandyte*

Reach	Location	Characteristics	
5	Top of Yering Gorge to Mullum Mullum Creek	Reach 5 runs from the top of Yering Gorge to the confluence with Mullum Mullum Creek at the downstream end of the Warrandyte Gorge and upper end of the lower floodplain. The reach includes two gorges (Yering and Warrandyte) and a short floodplain (Henley floodplain). Several small tributaries enter this reach including Brushy, Watsons and Andersons Creeks. Mullum Mullum Creek enters at the bottom end and represents the first major urban tributary input to the river. Urban stormwater and treated sewerage effluent are discharged to the river and tributary streams at several locations along this reach. The reach also includes the Melbourne Water pumping station at Yering Gorge where water is pumped to Sugarloaf Reservoir for water supply purposes.	 *Yarra River at Yering Gorge*
6	Mullum Mullum Creek to Dights Falls	The river through this reach flows across the lower floodplain before flowing through a short gorge section downstream of Chandler Highway to Dights Falls. The catchment is heavily urbanised and several urban tributaries enter, including Mullum Mullum, Diamond, Ruffey, Koonung, Darebin and Merri Creeks and Plenty River. There are several significant billabongs that retain significant environmental values in this urban landscape, including Banyule Flats, Bolin Bolin and Annulus. Much of the floodplain was cleared in the late 1880s but the river bank is now well vegetated following revegetation works associated with the establishment of a linear park along the floodplain.	 *Dights Falls, with fishway in foreground*

Reach	Location	Characteristics	
7	Yarra Estuary	The Yarra estuary extends from downstream of Dights Falls to the river mouth at Hobsons Bay. The channel through the estuary reach is heavily modified. The lower estuary has been enlarged for port activities, and the mid estuary has been channelised with rock walls and beaching along most of the banks. The upper estuary has a more natural channel within confined banks. Under low flow conditions the estuary is stratified with a bottom layer of salt water extending upstream towards Dights Falls, overlain by a layer of fresher water that flows out to Port Philip Bay. The estuary provides important recreational and amenity values for Melbourne. Activities such as fishing, rowing, running and bike riding are popular. The estuary is a central feature of the Melbourne city landscape and is the focal point of community events such as the Moomba Festival.	 *Yarra Estuary at Southbank*
8	Watts River from Maroondah Reservoir to Yarra River confluence	Reach 8 encompasses the Watts River from Maroondah Dam to the confluence with the Yarra River. The flow regime of the Watts River has been impacted by Maroondah Reservoir. Flow rapidly increases with tributary inflows downstream of the dam from Donnellys, Myers and New Chum Creek and Grace Burn. The reach is characterised by a relatively confined channel with some small alluvial flats and benches located within the channel. There are some sections of remnant vegetation in the upper reaches but the mid and lower reaches are degraded from agricultural and urban development and weed infestation.	 *Watts River*

Reach	Location	Characteristics	
9	Plenty River from Toorourrong Reservoir to Mernda	Reach 9 extends from Toorourrong Reservoir to the upstream reaches of the Plenty Gorge at Mernda. The Plenty River downstream of Toorourrong Reservoir is significantly flow stressed with only a 0.2 ML/d release from Toorourrong Reservoir to the Plenty River East Branch. The first major tributary inflows are the Plenty River West Branch and Bruces Creek. This reach is not within the scope of the EWMP	 *Plenty Gorge*
3, 4 and 6	Yarra River floodplain	In the Yarra River catchment, billabongs occur on the broad floodplain and are a particular feature of Reaches 3, 4 and 6. Most billabongs take the form of an oxbow lake, an old river channel or a waterhole, and many have undergone considerable changes since European colonisation.	 *Yering Backswamp near Yarra Glen*

1.6 Environmental water management

Typically in Victoria, the scope of EWMPs is defined by the extent of a waterway that can be targeted for management intervention through:

- For regulated systems - Releases from an environmental water holding such as an Environmental Entitlement, or passing flow releases obligated through conditions defined in bulk entitlements
- For unregulated systems - Conditions on diversions under any Section 51 (*Water Act 1989*) take and use licences
- For wetlands – Arrangements for the provision and/or exclusion of water from nearby surface water sources through formally agreed environmental water management strategies or plans.

Because it is in a largely regulated system, the Yarra River environmental water management program is thus primarily defined by the extent of the system that can be watered via the use of the *Yarra Environmental Entitlement 2006*. The Environmental Entitlement consists of:

- The first 17,000 ML (17 GL) of net inflow into the Yarra headworks system reservoirs in any watering year
- Minimum environmental flows (passing flows), which are specified for 22 sites within the system and detailed within Schedule 1 of the Entitlement
- A 55 ML per year allocation for use downstream of the Olinda Creek and Yarra River confluence (DEPI 2014b).

It is important to note that EWMPs are developed such that they focus on the broader and longer-term management objectives for a waterway, and importantly they should not be limited by the extent of environmental water that is currently available. Although the current Environmental Entitlement is limited in terms of the volume available to address environmental needs of the Yarra River, the role of the EWMP is thus to extend the scope of management objectives beyond what is immediately feasible.

1.7 Roles and responsibilities

The roles of various agencies in environmental water management for the Yarra River are summarised in Table 2.

Table 2 : Yarra River environmental water management roles and responsibilities

Agency / Group	Responsibilities
Victorian Minister for Energy, Environment and Climate Change, or the relevant Minister	• Oversees Victoria's environmental water management policy framework • Oversees the Victorian Environmental Water Holder, including appointment and removal of commissioners and the creation of rules ensuring Environmental Water Holdings are managed in line with environmental water management policy
Victorian Environmental Water Holder (VEWH)	• Independent statutory body responsible for holding and managing Victoria's environmental water entitlements and allocations • Makes decisions on the most effective use of the Water Holdings, including use, carryover and trade and authorises waterway managers to implement watering decisions by issuing Seasonal Watering Statements • Liaises with other environmental water holders such as CEWH to ensure coordinated use of all sources of environmental water and works with storage managers to coordinate and maximise environmental outcomes from the delivery of all water • Publicly communicates environmental watering decisions and outcomes

Agency / Group	Responsibilities
Victorian Department of Land, Environment, Water and Planning (DELWP)	• Manages the water allocation and entitlements framework • Develops state policy on water resource management and waterway management, including the management of environmental water in regulated and unregulated systems • Acts on behalf of the Minister for Energy, Environment and Climate Change to maintain oversight of the VEWH and waterway managers
Melbourne Water Waterway Manager	• In partnership with the community, identifies the environmental water requirements of the Yarra River according to agreed ecological objectives • Identifies and implements environmental works (including monitoring) that increases the effectiveness, understanding and efficiency of the environmental watering program • Develops the Yarra River Seasonal Watering Proposal each year and implements the Seasonal Watering Statement issued by the Victorian Environmental Water Holder • Provides critical input to management of other types of environmental water (e.g. passing flows management and Stream Flows Management Plans) • Reports on environmental water management activities undertaken in the Yarra system
Melbourne Water Storage Manager	• Operates water supply system infrastructure to deliver minimum passing flows and to deliver environmental flow events.
Environment Protection Authority	• 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 • Provides advice regarding SEPP WoV issues for the Yarra River
Parks Victoria	• Responsible for management of a number of waterway assets and values along the length of the Yarra River, including parks, billabongs and water frontages • Provides advice regarding water-dependent ecological values
Water retailers: • City West Water • Yarra Valley Water • South East Water	• Primary entitlement holders of delivery bulk entitlements for Melbourne's consumptive-use water allocation. Strong influence on the regulation and management of the Yarra River, including releases from storages, infrastructure operation and water harvesting. • Requires up-to-date information regarding current and planned releases from the Yarra Environmental Entitlement as well as the strategic management of the Melbourne headworks system for environmental objectives. • Provides input and advice in the development and implementation of the Yarra EWMP.

Agency / Group	Responsibilities
Aboriginal Traditional Owners: • Wurundjeri community • Wurundjeri Tribe Land Compensation and Cultural Heritage Council	• Traditional Owners of the Yarra River, with significant and long-lasting connections to the River. • Provides input and advice on matters relating to the protection of indigenous cultural heritage and cultural values in the Yarra River catchment. • A project is underway between the Wurundjeri, VEWH and Melbourne Water will see a more inclusive collaborative management of the Yarra River Environmental Entitlement once completed, with environmental flow releases targeting water-dependent cultural values where co-benefits can be realised. This is discussed further in Section 2.8.1.
Yarra River Environmental Flows Advisory Group: • Local councils • Irrigators and landholders • Yarra Valley Water • Environment Protection Authority (Victoria) • Yarra Riverkeepers • Native Fish Australia • VR Fish • Kew Golf Club • Environment Victoria • Parks Victoria	• A cross-jurisdictional group comprising representatives of government agencies and local stakeholders • Provides input and advice to Melbourne Water on matters relating to the management of the Yarra River and its environmental watering program
Recreational users: • VR Fish • Non-motorised boating clubs – kayaking, canoeing, rowing	• Strong interest in and advocacy for the environmental health and sustainable use of the Yarra River • Strong interest in co-beneficial application of environmental flows for recreational purposes • Provides input and advice into the development and implementation of the Yarra River environmental watering program.
Environment groups: • Environment Victoria • Native Fish Australia • Yarra Riverkeeper	• Strong interest in and advocacy for the environmental health and sustainable use of the Yarra River • Strong interest in the contribution and influence of Yarra flows for the maintenance and/or enhancement of fish species in the freshwater and estuarine reaches of the Yarra River, as well as Port Phillip Bay • Provides input and advice into the development and implementation of the Yarra River environmental watering program.
Local Government: • City of Melbourne • Yarra Ranges Council • Nillumbik Shire Council • Banyule City Council • Manningham City Council • City of Stonnington • City of Yarra • City of Boroondara	• An important influence on water management through their responsibility for land-use planning, development approvals, programs that aim to conserve and improve the environment, rates, and a variety of services such as road construction and maintenance. • Local councils also own and manage large areas of land immediately adjacent to the Yarra River.

Agency / Group	Responsibilities
Port Phillip and Westernport Catchment Management Authority	• The peak natural resource management body in the Port Phillip and Westernport region to develop and oversee the implementation of the Regional Catchment Management Strategy. The strategy is implemented through partnerships with communities, businesses and agencies, including Melbourne Water. • Identifies regional priorities for catchment management in the Port Phillip and Westernport region. • Provides input and advice into the development and implementation of the Yarra River environmental watering program

1.8 Environmental water sources and governance

Environmental water for the Yarra River's water-dependent values comes from what is collectively called the Environmental Water Reserve (EWR). The EWR is the legal term used to describe the amount of water set aside to meet environmental benefits. It includes water provided through:

- Statutory environmental water entitlements, such as a volume of water held in storage - These entitlements, usually called environmental entitlements or bulk entitlements, are the components of the EWR that can be actively managed. The Yarra River has an environmental entitlement, called the *Yarra Environmental Entitlement (2006)*
- Water set aside for the environment as obligations on consumptive water entitlements held by urban and rural water corporations - These are usually called 'passing flows' that need to be released from storages or provided at a particular point on a river
- Unregulated flows and spills from storages.

The Yarra Environmental Entitlement (the Entitlement) is held by the Victorian Environmental Water Holder (VEWH), and Melbourne Water manages the entitlement on behalf of VEWH.

The Entitlement is comprised of:

- Minimum passing flows at various tributaries, weirs and gauges throughout the Yarra catchment, which are specified in Schedule 1 of the Entitlement
- The first 17 GL of inflows into the Melbourne Headworks system and reservoir storage space
- 55ML of unregulated water per year in the Yarra River downstream of the confluence with Olinda Creek.

The Entitlement is highly reliable due to being allocated the first inflows into the system and having very secure storage. When the Melbourne headworks system spills, any Entitlement volume held in storage that is over and above the 17GL is reduced by the amount of the spill. The headworks system is deemed to be spilling when both Upper Yarra Reservoir and the Thomson Reservoir exceed their maximum operating capacity.

1.8.1 Related agreements, policies, plans and reports

A wide variety of legislation, as well as policies, strategies and plans are relevant to the governance and management of environmental water for the Yarra River. These are listed in Table 3.

Table 3 : Relevant management instruments for Yarra River environmental water

Management Instrument	Description
Victorian Legislation	• Victorian Water Act (1989) • Catchment and Land Protection Act (1994) • Flora and Fauna Guarantee Act (1988)

Management Instrument	Description
	• 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	• Bilateral Migratory Bird Agreements: - Japan-Australia Migratory Bird Agreement (JAMBA) - China-Australia Migratory Bird Agreement (CAMBA) - Republic of Korea Migratory Bird Agreement (ROKAMBA)
Plans and Strategies	• Victorian Waterway Management Strategy (2013) • Melbourne Water Healthy Waterways Strategy (2014) • Water For Victoria Discussion Paper (2016) • 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) • Biodiversity Conservation Strategy for Melbourne's Growth Corridors (2013) • Plan Melbourne: Metropolitan Planning Strategy (2014) • Victorian Climate Change Adaptation Plan (2013)
Technical Studies	• 2005 Determination of the Minimum Environmental Water Requirement for the Yarra River. Minimum environmental water requirement and complementary works recommendations (SKM 2005a) • 2012 Yarra River Environmental Flow Study Review (SKM 2012d) • 2013 Yarra River Estuary EEFAM Scoping Report (Cooling et al. 2013) • Yering Backswamp: An assessment of temporal change in floristic composition and values (Jolly and Osler 2013)

VALUES, CONDITION AND THREATS

2. Values

The key values targeted through the Yarra EWMP reflect an in-depth review of relevant waterway management science and extensive consultation undertaken for the development of Melbourne Water's Healthy Waterway Strategy. The values closely align with the community expectations and aspirations for waterways in Melbourne's region, and have been selected based on:

- Their importance to the community
- The availability of data to assess their condition
- The ability to appropriately represent the range of values found in rivers, estuaries and wetlands (Melbourne Water 2013a).

The values are as follows:

- Fish
- Platypus
- Vegetation
- Water-dependent birds
- Frogs
- Macroinvertebrates.
- Amenity

Figure 10 illustrates the process by which the Yarra River EWMP key values have been determined.

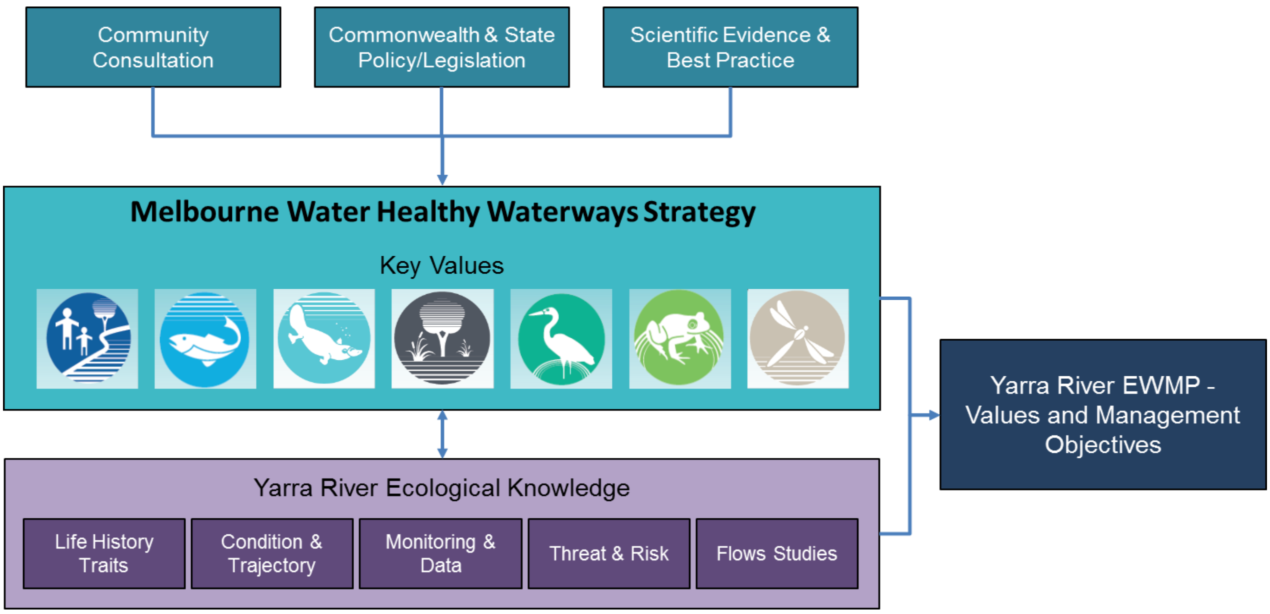

Figure 10 : Development process for determining the key values and management objectives of the EWMP

2.1 Fish

The Yarra River provides a diverse range of habitats for fish. Fish are a key value of the Yarra 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, other mammals, and some birds. Fish are also valued for recreational purposes, with the River Blackfish highly prized by Melbourne's fishing community for example.

Fish are generally categorised according to whether they are freshwater or estuarine, and if they are marine[3] or freshwater derived. They are also categorised according to whether they are migratory or non-migratory[4]. Twenty-nine species of freshwater fish (21 native and 8 exotic), and 16 species of estuarine/marine fish have been recorded as present in the Yarra River catchment (SKM 2005c). A number of the native species are not actually indigenous to the waterway, having been translocated from other areas; notably Murray Cod (*Maccullochella peelii*) and Macquarie Perch (*Macquaria australasica*), which have both established significant self-sustaining populations in the mid to lower reaches of the Yarra River.

Fish recorded from the Yarra River catchment are separated into four groups based on their migratory and fish passage requirements:

- Resident – Species which require passage only within freshwater and the local environs
- Potamodromous – Species which can migrate within freshwater for specific spawning or dispersal requirements
- Diadromous – Species that migrate to and from the sea. This includes anadromous[5] fish, which spend most of their adult lives at sea, but return to fresh water to spawn, and catadromous[6] fish, which live in fresh water and enter salt water to spawn. About 70% of all Australian fish are thought to be migratory
- Estuarine – Species which inhabit the brackish and/or marine environment (SKM 2005c).

For the estuarine fish species, they are further 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).

Appendix A.2.2 lists fish species found in the Yarra River catchment.

2.1.1 Fish species with high conservation value

There are a number of primarily freshwater species recorded within the Yarra River that have high conservation values. These are:

- Australian Grayling
- Macquarie Perch
- Murray Cod.

Australian Grayling (*Prototroctes maraena*) are listed as vulnerable under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act), threatened under the Victorian *Flora and Fauna Guarantee Act 1988* (FFG Act), and are listed as vulnerable in Victoria according to the Department of Environment, Land, Water and Planning (DELWP)'s Advisory List of Threatened Vertebrate Fauna in

[3] 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.
[4] Migratory fish have life stages in both freshwater, estuarine and/or marine environments, and non-migratory species spend their entire lifecycle in freshwater.
[5] Anadromous means "upward-running", and refers to the upstream migration of adults.
[6] Catadromous means "downward-running," and refers to the downstream migration of adults.

Victoria (DELWP 2015a). Australian Grayling were once common in the Yarra River but a range of factors including barriers to fish passage, particularly at Dights Falls[7], and perhaps poor water quality in the lower reaches from historic industrial discharges, has resulted in their near elimination from the system. Recent evidence suggests that juveniles do not necessarily return to the same rivers where they were spawned (Crook *et al.* 2006, Schmidt *et al.* 2011), and populations may persist in some rivers where adults have failed to spawn for several years.

Macquarie Perch were introduced to the Yarra River from the Goulburn River between 1912 and the 1940s (Cadwallader 1981). They have become established throughout the river and are found along approximately 130 km of the system from below Dights Falls to above Healesville. The population is now considered one of the most significant in Victoria (SKM 2005c, DOE 2015b). Macquarie Perch is listed as endangered under both the EPBC Act and FFG Act (DOE 2015a) . It is also listed on the IUCN red list[8] (DSE 2009). From once being widespread through the Murray-Darling river system in Victoria and New South Wales the species is now in decline, and has undergone a dramatic reduction in abundance. A 2007 study found the Yarra River population of Macquarie Perch to be self-sustaining, one of only three such populations in Victoria (Pitman *et al.* 2007). The Yarra population provides a unique opportunity to gain a better understanding of the biological requirements of Macquarie Perch, which will improve the ability to manage remnant riverine populations across its current distribution.

Murray Cod is listed as endangered under the EPBC Act, and is a threatened species under the FFG Act (DSE 2010). It is a large predatory freshwater fish, exclusively freshwater, and also one of the largest freshwater fish in the world. Like Macquarie Perch, it has been introduced to the Yarra system from the Murray Darling Basin. It is an iconic species in Australia and has significant economic, cultural, recreational and environmental values. The species has suffered a substantial decline in abundance since European settlement, particularly in the last 70 years (DOE 2015a). Reasons for the species' decline include habitat loss and degradation, barriers to fish passage, flow regulation, cold water releases, and fishing (both legal and illegal) (DOE 2015a).

2.1.2 Estuarine fish species with high commercial/recreational value

A number of the Yarra River's estuarine fish species have significant conservation, commercial and recreational fishing values. Fishing is one of the most popular recreational pursuits in Victoria, with over 835,000 people participating in recreational fishing each year (Ernst & Young 2015). In the Melbourne and Port Phillip region alone, over $1 billion was generated by recreational fishing in 2013/14 (Ernst & Young 2015). High value fish species that are dependent on the estuary for aspects of their life-cycle include the Snapper (*Chrysophrys auratus*), Sand Flathead (*Platycephalus bassensis*) and Black Bream (*Acanthopagrus butcheri*).

Snapper are one of the most popular food fishes in Australia. The species is highly dependent on the nutrients that Yarra River flows provide to Port Phillip Bay, because these nutrients influence the productivity of food sources for juvenile Snapper (Hamer and Jenkins 2007). In Port Phillip Bay and Westernport, Snapper is one of the most popular recreational fish, with a significant proportion of fishers targeting this species (Ernst & Young 2015).

Sand Flathead was once a significant commercial fishing species and the most popular recreational fishing species in Port Phillip Bay (Ryan *et al.* 2009). Since 2000 however, stocks have declined substantially in the Bay, and the causes of this decline are unknown (Hirst *et al.* 2014). Sand Flathead are bottom dwellers, living on sandy, shelly or muddy bottoms to 100 m depth. In Port Phillip Bay they are most abundant in deeper habitats (>15 m), living on silty and muddy bottoms (Hirst *et al.* 2014).

Black Bream is an estuarine resident species, relying on freshwater flows to provide appropriate habitat as well as reproduction opportunities. The species is prized for its sporting qualities and high quality flesh. Black Bream 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 Yarra estuary is 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.* 2014).

[7] The installation of a fishway to provide passage above the weir at Dights Falls has enabled Australian Grayling to move upstream into areas from which the species had been absent for many decades (Backhouse *et al.* 2008)

[8] The International Union for the Conservation of Nature (IUCN) is the world's main authority on the conservation status of species.

2.1.3 Key flow requirements for fish

Migratory Fish

Migratory fish require a range of different flows for their general lifecycle requirements, and for movement within and between their habitats. For example, Australian Grayling need high flows in autumn to facilitate their downstream migration, to cue spawning, and to carry their eggs and larvae out to sea. Individuals live for 3-5 years, but females do not mature until they are two years old (McDowall 1996), and do not release their eggs without high autumn flows. This means that if these flows do not occur for three or four successive years, an entire population of the species may die without reproducing (O'Connor and Mahoney 2004).

Non-Migratory Fish

Non-migratory fish need flows to provide them with habitat, food, breeding opportunities and protection from predators. Flows may also provide cues for spawning for some of these species. The River Blackfish for example is a non-migratory species that lives under snags or rocks in pools, is territorial, and tends not to travel very far (i.e. generally less than 30 m). Although the species can be found in both slower and faster flowing waters, it prefers to stay in low-velocity, highly sheltered pools (SKM 2011b). This species relies on flows and freshes to inundate instream hard surfaces such as hollow logs to lay their eggs. High flows are risky for their reproductive success because they can scour away eggs and wash their larvae away (SKM 2011b).

Estuarine and Marine Fish

Freshwater flow is the principal physical variable determining the characteristics of an estuary, and estuarine systems are characterised by a salinity structure that varies in relation to the amount of freshwater flow they receive (Kurup *et al.* 1998). Some freshwater fish species may move downstream into an estuary during periods of high flow, and some marine species may move up into estuaries and/or freshwater reaches with an incoming sea tide flow (Arundel and Barton 2007). Other species, such as Eels and Galaxiids, migrate between the freshwater, estuarine and marine environments at different times of the year.

The Yarra River is a major source of nutrients into the Bay, which stimulate phytoplankton (algae) productivity, which feeds zooplankton, and which then provides food for fish larvae. If there isn't sufficient food for fish larvae they are unable to grow and survive to breeding age. The plumes from the Yarra River and the subsequent mixing zone in the Bay are associated with areas of high phytoplankton and zooplankton productivity (Black *et al.* 2011). Evidence suggests that there is a strong correlation between Sand Flathead and Snapper recruitment and river flows into Port Phillip Bay (Hamer and Jenkins 2007, Hirst *et al.* 2014). Almost all low flow years during the 1997 – 2009 Millennium Drought for example corresponded with low recruitment for Sand Flathead (Hirst *et al.* 2014).

2.2 Platypus

The Platypus (*Ornithorhynchus anatinus*) is one of only five species of egg-laying mammals in the world, and the only species within the family Ornithorhynchidae. It is one of the most evolutionarily distinct mammals on Earth, belonging to a subclass separated from all other living mammals, making it of exceptional scientific value and an irreplaceable component of Australian and global biodiversity (Bino *et al.* 2015). Melbourne Water is committed to protecting and improving Platypus habitat throughout the Greater Melbourne area through its Melbourne Water Urban Platypus Program (MWUPP). The Platypus is considered "of least concern", under current IUCN red listing (Lunney *et al.* 2008a), but the national conservation status of the species has recently been elevated to 'Near Threatened' in the CSIRO's 'Action Plan for Australian Mammals' (Woinarski *et al.* 2014), in recognition that its numbers have been declining in many areas over the past few decades and it has already disappeared from some catchments.

Platypus require access to freshwater habitats to forage, and river banks to dig their burrows. Their ideal habitat includes rivers or streams with earthen banks consolidated by the roots of native vegetation, macroinvertebrate food sources, cobbled or gravel substrates, overhanging shady vegetation, and a sequence of pools and riffles (Grant and Fanning 2007). Platypus can occupy lakes and farm dams however, and can also be found in some streams moderately degraded by human activities (Grant and Fanning 2007).

2.2.1 Key flow requirements for platypus

The ideal foraging habitat for platypus 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 and 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). Platypus build burrows on steep or undercut banks that are usually at least 1m high with a dense cover of vegetation. Burrow openings are also at least 0.5m above normal river flow levels to reduce the risk of flooding, and breeding females prefer to build their burrows at least 0.5m above the winter high water mark to reduce the risk of their young drowning during high spring or summer flows (Serena *et al.* 2001).

Researchers believe that Platypus change their behaviour in response to different flow profiles. During high flow events or floods for example, they may avoid the high energy cost of swimming in strong currents by temporarily suspending activity or foraging in slower moving water such as eddies or backwaters (Gust and Handasyde 1995, Griffiths *et al.* 2014). During very low flows, such as droughts, they are at higher risk of predation and may seek refuge in deeper pools along a waterway, or migrate downstream to a larger, more permanent river (where possible) (Gust and Handasyde 1995).

Key flow-dependent factors for the Platypus include:

- Extreme low flows may limit their foraging activity and increase their susceptibility to predation
- Summer/autumn high flows may present a high risk. Although small to moderate summer freshes are generally beneficial, flows that result in water depth increasing significantly compared to spring baseflow (e.g. rise greater than 1 m) can inundate breeding burrows, causing young animals to drown (the highest risk period is December-early February). Juveniles that are just learning to swim may also drown or be swept downstream in flows of this magnitude (highest risk period is late January-early March). High flows should therefore be avoided if possible in these months
- Moderate summer/autumn baseflows are important because platypuses need to feed on a daily basis all year. Moderate baseflow supports macroinvertebrate production and provides adequate water depth and connectivity for efficient foraging (adults and juveniles).
- Stable flows from December to February support platypus reproduction: the energy needs of lactating females peak from December to early February
- The height of high flow events will influence choice of burrow location for platypus, because overbank flow may inundate burrows with eggs or nesting juveniles.

2.2.2 Other native mammals

There are other water dependent mammals found within and near the banks of the Yarra River. The Rakali, or Australian Water-rat (*Hydromys chrysogaster*), is found occupying a wide variety of natural and manmade freshwater habitats, including billabongs, ponds, lakes, rivers, creeks and irrigation channels. They also inhabit brackish estuaries and sheltered ocean beaches. Rakali feed primarily on aquatic prey (including fish, frogs, turtles, crayfish, crabs, large aquatic insects, mussels and clams), but the remains of terrestrial prey such as mice and bats have also been discovered in their faeces.

Rakali have a fairly short natural lifespan (in most cases living no more than 3-4 years), and local populations may decline in size and even disappear if they fail to reproduce successfully for several years in a row, for example because of the combined effects of poor habitat quality and drought (Australian Platypus Conservancy 2016). Very little is known however of the key flow requirements for this species, although the species can be found sharing the same habitat as Platypus in many places (Australian Platypus Conservancy 2016).

The Yarra estuary is also known to receive the occasional visit from Australian Fur Seals (*Arctocephalus pusillus doriferus*), and Burrunan Dolphins (*Tursiops australis*). Melbournians have affectionately named one Australian Fur Seal believed to have taken up residence in the estuary ‘Salvatore’, and this 200+kg male is seen regularly as far up as Richmond (Marika Dobbin Thomas 2017). Burrunan Dolphins have also been recorded swimming up the estuary. Discovered in 2011, the Burrunan Dolphin is listed as threatened under the FFG Act (1988), and Port Phillip Bay is one of only two known places in the world that this species has an established population (Charlton-Robb *et al.* 2011). Again, there is very little information regarding the flow requirements of these species.

Appendix A.2.5 lists mammal species recorded for the Yarra River in the Victorian Biodiversity Atlas database (VBA_Fauna25).

2.3 Vegetation

The Yarra River catchment lies across two bioregions, Gippsland Plains and Highlands-Southern Fall, and also abuts the Victorian Volcanic Plain near the Merri Creek and Darebin Creek confluences (Figure 11).

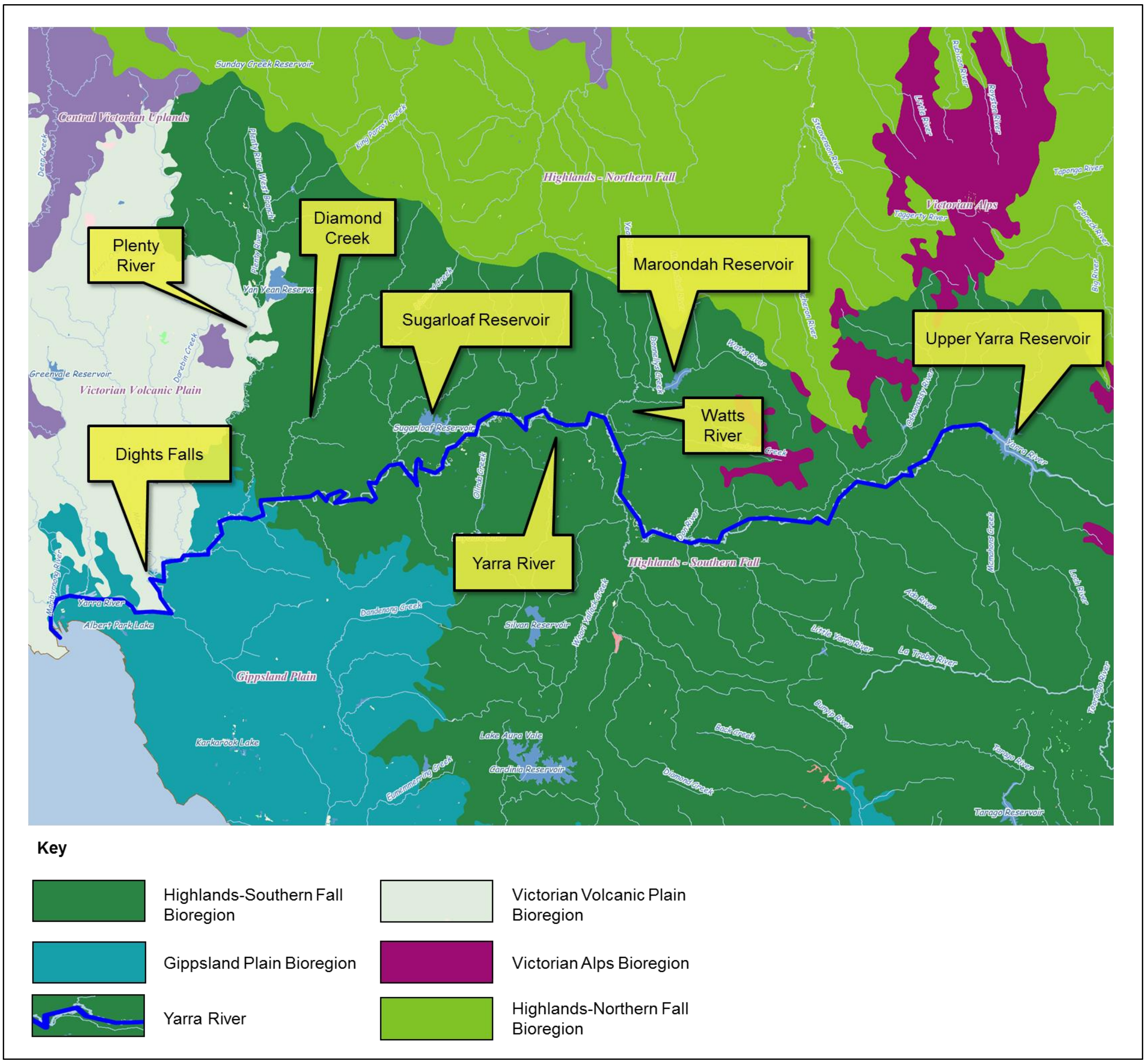

Figure 11 : Yarra River bioregions (Source: (State of Victoria 2015))

The Gippsland Plain bioregion includes flat, low-lying coastal and alluvial plains with a gently undulating terrain, and is dominated by barrier dunes and floodplains and swampy flats (VEAC 2010). The bioregion retains native vegetation of a fragmented pattern, reflecting a variety of land-use histories. Less than 1% of the bioregion is considered intact, with most of the region heavily modified and only a quarter of the original extent of native vegetation remaining, of which about half is on public land (VEAC 2010).

In contrast, the Highlands-Southern Fall bioregion is the southerly aspect of the Great Dividing Range and has moderate to steep slopes, high plateaus and alluvial flats along the main valleys. In the Yarra Valley, the switch from Highlands-Southern Fall to the Gippsland Plain bioregion is near Diamond Creek, and there is a noticeable change in vegetation structure, from riparian forest to woodland, and in dominant tree species, from Manna Gum (*Eucalyptus viminalis)* in drier parts and Mountain Swamp-Gum (*Eucalyptus* *camphora ssp. Humeana)* in the wetter parts of the former bioregion, to River Red Gum (*Eucalyptus camaldulensis)* and Swamp Gum (*Eucalyptus ovata)* in the latter bioregion (SKM 2012c).

One third of the Highlands–Southern Fall bioregion is fragmented (VEAC 2010). Within the fragmented landscape of this bioregion, extensive areas of native vegetation remain (59.7%), with almost half of this on public land. A moderate proportion is within conservation reserves (8.4%), many of which extend into the largely intact landscape (VEAC 2010).

Native vegetation in Victoria is described in terms of Ecological Vegetation Classes (EVCs). EVCs are one or more of a number of plant and structural types that appear to be associated with a recognisable environmental niche and they can be characterised by their adaptive responses to ecological processes that operate at the landscape scale (SKM 2012c). The contrast between present distributions of an EVC (i.e. 2005 EVCs) with its modelled extent prior to 1750 is one of the criteria used to determine the Bioregional Conservation Status (BCS) of remnant native vegetation (SKM 2012c).

Appendix A.1.1 lists key EVCs for the Yarra catchment bioregions and indicates their bioregional conservation status.

2.3.1 Freshwater vegetation values

A list of plants recorded from the Yarra catchment, for both the Yarra River and Watts River reaches, includes 70 threatened species (SKM 2012c) and is provided in Appendix A.1.3. Of these species, six are associated with aquatic environments and have been classed as hydrophytes, which are plants that are adapted to grow in water or very wet environments. A number of threatened trees and shrubs are also found in the riparian zone of the Yarra River catchment. These include the acacias (Sticky Wattle, Southern Varnish Wattle) and eucalypts (Yarra Gum, Buxton Gum and Spotted Gum). The Yarra Gum is endemic to Victoria (Walsh and Entwistle 1996).

2.3.2 Key flow requirements for freshwater vegetation

Overall, vegetation condition along the freshwater reaches of the Yarra system is relatively poor, particularly in the floodplain reaches where extensive clearing has occurred. Across all reaches, terrestrial vegetation is encroaching down the bank as a result of reduced variability in in-channel flows and a reduction in the duration of bank inundation during high flows in spring. To rehabilitate bank vegetation, structure and diversity this type of vegetation requires a disturbance regime, with flows that inundate terrestrial vegetation during its growing season. This can help to reinstate a wider zone of flood-tolerant species on the banks and may also help control the infestation of terrestrial weed species.

2.3.3 Estuary vegetation values

The Yarra River estuary is located in the Gippsland Plain Bioregion and has a number of key EVCs:

- Coastal Saltmarsh (EVC 9), which has an Endangered conservation status in the Bioregion
- Brackish Wetland Aggregate (EVC 656), which has an Endangered conservation status
- Brackish Grassland (EVC 934) which has an Endangered conservation status
- Estuarine Flats Grassland (EVC 914) which has an Endangered conservation status
- Floodplain Riparian Woodland (EVC 056), which has an endangered conservation status
- Seagrass Meadow (EVC 845), which is not currently classified for its conservation status
- Damp Sands Herb Rich Woodland (EVC 3) which has a Vulnerable conservation status
- Reed Swamp (EVC 300) which has an Endangered conservation status
- Swamp Scrub (EVC 53) which has an Endangered conservation status
- Mangrove Shrubland (EVC 140) which has a Least Concern conservation status
- Floodplain Riparian Woodland (EVC 14) which has an Endangered conservation status (Arundel and Barton 2007, DELWP 2015b).

Plant species of conservation significance in the Yarra estuary were reported by Arundel and Barton (2007), and are listed in Appendix A.1.3.

Although now significantly altered from its pre-European settlement state, the Yarra estuary would have originally supported paperbark swamps and coastal woodlands, and is thought to have supported about 335 ha of wetlands, most of which were saline (Cooling *et al.* 2013). Of particular importance to the Yarra estuary is the presence of Common Reed (*Phragmites australis*) in the littoral zone. Common Reed is tolerant of slightly brackish water up to 10,000 ppm total dissolved salts, and is important in the Yarra estuary because it provides one of the only physical habitats for estuarine fish, macroinvertebrates and birds (SKM 2005c). It is also likely to provide significant nursery habitat for Black Bream and other fish species (SKM 2005c).

2.3.4 Key flow requirements for estuarine vegetation

The presence or absence of estuarine vegetation is significantly influenced by the hydrological regime of the area. This includes factors such as the period of inundation, the period since the area was last inundated, the depth of water, and the levels of salinity. However, little is currently known of the flow requirements for Yarra estuary vegetation. Work has been completed recently by DELWP to describe the water, salinity regime and depth preferences for Victorian wetland EVCs (DELWP 2012), including those in estuarine areas. Wetland EVCs were assigned to pre-determined water and salinity regime categories, indicating a range of limits within which they may occur, although their optimum watering regime was not assessed (DELWP 2012). It is likely that vegetation values in the tidal zone of the estuary, such as Mangrove Shrubland (EVC 140) and Coastal Saltmarsh Aggregate (EVC 9), rely on the twice daily semidiurnal tides for inundation events, as well as the less frequent Spring tides which occur a few times a year. Vegetation less likely to be inundated by tides because of its location, will be more reliant on seasonal inundation, such as Brackish Wetland Aggregate (EVC 656) (DELWP 2012).

2.3.5 Billabong vegetation values

Billabong vegetation values along the Yarra River are varied, reflecting surrounding floodplain use and inundation regimes. The available information on macrophyte distribution and abundance for example, indicates that plant communities vary greatly from billabong to billabong, and even across different years in the one billabong. In some cases, changes in plant communities can be linked to wetting and drying cycles (Boon 2009a). Billabongs, at least those in catchments not disturbed for agricultural production, are characterised by fringes of emergent vegetation and trees. They often support dense beds of emergent vegetation, including rushes, sedges and reeds, along the perimeter, as well as large trees on higher ground. River Red Gum (*Eucalyptus camaldulensis)* is common along billabong edges, but other taxa (e.g. Melaleuca and Leptospermum) may occur as well (Boon 2009a).

Yering Backswamp contains the only intact Swamp Paperbark (*Melaleuca erificolia*) scrub within northeast Melbourne. It also contains some of the most mature stands of Kunzea sp. within the mid-Yarra section (Boon 2009b). Twelve EVCs were recorded in a field study by Australian Ecosystems (Australian Ecosystems 2007), and the majority of these are considered as endangered in the bioregion. EVCs at the site include: Riparian Forest (EVC 18); Herb-rich Foothill Forest (EVC 23); Damp Forest (EVC 29); Swamp Scrub (EVC 53); Aquatic Sedgeland (EVC 308); Aquatic Herbland (EVC 653); Fern Swamp (EVC 721); Floodway Pond Herbland (EVC 810); Tall Marsh (EVC 821); Escarpment Shrubland (EVC 895); Wet Verge Sedgeland (EVC 932); and Dwarf Floating Aquatic Herbland (EVC 949).

Yering Backswamp is considered a Site of Biological Significance within Victoria. It supports 27 species of rare or endangered plants and 10 of regional significance. Recommendations have previously been made to incorporate it into a biological reserve (Beardsell 1997).

2.3.6 Key flow requirements for billabong vegetation

Flow requirements for billabong vegetation are often determined according to a number of keystone species, such as River Red Gum, Common Reed and Cumbungi (*Typha sp*). River Red Gum, a species commonly found at the floodplain billabongs of the Yarra system, should typically experience flooding in July to September, remain wet over spring, then dry out in December or January. Inundation is usually required for 2–3 months to allow their seeds to germinate and young plants to establish (Boon 2010). Although adult trees are relatively flood tolerant, River Red Gum communities generally should not experience continuous flooding for more than 2 years or go for periods without flooding of more than 2 years (Boon 2010).

Other vegetation species are more tolerant of flooding at different times of year. Common Reed for example favours inundation from late winter to late summer and its canopy reaches maximum density in mid–summer. For this species, winter floods are often ineffective in promoting vegetative growth because the plant enters a long period of dormancy over winter (Boon 2010). Cumbungi behaves similarly, but can become invasive if water levels are kept too high over summer. In the case of submerged species (such as Eelgrass), permanent inundation is usually required, even if plants can survive some period of drawdown (Boon 2010).

2.4 Water-dependent birds

Water-dependent birds live on or around waterways, or source their food from waterways. Freshwater, wetland and estuarine birds are included within this definition for the EWMP, as are some seabirds. For freshwater birds, the main stem, floodplains and billabongs of the Yarra River are likely to provide important breeding habitat for species such as Musk Duck[9] (*Biziura lobata*), Hardhead[10] (*Aythya australis*), Rufous Songlark (*Cincloramphus mathewsi*) and Latham's Snipe[11] (*Gallinago hardwickii*) (SKM 2005c). However, limited information is available on the distribution of these birds in the Yarra River catchment, and little is known of the effects of river regulation and changing flow regimes on their distribution and abundance in the catchment (SKM 2005c). Estuarine bird species can be assigned to five functional groups, according to what part of an estuary's habitat they utilise (Arundel 2006). The functional groups are: raptors and other predators; aerial feeders; margin dwellers; surface feeders and sandy shore birds.

There are also a large range of seabirds dependent on flows from freshwater sources for aspects of their lifecycle, including sources of food and cues for migration and breeding behaviours. The Little Penguin (*Eudyptula minor*) is one such species.

For primarily land-based waterbirds, some 57 wetland bird species and 113 streamside bird species are expected in the Yarra catchment, being regularly found at water habitats and occurring widely within the Port Phillip and Westernport region (Melbourne Water 2013a).

A list of all bird species recorded within the Victorian Biodiversity Atlas (VBA_Fauna25) database for the Yarra River is provided in Appendix A.2.1.

2.4.1 Key flow requirements for water-dependent birds

The Yarra River supports abundant and diverse populations of water-dependent birds, especially after flooding and also during drought when it can provide important refuge for some species. Streamside birds, estuarine birds and wetland birds are all dependent on flows for the provision of habitat, feeding opportunities, nesting locations, and cues for breeding and migration. In the case of waterbirds for example, it is known that many species will breed after wetland flooding, and only two species known to be in the Yarra catchment, Musk Duck and Blue-billed Duck (*Oxyura australis),* are largely unaffected by water levels, breeding on a strongly seasonal basis instead (Briggs 1990, Boon 2009a).

The understanding of flow-ecology relationships for water-dependent birds in the Yarra River system remains poor (Melbourne Water 2013a). It is assumed that by providing the flow requirements for other biota, such as vegetation and fish, and by re-engaging floodplain billabongs, this will also have beneficial effects for water-dependent birds (Melbourne Water 2013a).

Case Study: Little Penguins foraging behaviour

Marine animals such as seabirds forage in areas where their prey aggregates (called foraging 'hotspots'), to minimise the energy expended in foraging/hunting and maximise their intake of food. Rivers entering coastal systems contain high quantities of nutrients that attractive as a food source for planktonic organisms, which in turn are attractive to schools of planktivorous fish, and which are attractive in turn to seabirds such as Little Penguins (*Eudyptula minor*). The foraging behaviour and diet of Little Penguins in Port Phillip Bay was studied over 3 years (2008, 2011, and 2012), a period of time which included the final years of the Millennium Drought and its eventual breaking. Little Penguins eat Anchovy (*Engraulis australis*), Pilchard (*Sardinops sagax*) and Sandy Sprat (*Hypherlophus vittatus*), and are particularly vulnerable to changes in the distribution and abundance of these species (Kowalczyk *et al.* 2015).

The researchers found that the level of freshwater inputs to the Bay from the Yarra River strongly

[9] Listed as Vulnerable in the Advisory List of Threatened Vertebrate Fauna in Victoria: 2013 list (DSE 2013)
[10] Listed as Vulnerable in the Advisory List of Threatened Vertebrate Fauna in Victoria: 2013 list (DSE 2013)
[11] Listed as a protected migratory species under the EPBC Act under Bonn, JAMBA and ROKAMBA international agreements

influenced the foraging behaviours of Little Penguins. In particular, the rise and fall of water depth in the river, and fluctuations in salinity are thought to play an important role in distributing both prey species and Little Penguins in Port Phillip Bay (Kowalczyk *et al.* 2015).

In periods of low flows into the Bay, such as during the Millennium Drought, the penguins were found to remain in close proximity to the river outlet. In periods of high inflows into the Bay, the penguins travelled greater distances in search of food. The researchers attributed this change in foraging behaviour to be a response to the increased dispersion of the species' prey following periods of heavy rainfall. This is in keeping with previous research that has found that during flood events or in periods of heavy rainfall, the size of river plumes increase, dispersing nutrients and affecting the distribution of planktivores and their predators (Kowalczyk *et al.* 2015).

2.5 Frogs

Most frog species require surface water for food and breeding habitat during their life cycles, and therefore waterways represent a critical habitat for them. Appendix A.2.3 lists the frog species recorded in the Yarra catchment, based on a search of the Victorian Biodiversity Atlas (DELWP 2015d). Most of these species are common and widespread across Victoria, although there are three species with high conservation status on the list, the Southern Toadlet *(Pseudophryne semimarmorata),* Growling Grass Frog *(Litoria raniformis) and* Brown Toadlet (*Pseudophryne bibronii).*

Of the frog species that are known to occur in the Yarra River catchment, they include those that use permanent pools and other in-stream habitats, and those that use off-stream habitats such as wetlands. Different frog species can breed in a variety of waterbodies, from exclusively rain-fed ponds and small depressions, to rivers and river-flow controlled billabongs. Frogs that use permanent pools and other in-stream habitats include the Growling Grass Frog, the Pobblebonk (*Limnodynastes dumerilii insularis)*, the Striped Marsh Frog (*Limnodynastes peronei)*, the Spotted Marsh Frog (*Limnodynastes tasmaniensis)*, and the Southern Brown Tree Frog (*Litoria ewingii)*. These species use permanent pools or slow flowing channel habitats with good vegetation to provide cover. They also 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 (SKM 2012c). Species that use off-stream habitats such as the Yarra River's billabongs include the endangered Bibron's Toadlet (*Pseudophryne bibronii*), and the Common Froglet (*Crinia signifera)*. These species are more dependent on catchment rainfall rather than stream flows for their sources of water (Otto 2009).

2.5.1 Key flow requirements for frogs

Some key flow-dependent factors that influence the distribution and abundance of frog species in the catchment include:

- The availability of surface water at the right time of year - The majority of Victorian frog species mate in water and lay their eggs near, or attached to, fringing vegetation
- The ability of flows to vary salinity levels - Recent research has identified a relationship between salinity and the probability and intensity of *Chytridiomycosis* fungus infections in frogs, particularly for the Growling Grass Frog (Heard *et al.* 2014a). Areas with higher salinity may provide refuges from the fungus
- The duration that waterways hold water - For successful breeding, waterways need to hold water for long enough to allow tadpoles to develop and metamorphose into adult frogs. The duration of wetting can be as short as 6 weeks for small, fast developing species, but for larger species it may need to be as long as a 12 months (Wassens 2011).
- The timing and velocity of flows - Still or slow flowing conditions are essential for tadpoles because high flows and fast moving water occurring at the wrong time can wash tadpoles out of suitable habitat. Tadpoles are not strong swimmers, and therefore most species need to breed in still, or very slow flowing water.

2.6 Aquatic macroinvertebrates

Aquatic macroinvertebrates are a diverse group of animals found in waterways. 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 Yarra River ecosystem because they are a major component of the diets of mammals such as the Platypus, as well as 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 a major determinant of the spatial and temporal dynamics of macroinvertebrate communities in streams (Bunn and Arthington 2002). Rivers with unstable substrates tend to be characterised by low species diversity, and the communities present will often have life history or behavioural characteristics adapted to live in frequently disturbed environments, such as the ability to lie dormant in burrows if parts of their habitat dry up (Bunn and Arthington 2002). Macroinvertebrates are vulnerable to rapid diurnal changes in flow; and streams with erratic flow patterns are typically characterised by species-poor macroinvertebrate communities (Bunn and Arthington 2002). Available habitat, sources of food, and water quality are also major determinants of the abundance and composition of macroinvertebrate fauna.

Appendix A.2.4 lists the invertebrate species recorded for the Yarra River in the Victorian Biodiversity Atlas (VBA_Fauna25).

2.6.1 Key flow requirements for macroinvertebrates

Very little is known about the specific flow requirements of individual groups or species of macroinvertebrates. In fact, there is very little evidence that macroinvertebrate communities respond directly to particular flow components in the same way that fish or vegetation communities may (SKM 2011b). Recent research has indicated that macroinvertebrate species may be just as diverse in intermittent and ephemeral headwaters (non-perennial) where flow is less regular and smaller in volume, or even more so, than perennial waterways (Santos and Stevenson 2011). This is thought to be because non-perennial streams are able to maintain distinct biological communities with adapted species.

River health monitoring in the Yarra River conducted by the Victorian EPA suggests that the Millennium Drought reduced the diversity and abundance of macroinvertebrates at some sites in the Warrandyte Gorge (SKM 2007). Walsh *et al.* (2011) have found that lower than normal flow in the two years prior to a sampling event can be a strong predictor of poor macroinvertebrate condition in the Yarra River. This finding suggests that when rivers are flow stressed, such as during drought, the condition of the macroinvertebrate communities in those rivers can decline. It is thought that the macroinvertebrate communities are responding to a general decline in the quality and quantity of available habitat, rather than to specific flow components (SKM 2011b).

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

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

2.7 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*" (Melbourne Water 2013a). Amenity attributes contribute to the way people appreciate and value the Yarra River and can be tangible, such as paths and natural vegetation, and intangible, such as beautiful views, cultural and spiritual places, links to history and stories, or even just knowing that wildlife is present. The amenity values derived from the Yarra River are intrinsically linked to the quality and extent of its natural vistas, the green space it provides, its vegetation and its 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 the 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 for the Yarra River

(Melbourne Water 2013a). A community perceptions survey completed by Melbourne Water every two years has found that the majority (approximately 95%) of survey participants view waterways as very important to Greater Melbourne's liveability (Melbourne Water 2012). Melbourne Water's key responsibility in managing for this value is to manage waterways as a setting that provides the tangible and intangible benefits of amenity to the community.

Open spaces associated with the Yarra River represent the largest and most important resource of parklands and green space in inner Melbourne, particularly in the more built-up areas, where the density of development is such that access to open space is limited (Planisphere 2014). These spaces are vital in contributing to the health and wellbeing of the community and the character of the local and regional landscape. Green space has been associated with a number of beneficial health effects including for reduced mortality and increased longevity, cardiovascular disease, people's self-reported general health, mental health, children's behavioural problems, sleep patterns, recovery from illness, social contacts, birth outcomes and even our microbiome (Nieuwenhuijsen 2016). Increased physical activity and social contacts, psychological restoration/stress reduction, and a reduction in pollutants such as noise and air pollution and heat have been proposed as possible mechanisms for the health benefits of green space (Nieuwenhuijsen 2016).

The extent of the remnant bushland and riverine environment that provides habitat for wildlife, and a secluded and peaceful haven for visitors, is a highly valued and unique asset contributing to the character and amenity of Melbourne.

For more information regarding the amenity value, please refer to Melbourne Water (2013b).

2.7.1 Key flow requirements for amenity

Flow requirements for amenity are difficult to define, and remain a work in progress for environmental water managers around the world. Melbourne Water has assumed that by providing flows for the ecological needs of biota within and surrounding the Yarra River, this will help to support a variety of amenity values. Amenity is currently measured through social survey results around visitation scores and the provision of facilities, and Melbourne Water is working to improve the sub-measures that make up these social, cultural and economic values.

Melbourne Water is also working to incorporate additional measures of waterway condition that better capture amenity values, and this requires an exploration of social and cultural values such that their benefits are better understood and articulated (Melbourne Water 2013b, 2015b). Linking this knowledge with environmental flows will be an ongoing activity for Melbourne Water.

2.8 Social and cultural values

The social and cultural values of rivers are often intangible and hard to define, but when asked, many people are able to talk broadly of why they like to spend time near rivers, why they like the fact that there are rivers in their region, and why they feel concerned when rivers are unhealthy. The Yarra River has woven its stories through countless generations of people, both Aboriginal and non-Aboriginal, and is prized and protected for all of the positive attributes and services it provides for the people and other inhabitants of the Yarra catchment.

Some of the social and cultural values of the Yarra River include: recreational and nature tourism opportunities; its beauty and scenic amenity; its place as the location of rituals, gatherings and ceremonies; its location for family and community events; its inspiration for art and culture; and its contribution to peoples' mental health and wellbeing. A biennial Melbourne Water community perceptions survey, the most recent conducted in 2014, identified that 95% of people consider waterways as 'very important' to Greater Melbourne's overall liveability (The Klein Partnership 2014).

2.8.1 Emerging Issue - Water-dependent Aboriginal cultural values

The way in which water-dependent cultural values of the Yarra River are best managed through the EWMP is an emerging issue for Melbourne Water.

People have lived and prospered in south-eastern Victoria for at least 30,000 to 40,000 years (Presland 2001), and the physical evidence of this occupation is present almost everywhere. Sub-surface archaeological deposits, shell middens, quarries, eel traps, artefacts scatters, scarred trees and earth mounds bear witness to many generations of continuous use by people prior to the arrival of Europeans. This enormous span of time prior to the occupation by Europeans in the Melbourne area is often a missing element in narratives about Australia (Presland 2001), and the water-dependent Aboriginal values of waterways are also only just beginning to be documented and incorporated into management plans in this country (Finn and Jackson 2011).

The Yarra catchment rests upon the ancestral lands of the Kulin Nation, who continue to live on Country and whose totems Bunjil the Wedge-Tailed Eagle and Waa remain watching over Country. These totems are still respected, and art works can be seen about the Yarra catchment in their honour (Figure 12). The collective territory of the Kulin Nation extends around Port Phillip and Western Port, up into the Great Dividing Range, and over to the Loddon and Goulburn River valleys.

The Kulin Nation is comprised of five different language groups:

- Wathaurong (Wath-er-rong) - The Wathaurong People
- Woiwurrung (Woy-wur-rung) - The Wurundjeri People
- Taungerong (Tung-ger-rong) - The Taungerong People
- Dja Dja Wurrung (Jar-Jar-wur-rung) - The Jaara People
- Boon Wurrung (Bun-er-rong) - The Boon Wurrung People (Presland 2001).

The traditional custodians of the Yarra River are the people of the Woiwurrung language group, the Wurundjeri. The Yarra River is called 'Birrarung' in Woiwurrung, which means 'River of Mists' (Presland 2001).

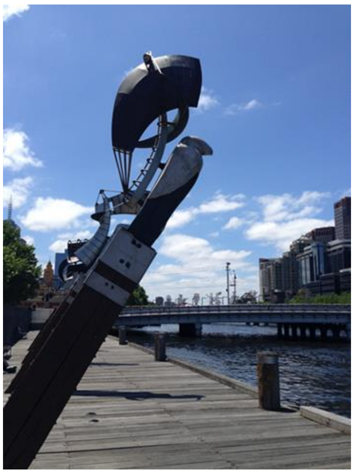

Figure 12 : Contemporary sculptures of Bunjil the Eagle. On the left is "*Constellation*", by Geoffery Barlett & Bruce Armstrong (1997), and on the right is "*Bunjil*", by Bruce Armstrong (2002)

At a local level, Registered Aboriginal Parties (RAPs) provide a voice for Aboriginal people in the management and protection of Aboriginal cultural heritage values in Victoria. The Wurundjeri Tribe Land and Compensation Cultural Heritage Council are the recognised Traditional Custodians of the country that includes the Yarra River. Figure 13 illustrates the extent of Yarra River country covered by the Wurundjeri RAP area within Melbourne Water's jurisdiction.

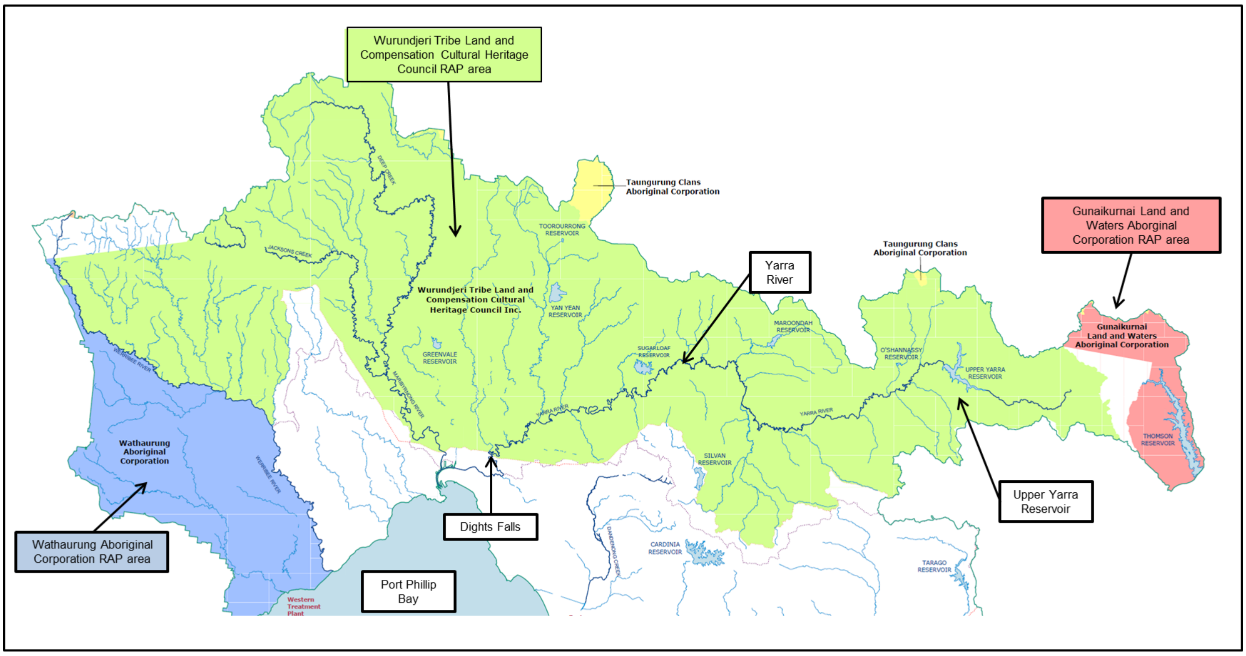

Figure 13 : Extent of overlap between Wurundjeri RAP area and Melbourne Water area

There are a large number of previously recorded Aboriginal archaeological sites located along the Yarra 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 some of these sites, their specific locations along the river cannot be discussed for the EWMP. There are, however, many sites of significance along the Yarra River that are well known in the public domain including:

- Yingabeal Scar Tree at the Heide Museum of Modern Art - A canoe tree and a Marker Tree at the junction of five Wurundjeri Songlines[12]
- Bolin Bolin Billabong and Banyule Flats Billabong - These billabongs were meeting points for Kulin nation people as well as groups as far away as the Murray region to carry out trade, ceremonies, initiations and marriages, and to resolve interpersonal conflicts (Context 2014)
- The confluence of Merri Creek and the Yarra River – The burial site of Billibellary, the clan headman of the Wurundjeri when Europeans began arriving in the Yarra catchment area, still honoured to this day for his strong and charismatic leadership qualities (Otto 2009). This site was also the location of an 1850s Aboriginal school and Native Police station (Canning and Thiele 2010)[13].
- The Battle of Yering Memorial at the Murrup Brarn Yering Flats billabongs - The site of a battle between Border Police and 50 members of the Wurundjeri in 1840
- Pound Bend – A central living and gathering place for the Wurundjeri and the site of the Pound Bend Aboriginal Reserve which was created in 1850. With the last Gayip (Corroborree) held in 1852 at the site, it also marks the site where traditional Wurundjeri life ended (Canning and Thiele 2010).

A recent discovery along the Yarra River has been an eel trap site at Laughing Waters near the suburb of Eltham. The eel trap was discovered after willows were cleared from the river, and has been extensively repaired by the Wurundjeri. The site is now the location of education and ceremonial events for the Wurundjeri, and an annual eel trap site visit is held to educate visitors on the traditional and contemporary uses of the Yarra River (Figure 13 and Figure 15). Prior to European occupation, the Wurundjeri would

[12] A songline, also called a dreaming track, is one of the paths across the land which mark the route followed by localised creator-beings during the Dreaming. The paths of the songlines are recorded in traditional songs, stories, dance, and paintings. Knowledgeable people are able to navigate across the land by repeating the words of the song, which describe the location of landmarks, waterholes, and other natural phenomena. Songlines also described seasonal firestick farming schedules, species conservation and land management practices, as well as the Dreamtime creation stories of each area.

[13] Government in the 1850s encouraged the 'civilisation' of Aboriginal people through the establishment of a Native Police corps. The corps was mainly composed of Aboriginal men, often Elders, who the government hoped would become 'civilised' through their experience as policemen (Canning and Thiele 2010).

have extensively used the site for eel harvesting, and with agricultural activities nearby such as the growing of Murnong (Yam Daisy) (*Microseris lanceolate*), would have led to a relatively comfortable existence (Wurundjeri Elder Uncle David Wandin, pers.comm.)

Figure 14 :Eel trap rock structure

Figure 15 : Wurundjeri Elder, Uncle David Wandin, demonstrating the use of a woven eel basket

Recent scans of the floor of Port Phillip Bay have revealed ancient channels of the Yarra and Werribee River, which would have flowed over what was once dry land before joining up and entering a much smaller lake closer to the southern side of the Bay (Lake Phillip). At some stage about 1000 years ago a seismic event is thought to have flooded the region, creating the Bay as we know it now (Holdgate *et al.* 2011). Aboriginal stories and memories of the Yarra River and Port Phillip Bay extend back thousands of years (Nunn and Reid 2015), and a Wurundjeri creation story about how the Yarra River was formed is now thought by researchers to reflect a long-standing cultural memory of the Port Phillip Bay flooding event. The story is told below.

How the Yarra was formed – A Kulin Creation Story

“Once the water of the Yarra was locked in the mountains. This great expanse of water was called Moorool, or Great Water. It was so large that the Woiwurong had little hunting ground. This was in contrast with the Wothowurung and the Bunurong, whose hunting ground was the lovely flat which is now Port Phillip Bay.

Mo-yarra, slow-and-fast-running, was the head man of the Woiwurong. He decided to free the country of the water. So he cut a channel through the hills, in a southerly direction, and reached Western Port. However only a little water followed him and the path cut for it gradually closed up and the water again covered the land of the Woiwurrung. At a later time the head man of the tribe was Bar-wool. He remembered Mo-yarra's attempt to free the land. He knew that Mo-yarra still lived on the swamps beside Western Port (Koo-wee-rup). Each winter he saw the hill tops covered with the feather down which Mo-yarra plucked from the water birds sheltering on the swamps.

Bar-wool resolved to free the land. He cut a channel up the valley with his stone axe. But he was stopped by Baw-baw, the Mountain. He decided to go northwards, but was stopped by Donna Buang and his brothers. Then he went westwards and cut through the hills to Warr-an-dyte. There he met Yan-yan, another Woiwurong, who was busily engaged in cutting a channel for the Plenty River in order to drain Morang, the place where he lived. They joined forces, and the waters of Moorool and Morang became Moo-rool-bark, the Place-where-the-wide-waters-were. They continued their work and reached the Heidelberg-Templestowe Flats, or Warringal, Dingo-jump-up, and there they rested while the waters formed another Moorool.

Bar-wool and Yan-yan again set to work, but this time they had to go much slower because the ground was much harder. They were also using up too many stone axes. Between the Darebin and the Merri Creeks they cut a narrow, twisting track, looking for softer ground. At last they reached Port Phillip and the waters of Moorool and Morang rushed out. The country of the Woiwurrong was freed from water but Port Phillip was inundated." (Source: Museum of Victoria (2016))

2.8.2 Key flow requirements for Aboriginal water-dependent values

Aboriginal people hold distinct cultural perspectives on water, relating to identity and attachment to place, environmental knowledge, resource security, and the exercise of custodial responsibilities to manage the inter-related parts of their country (Jackson 2006). In their belief systems, water is a sacred and elemental source and symbol of life, and aquatic resources constitute a vital part of this value. It is only recently that work has begun to conceptualise the nature of Aboriginal water uses and needs, and to develop techniques to understand the relationship between flow and Aboriginal water values (Jackson 2006, Jackson and Morrison 2007).

At least until recently, the approach has been to assume that Aboriginal requirements would be served through a surrogate environmental flow (Jackson and Morrison 2007). This becomes a problem when flows studies, with their strong ecological focus, do not identify sites within or near waterways that are significant for reasons other than Western-accepted ecological and/or economic values. For example, environmental flow studies will typically assess the flow requirements of high conservation value species, which are then seen as appropriate target species for environmental flows due to their threatened nature (Finn and Jackson 2011). Other species that are relatively common and abundant, such as eels or turtles, are less likely to be incorporated into flow recommendations. Waterways that support fewer environmental conservation values, but which may still be highly valued by Aboriginal communities for sites of spiritual significance and for their role as a nursery ground for a wide variety of plants and animals with totemic, ceremonial, seasonal change and food resource values, may also be excluded from environmental flow planning exercises.

It is likely that Aboriginal people will have different management objectives to other stakeholders in the management of the Yarra River and Country. Melbourne Water is currently undertaking a collaborative project with the Wurundjeri to better understand these water-dependent values, and as this knowledge is gained, it will be incorporated into the Yarra River EWMP and more broadly as policy for water resource management.

Case Study – Eel flow requirements

It was once common practice in parts of Victoria for traditional Aboriginal communities to farm and harvest eels, and this activity remains an important contemporary value for the Wurundjeri. In the past, extensive and complex channel, embankment and trapping networks were constructed to support the control, farming and harvesting of eel populations. Stone weirs were constructed, such as that shown in Figure 13 and were used to guide migrating eels into nets or basket traps (DNRE 2002). Eel fishing seasons at such locations extended for 1-2 months per year, sometimes with individual family groups harvesting from their own dedicated weir (DNRE 2002). Large numbers of people often gathered for "eel feasts", with attendances of up to 2500 recorded in some regions (DNRE 2002).

Victorian freshwater eels undertake a large migration journey in late summer and autumn to a location somewhere southeast of New Guinea in the Coral Sea. This is the sole spawning site for all Australian and New Zealand freshwater eels, with some eels having to travel in excess of 3,000 kilometres to get there. They begin their lives at this spawning site as tiny transparent larvae, and as they move with the currents to the east and southeast coast of Australia, they metamorphose into juvenile 'glass eels'.

Once glass eels move closer to land they commence migrating towards estuaries. The species' attraction to an estuary depends on the ability of the juveniles to detect freshwater flows. In years when river flows are low and estuaries may even be closed, the recruitment of glass eels is reduced or may be zero (DNRE 2002). Short-finned glass eels enter estuaries mainly during mid-winter to late spring, while long-finned glass eels enter estuaries from mid-summer to late autumn, with both species relying on tides to move upstream (DNRE 2002). During their migration upstream to freshwater, the young eels are able to climb barriers such as waterfalls and even dam walls (Gomon and Bray 2011). Once eels arrive in the upper reaches of the river around springtime, they can remain there for decades before migrating back out to the ocean to breed and die. It is thought that migration out to sea is cued by increased river flows, but the data on this is currently poor (Crook *et al.* 2014).

2.9 Other social and cultural values

The upper Yarra region is a favourite holiday destination for Melbournians, and it is particularly popular for sightseers visiting the forested areas close to Melbourne and the Yarra Valley wine region. For over 150 years, the Yarra has been the location of recreational pursuits such as swimming, boating, fishing and walking. Many swimming clubs were once located along the banks between Collingwood and Heidelberg, including the Fairfield swimming club, where a bend on the river was enlarged and steps built to create a safe swimming area (SKM 2005c). Rowing regattas remain popular social events on the lower reaches of the river, and hundreds of rowers can be seen along the River most mornings as they train. Canoeing and kayaking are also popular recreational and competitive pursuits on the river, and a strong non-motorised boat users community is keen to make use of the shared benefits of environmental flow releases.

Swimming is currently prohibited in the lower estuary for safety reasons associated with boating, but there are a number of popular swimming holes in the upper reaches, including at Laughing Waters near Eltham. An extensive network of bike paths, urban parks and golf courses along the river between Melbourne and Warrandyte ensures easy access for people, and is also one of the reasons why the Yarra River is of such considerable social value to the people of Melbourne (SKM 2005c).

The social values of the Yarra River were categorised during the development of Melbourne Water's Healthy Waterways Strategy using a consultative process (Melbourne Water 2013a). A community survey is also undertaken every two years to examine the perceptions that Melbournians have of their local waterways and the elements of waterways that they value. These surveys have found that exercising is one of the main reasons people visit a waterway in the Melbourne region, followed by relaxation and social gatherings such as picnics and BBQs (The Klein Partnership 2014).

2.9.1 The artistic values of the Yarra River and its billabongs

Inspired by the beautiful landscapes of the Yarra and the unique light that typifies the Australian bush, the Yarra River, its tributaries and its billabongs have been the subject of many paintings by Aboriginal and European artists. For example, the Yarra River near Banyule Flats Billabong is well-known internationally because it has been the subject of many landscape paintings of the Heidelberg School (Figure 16), a famous Australian art movement originating in the late 19th century and often described as the first important Australian art movement (Context 2014).

Figure 16 : A painting by Heidelberg School artist Charles Conder titled: 'On the River Yarra near Heidelberg' (circa 1890). Source: (Art Gallery NSW 2015)

2.10 Economic Values

Many commercial enterprises are highly dependent on the Yarra River. The River contributes to the economy via the direct supply of goods and services associated with its flowing waters, and by more intrinsic values that are harder to quantify. Some general economic values for the Yarra River include the following:

- Provides water, transport and storage for farming, recreation, industrial and urban users and provides stable, clean water supplies
- Commercial fisheries and recreational fishers in freshwater reaches, the estuary and Port Phillip Bay are reliant on its flows
- Supports sporting, tourism and recreation industries
- Scientific and education industries
- Transport and port facilities in the lower reaches
- Amenity values, which are known to increase property values and improve consumer activity in some areas
- Strong influence on the liveability[14] of the Melbourne region
- The provision of ecosystem goods and services[15], such as nutrient cycling, carbon storage, and reduction of the urban heat island effect[16]
- Provides a location for important social and cultural events, such as Melbourne's annual Moomba Festival (Jones *et al.* 2015).

Melbourne Water has commissioned a project to value the benefits of Environmental Water from the three environmental entitlements that it manages in the Port Phillip and Westernport Region (in conjunction with VEWH). The Yarra River Environmental Entitlement 2006, the Tarago and Bunyip Rivers Environmental Entitlement 2009, and the Werribee River Environmental Entitlement 2011 will all be assessed. The project is identifying and measuring how priority watering actions contribute towards achieving environmental outcomes and the scale and extent of these (e.g. measured in fish population numbers), compared with what would happen if the flows did not happen. The project is then identifying and measuring how much people value these 'with versus without' environmental flow outcomes; that is, how much are people willing to pay for these outcomes to occur. The project is developing an evidence base to show the economic value that these environmental watering investments generate, and will help with identifying priorities when compared with other investment options (like revegetation or development of wetlands or provision of other habitat etc.)

The 2005 environmental flows study and 2012 flows study review for the Yarra River summarised a range of social and economic values for the Yarra River on a reach by reach basis. These are listed in Table 4.

Table 4 : Economic and social values of the Yarra River (Source: Adapted from SKM (2005c))

Reach	Location	Description
Reach 1	Upper Yarra Reservoir to the Armstrong Creek Junction	Social values in Reach 1 are relatively low but do include its landscape value, public open spaces, and habitat for flagship species, specifically River Blackfish. Heritage values associated with the Upper Yarra Reservoir and the mining and forestry history in the region are also important.

[14] Liveability roughly equates to how a particular place contributes to the social welfare of its people and communities.
[15] Ecosystem services are the benefits that are obtained from the environment that contribute directly or indirectly to human wellbeing, such as clean air, clean water and climate regulation
[16] The urban heat island effect is where a city or metropolitan area is significantly warmer than its surrounding rural areas due to human activities.

Reach 2	Armstrong Creek to Millgrove	Social values increase significantly in Reach 2 and include active and passive recreation activities such as sightseeing, camping, fishing and swimming. Cultural values, open space and the presence of flagship species are also important to the community. Economic values associated with tourism and water supply are important in this reach. Recreational fishing is a particular value with the target species being the introduced brown and rainbow trout, although angling for River Blackfish also occurs.
Reaches 3 and 4	Millgrove to the Watts River junction	Values in Reach 3 and 4 are very similar and include fishing, passive recreation, flagship species and heritage values. Exotic fish, weeds and degradation of the streamside zone represent threats to these values. However, access to the river through reaches 3 and 4 is limited and may impact on values to some extent. Economic values associated with tourism and agriculture, particularly associated with the wine and gourmet food industry, are high.
Reach 5	Top of Yering Gorge to Mullum Mullum Creek	Values in this reach include opportunities for active and passive recreation, particularly fishing, canoeing, swimming and access to public open space. The presence of flagship species (eg platypus and water rats) is also considered important. Economic values include increasing tourism, water supply and land values. Recreational fishing is an increasingly popular activity with the main target species Macquarie Perch and Murray Cod.
Reach 6	Mullum Mullum Creek to Dights Falls	Values in Reach 6 are similar to those in Reach 5 with increasing value associated with passive recreation opportunities and a sense of naturalness in an urban environment. Aboriginal and European cultural and heritage values through this reach are very high. The formation of parklands through this reach has resulted in a significant revegetation of the riparian zone.
Reach 7	Yarra Estuary	The linear parklands along this reach allow easy access and provide for a sense of open space in a heavily urbanised environment. Values include fishing, boating, picnicking and walking. The Yarra through this reach is also the focus of urban development and renewal with the construction of promenades and commercial and residential developments on the water's edge, particularly through the Docklands area.
Reach 8	Watts River from Maroondah Reservoir	Social values in this reach are moderate to high and include fishing, the presence of flagship species, landscape, and passive recreation. Values are typically localised to the community around Healesville.

2.11 Ecosystem functions of the Yarra River

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 5 provides a description of a range of key ecosystem functions that are critical in supporting the water-dependent environmental values of the Yarra River.

Table 5 : Key ecosystem functions

Ecosystem Function	Description
Supports the creation and maintenance of vital habitats and populations	The Yarra 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 Yarra 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 flow requirements of the waterway's biota.
	The Yarra 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 Yarra 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.
Supports vital social services	The Yarra's billabongs provide flood control (risk reduction), cooling, visual amenity, nutrient cycling, carbon storage and educational services. At the individual scale, people enjoy additional wellbeing, recreation and visual amenity as social services for billabongs. At the community scale, a billabong may be a place of shared values, act as a meeting place and have a 'Friends' group, which adds value to the billabong and to the community
Provides connections along a watercourse (longitudinal connections)	The Yarra River requires environmental watering to sustain it because it provides longitudinal connections to Port Phillip Bay and the ocean for numerous migratory species that need to fulfil stages of their life-history in the ocean and/or in the freshwater reaches of the river.

2.12 Conceptual models

FLOWS studies for the Yarra River have considered the following flow components:

- Winter/Spring and Summer/Autumn low flows, freshes and high flows; and
- Winter/Spring bankfull flows and overbank flows.

In summary:

- Low flows generally provide a continuous flow through the channel. This may either maintain the flow above a 'cease to flow', or provide habitat as a change from 'high flows'
- Freshes are small or short duration peak flow events. These flows exceed the base flow and last for at least several days. Freshes are a key contributor to the variability of flow regimes, providing short pulses in flow
- High flows are persistent increases in the seasonal base flows that remain within the channel. They do not fill the channel to 'bankfull'.
- Bankfull flows are flows of sufficient size to reach the top of the river bank with little flow spilling onto the floodplain
- Overbank flows are flows that result in inundation of adjacent floodplain habitats. These flows are critical for a range of ecological factors, including floodplain productivity (Figure 17).

Billabong assessments have also documented the need for periods of dryness for these wetlands.

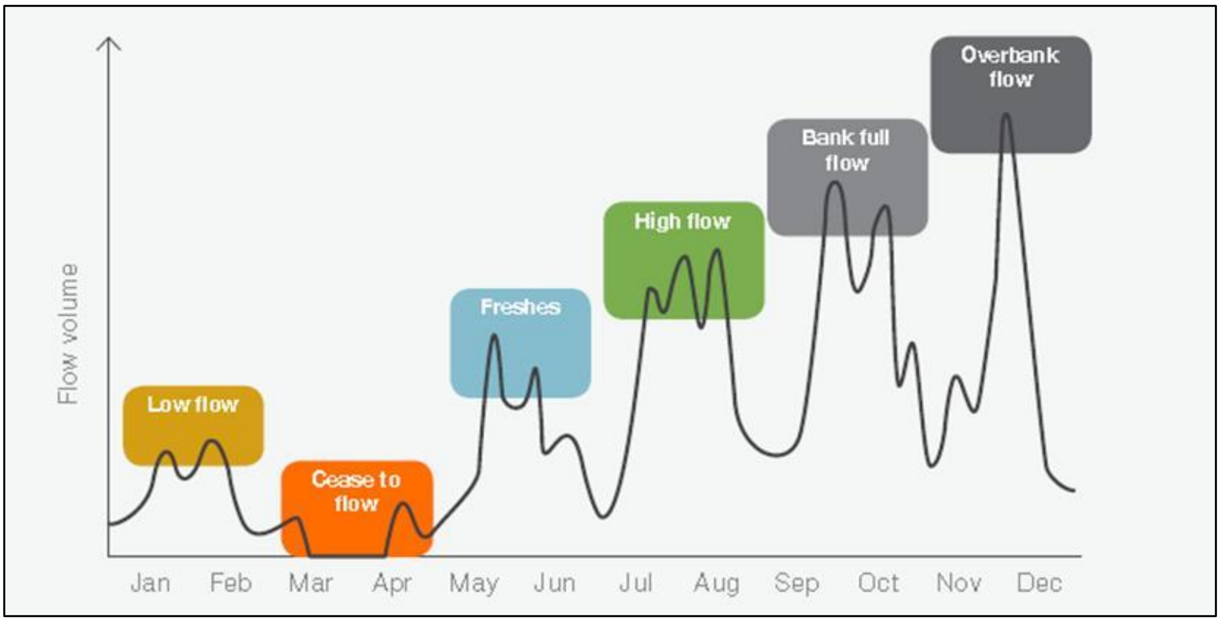

Figure 17 : Typical natural flow pattern of a Victorian river before construction of dams, weirs and channels (Source: (VEWH 2016)

A number of conceptual models have been developed for the Yarra River, and incorporate these flow components, linking to life cycle requirements for a range of key values in the waterway.

2.12.1 Freshwater reaches

The conceptual model illustrated in Figure 18 shows how different flow components and ecological processes interact for a range of freshwater values in the main reaches of the Yarra River. 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 small-bodied fish (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, for example 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 Platypus locate their burrows to ensure they are high enough up the bank to not be flooded when juveniles are present (12).

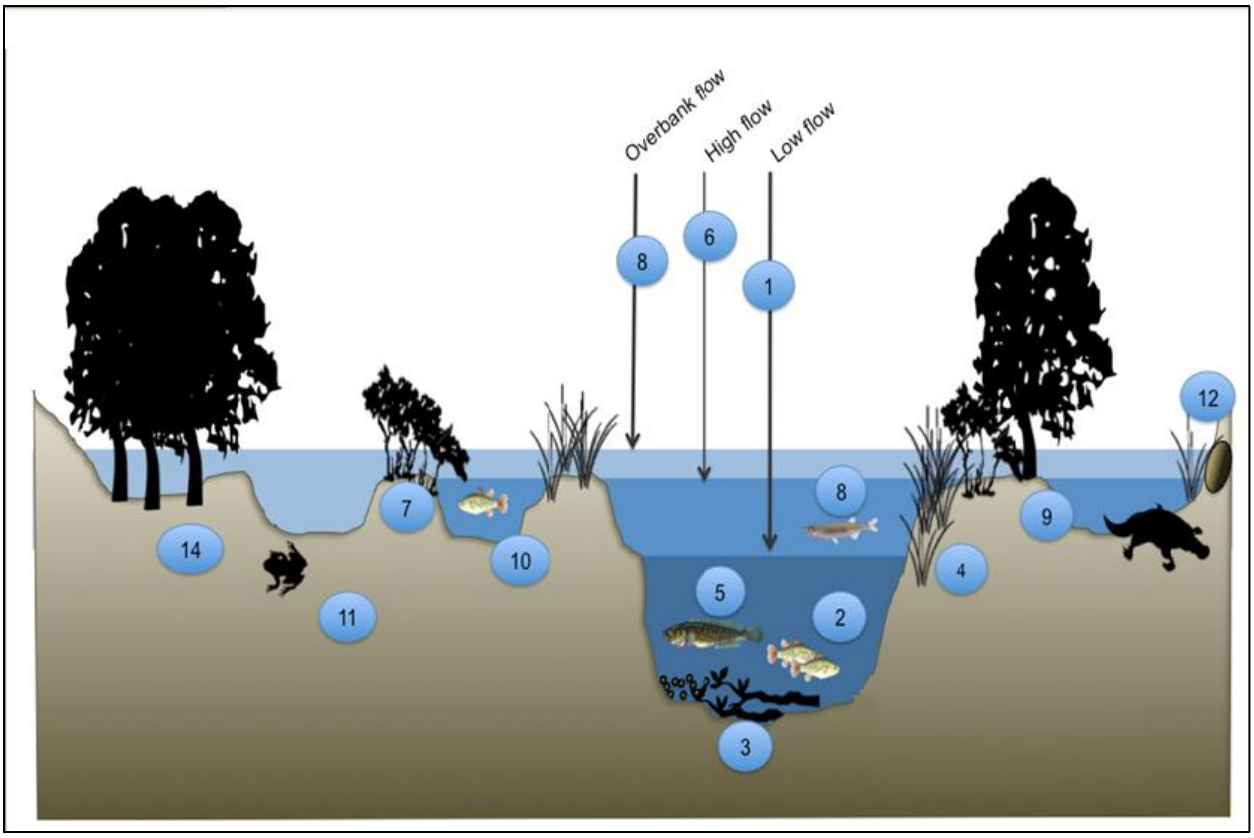

Figure 18 : Conceptual model for freshwater reaches of the Yarra River

2.12.2 Estuary

The conceptual model illustrated in Figure 19 illustrates how a range of hydrology and ecological processes interact for some of the estuarine values of the Yarra 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 or other submerged vegetation (4) until more mature.
- Zooplankton (5) are a valuable food source for fish and other organisms in the estuary. Freshwater flows bring a range of nutrients into the estuary (11), and in the soil and the water of the estuary, zooplankton, bacteria and other living organisms such as microscopic plants will use these nutrients to grow. Some marine species, such as Snapper (6), breed in the marine environment, and their larvae are heavily reliant on zooplankton for food once hatched.
- The Common Galaxias, a migratory fish (7), relies on freshwater flows to cue its movement from the upstream freshwater reaches down into the estuary. Common Galaxias lay their eggs on samphire[17] and in flooded wetlands of estuaries (8), and once the eggs hatch the juveniles are washed out to sea, to return once mature.
- Overbank flows support estuarine wetlands (8), EVCs such as coastal saltmarsh (9), and swamp scrub (10), with these vegetation communities requiring regular inundation from overbank flows to maintain their ecological health.

[17] Samphire is a native succulent plant found on coastal flats.

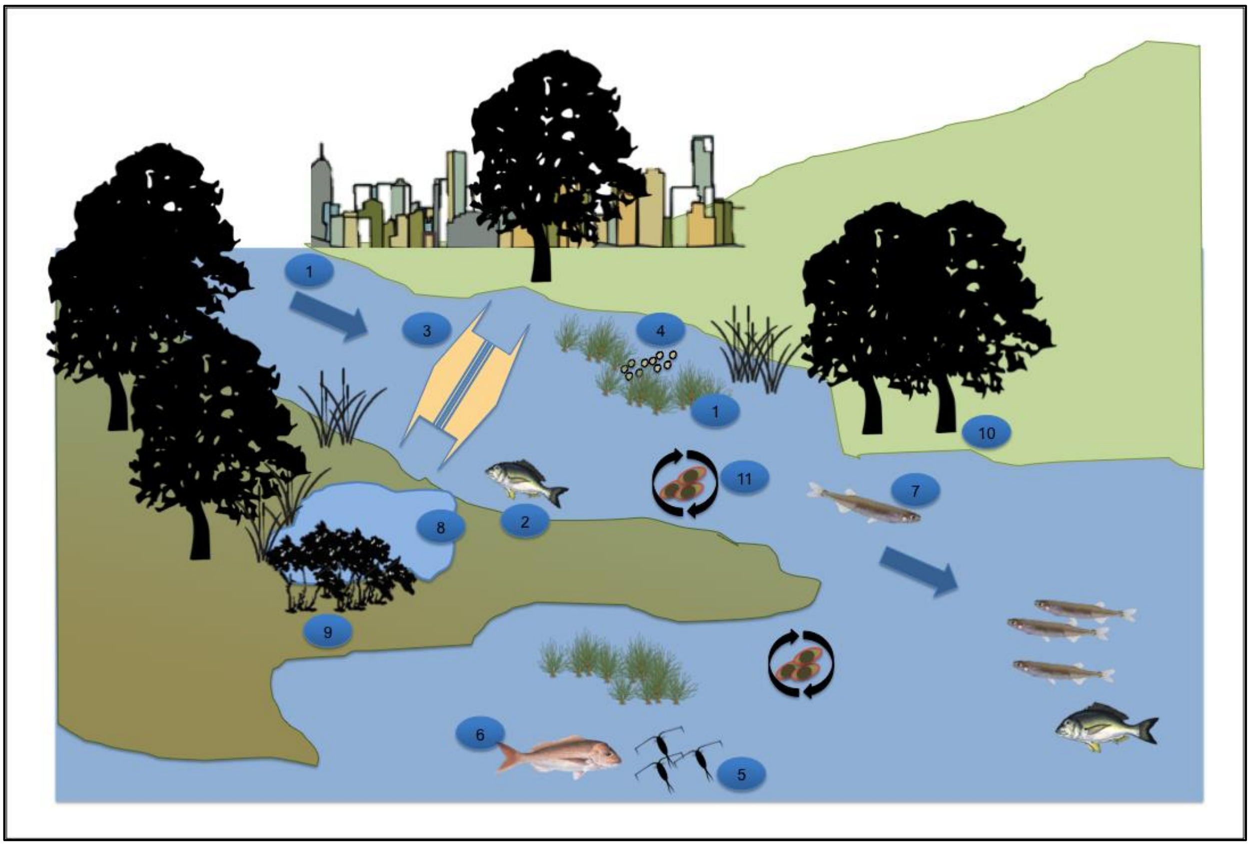

Figure 19 : Conceptual model for the Yarra River Estuary

2.12.3 Billabongs

The conceptual model shown in Figure 20 illustrates how hydrological and ecological processes interact for a range of billabong values along the Yarra River. The explanation is as follows:

- Flood tolerant floodplain vegetation communities around billabongs (1) such as River Red Gum, often require regular inundation to enhance their recruitment success, and to maintain and enhance their extent and diversity.
- Waterbirds, frogs and reptiles (2), rely on a diverse range of habitat types in and near billabongs that have been created by a range of river flows, and they also rely on the feeding and breeding opportunities created by seasonal patterns of inundation in the billabongs.
- Carbon decomposition, nutrient cycling and sedimentation, and transport processes (3) are influenced by the variable and seasonal regime of inundation and drawdown in billabongs. This in turn influences the abundance of food such as zooplankton for fish to feed on (4).
- Pest species such as Gambusia (7) are less able to tolerate a seasonal draw down of billabongs, which will in turn benefit small-bodied native fish due to less predation, disease and competition for resources (4).
- A diverse submerged and emergent vegetation community (6) can provide small-bodied native fish with better refuge from predation.
- Emergent macrophytes (e.g. sedges and rushes) in the wet-dry littoral zones of billabongs (5) will improve in extent and diversity with a more seasonal wetting and drying regime.
- Lateral connectivity (8) is enhanced and maintained between the billabongs of the floodplain and the river where there are seasonal inundation regimes that allow for overbank flows to spread across the floodplain.

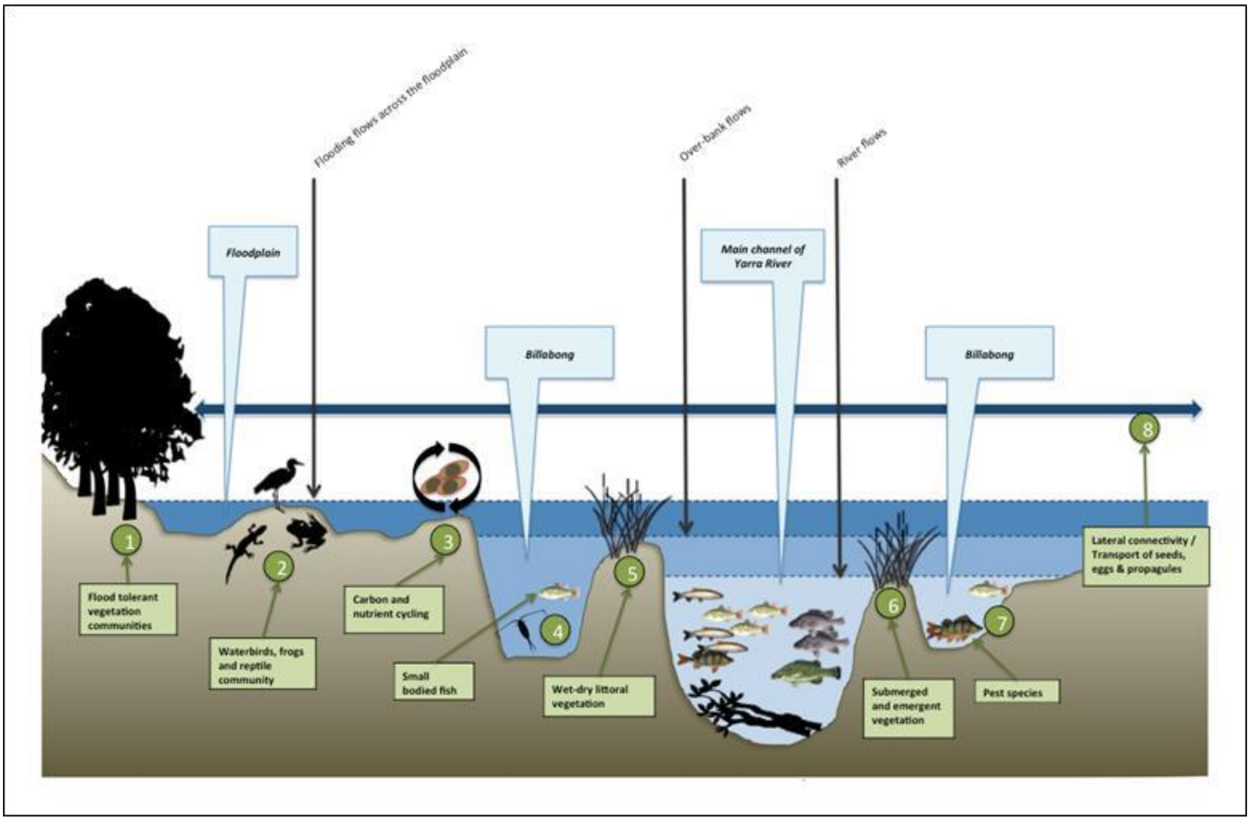

Figure 20 : Conceptual model for the billabongs of the Yarra River

3. Condition

3.1 Index of Stream Condition

Waterway condition for the Yarra 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 most reaches along the Yarra River were in moderate to very poor condition, with only one reach in good condition.

Table 6 shows the 2010 scores for the range of sub-indexes assessed for the ISC, where 0 equals very poor and 10 equals excellent. The approximate correspondence with environmental flows study reaches is also indicated in the table.

Table 6 : 2010 ISC results for the Yarra River and Watts River (Source: http://ics.water.vic.gov.au/ics/ Viewed 18/07/2016)

River	ISC Reach No.	Corresponding flows study Reach	Hydrology	Physical Form	Streamside Zone	Water Quality	Aquatic Life	Total Score	Condition
Yarra	1	5 and 6	6	6	9	6		33	Moderate
	2	4	1	7	7	7	2	27	Moderate
	3	3	1	5	6	5	8	29	Moderate
	4	2 and 3	1	5	8	8		34	Moderate
	5	1 and 2	10	7	9			39	Good
	6	1	0	6	10		10	25	Moderate
	117	6	1	7	7		4	19	Very Poor
	118	7	1	8	7	4		19	Very Poor
	218	7		10	6			19	Very Poor
	219	7		10	4	3		14	Very Poor
Watts	22	8	1	6	7	4		18	Very Poor

The condition of ecological values dependent on the Yarra River is highly influenced by the impacts of human activities in the Yarra catchment. Urbanisation, river regulation, pest plants and animals, and agriculture and land clearing have all significantly reduced the abundance, diversity and extent of these values. While much work is underway to rehabilitate, maintain and improve the condition of Yarra River values, a range of risks and threats continue to provoke a downwards trend. Emerging issues such as climate change and increasing urbanisation in the upper catchment are likely to have additional serious impacts on the condition of already vulnerable species and communities.

3.2 Platypus

Although the platypus remains widely distributed across its natural range in Australia, scientists are becoming increasingly concerned at the species' downwards trajectory. Monitoring is showing that in many areas within its natural range, platypus populations are decreasing, to the point of extinction in some catchments (Lunney *et al.* 2008a). The platypus is currently still considered of "least concern" under the current IUCN red listing, but its current conservation status in Australia was recently changed to "Near Threatened" under the CSIRO's 'Action Plan for Australian Mammals (Lunney *et al.* 2008b, Woinarski *et al.* 2014).

The Melbourne Water Urban Platypus Program (MWUPP) has been in operation since 1995 and provides invaluable data on the condition and trajectory of Melbourne's platypus populations as well as important biological information on the species. Although the platypus remains widely distributed throughout Melbourne's catchments, a significant decline in their abundance and distribution has been detected over the past two decades, with many surveyed locations indicating low or very low abundances (cesar Unpublished report 2015). The extended drought conditions through the Millennium Drought and habitat fragmentation are thought to be the major factors behind the decline, but additional pressures from human activities such as habitat degradation, litter[18], fishing practices and introduced predators (Lunney *et al.* 2008b) are also likely to have significantly impacted the platypus population in the Melbourne region (Serena *et al.* 2016).

The Yarra catchment contains the most extensive interconnected network of waterways in the Melbourne region, including some areas of good platypus habitat (Serena *et al.* 2016). The Yarra catchment also has the largest and healthiest population (Weeks 2014), with platypuses known to occur along the middle and upper Yarra River and associated tributaries as far downstream as Heidelberg. A number of the large weirs in the upper Yarra region (e.g. Upper Yarra Reservoir, O'Shannassy Reservoir, McMahons Reservoir, Maroondah Reservoir and Lillydale Lake) also have populations of platypuses. The populations upstream of the weirs are likely to be at least partially isolated from the rest of the catchment although little information on the state of these populations is available (Serena *et al.* 2016).

Table 7 summarises condition, trend and predicted trajectories for platypus in the Yarra River, broken down into the Upper, Middle and Lower Yarra management units.

Table 7 : Condition rating and trends for platypus in in the Yarra catchment (Source: Melbourne Water (2013a)

Management Unit	Condition Rating and Trend	Comment
Upper Yarra	Very low and decreasing	Platypus populations have declined over the past decade, which is attributed to the long Millennium Drought. However, platypus populations are still relatively large and so sightings of platypus in the upper tributaries are common.
Middle Yarra	Very low and decreasing	The Millennium Drought saw platypus numbers reduce significantly. Populations in the Middle Yarra are still common although population sizes are smaller than those found in the Upper Yarra.
Lower Yarra (including estuary)	Very low and decreasing	Platypus habitat has been significantly altered by the impacts of urban development. Platypus population sizes have declined since 1990, possibly due to the effects of reduced flows. Platypus are now rare, however medium-size populations are found in some urban sections of the Yarra River.

For more detail about the threats faced by platypus in the Yarra River, please refer to SKM (2012c) and (Jacobs *et al.* 2016).

3.3 Fish

Native fish condition was extensively assessed by Melbourne Water at the catchment scale during the development of the Healthy Waterways Strategy, using species richness and nativeness indicators and a range of metrics from an Independent Sustainable Rivers Audit (SRA) (Alluvium 2011, Melbourne Water 2013a). Table 8 summarises condition, trend and predicted trajectories for fish in the Yarra River, broken down into the Upper, Middle and Lower Yarra management units. The condition of a small selection of specific native species is also discussed.

For further detail regarding the condition and trend of fish species, please refer to SKM (2012c).

[18] Litter entanglement is known to injure and kill significant numbers of platypus in the Melbourne region each year, particularly in the more urbanised areas where there is higher litter input into waterways.

Table 8 : Condition rating and trends for fish in in the Yarra catchment (Source: Melbourne Water (2013a)

Management Unit	Condition Rating and Trend	Comment
Upper Yarra	Moderate but stable	Fish populations have declined in abundance and extent over the past 200 years. However, a large number of native species occur and populations have been stable in terms of diversity over the past decade. The decline in abundance and extent is largely due to introduced fish and river regulation.
Middle Yarra	Moderate and stable	Native freshwater fish species recorded in this system have been stable over the past decade, but introduced fish species are widespread.
Lower Yarra (including estuary)	Moderate and declining	A decline in the variety and proportion of native fish species vs introduced fish species in the lower freshwater reaches of the Yarra has occurred since the 1990s. There is a moderate variety of native fish species, but introduced species are relatively abundant. Declines in the condition of estuarine species have also been detected, for example Black Bream, Snapper and Sand Flathead.

3.4 Macroinvertebrates

The Healthy Waterways Strategy uses SIGNAL scores (Stream Invertebrate Grade Number – Average Level) and AUSRIVAS to assess the condition of macroinvertebrates in the Yarra system. The two measures are combined to form an overall ISC sub-index – Aquatic Life (Melbourne Water 2013b). In general, macroinvertebrate condition decreases downstream and very few sites along the Yarra River can be considered to be of reference condition for macroinvertebrates (SKM 2012c). A sudden decline in macroinvertebrate condition is particularly notable at the transition from the forested areas, higher in the catchment, to the main agricultural region in the Yarra valley. Severely degraded riparian zones in the agricultural mid-Yarra Valley limit the availability of edge habitat and as a consequence have reduced macroinvertebrate species richness, with hardier communities that are less sensitive to poor habitat conditions tending to be more common (Bessell-Browne, 2000a in SKM (2012b)).

Table 9 summarises condition rating and trends over the past decade for macroinvertebrates, broken down into the Upper, Middle and Lower Yarra management units.

Table 9 : Condition rating and trends for macroinvertebrates in the Yarra catchment (Source: Melbourne Water (2013a)

Management Unit	Condition Rating and Trend	Comment
Upper Yarra	High and stable	Macroinvertebrate populations have remained generally stable over the past decade due to the high quality of vegetation and water in the upper catchment.
Middle Yarra	Moderate and stable	The condition of macroinvertebrate communities is highly dependent on the quality of water in the system. Rural and urban development has led to a decline in water quality and for this reason macroinvertebrate condition is moderate.
Lower Yarra (including estuary)	Low and stable	Many waterways have been substantially modified in the Lower Yarra, including straightening, diversions of water upstream, channelling and concrete-lining, reducing the amount and quality of natural vegetation and ecosystem function and also resulting in low flows and low dissolved oxygen, which are detrimental to macroinvertebrate communities.

3.5 Frogs

Frog condition in the Yarra catchment is determined by measuring species richness, and comparing species numbers determined through recent surveys to the number of species expected to have occurred historically (Melbourne Water 2013b). 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. Investigations to determine the condition of frog populations in the Yarra catchment are limited, but it is known that diversity has declined significantly since European occupation, (Melbourne Water 2013).

Table 10 summarises condition rating and trends over the past decade for frog species in the Yarra catchment.

Table 10 : Condition rating and trends for frogs in the Yarra catchment (Source: Melbourne Water (2013a)

Management Unit	Condition Rating and Trend	Comment
Upper Yarra	Moderate	Nearly all of the expected 13 species have been recorded in this management unit, which is home to endangered and vulnerable species such Bibrons Toadlet, Growling Grass Frog and Southern Toadlet
Middle Yarra	Very high and stable	The diversity of frog species has remained high. This management unit is home to endangered and vulnerable species such as Bibrons Toadlet, Growling Grass Frog and Southern Toadlet
Lower Yarra (including estuary)	Very high and stable	Fourteen of an expected 15 species have been recorded and endangered and vulnerable species such as Bibrons Toadlet, Growling Grass Frog and Southern Toadlet are present.

3.6 Vegetation

In the Healthy Waterways Strategy, vegetation condition is assessed using the ISC Streamside Zone score. The ISC combines information on the width, continuity and diversity of native vegetation, with information on weed cover to evaluate the overall health and quantity of streamside vegetation by comparing it with an Ecological Vegetation Class (EVC) benchmark (Melbourne Water 2013b). Table 6 shows the 2010 ISC scores for the Streamside Zone sub-index across the Yarra River catchment.

The width of the riparian zone in the Yarra River catchment is variable and dependent on the surrounding land use. In the upper reaches and where access is limited, much of the original vegetation remains intact and is continuous. However in agricultural and urban areas, the riparian zone is sometimes no more than one tree wide and is dominated by alien species. Clearing of land for agriculture has been most intense in the low-lying floodplains and where the river flows through flat land and the impact has been that riparian EVC's are now considered regionally endangered (Craig *et al.* 1995). Exotic species are widespread throughout the catchment, especially in the urban fringes and the two most significant exotic species present in the catchment are Willows (*Salix spp.)* and Blackberries (*Rubus fruticosus*) (Craig *et al.* 1995).

Table 11 shows the condition rating and trends for vegetation in the Yarra catchment, as specified in the Healthy Waterways Strategy.

Table 11 : Condition rating and trends for vegetation in the Yarra catchment (Source: (Boon 2009b, a, Melbourne Water 2013a)

Management Unit	Condition Rating and Trend	Comment
Upper Yarra	High and improving	Much of the native vegetation in the forested headwaters is protected within public land and is of very high quality with minimal weed invasion.
Middle Yarra	Moderate to low, but improving	A significant decline in the condition of vegetation has occurred over the past 100 years due to extensive clearing for rural and urban development. However, this trend has reversed in the past 10

Management Unit	Condition Rating and Trend	Comment
		years
Lower Yarra (including estuary)	Very low, but improving	Extensive clearing of vegetation, due to urban development, has occurred over the past 200 years. Consequently, streamside vegetation quality is rated as very low.
Billabongs	Not available	Infilling and drainage, as well as changing land uses have extensively reduced the number and extent of billabongs within the catchment. As a consequence, billabong vegetation has declined in condition, extent and distribution.

3.7 Amenity

It is relatively difficult to measure the condition of amenity for waterways. In putting together the Healthy Waterways Strategy, a tailored social research program survey was used by Melbourne Water to assess how the community values and relates to waterways in the region. The survey collected 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 also used.

Table 12 shows the condition rating and trends for frogs in the Yarra catchment, as specified in the Healthy Waterways Strategy.

Table 12 : Condition rating and trends for amenity in the Yarra catchment (Source: Melbourne Water (2013a)

Management Unit	Condition Rating	Comment
Upper Yarra	Very high	The management of public land means it has retained many natural features. Very high amenity is still enjoyed through natural forests, picnic areas at the dams, and views along the waterway corridors.
Middle Yarra	Low	Many areas provide high amenity through intact streamside vegetation, natural waterway features and parkland where relaxation can occur, but the average score is low.
Lower Yarra (including estuary)	Moderate	The amenity enjoyed from waterways is moderate, with specific areas providing important areas for relaxation and rejuvenation.

3.8 Waterbirds

There is little information available on the condition and distribution of waterbird species in the Yarra River catchment, or the effects of river regulation and reduced inundation of wetlands and billabongs on waterbird distribution and abundance. The Healthy Waterways Strategy provides a brief synopsis of waterbird condition, summarised in Table 13, and this remains a significant knowledge gap in the management of environmental watering for the Yarra River. Waterbirds are highly mobile animals that can access a range of habitats. The loss and change in wetland habitat in the lower reaches of the Yarra River through regulation, drainage and filling has resulted in a significant loss of habitat and as a result it is possible that many waterbirds have moved to other regions (SKM 2012c).

Table 13 : Condition rating and trends for birds in the Yarra catchment (Source: (Boon 2009b, a, Melbourne Water 2013a)

Management Unit	Condition Rating and Trend	Comment
Upper Yarra	Very high and stable	The high quality of vegetation and a long history of habitat protection have allowed the condition of bird populations to remain very high
Middle Yarra	Low and stable	Extensive vegetation clearing has occurred, which is reflected in the

Management Unit	Condition Rating and Trend	Comment
		low condition of bird populations. These populations appear to be stable from the 1990s.
Lower Yarra (including estuary)	Low and stable	Urban development has been substantial and the condition of bird populations is rated as low. The long-term potential for bird populations to improve in condition is limited due to restricted availability of land to create large-scale connectivity.

4. Threats

The major threats to Yarra River values are summarised in Table 14.

Refer to SKM (2005c), SKM (2011b) and SKM (2012b) for a more detailed discussion regarding these threats.

Table 14 : Overview of threats to key values in the Yarra River

Threat	Description	Key Values Impacted
Altered hydrology	With extensive modifications to the timing, duration and volume of the natural flow regime, regulation has significantly altered the hydrological character and functioning of the Yarra River. This has implications for the Yarra River's values in terms of: • Changes to, or even the loss of, important flow pattern cues for migration, mating and spawning behaviours for aquatic fauna • Habitat availability, for example the maintenance of connectivity to floodplains and billabongs, which may function as nursery areas for juvenile fish; and the loss of pools, riffles and other river physical qualities which will reduce the amount of available habitat for shelter and feeding opportunities for platypus and birds • Habitat quality, where reduced flows may increase the temperature of pools, decrease dissolved oxygen levels and increase salinity to beyond the tolerance thresholds of aquatic flora and fauna • Loss of connectivity, with a reduction in opportunities for dispersal and recolonisation, reducing the diversity and abundance of aquatic biota • Lack of food resources reducing overall floodplain and billabong productivity For fauna species, this can result in • A reduction in the diversity and abundance of food sources • Stable water levels and open water habitat favouring introduced fish such as Redfin Perch, which prey on small native fish. • A consequent reduction in species diversity and abundance. For example, very large flows during the breeding season (September to January), can threaten the viability of platypus populations by flooding the burrows of nesting platypus and drowning the juveniles (Serena & Williams (2008) in SKM 2012b). High flows can also be detrimental for frogs as fast moving water at the wrong time can wash tadpoles out of suitable habitat, and a lack of surface water can also hinder the ability frog species to breed. The majority of species mate and lays their eggs near, or attached to, fringing vegetation. For successful frog breeding, a water body also needs to contain water long enough for tadpoles to develop and metamorphose into adult frogs.	All
Climate Change	This threat is discussed in Section 8 of this EWMP.	All
Barriers to fish movement, including reduced connectivity to the floodplain and billabongs	The capacity to move is crucial to fish recolonisation after disturbance and to allow fish to move within and between habitats when seeking food and shelter, for mating and spawning, and for migration. Fish movement along the Yarra River channel and laterally across the floodplain and/or into billabongs can be obstructed by barriers to their passage. Large dams, weirs, regulators, levees and road crossings can also act as barriers, and can apply upstream and downstream, as well as laterally onto the floodplain.	Fish Macroinvertebrates Platypus

Threat	Description		Key Values Impacted
	Dights Falls is the only major potential instream fish barrier that exists on the Yarra River downstream of the Upper Yarra Dam. A recent upgrade to this location has included a fish ladder that will work under a broad range of flow conditions.		
Urbanisation and increased Directly Connected Imperviousness (DCI)	Increased DCI can increase the inputs of polluted water into waterways and reduce water quality, and can significantly change the flow regime of the system. This alters the availability and quality of habitat for biota. For example, high velocity stormwater inputs can damage and uproot instream vegetation, cause bed and bank erosion issues, and increase the amount of sedimentation within the waterway. For a more detailed discussion of this threat, please refer to Section 4.1.1 of this EWMP.		All
Temperature	Alteration of the natural temperature downstream of large dams poses a significant threat to a range of aquatic biota and ecosystem processes. Native fish can be particularly intolerant of low temperatures, as well as temperatures that are too high. For example, species such as River Blackfish require water temperatures above 16^{O}C to initiate spawning in late spring and summer. It is possible that releases from Upper Yarra Reservoir for environmental purposes may impact on the spawning potential for River Blackfish, particularly if increased releases occur during the spring - summer period (SKM 2012c). The temperature related impacts associated with climate change are discussed in greater detail in Section 4.2 and Section 8.		Fish Macroinvertebrates Platypus
Water quality	Elevated salinity	Most aquatic species are adapted to tolerate a certain range of salinity, and conditions outside this tolerable range can exclude and/or lead to mortalities of any sensitive species. The impact of saline conditions on aquatic vegetation and macroinvertebrates for example can lead to reduced overall biodiversity and limit the availability of food resources for fish. Although not a major issue for the Yarra River, during very low flows there is an increase in the salinity of the bottom waters of deeper pools, particularly in the Dights Falls weir pool. The increase in may be a contributing factor to stratification of the water column, which in turn can lead to deoxygenation of the bottom waters (SKM 2012c). Salinization is one of the major threats to wetlands in south-east Australia.	Fish Macroinvertebrates Platypus
	Decreased salinity	A relationship has also been established between salinity and the probability and intensity of Chytridiomycosis fungus infections with frogs, especially for the Growling Grass Frog (Heard *et al.* 2014b). Higher levels of salinity in some riparian and floodplain zones are thought to moderate the occurrence of the fungus and protect frogs living in those habitats. Urban development and increasing stormwater flows, with the associated dilution of salinity in these areas, may increase the risk that the individuals in these areas contract the disease.	Frogs
	Low Dissolved Oxygen (DO)	The survival of aquatic life depends on a sufficient level of oxygen dissolved in water. When it drops below levels necessary for sustaining aquatic life, it becomes a significant water quality impairment. Stratification and the development of anoxic conditions in bottom waters occurs during very low flow conditions in the Dights Falls Weir pool downstream of Chandler Highway, but not in pools upstream (SKM 2012c). Analysis suggests that there is an	Fish Macroinvertebrates Platypus Frogs

Threat	Description		Key Values Impacted
		increased risk of low DO occurring in the weir pool when flow falls below 300 ML/d and when water temperature is above 16 ^{O}C (SKM 2012c).	
	Increased nutrient input, such as Nitrogen (N) and Phosphorus (P)	The main nutrients in waterways come in the form of inorganic N and P. Only small amounts of each are required in a natural ecosystem and any additional increase can quickly become a nuisance by causing excessive algae and plant growth. An increase in the available nutrients in waterways is called eutrophication, which can have severe environmental effects. An increase in algae growth, sometimes called an algal bloom, reduces DO in the water when the algae die and decompose and it also reduces water clarity, reducing the ability of some animals to see prey or predators. If the cycle happens repeatedly, species may be lost from the waterway. Increased nutrient inputs from the freshwater reaches of the Yarra River may also cause severe eutrophication of the Bay, reducing habitat availability and quality, and reducing the recruitment and survival of migratory, estuary and marine derived animal species.	All
	Toxicants	Rivers are natural depositories for pollutants that have come from higher in the catchment or from use of their floodplains for agriculture, industry or urban populations. The Yarra River has received atmospheric and water-borne industrial and urban toxicants for well over 100 years. The broad pathways and sources for toxicant include surface water inflows; groundwater discharges and atmospheric deposition. Toxicants that pose a threat include heavy metals, pesticides, herbicides and aromatic hydrocarbons. Other toxicants that pose a threat, particularly in urban landscapes, are polychlorinated biphenyls (PCB's). All of these toxicants can have significant effects on plants and animals, including death, impaired health, and loss of condition. Billabongs are often the final receiving water for pollutants generated or applied in the broader catchment, and many billabong biota are significant bio-accumulators of contaminants.	All
	Acid Sulfate Soils	Acid Sulfate Soils are soils that contain iron sulphides. When these soils are disturbed, exposure to oxygen tends to produce sulphuric acid causing the release of soluble iron, sulphate, aluminium and other potentially toxic metals. Most aquatic life needs a minimum pH of 6 to survive (DPI 2016). Testing in the Yarra catchment has shown the presence of acid sulphate soils (SGS Australia 2014). Risks to the Yarra River itself are low, but the potential for ASS soils to be present on floodplains and in billabongs needs to be considered when undertaking works on the floodplain or watering billabongs.	All

Threat	Description	Key Values Impacted
Bushfire	Biota in bushfires experience increased water temperatures and ash and debris deposits into the waterways as the flame front passes. This can reduce dissolved oxygen and increase pH, nutrient loads and temperatures, which can cause fish kills (SKM 2009). Ash and sediment from the surrounding catchment also washes into the stream where it can smother fish gills, eggs, pools and food sources. The ash also reduces dissolved oxygen. The heavier silt and gravel will settle in the vicinity of the fire, but fine ash and silt can travel a long distance, affecting fish lower in the catchment (SKM 2009).	All
Introduced fish	Introduced fish species, such as Carp, Goldfish, Roach, Tench, Redfin and Mosquito Fish, compete with native fish for food and habitat, can negatively impact on habitat availability and quality, can introduce disease to native fish populations, and can also prey on smaller fish and frog species. Competitive behaviour that excludes native fish from food resources and habitat, as well as aggressive interactions in confined environments have also resulted in reduced condition of native fish and reduced population sizes and distribution. These fish compete with native fish for food and habitat, and also prey on smaller fish species (MDBC 2003). For example, Carp now make up an estimated 60 to 90 per cent of the total fish biomass at many sites, with densities as high as one carp per square metre of river surface area (MDBC 2003). When carp are present in high densities, the resultant suspended sediment can result in a number of problems, including the direct deterioration of water quality due to sediment and increased nutrient levels, reduced plant growth, the clogging of gills of other fish species, and fewer plant species because they have either been eaten or uprooted (Rowe *et al.* 2008). Gambusia's aggressive nature, high reproductive potential, fast maturation rate, flexible behaviour and broad environmental tolerances have contributed to its success as invader, and the species is considered to pose a serious threat to native fishes in Australia and overseas (Rowe *et al.* 2008). Competitive behaviour that excludes native fish from food resources and habitat, as well as aggressive interactions in confined environments, has resulted in reduced condition of native fish and reduced population sizes and distribution.	Fish Frogs
Sedimentation	Although sediment and its associated effects on water clarity and turbidity is an inherent component of aquatic systems, there is an increased risk to the survival and well-being of fish when levels exceed background values for a particular period of time. Sedimentation can be harmful by acting directly on aquatic fauna in the water, either killing them or reducing their growth rate, resistance to disease etc. It can also: prevent the successful development of eggs and larvae; modify natural movements and migrations; reduce the abundance of food available; and affect the efficiency by which animals can catch or harvest their foods.	Fish Platypus Macroinvertebrates
Disease – Chytridiomycosis (Chytrid fungus)	Chytridiomycosis is a water-borne and often fatal fungal disease that mostly affects amphibian species associated with permanent water, such as streams and wetlands. Since its first recorded appearance in Australia, the fungus has been directly implicated in the extinction of at least four species and the dramatic decline of at least 10 others, including the Growling Grass Frog.	Frogs
Foxes, dogs and cats	Predation by foxes, dogs and cats when platypus travel overland or in shallow water to find suitable foraging habitats and burrows, is major threat to the species. Foxes and cats have been classified as keystone species in Australia because by preying on native animals, they have reduced biodiversity and impacted on the survival of native animals over large areas of entire ecosystems. For example feral cats have been	Platypus Birds Frogs

Threat	Description	Key Values Impacted
	implicated as a threat to 142 species and sub-species, comprising 40 mammal species and sub-species (Woinarski *et al.* 2014), 40 birds, 21 reptiles and four amphibians (Department of the Environment 2015). Predation by foxes, dogs and cats can also cause the loss of eggs, chicks and adult birds, and the presence of these predators in an area may deter breeding.	
Urbanisation in the upper reaches and headwaters	Urbanisation has significant effects on the amenity values of waterways, and is thought to foster a sense of disconnection within people from the natural world around them. This threat is discussed in greater detail in Section 4.1 of this EWMP.	All
Introduced plants	Invasive plants outcompete native plants for habitat, and in some cases are harmful to native animals that eat them. Aquatic weeds can reduce light penetration, reducing photosynthesis by submerged aquatic plants and reducing the oxygen levels in the water. Reduced light can inhibit visual feeding by fish and movement by platypus, and reduced oxygen levels may be fatal to fish. Aquatic weeds can also smother waterways, and they can greatly alter flow rates. This reduces native species diversity and abundance. Willows are particularly problematic for waterways because they clog up the channel with their large matted roots, consume large amounts of water via transpiration, and out-compete native plants. Willow infestations on the riparian zones of rivers are known to impact on the ability of platypus to build burrows, and also reduce the availability of food sources for them (Serena and Williams, 2008 in SKM 2012b). Other problems posed by willows include that they drop large amounts of leaf material over a short period in autumn, unlike the more uniform input of material into streams provided by native riparian taxa such as eucalypts, wattles and tea trees, possibly causing alterations to macroinvertebrate communities. Willow wood breaks down faster than does eucalypt wood once trunks or limbs have fallen into the stream, and so provides only minimal amounts of coarse woody debris as habitat for fish and as a substrate for biofilms of aquatic algae.	All
Desnagging	Snag or timber removal was once a very common management practice along the Yarra River and its floodplain waterways, with de-snagging practices aimed to improve stream flow, reduce severity of flooding, and improve the passage for boat navigation. Aquatic and terrestrial floodplain flora and fauna require woody habitat for: • In-stream habitat • A food source • Sites to spawn and rear juveniles • Protection from strong currents and sunlight • Orientation points to identify habitat and territory • Shelter from predators	Fish Macroinvertebrates Platypus Birds

Threat	Description	Key Values Impacted
	• Vantage points to help capture prey (Treadwell *et al.* 1999). Removing these timber structures has a huge impact on entire food chains (Treadwell et al. 1999) and efforts are now in place in many locations to restore snags to riverine environments. In the Yarra River catchment snag restoration has occurred in the Little Yarra River near Yarra Junction.	
Degradation or loss of riparian vegetation	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. Riparian vegetation clearance reduces stream shading. Research in Victoria during the Millennium Drought showed that streams with intact catchment and riparian vegetation started in better condition prior to drought conditions and remained in better condition throughout the drought (Thomson et al., 2012). Evaporation of water from pools is exacerbated with the loss of riparian shade, and can lead to a decline in water quality as levels of dissolved oxygen decrease and salinity increases.	All
Recreational and commercial fishing	Recreational and commercial fishing directly remove fish species from the river, estuary and Bay, reducing overall population abundance and injuring individuals that survive. 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 can already be considerably reduced. Illegal fishing nets are known to trap and kill platypus. The behaviours of some fish species, such as Macquarie Perch, place them at higher risk of population depletion from fishing because they gather together in larger groups in preparation for movements upstream over the spawning season.	Fish Platypus
Domestic stock access and grazing	Domestic stock grazing can potentially lead to pugging, selective plant removal, weed invasion, soil compaction, erosion and increased sediment and pollutants in rivers and wetlands. Grazing stock also compete for food with native animals and damage habitat (such as damaging invertebrate burrows because of soil compaction) (VEAC 2008). Grazing can result in habitat loss or modification, the introduction and spread of exotic plants as well as the inhibition of native vegetation establishment and growth, particularly seedlings. Damage to rivers and wetlands by grazing has also been demonstrated to affect habitat values for animals such as frogs and birds (VEAC 2008). Livestock grazing may also adversely affect soil structure, bed and bank stability, and water quality (VEAC 2008). Grazing can also reduce the capacity of riparian zone vegetation to act as a nutrient ‘filter’ by compacting the soil, increasing erosion and sediment input into waterways. These effects are strongest where grazing is continuous (VEAC 2008).	All
Litter	Increased levels of litter in and around waterways significantly decreases their amenity values for people. Litter is also particularly dangerous for platypus in the Yarra River, affecting water quality and entrapping or injuring individuals, sometimes killing them (Serena and Williams, 2008 in SKM 2012b)..	Platypus Amenity

4.1 Emerging threats

Emerging threats such as urban development and climate change also have a significant ability to influence the condition of water-dependent values in the Yarra River.

4.1.1 Urbanisation in the catchment

Melbourne's continuing population growth means that a number of the Yarra River's major tributaries, particularly the Merri and Darebin Creeks and the Plenty River, will be urbanised over the coming years[19]. Urban development presents a number of risks to the Yarra River, particularly because of changes to flow regimes and water quality. An increase in catchment imperviousness as a result of urbanisation reduces the infiltration of rainfall into the soil, decreasing recharge to groundwater and increasing the rate of surface water runoff. This increased surface water runoff is collected in stormwater drainage systems and is then discharged to the tributaries and then the Yarra River. The alteration of infiltration and runoff regimes ultimately results in an increase in the volume and velocity of water entering the river, an increase in the frequency of high flow events it experiences, and a deterioration in its water quality as sediment, nutrients and other contaminants that would otherwise have been trapped and recycled in the catchment now enter the waterway (Walsh *et al.* 2005, Walsh *et al.* 2012). These changes to the water balance are exacerbated, and their effects transferred to streams and rivers, by stormwater drainage systems: a network of pipes under cities (that have separate sewers), which is designed to minimise flood risk, by efficiently draining all runoff from impervious surfaces directly to the nearest receiving water (Walsh *et al.* 2012).

Table 15 summarises the threats to both ecological values and habitat values associated with urbanisation.

Table 15 : Threats to habitat and ecological values as a result of urbanisation

Value	Threat
Habitat Value	
Water Quality	• Increased freshwater flows may dilute naturally elevated salinity • A shift from ephemeral to permanent base flow may decrease nutrient retention and assimilation at the reach scale and increase the export of nutrients to downstream reaches, including the Yarra River estuary and Port Philip Bay.
Stream Geomorphology	• Urbanised headwaters are highly prone to channel incision (headcuts and channel widening). • Some scouring of bars and benches is also likely. • Removal of substrate gravels is also likely in the lower reaches, as is scouring of the floodplain
Ecological Value	
Fish	• Increased frequency of high flows may scour vegetation from pools and reduce pool habitat quality for fish, for example River Blackfish. • The increased frequency of high flows as a result of urbanisation generally has a negative impact on all native fish because these flows can cause direct mortality and displacement of eggs and juveniles, remove key physical habitat (e.g. woody debris, undercut banks, rocks, aquatic vegetation), and render large sections of channel unsuitable due to elevated flow velocities. • Flow events may, however, provide cues for the downstream movement of larger migratory fish and allow broad-finned galaxias to spawn in riparian vegetation.
Frogs	• Increased frequency of high flows may scour vegetation from pools, hence reducing

[19] The 2014 expansion to Melbourne's Urban Growth Boundary has allowed for the creation of at least 90,000 new residential homes and up to 1,050 hectares of new employment land (DTPLI 2014).

Value	Threat
	quality of habitat, particularly for Growling Grass Frog. • Increased frequency of high flows may flush tadpoles from nursery habitats, hence reducing recruitment success • Increased freshwater flows may also reduce naturally elevated salinity and hence reduce buffering capacity against Chytrid fungus. However, permanent low flows may help extend the range of some frogs into areas.
Macroinvertebrates	• Introduction of a more permanent flow regime may result in a shift in species diversity and richness with a loss of species adapted to ephemeral flows and an increase in species that prefer permanent flowing conditions
Vegetation	• Increased frequency of high flows may scour pools and reduce opportunities for submerged macrophytes to persist. • Increased frequency of high flows may result in changes to vegetation zonation in the littoral zone.

The issue is further compounded by urbanisation in the upper reaches of the Yarra River's connected tributaries. For example, Merri Creek is predicted to be substantially impacted by urban development in Melbourne's Northern Growth Corridor in terms of alterations to its hydrology, water quality parameters and physical habitat. The upper reaches of the Merri Creek have an ephemeral flow regime and urbanisation is likely to make flow in these areas more permanent and increase the frequency of high flows. Both of these changes can be detrimental to stream geomorphology and water quality and will have subsequent negative impacts on the water-dependent values in the receiving reaches.

In the case of water quality, the possible shift from an ephemeral to permanent base flow in the Merri Creek as result of urbanisation is concerning because it is likely to decrease nutrient retention and assimilation at the reach scale and significantly increase the export of nutrients to downstream reaches, including the Yarra River estuary and Port Philip Bay. Cease-to-flow periods in ephemeral streams are important because they dry out and re-oxygenate the sediment. The drying cycle is important for releasing nitrate, which upon rewetting, promotes the growth of algae, bacteria and plants in aquatic environments (Corrick and Norman 1980), and helps recycle nitrogen back into organic material, reducing the concentration of the dissolved forms and hence minimising downstream transport.

In the case of Merri Creek, this includes downstream reaches of Merri Creek, the Yarra River estuary and Port Philip Bay. Unpublished analysis commissioned by Melbourne Water for the Merri Creek suggests that even by adopting current best practice environmental management (BPEM) stormwater management techniques, the TN load could be expected to increase 4-fold to the Bay compared to the undeveloped load (Melbourne Water 2016c).

Melbourne Water is working with State Government, technical experts, developers and planners to assess and develop appropriate stormwater harvesting systems that help to help protect flow regimes in the newly urbanised areas of Melbourne. Stormwater management objectives such as "meeting near natural flows" can be difficult to meet, because they require land developers to address the location, frequency, magnitude and duration of flows. A carefully designed regional stormwater harvesting scheme is thought to have the greatest potential to fill this gap – noting that no solution will completely mirror the complexity of nature.

4.1.2 Yarra River corridor planning controls

Over the course of its history, the Yarra River corridor has faced various development pressures and threats to its landscape and environment. Formerly this was due to the location of industry or agriculture along the river's edge. From the second half of the twentieth century, the river's attractiveness for residential and commercial use also began to cause concern (Planisphere 2014). In recent years, an emerging issue for the Yarra River has been the need to protect it from the impacts of development, particularly encroachments into its open space and poor compliance with building setback limits, height limits, and the overshadowing of valuable social, recreation, environmental and amenity values (Yarra MAC 2016). The impacts of development on riparian vegetation are also of concern (Planisphere 2014, 2015).

Notwithstanding the objectives for the river corridor expressed in planning schemes and other management strategies, current planning controls are largely discretionary - mainly in the form of planning overlays and guidelines (Planisphere 2014, 2015). Concern is growing regarding inconsistent application of building heights and setbacks along the corridor, and that effective controls over water and run-off management are stipulated only for large residential subdivisions, with non-residential and small developments exempt (Yarra MAC 2016).

Table 16 summarises key threats associated with urban development along the Yarra River corridor

Table 16 : Summary of Yarra River corridor threats associated with urban development

Threat Type	Description
Major developments, such as multi-storey apartment blocks	• Development on and too close to the banks of the Yarra River • Greater intensity of development on private land close to the river, particularly larger lots • Built forms that dominate the river, its banks and the vegetation (for example apartments that are taller than the predominant tree canopy height, insufficiently screened by vegetation, or highly visible from publicly accessible areas) • Pressure to redevelop former industrial sites
Minor developments and works	• Inappropriate boating infrastructure • Fences along the river frontage
Built form elements	• Materials with reflective finishes • Large surface areas, particularly of light and bright hues and highly saturated primary colours
Modification of the landform	• Increased paved and impermeable surface areas, impacting important ecosystem functions such as nutrient processing, flood mitigation, and modifying flow regime patterns • Increased stormwater run-off from built up areas polluting the waterway • Increased flooding and associated risks • Erosion (for example due to loss of vegetation or flooding) • Pollution and litter
Vegetation	• Loss of vegetation, particularly native and mature vegetation and canopy trees • Formal gardens along the river bank that are contrary to the informal and naturalistic landscape, with the use of non-indigenous plants • Environmental weeds

A Yarra River Ministerial Advisory Committee (MAC) has been set up to explore issues associated with development along the banks of the Yarra River and the protection of the Yarra River corridor, with the view to developing new legislation for the protection of the Yarra River, through a proposed Yarra River Protection Act (Yarra MAC 2016). The MAC will recommend changes to state planning rules to allow for consistent decision-making and to address issues such as building heights, setbacks, overshadowing and vegetation protection.

Interim changes have also been made to the Victorian State Planning Policy Framework to support a more consistent decision-making across council boundaries and deliver a set of dedicated policies with clear objectives for the entire Yarra River corridor, including the development of a framework of standardised planning controls to be applied, comprising primarily of a Yarra River focused Design and Development Overlay (DDO) to manage built form outcomes, and the use of a 'whole of river' corridor Environmental Significance Overlay (ESO) to manage vegetation and environmental outcomes.

The findings of the MAC and any subsequent changes to the governance and management of the Yarra River are likely to have implications for the management and delivery of the Yarra River Environmental Entitlement, as well as for the management objectives within this EWMP. The EWMP will be reviewed in light of these changes as required.

4.2 Climate Change

The 13-year Millennium Drought in Victoria was unprecedented compared with other recorded droughts since 1900. This was because it was largely constrained to the southern‑Australian region, with lower year-to-year rainfall variability and no 'wet' years through this period, and also because the seasonal pattern of the rainfall decline was at a maximum in autumn but included losses in winter and spring (CSIRO and Bureau of Meteorology 2015). Scientists have analysed the observed climate record and have found a strong relationship between the rainfall decline in south-eastern Australia and global warming, and they now believe that the Millennium Drought was in part created by the effects of climate change (CSIRO 2015).

CSIRO modelling of the effects of climate change on the hydrology of the Yarra Basin has found that a median climate change scenario may result in average surface water availability reducing by as much as 34% by 2030 (CSIRO 2015). Fire frequency is also expected to increase with climate change (Pittock and Finlayson 2011), potentially further reducing water quality and flows.

The implications of climate change for the condition and health of the Yarra River are profound and water resource managers must focus on the need to develop resilience to the potential changes caused by such extremes. Reductions in water availability, increasing temperatures, and changes in rainfall patterns will all significantly affect the pattern and volume of inundation events experienced by the Yarra River as well as the quality of the water it receives. This in turn will significantly change the structure and ecological functioning of the system, and is likely to cause widespread changes to the river's biodiversity in terms of the water-dependent species that are able to survive as well as their relative abundance and distribution.

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

This threat is discussed further in Section 8, with an analysis of the vulnerability to the impacts of climate change for a range of Yarra River values.

5. Hydrological Condition

Although the Yarra River is not large by Australian standards, it is situated in a very productive catchment, generating the fourth highest yield of water per hectare of catchment in Victoria (Melbourne Water 2016d). The average annual inflows to the Melbourne Water storages located in the upper catchment are 9,464,000 ML/year and are 32% of the total basin inflows (SKM 2012c). The highest rainfall occurs in the upper Yarra catchment, dropping off in the lower reaches of the basin (refer to Figure 6).

5.1 Operations and water use

Most of the water used by Melbourne comes from the Yarra catchment. Water can also be transferred from the Thomson Reservoir to the east, and from streams in the Goulburn basin to the north to help meet demand. A Bulk Entitlement for the Melbourne water retailers (City West Water, Yarra Valley Water, South East Water), referred to as the *Bulk Entitlement (Yarra River - Melbourne Water) Order 2014*, allows for approximately 400 GL/year to be harvested from the Yarra River annually for urban supply. The Bulk Entitlement (BE) has a source (harvesting) and delivery model that has an annual seasonal determination process, measured as a rolling average, and unused water allocations can be carried over. The BE requires that water diversions are measured downstream of the main reservoirs in the Melbourne Headworks System[20].

5.1.1 Water Entitlements

Rights to water in the Yarra basin are outlined in Table 17.

Table 17 : Rights to water in the Yarra basin (Source: Adapted from DELWP (2015e))

Entitlement Holder	Bulk Entitlement	Annual Entitlement Volume (ML)
City West Water Corporation	Bulk Entitlement (Greater Yarra System – Thomson River Pool – City West Water) Order 2014	400,000
South East Water Corporation	Bulk Entitlement (Greater Yarra System – Thomson River Pool – South East Water) Order 2014	
Yarra Valley Water Corporation	Bulk Entitlement (Greater Yarra System – Thomson River Pool – Yarra Valley Water) Order 2014	
Victorian Environmental Water Holder	Yarra Environmental Entitlement (2006)	*High reliability entitlement* - 17,000 *Unregulated surface water* - 55
Take and use licences – unregulated surface water		42,889
Total volume of water entitlements in the Yarra basin		**459,944**

Major diversions occur in the Upper Yarra catchment including:

- Diversions from the major storages of Upper Yarra Reservoir, Maroondah Reservoir and O'Shannassy Reservoir
- Diversions from weirs on tributary streams, such as Coranderrk Creek Weir and Graceburn Creek Weir
- Direct diversions from the Yarra River, such as pumping from Yering Gorge (SKM 2012a).

[20] The Melbourne Headworks system includes storages that harvest water from protected water supply catchments: Thomson, Yarra, Silver and Wallaby Creeks, Tarago and Bunyip rivers. It also includes water from the Victorian desalination plant and the Northern Victorian Connections Project.

Private diverters and farm dams also harvest water that would have naturally flowed into the Yarra River. Table 18 outlines the estimated small catchment dam information for the Yarra basin for the 2013-14 watering year, the most recent analysis that was publically available at the time of writing the EWMP in 2016 (DELWP 2015f).

Table 18 : Estimated small catchment dam information for the Yarra Basin (Source: DELWP (2015e))

Type of Small Catchment Dam	Capacity (ML)	Usage (ML)	Total Water Harvested (ML)
Domestic and stock (not licensed)	10,524	5,262	N/A
Registered commercial and irrigation (licenced)	12,574	10,562	N/A
Total	**23,098**	**15,824**	**17,092**

Licence holders are able to take and use water from waterways, catchment dams, springs, soaks or aquifers in the Yarra basin. There are approximately 1,800 of these types of licences in the Yarra catchment (DELWP 2015g). These are outlined in Table 19.

Table 19 : Licensed entitlements and recorded use in 2014-15 for the Yarra basin (Source: (DELWP 2015g)

Type of Licence	Number	Volume (ML)	Recorded use in 2014-15 (ML)
Take and Use	1,264	43,791	7,814
Registration	523	6742	34
Stormwater/Drainage	16	581	186
Total	1803	50,567	8,034

5.2 The impacts of regulation on hydrology

The hydrologic regime of the Yarra River has changed significantly since the system was first regulated. Unlike many other highly regulated systems that are used to transport water for irrigation in Australia, the Yarra River has preserved its natural seasonality (SKM 2012c), but the system now experiences lower flows and fewer floods. Water harvesting has reduced the mean annual flow in the Yarra River at Chandler Highway (the most downstream freshwater gauging point) from 2,505 ML/day to 1,408 ML/day (SKM 2012a). In very dry years, this impact is even more noticeable. At the end of the Millennium Drought for example, only 33% of the total inflows to the Yarra basin actually flowed out into Port Phillip Bay (DSE 2011).

Table 20 summarises the major alterations to hydrology for reaches 1 to 6 and 8 of the Yarra River.

Table 20 : Summary of hydrological changes as a result of regulation of the Yarra River system (Source: Adapted from SKM (2012c))

Reach	Current Flow Regime	Natural (i.e. pre-regulation) Flow Regime	Changes to Seasonality	Changes to Flooding
1 Upper Yarra Reservoir to	10 ML/day as passing flows	Ranged between a low flow of 80 ML/day, up to high flows of 616 ML/day	Pre-regulation there would have been a distinct seasonality, but there is currently little variation between	The magnitude of flood events has decreased. Under current conditions a 1 in 5 year flood event has a magnitude of 2,400 ML/day whereas

Reach	Current Flow Regime	Natural (i.e. pre-regulation) Flow Regime	Changes to Seasonality	Changes to Flooding
Armstrong Creek			seasons.	before regulation this would have been 3,530 ML/day
2 Armstrongs Creek to Millgrove	Mean daily flow of approximately 544 M/day. A summer low flow is around 165 ML/day	Mean daily flow of approximately 1,013 ML/day. A summer low flow was around 321 ML/day	Seasonality has been retained because of unregulated tributary flows. Low flow period starts earlier and lasts longer under current conditions	The frequency and duration of flood events has been reduced compared to natural conditions. The magnitude of large floods has not changed substantially.
3 Millgrove to Watts River Junction	Mean daily flow of approximately 1,215 ML/ day. Current summer low flows are 357 ML/day. Winter high flows are approximately 1,641 ML/day	Natural mean daily flow of approximately 1,848 ML/day. Summer low flows would have been 635 ML/day. Winter high flows would have been approximately 2,701 ML/day	Seasonality has been retained due to tributary inflows.	The frequency of flood events has decreased. Under natural conditions a 1 in 5 year flood event had a magnitude of approximately 13,700 ML/day. Under current conditions a 1 in 5 flood event is approximately 12,600 ML/day
4 Watts River to the top of Yering Gorge	Mean daily flow of 1,274 ML/ day. Current summer low flows are 376 ML/day. Winter high flows are 1,715 ML/day.	Natural mean daily flow of 1,924 ML/day. Summer low flows would have been 663 ML/day. Winter high flows would have been 2,795 ML/day.	Seasonality has been retained due to tributary inflows.	The frequency of flood events has decreased. Under natural conditions, a 1 in 5 year flood event had a magnitude of approximately 14,400 ML/day. Under current conditions, the 1 in 5 flood event is approximately 13,600 ML/day
5 Top of Yering Gorge to Mullum Mullum Creek	Mean daily flow of 1,313 ML/ day. Current summer low flows are 324 ML/day. Winter high flows are 1,778 ML/day.	Natural mean daily flow of 2,188 ML/day. Summer low flows would have been 740 ML/day. Winter high flows would have been 3,121 ML/day.	Seasonality has been retained due to tributary inflows.	The frequency of flood events has decreased. Under natural conditions a 1 in 5 year flood event had a magnitude of approximately 20,400 ML/day. Under current conditions a flood of this magnitude would occur in 1 in 20 years on average.
6	Mean daily flow of approximately 1,408	Natural mean daily flow of approximately 2,505	Seasonality has been retained due to tributary	The frequency of flood events has decreased.

Reach	Current Flow Regime	Natural (i.e. pre-regulation) Flow Regime	Changes to Seasonality	Changes to Flooding
Mullum Mullum Creek to Dights Falls	ML/ day. Current summer low flows are approximately 336 ML/day. Winter high flows are approximately 1,869 ML/day.	ML/day. Summer low flows would have been approximately 814 ML/day. Winter high flows would have been approximately 3,497ML/day.	inflows.	Under natural conditions, a 1 in 5 year flood event had a magnitude of approximately 31,800 ML/day. Under current conditions, a flood of this magnitude would occur in 1 in 100 years on average.
8 Watts River from Maroondah Reservoir to Yarra River	Mean daily flow of 158 ML/ day. Current summer low flows are 103 ML/day. Winter high flows are 237 ML/day.	Natural mean daily flow of 287 ML/day. Summer low flows would have been 26 ML/day. Winter high flows would have been 421 ML/day.	Seasonality has been retained due to tributary inflows and frequent spills from Maroondah Dam in winter and spring.	The frequency of flood events has decreased. Under natural conditions a 1 in 5 year flood event had a magnitude of approximately 2,800 ML/day. Under current conditions, a flood of that magnitude would occur in 1 in 15 years on average.

Detailed figures showing changes in flow duration curves and unimpacted and current average daily flows are provided in Appendix C.

5.3 Estuary hydrology

The Yarra River estuary is narrow (30 to 120 m wide) and naturally shallow (maximum depth of 8 m) (Bruce *et al.* 2011). For most of the length of the estuary, the banks have been stabilised by rocks, and little is left of the natural bank and riparian zone (SKM 2005c). The lower portion of the estuary has been physically modified into a series of docks and wharves, with the first major modifications occurring in the 1880s, including straightening the course and dredging to increase its depth, making it navigable for shipping (PoMC 2007, Bruce *et al.* 2011). In 2008 and 2009 the navigable depth of the estuary was increased to a maximum of 15.5m under the Channel Deepening Project, which removed approximately 5 million m^3 from the estuary and berths (EPA Victoria 2013).

The estuary is a permanently open, river dominated system that discharges into a sheltered Bay. River flow is permanent, but is highly variable over seasonal and longer climatic scales. Flow is also generally higher in winter and spring, and lower in summer and autumn (Beckett *et al.* 1982). This variability in flow can be seen in Figure 21, which shows the difference in daily flow during drought conditions between 2008 and 2011, a time period during which the Millennium Drought was occurring and which was broken by above average rainfall in 2010-11.

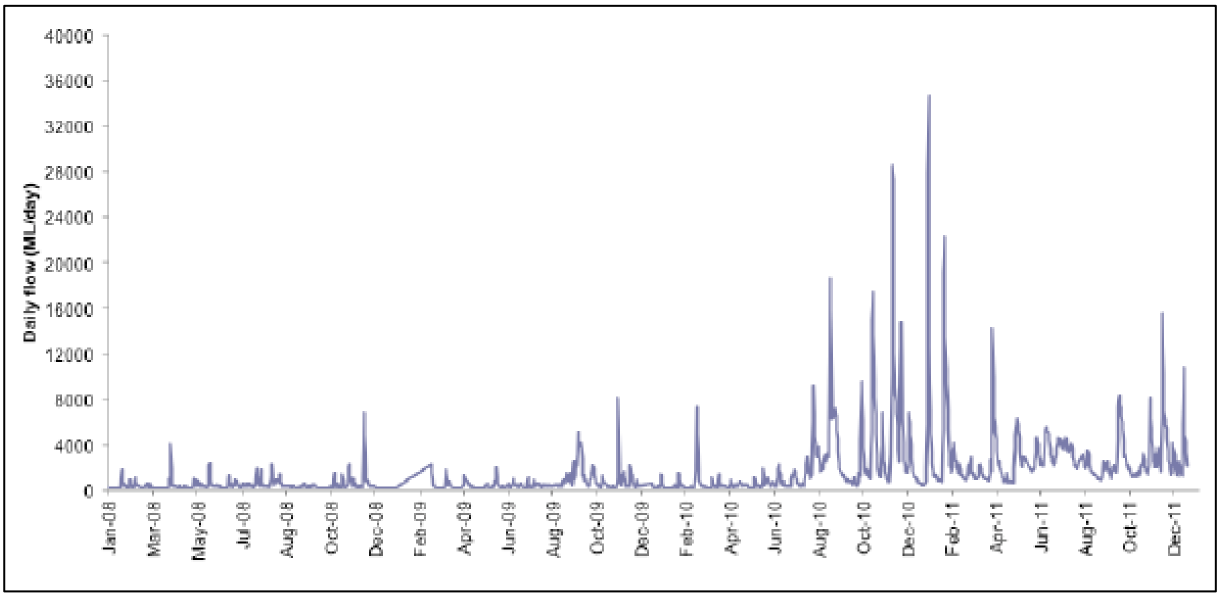

Figure 21: Total flow (Yarra and Maribyrnong Rivers) from June 2008 to December 2011 (Source: EPA Victoria (2013). Note that while this figure includes flow from both the Yarra and Maribyrnong Rivers entering the estuary, it does not provide an indication of stormwater inputs from the adjacent city areas (downstream of flow gauging stations). Note also that there is no stream gauge data for the estuary.

Water levels and salinity levels in estuaries vary with freshwater inflow discharge and tidal fluctuations. Seawater enters the Yarra River estuary from Port Phillip Bay on semidiurnal tidal cycles. The Bay is a large basin, and has a narrow connection to the Southern Ocean through the Heads in the south, which are at some distance from the estuary. The estuary discharges into the north of the Bay. Because of this, tidal fluctuations are smaller in the estuary than the open ocean and smaller than those experienced within the southern areas of the Bay (EPA Victoria 2013). Tides at the estuary mouth have an average range of around 0.5 m but can vary from 0.3 up to 0.8 m (Beckett *et al.* 1978).

The hydrology of the Yarra River estuary is highly dynamic, with freshwater flows mixing with salt water from Port Phillip Bay and extending upstream under the tidal influences as a salt wedge (Cooling *et al.* 2013). The salt wedge in the Yarra estuary creates a stratified water column, with a top layer of fresher river water (with salinity levels of less than 5000 mg/L) overlaying more saline water (where salinity is greater than 30,000 mg/L) (Beckett *et al.* 1978).

Figure 22 illustrates a conceptual model of the salt wedge in the Yarra estuary. The surface layer of freshwater flows continually downstream to the Bay, while the tip of the salt wedge moves up and down the estuary with the tide (Beckett *et al.* 1978). The position of the salt wedge also responds on two time scales: hours (tide and river flow); and months (river flow) (Beckett *et al.* 1978).

Figure 23 shows longitudinal salinity profiles for the estuary for a range of flows considered by Beckett *et al.* (1978). In summary:

- Under **low flows** (~350 ML/day) - Fresh surface waters extend downstream to around Punt Road, and the tip of the salt wedge is thought to be located just upstream of Punt Road. The saline bottom waters (salinity 5000 – 25,000 mg/L) extend to Bridge Road in the upper reaches of the estuary.
- Under **medium to high flows** (~2000 ML/d) - The tip of the salt wedge remains around Punt Road, and fresher surface waters extend downstream to the Port section and the water column is fully mixed in the upper reaches to a point around Grange Road.
- Under **high flows** (~9000 ML/d) - The tip of the salt wedge is located near King Street and fresh surface waters extend to the Westgate Bridge. The water column is well mixed to around King Street, but stratification is still evident in the port region.

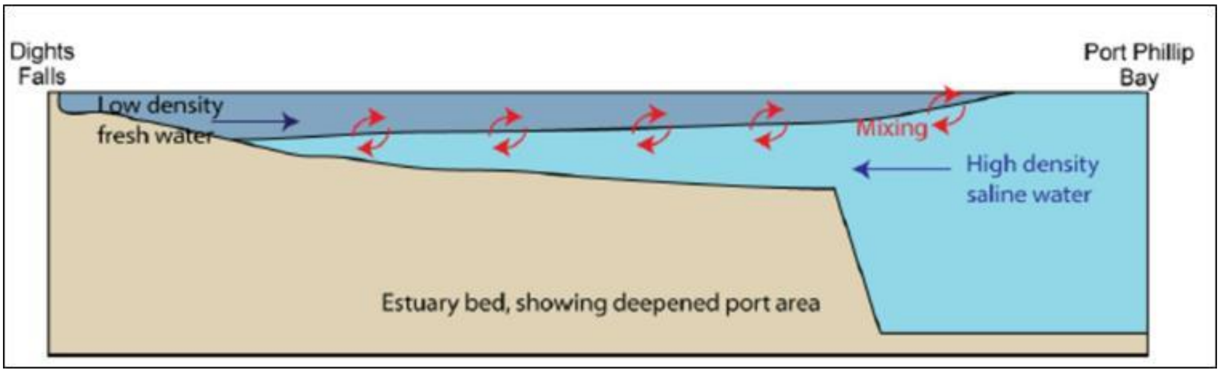

Figure 22: Conceptual model of the salt wedge in the Yarra estuary (Source: SKM (2005c)

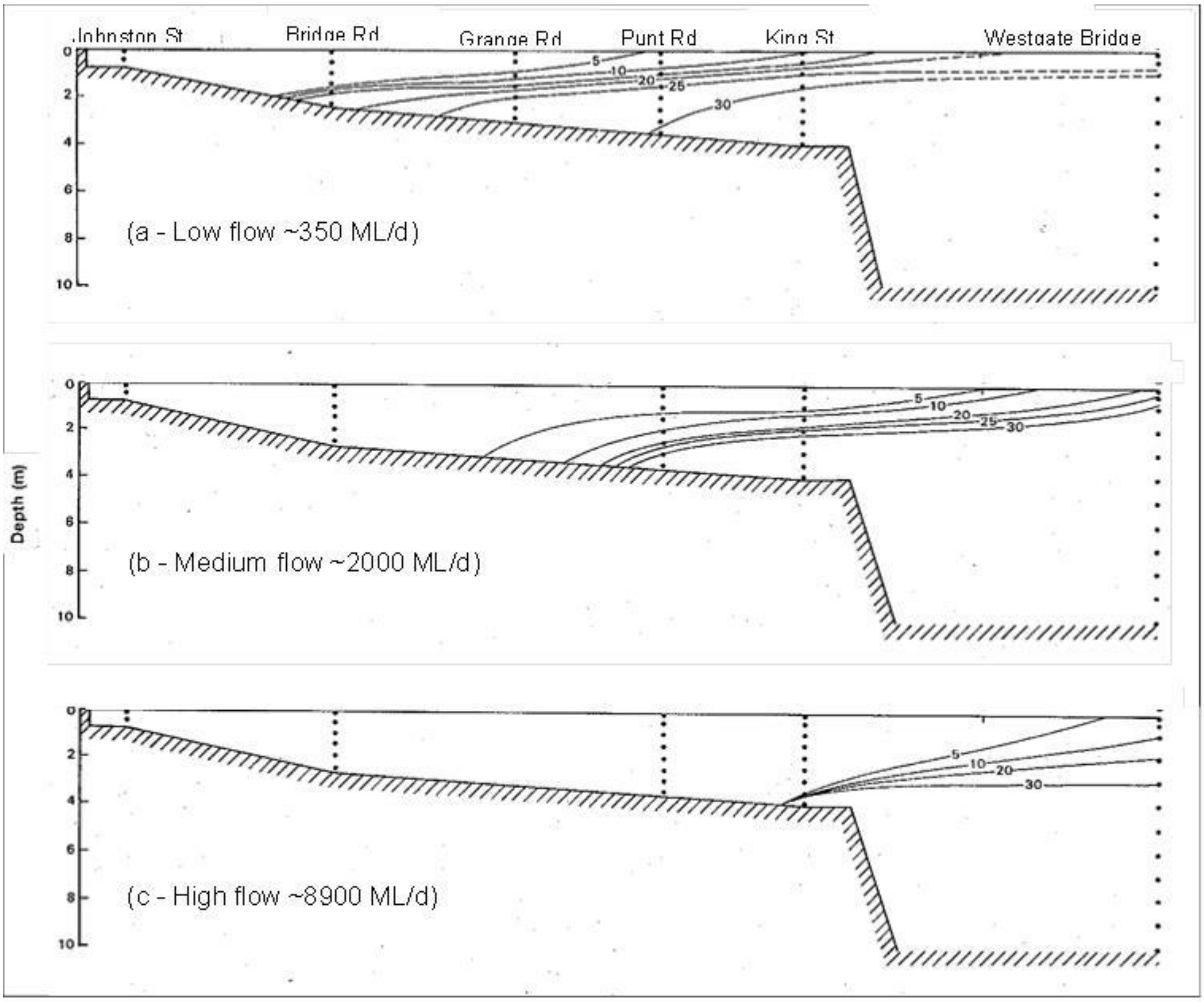

Figure 23: Longitudinal salinity profiles in the Yarra estuary showing the stratification and approximate location of the tip of the salt wedge under a range of flows (adapted from Beckett et al. 1982).

Modelled hydrology data for the freshwater reaches of the Yarra River, for the period 1963 to 2010, was used to provide flow recommendations for the estuary as part of the 2005 flows study. The recommendations were made on the assumption that the flows for Reach 6 would also be able to provide suitable flows for estuarine objectives (SKM 2005a). Flows to the estuary are equivalent to those in Reach 6 plus some small inflows from the Merri Creek immediately upstream of Dights Falls and further inflows from Gardiners Creek about one third of the way down the estuary (SKM 2005c). A number of large stormwater drains also enter the estuary and these can contribute significant volumes of flow during rainfall events. Further down the estuary in its lower reaches Moonee Ponds Creek and the Maribyrnong River also enter.

SKM (2005a) noted the following points regarding the hydrology of the Yarra River at Chandler Highway (Reach 6):

- The Yarra River at the Chandler Highway had a natural mean annual flow of 2,571 ML/day. This has been reduced by 38% under current conditions to 1,571 ML/day
- The reduction in flow has occurred across the entire flow regime but is most noticeable at lower flows
- The frequency of flood events has also decreased. Under natural conditions a 1 in 5 year flood had a magnitude of approximately 28,000 ML/day. Under current conditions a flood of this magnitude now has a frequency of 1 in 50 years.

High radon concentrations in the salt wedge also indicate groundwater exchange in the estuary (Santos *et al.* 2012), and it is thought that saline groundwater discharge to the estuary may help to augment the stability of the salt wedge (SKM 2005c).

5.4 Billabong hydrology

Billabongs are lentic (standing or still) wetlands that are usually formed on the floodplains of rivers because of the geomorphic action of the waterway (Hillman 1986). Billabongs provide important habitat for a range of fauna, such as fish, macroinvertebrates, birds, frogs, and riparian and aquatic vegetation. Billabongs can form in a number of ways. One of the most common (but not the only) type of billabong, an oxbow lake, forms when the path of a river changes to cut off a bend, or meander, leaving the original path of the river separated from the new path (Figure 24). In addition to oxbow lakes, a variety of other types of billabongs can form on floodplains, including backwater remnants that have been isolated by deposits along the banks, floodplain depressions, intermittently dry anabranches and stranded riverine pools (Boon *et al.* 1990).

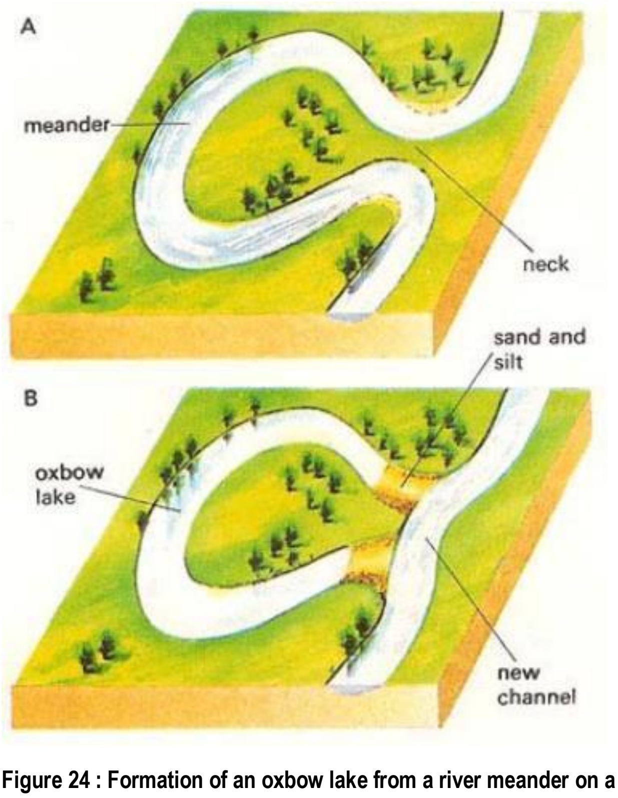

Figure 24 : Formation of an oxbow lake from a river meander on a floodplain (Source: SOSC (2015)).

Billabongs are typically shallow aquatic environments (<5 m in depth), which fill with water seasonally and then dry for the remainder of the year (SKM 2012a). A feature common to all billabongs is that they are filled by water from their associated river when the river level is high or after overbank flows, such as during floodplain inundation (SKM 2012a). This means that the factor that overwhelmingly controls the ecological structure and function of billabongs is their hydrology.

A large proportion of billabongs in the Greater Melbourne area are associated with the Yarra River and tributaries (SKM 2005c, Boon 2009a, SKM 2012a). Wetlands in Victoria are generally classified according to the Corrick and Norman system (Corrick and Norman 1980), which classes wetlands based on depth and duration of inundation. Billabongs are abundant along Reach 3, Reach 4 and Reach 6, and consist of both Freshwater Meadow and Deep Freshwater Marsh categories[21] under this classification system (Boon 2009a). These reaches are broad, alluvial floodplains with broad bends and large meanders (SKM 2012c). In contrast, other reaches of the river flow through a confined channel and there are significantly fewer billabongs (SKM 2012c). For example, Reach 2 flows through a narrow bedrock valley and there are few floodplain elements in this reach (SKM 2012c). Reach 5 is made up of the Yering and Warrandyte Gorges, but some floodplain wetlands are present (SKM 2012c).

Table 21 provides a summary of billabong hydrology where known for the main stem of the Yarra River.

Table 21 : Billabong hydrology summary

Reach	Corrick and Norman Classification	Hydrology
1	N/A	N/A
2	N/A	N/A
3	In Reach 3, all wetlands listed on the Wetlands Database have changed from Deep Freshwater Marsh to Freshwater Meadow	Flow regulation has meant that the frequency of bankfull and overbank flows have reduced slightly in Reach 3, contributing to the reduced inundation. Bankfull flows (approximately 7,500 ML/day) would have naturally occurred once a year, but now occur on average two in every three years. Overbank flows (approximately 9,000 ML/day) would have occurred two in every three years, but now occur once every four years.
4	In Reaches 4 and 5, ~80% of wetland number and area has changed from Deep Freshwater Marsh to Freshwater Meadow	The upstream part of Reach 4 passes through the Healesville Gorge, but downstream the river flows out onto the Yering floodplain, which is up to several kilometres wide (SKM 2012a). Like Reach 3, the wetlands and floodplain elements of Reach 4 are in poor condition due to a combination of land clearing, stock access and the reduced frequency of overbank flows (SKM 2012a).
5		No information available
6	In Reach 6, 33% of wetland number and 17% of wetland area has changed from Deep Freshwater Marsh to Freshwater Meadow.	Billabongs through this reach are expected to commence to fill at bankfull flows around 13,000 ML/d. Under natural conditions a 13,000 ML/d flow occurred once every year. Under current conditions this has reduced to once every three to four years. Billabongs along this reach would be expected to be filled under moderate flood conditions (~26,000 ML/d). Such a flow corresponds to the Bureau of Meteorology's definition of a moderate flood level (6.0 m at Chandler Highway; SKM 2012a).
7	No information available	No information available
8	No information available	No information available

[21] Freshwater Meadows are wetlands that are shallow (up to 0.3 m) and temporary (less than four months duration), although soils are generally waterlogged throughout winter. Deep Freshwater Marshes are wetlands that generally remain inundated to a depth of 1–2 m throughout the year

It has been estimated that since European occupation, nearly two-thirds of natural billabongs in the Greater Melbourne region have been lost to draining, filling or other modifications (SKM 2005c). When analysing billabongs in the Yarra River catchment for the 2005 Yarra River flows study, SKM (2005c) found that the majority of floodplain billabongs along the Yarra River in 1788 were likely to have been categorised as Deep Freshwater Marshes; they would have been flooded almost all of the time, to a depth of up to 2 m, but may have occasionally dried out during droughts. Urbanisation and development of the Yarra River floodplain has seen extensive drainage and flood mitigation works being put in place (such as levee banks), and the regulation of the waterway itself, causing most of these billabongs to become flooded for shorter durations, at shallower depths, and at a decreased frequency. The result is that many billabongs have shifted in their hydrological regime to a Freshwater Meadow category instead (SKM 2005c). As a consequence, billabongs associated with the Yarra River have become 'drier' since European occupation, and the estuarine reach of the Yarra River has experienced an almost complete loss of wetlands (96%) (Boon 2009a).

Billabong Case Study – Yering Backswamp

Yering Backswamp is located in a Melbourne Water restricted catchment area southeast of Sugarloaf Reservoir, approximately 5 km southwest of Yarra Glen and upstream of the Yering Gorge pump station (SKM 2012a). Historically, the billabong would have been filled by regular overbank flooding from the Yarra River (modelled as occurring naturally 1 in 5 years, compared to the current 1 in 12 years) (SKM 2012a). Runoff from the hills in the north would also have contributed additional water in winter/spring. The swamp was most likely seasonally wet and dry on an annual basis, except during periods of drought. It is unknown what contribution groundwater makes to the hydrology of the site. Regulation of the Yarra River and upstream extraction has changed the pattern of flows to the billabong, as has the building of the Maroondah Aqueduct, which leaked up to 0.5% of its flows prior to being lined in 2007 to limit transmission losses (SKM 2012a). Before the lining of the aqueduct, Yering Backswamp would have experienced artificially wet conditions, and is now set to become smaller and drier under the current water regime.

Melbourne Water is managing the site to maintain the current diversity. Infrastructure has been provided to allow for watering of the site from the Maroondah Aqueduct using water from the Yarra Environmental Entitlement.

Figure 25 : Yering Backswamp, looking east

Figure 26 : Yering Backswamp water outlet

5.5 Groundwater-surface water interactions

Groundwater is an important component in the hydrological regime of many species and ecosystems and can be crucial to their health. Such systems are called groundwater dependent ecosystems (GDEs) and can be classified into three different types (Richardson *et al.* 2011):

1. Ecosystems dependent on the surface expression of groundwater, e.g. wetlands, river pools or springs
2. Ecosystems dependent on the subsurface presence of groundwater, e.g. terrestrial or riparian vegetation
3. Caves and aquifers, in which groundwater provides a unique habitat for living organisms.

Types 1 and 2 are thought to exist in the Yarra River catchment (SKM 2012c).

The relative importance of groundwater and surface water inputs is poorly understood for the majority of the Port Phillip and Westernport region, but it is considered likely that groundwater discharge represents a significant component of the water balance at many locations. The geology, topography and related geomorphology of the Yarra catchment suggests that the main stem of the Yarra River has some sections where it gains groundwater (gaining), and some sections where it loses water to groundwater (losing).

Figure 27 shows that the upper reaches of the Yarra catchment are typically characterised by gaining conditions, but seasonally losing conditions (during higher flows in winter/spring) are identified between Healesville and Warrandyte. The lower reaches between Warrandyte and Heidelberg are classified as gaining but essentially neutral during summer. Neutral conditions (neither gaining or losing), occur between Heidelberg and Chandler Highway and persist to the river mouth.

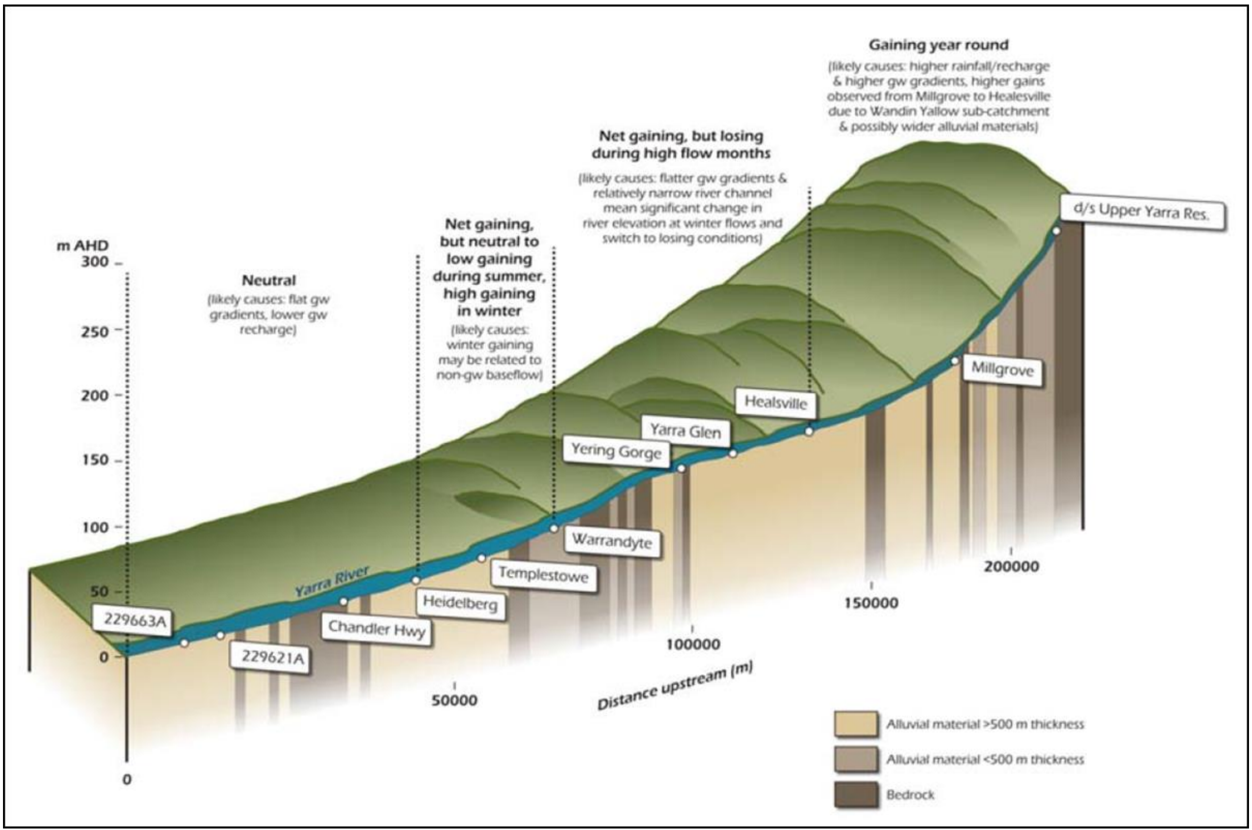

Figure 27 : Conceptual model of groundwater surface water interaction within the Yarra catchment (Source: SKM (2011a))

Survey and mapping undertaken of river flow before regulation, towards the end of summer in 1968, shows that the Yarra River and many of its tributaries continued to flow despite severe drought conditions over the previous decade (Figure 28). This is a strong indication that groundwater discharge was contributing to baseflow at the time. (SKM 2012c).

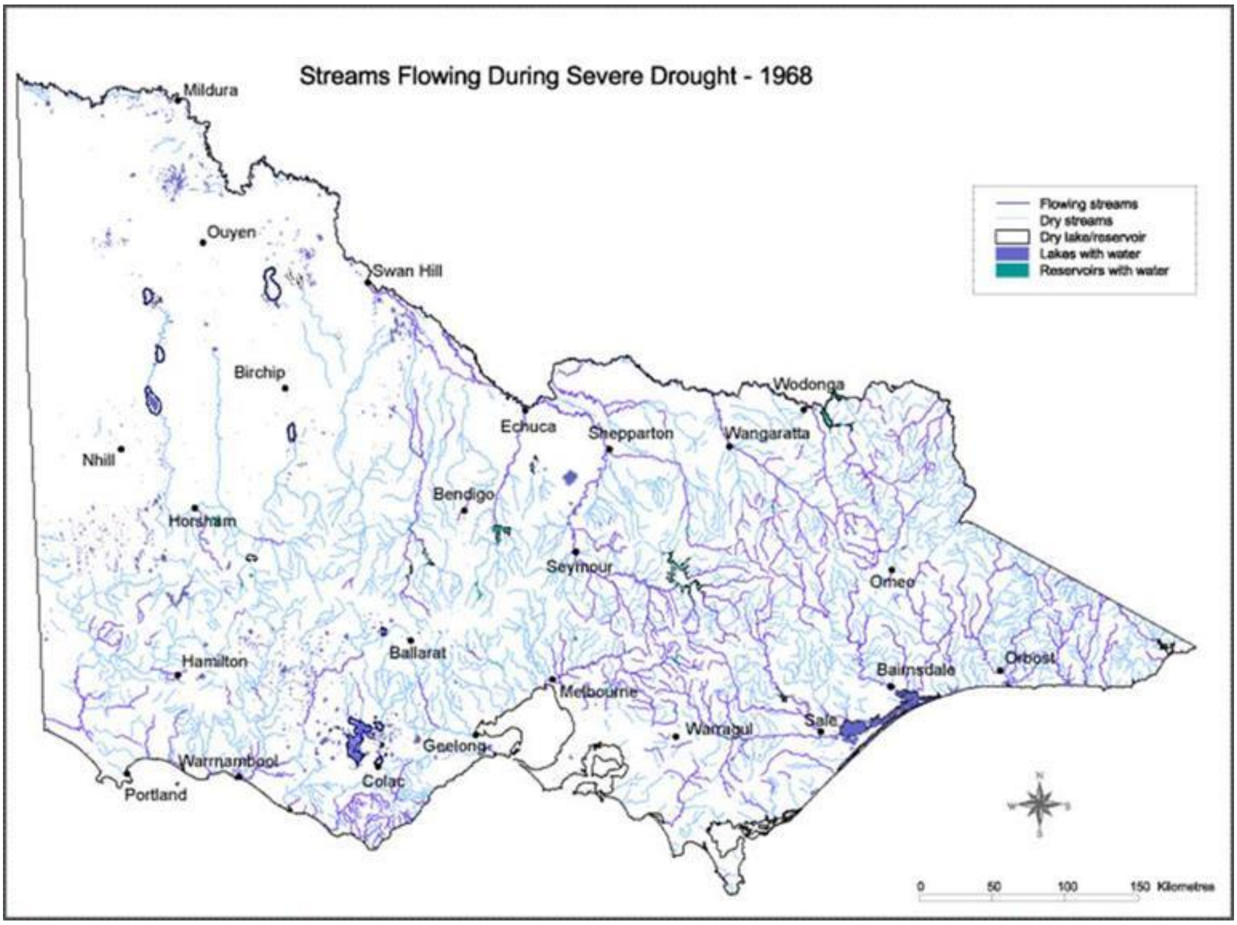

Figure 28 : Extract from Victorian Rivers Flowing During Drought (Source: SKM (2012c))

Groundwater is expected to be the dominant source of baseflow to the Yarra River and SKM (2011a) suggest that baseflow contributions to river flow in the Yarra catchment range from 30 to 80%, with an annual contribution of around 50%. This means that there are a number of reaches and pools along the Yarra River where groundwater inflow is likely to improve the survival chances of key species by providing refuges during drought. The shallow nature of the watertable close to the Yarra River channel also suggests that some stands of riparian vegetation (including fringing wetland vegetation) may be dependent on groundwater (SKM 2012c). This is particularly important for riparian vegetation and wetlands during times of low flows and drought when soil water stored in the river banks and floodplain may be depleted (SKM 2012c).

The potential terrestrial and wetland GDEs and drought refuges are shown in Figure 29 and Figure 30.

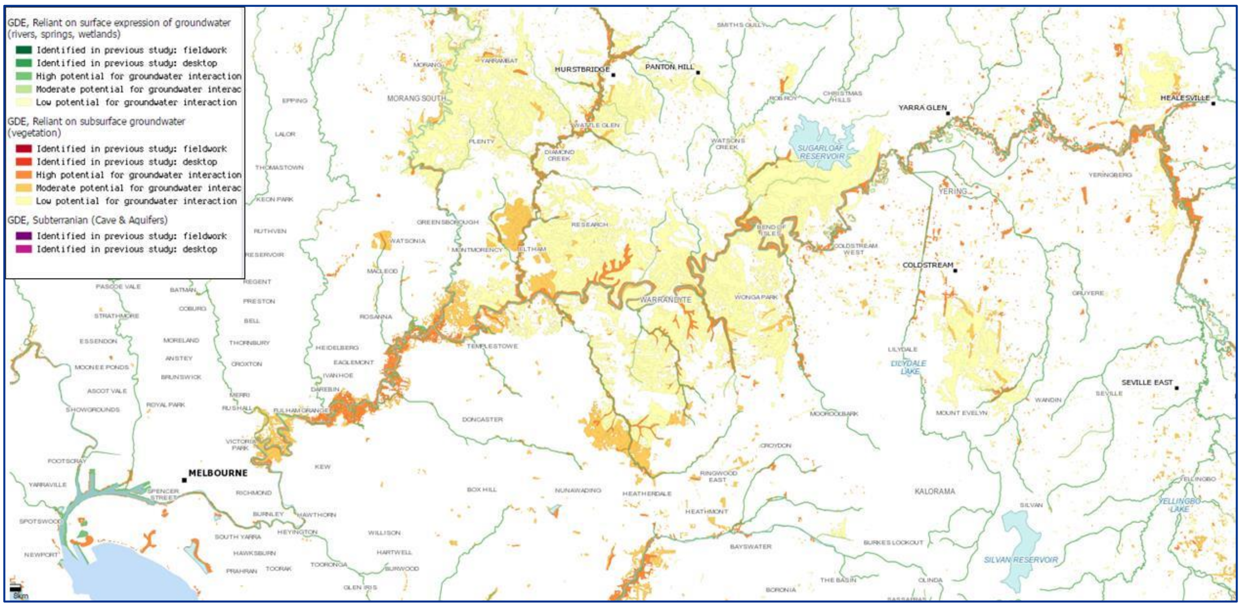

Figure 29 : Groundwater dependent ecosystems – From estuary and upstream to Healesville (Source: BOM (2016))

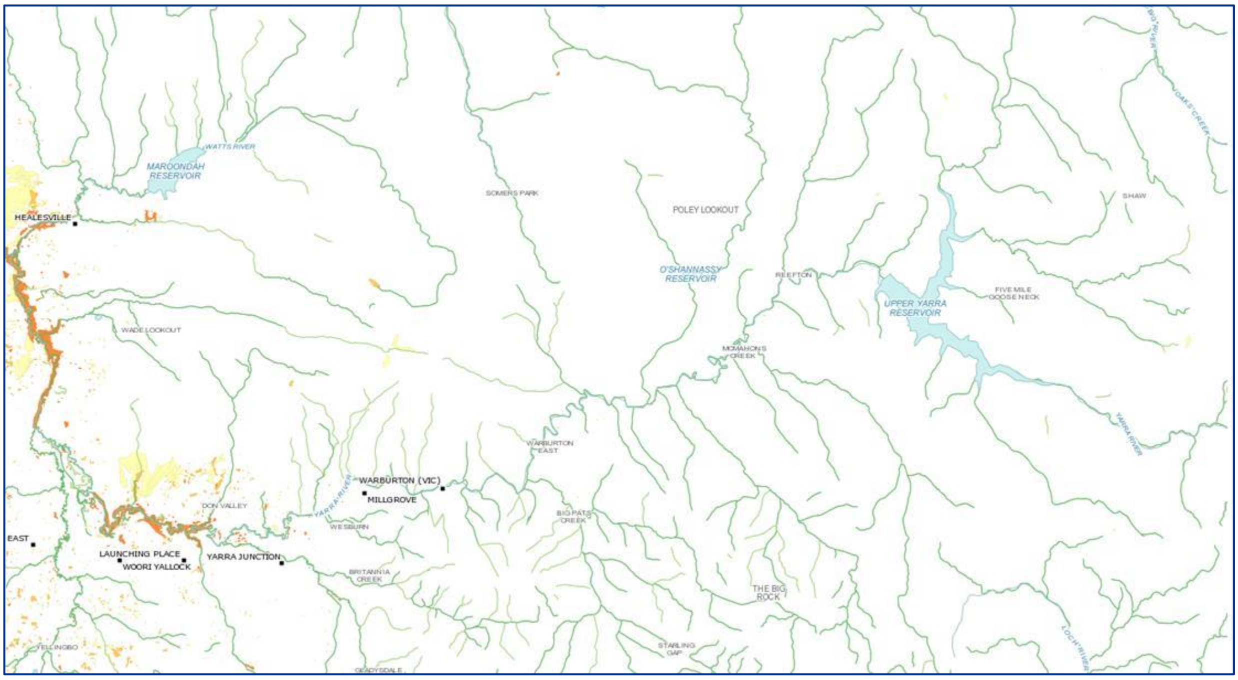

Figure 30 : Groundwater dependent ecosystems –From Healesville and upstream to Upper Yarra Reservoir (Source: BOM (2016))

5.6 Environmental Entitlement release locations

The 17,000 ML of water available under the Environmental Entitlement can be released from the Upper Yarra, Maroondah and O'Shannassy Reservoirs and can also be delivered by ceasing harvesting activities at Yering Gorge and the Yarra tributaries. Reach 1 and the upper part of Reach 2 can only receive environmental water from the Upper Yarra Reservoir, but the lower part of Reach 2 and Reach 3 can also be supplied from O'Shannassy Reservoir. Water from Maroondah Reservoir flows into the Yarra River via the Watts River at Reach 4.

Release locations and target reaches for the 17,000 ML Environmental Entitlement are outlined in Table 22.

Table 22 : Storages, release points and target reaches.

Storage / Weir	Release Locations	Target Reaches
Upper Yarra	• Upper Yarra Reservoir valves into Reach 1 • Upper Yarra – Silvan Aqueduct into Reach 2	Reaches 1 - 6
Maroondah Reservoir	• Maroondah Reservoir valves into Watts River (Reach 8). Delivers into Reach 4. • Maroondah Aqueduct at Yering Gorge (Reach 5)	Reaches 4 – 6, and Reach 8
O'Shannassy Reservoir	• O'Shannassy Reservoir valves into O'Shannassy River. • Delivers into Reach 2.	Reaches 2 - 6
Upper Yarra Tributaries	• MacMahons Creek, Starvation Creek and Armstrongs Creek weirs. • Delivers into Reach 2.	Reaches 2 - 6

Due to the configuration of possible release points, the priority reaches for environmental watering are Reaches 2 and 5, because delivery of water to these reaches is expected to achieve flow targets in downstream reaches.

Water from the 55 ML/yr environmental holding downstream of Olinda Creek is provided via the restrictions and specifications that apply to other entitlement holders in the Olinda Creek Water Supply Protection Area Stream Flow Management Plan 2007 and the Stringybark Creek Water Supply Protection Area Stream Flow Management Plan 2007.

5.6.1 Protecting environmental flow releases

Streamflow diverters licenced under Section 51 of the *Water Act (1989*) within the Yarra system are managed by the Melbourne Water Diversions Team. Bans and restrictions on diversion are detailed in the Drought Response Plan for Licence Water Users (Melbourne Water 2007). During a dedicated environmental flow release, diverters within the affected reaches of the Yarra River are generally kept on the level of restrictions that were in place prior to the release. At Melbourne Water's discretion, the level of restriction or ban may become less severe following a significant rainfall event that coincides with a release (Melbourne Water 2007).

The storage manager is able to use waterways within the Yarra Basin as a conduit to deliver water to the Yering Pump Station. This occurred for example during the Millennium Drought when the Yarra EE had been Qualified. By doing this, environmental conditions were improved in the River through the provision of additional water to the waterway. The Operating Arrangements state that where possible, the storage manager, waterway manager and VEWH will continue to seek opportunities to use consumptive water en route to meet ecological or social objectives, provided there is no material impact on existing entitlement holders or any other third party impact.

5.7 History of environmental water delivery

Prior to the development and implementation of the Yarra River's Environmental Entitlement, environmental water was delivered to the Yarra River through arrangements for passing flows from both storages and through conditions placed on diversion licences in the Yarra system. The creation of the Environmental Water Reserve via policies announced in the *Our Water Our Future* White Paper (DSE 2004), and updates to the Victorian *Water Act 1989*, allowed for the development of the environmental Bulk Entitlement for the Yarra River, gazetted as the *Yarra Environmental Entitlement 2006*. The entitlement became effective on the 26th October 2006 and set aside the first 17,000 ML of inflows from the 1st July of each year to be stored in the Melbourne Water headworks system specifically for achieving environmental objectives.

As the designated Environmental Water Manager, Melbourne Water was required to produce the first Annual Watering Plan by the 26th April in 2007, but this was deferred on the 16th April 2007 when the

Victorian Minister for Water, Environment and Climate Change enacted a Qualification of Rights (QoR) for the Yarra River in response to the severe impacts on Melbourne's water supply from the Millennium Drought. The QoR was enforced until water restrictions were eased in Melbourne in October 2010.

The Yarra received the first flows of its reinstated Environmental Entitlement in September 2011. The release of 783 ML from the Upper Yarra Reservoir marked the first time the Yarra received managed flows above minimum flow since the Environmental Entitlement was reinstated in 2010.

Melbourne Water has made releases under the Environmental Entitlement for Yarra River ecological objectives every year since the first flows were provided in 2011. These environmental watering activities reflect the flow recommendations developed under flow assessment studies, including the first Yarra River environmental flow assessment (SKM 2005c), and the 2012 flows study review (SKM 2012d).

5.8 Environmental water delivery operating arrangements

Managing and delivering environmental water requires careful planning. As the Waterway Manager for the Yarra River, Melbourne Water is responsible for developing and implementing the Healthy Waterway Strategy[22], the Environmental Water Management Plan, and the Seasonal Watering Proposal. Seasonal watering proposals are required under Section 192A of the *Water Act 1989*. The Seasonal Watering Proposal outlines Melbourne Water's annual priorities for the use of the Yarra Environmental Entitlement. It is used by the VEWH to inform the development of its Seasonal Watering Plan, which outlines the full scope of statewide priorities for the use of environmental Water Holdings in any year. Melbourne Water is also responsible for planning the implementation of specific Yarra River watering activities for each watering year. As part of its delivery planning and implementation, Melbourne Water reviews, updates and implements any risk mitigation actions identified in the Seasonal Watering Plan.

The framework that guides environmental water delivery arrangements for the Yarra River is shown in Figure 31.

Operating arrangements for the management of the Yarra River's environmental water holdings were developed by VEWH and Melbourne Water in 2014 (Melbourne Water and VEWH 2014). These arrangements specify the procedures for the release of environmental water to the Yarra River, the ordering protocol for regulating environmental water releases and the reporting arrangements.

SKM (2012d) recommends rates of rise and fall for water releases, which are designed to mimic natural rates of change in streamflows. Releases are made to ensure that rates of rise and fall do not deviate significantly from those of naturally occurring streamflow events. The rates of rise and fall are determined during the flow delivery planning process, and are confirmed during the ordering process

[22] Also called a Regional Waterway Strategy by Catchment Management Authorities, as per Figure 31

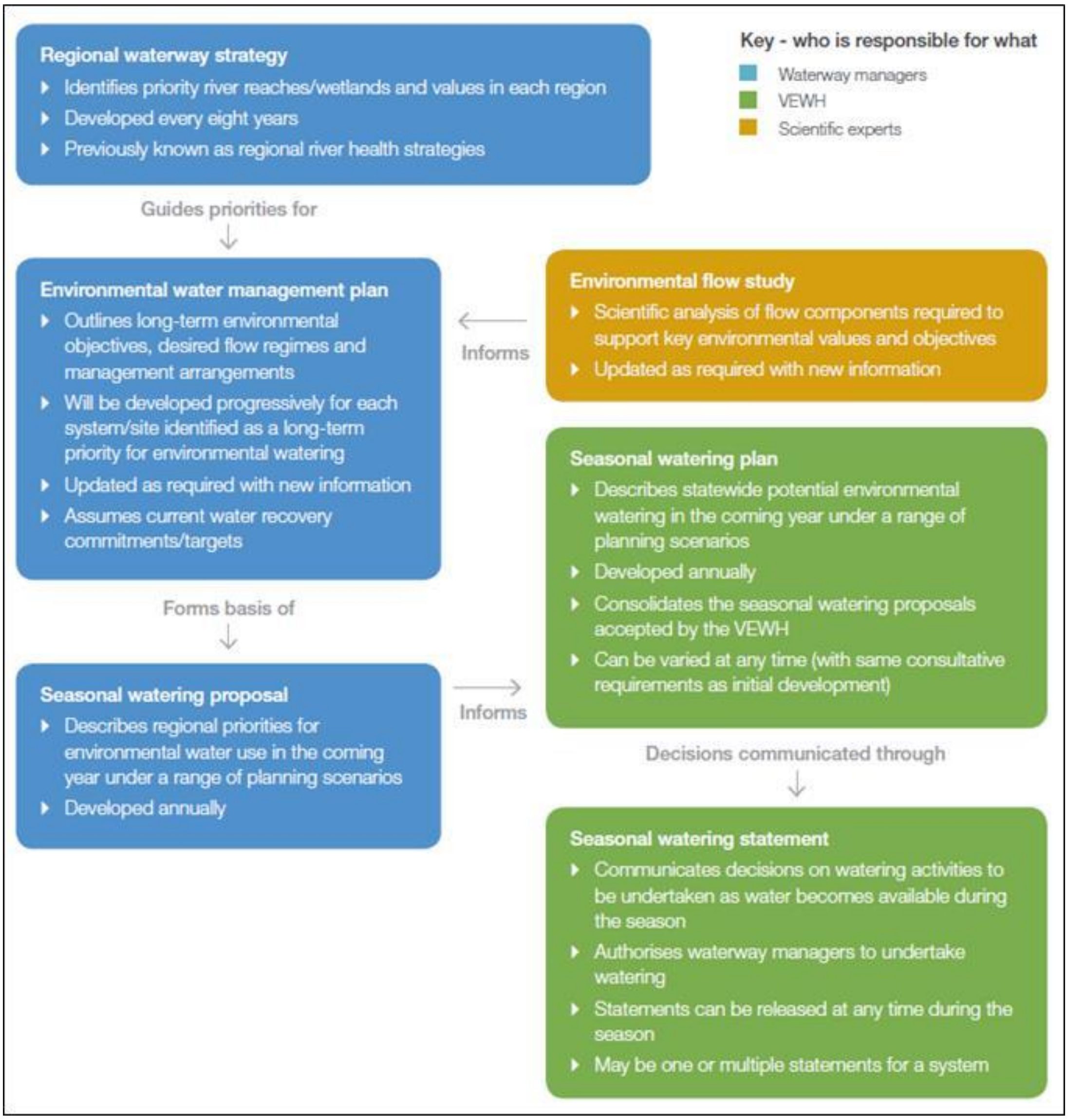

Figure 31 : Victorian environmental watering program planning and management framework (Source: VEWH (2015)

MANAGEMENT OBJECTIVES

6. The Vision for the Yarra River

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

The vision for the Yarra 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.

Vision Statement

The Yarra River is a unique, iconic and valuable waterway that is much loved by our community. We will work to protect and where possible restore and enhance its ecological health and functioning, so that it continues to contain a rich diversity of self-sustaining indigenous plants and animals. Using a catchment-wide approach, our work will apply from the river's headwaters to the Bay, and will target the water-dependent values our community sees as important. The environmental flows we provide to these values will be determined using robust and evidence-based science and strong community input, so that the Yarra River can continue to be enjoyed by future generations.

6.1 Ecological objectives

The key values of amenity, fish, birds, frogs, macroinvertebrates, platypus and vegetation in Melbourne Water's Healthy Waterways Strategy provide the basis for management objectives in the Yarra River EWMP, and have also been endorsed through extensive community consultation.

The EWMP acknowledges the important feedback provided by the community in developing the Healthy Waterways Strategy management objectives, but where possible, will aim to strengthen these objectives.

A summary of these objectives is shown in Figure 32. An explanation for each of the condition ratings is provided in Appendix F.

The Yarra River FLOWS studies provide the more detailed ecological objectives for a number of the river's key values. In 2005, the flow recommendations were developed for the freshwater reaches and the estuary (SKM 2005a). In 2012, these flow recommendations were then reviewed to incorporate relevant new knowledge (SKM 2012c, d, b). In 2013, a review of the original 2005 estuary recommendations was conducted, and a series of objectives for estuary values were then refined (Cooling *et al.* 2013). The flows studies have focused on determining ecological objectives and flow recommendations for vegetation, fish and macroinvertebrates, as well as geomorphology. Geomorphology is a key value within the flows studies because of its role in the provision and maintenance of good quality habitat, but it is not specifically recognised as a value in the Healthy Waterways Strategy. Flow requirements for birds, frogs, platypus and amenity were not able to be recommended due to insufficient knowledge at the time (SKM 2012c). This paucity of information is considered to be a knowledge gap, and is discussed further in Section 12.

Environmental flow recommendations are determined based on an assumption that particular flow components are able to provide an ecological function that then contributes towards the achievement of ecological objectives. Table 23 to Table 25 list the management objectives specified in the Healthy Waterways Strategy for each of the key values, and document the related ecological objectives and ecological functions for the key flow components recommended in the flow studies that help to achieve these management objectives. Note that because the key values of platypus, frogs, birds and amenity were not provided with specific flow recommendations in the flows studies, the ecological objectives of these values have been kept more generic for the EWMP. These objectives are focused on the need to rehabilitate, maintain or improve access to habitat, as well as protect and improve its quality (Table 26).

Lower Yarra Management Unit
Relevant Reaches - 6 & 7

Value	Overall HWS Objective	Yarra Priority?	Condition Rating: Current	Condition Rating: Expected in 20 years
Fish	Maintain the species richness, nativeness and abundance of fish populations	★	M	H
Platypus	Stabilise the relative abundance of the Platypus population		VL	VL
Frogs	Maintain diversity and improve the overall abundance and distribution of expected species of frog populations		H	H
Macroinvertebrates	Maintain the number of macroinvertebrate families present		H	VH
Birds	Maintain or improve the species richness and abundance of streamside and wetland bird populations		L	L
Vegetation	Maintain and improve vegetation condition Maintain vegetation at high quality	★	VL	M
Amenity	Maintain and/or improve amenity	★	M	H

Middle Yarra Management Unit
Relevant Reaches - 2, 3, 4, 5 & 8

Value	Overall HWS Objective	Yarra Priority?	Condition Rating: Current	Condition Rating: Expected in 20 years
Fish	Maintain the species richness, nativeness and abundance of fish populations	★	M	H
Platypus	Stabilise the relative abundance of the Platypus population		VL	VL
Frogs	Maintain diversity and improve the overall abundance and distribution of expected species of frog populations	★	H	H
Macroinvertebrates	Maintain the number of macroinvertebrate families present	★	L	M
Birds	Maintain or improve the species richness and abundance of streamside and wetland bird populations	★	L	L
Vegetation	Maintain and improve vegetation condition Maintain vegetation at high quality	★	M	H
Amenity	Maintain and/or improve amenity	★	L/M	H

Upper Yarra Management Unit
Relevant Reaches - 1

Value	Overall HWS Objective	Yarra Priority?	Condition Rating: Current	Condition Rating: Expected in 20 years
Fish	Maintain the species richness, nativeness and abundance of fish populations		M	H
Platypus	Stabilise the relative abundance of the Platypus population		VL	M
Frogs	Maintain diversity and improve the overall abundance and distribution of expected species of frog populations	★	M	H
Macroinvertebrates	Maintain the number of macroinvertebrate families present	★	H	VH
Birds	Maintain or improve the species richness and abundance of streamside and wetland bird populations		VH	VH
Vegetation	Maintain and improve vegetation condition Maintain vegetation at high quality	★	H	VH
Amenity	Maintain and/or improve amenity		H	H

Figure 32 : Summary of HWS management objectives, priorities and expected changes in condition for key values

Table 23 : Management objectives and ecological objectives for Fish

HWS objective	Season	Ecological objective and priority reaches	Ecological function	Key flow component
Maintain species richness, nativeness and abundance of fish populations	Summer / Autumn	Maintain or improve diverse populations of non-migratory and migratory native fish, with the aim of complying with Yarra SEPP Schedule F7 objectives	Provide suitable depth in pools and through riffles to maintain access to habitat	Low flow
			Provide opportunities for spawning, movement and downstream transport of eggs and larvae. Flushes sediment from spawning sites	Fresh
		Rehabilitate populations of Australian Grayling	Trigger Australian Grayling spawning and downstream transport of eggs and larvae to sea (Autumn)	High flow

HWS objective	Season	Ecological objective and priority reaches	Ecological function	Key flow component
		Maintain or improve non-migratory native fish diversity and abundance	Flush sediment to increase availability of spawning sites	
	Winter / Spring	Maintain or improve diverse populations of non-migratory native fish, with the aim of complying with Yarra SEPP Schedule F7 objectives	Provide suitable depth in pools and through riffles to maintain access to habitat	Low flow
			Provide suitable depth in pools and through riffles to maintain access to habitat	Fresh
			Flush sediment to improve quality and availability of spawning sites	
		Maintain or improve diverse populations of migratory native fish, with the aim of complying with Yarra SEPP Schedule F7 objectives	Trigger upstream/downstream migration and/or spawning (depending on species requirements)	High flow
		Prevent declines in Macquarie Perch distribution and abundance[23]	Flush sediment during pre-spawning period to improve quality and availability of spawning sites (early Spring)	

Table 24 : Management objectives and ecological objectives for Macroinvertebrates

HWS objective	Season	Ecological objective	Ecological function	Key flow component
Maintain the number of macroinvertebrate families present	Summer / Autumn	Rehabilitate macroinvertebrate community to maximum possible diversity and abundance possible downstream of a large dam, to meet Yarra SEPP Schedule F7 objectives (Reach 1 only) Maintain or rehabilitate macroinvertebrate community to comply with Yarra SEPP Schedule F7 objectives	Provide suitable depth through riffles to maintain access to habitat	Low flow
			Provide disturbance to scour biofilms and sediment and increase quality of macroinvertebrate habitat	Fresh
	Winter / Spring	Maintain or rehabilitate macroinvertebrate community to comply with Yarra SEPP Schedule F7 objectives	Provide seasonal increase in depth through riffles and increased width of wetted habitat to support macroinvertebrate production during cooler temperatures	Low flow
			Provide disturbance to scour biofilms and sediment and increase quality of macroinvertebrate habitat	Fresh

[23] Ongoing research into the spawning habits of Macquarie perch has raised doubt about the need for this flow. A review of the linkage between this objective and associated ecological function will be undertaken as part of the next Environmental Flow Study review.

Table 25 : Management objectives and ecological objectives for Vegetation

HWS objectives	Season	Ecological objective	Ecological function	Key flow component
Maintain and improve vegetation condition **Maintain vegetation at high quality**	Summer / Autumn	Maintain current in-stream & riparian vegetation extent, structure & composition	Provide suitable range of depths for growth of in-stream macrophytes	Low flow
			Provide suitable depth and inundation extent within channel to create depth range for emergent vegetation (e.g. Cumbungi, Common Reed and other reed, sedge and rush assemblages)	
			Provide periodic inundation of lower banks to maintain soil moisture for flood-dependant littoral vegetation (e.g. water ferns)	Fresh
			Provide periodic inundation of lower banks to extend range over which emergent vegetation can colonise banks.	
	Winter / Spring	Maintain/improve in-stream and fringing emergent vegetation	Provide suitable range of depths for growth of in-stream macrophytes and biofilms	Low flow
			Provide periodic inundation of lower banks to maintain soil moisture for flood-dependant littoral vegetation (e.g. water ferns)	Fresh
		Maintain inundation-tolerant vegetation in riparian zone on upper banks and lower levels of riparian zone	Remove mud and silt from subsurface cobbles and boulders	Bankfull
			Provide periodc inundation of upper banks to maintain soil moisture and promote germination and seedling growth of riparian shrubs and trees (e.g. Paperbarks, Callistmons and Tea Tree)	
		Maintain and/or rehabilitate floodplain and billabong vegetation	Provide periodic inundation of floodplains to maintain sedimentation processes and enhance soil moisture for growth and recruitment of floodplain vegetation (e.g. river red gums), and to fill wetlands and billabongs	Overbank

Table 26 : Management objectives and ecological objectives for Platypus, Birds, Frogs and Amenity

HWS objectives	Season	Ecological Objective	Ecological Function	Key flow component

HWS objectives	Season	Ecological Objective	Ecological Function	Key flow component
Platypus – Stabilise the relative abundance of the population **Birds** – Maintain or improve the species richness and abundance of streamside and wetland populations **Frogs** – Maintain diversity and improve the overall abundance and distribution of expected species **Amenity** – Maintain and/or improve condition	Summer / Autumn	Maintain access to good quality physical habitat, provide good water quality, and support the growth of instream vegetation, an important source of food resources and habitat	Maintains permanent pools with an adequate depth of water for habitat for biota such as macroinvertebrates, an important food source for birds, frogs and platypus Provides disturbance to scour the river bed of sediment and improve the quality of instream habitat Also provides a suitable range of depths for the growth of in-stream vegetation	Low flow
			Provides disturbance to scour the river bed of sediment and improve the quality of habitat within the river Provides a suitable depth of water for waterbirds and platypus, maintaining the extent of habitat range they can utilise Provides flow variability to maintain a diversity of emergent and riparian vegetation and helps to influence vegetation zonation patterns across the channel, which then provides a variety of habitats.	Fresh
		Rehabilitate and maintain habitat within the higher parts of the river channel	Moves sediment along the river improving the quality of, and access to, instream habitat Sustains longitudinal connectivity, providing opportunities to move along and between habitats for platypus and waterbirds. Helps to influence vegetation zonation patterns across the channel, which provides a variety of habitats.	High flow
	Winter / Spring	Maintain access to good quality physical habitat, provide good water quality, and support the growth of instream vegetation, an important source of food resources and habitat	Increases habitat area for instream flora and fauna including access to large woody debris and overhanging banks. Encourages the die-back of terrestrial vegetation that has encroached down the bank during the summer low flow period	Low flow
			Provides flow variability to maintain a diversity of emergent and riparian vegetation and to influence vegetation zonation patterns across the channel, which provides a variety of habitats for birds and platypus Moves terrestrial organic matter along that has accumulated on benches.	Fresh

HWS objectives	Season	Ecological Objective	Ecological Function	Key flow component
		Rehabilitate and maintain appropriate habitat within the higher parts of the river channel Maintain important flow cues for a range of animal behaviours	Moves sediment along the river improving the quality of, and access to, instream habitat Sustains longitudinal connectivity, providing opportunities to move along and between habitats. Provides flow cues for platypus behaviours, such as choice of burrow sites Helps to influence vegetation zonation patterns across the channel, which provides a variety of habitats.	High flow
		Maintain instream habitats and improve the condition of billabongs connected around bankfull Maintain important flow cues for animal behaviours	Increases habitat area, including access to large woody debris and overhanging banks for instream biota, and engage floodplain and billabong habitat for frogs and waterbirds Helps to disturb and reset aquatic and riparian vegetation communities, important for a range of diverse habitat types for birds, frogs and platypus Provides flow cues for platypus behaviours, such as choice of burrow sites Moves along organic matter and sediment that has accumulated in pools and the upper channel, improving habitat quality for platypus.	Bankfull *(avoid Oct, Nov if possible)*
		Reconnect the floodplain and floodplain billabongs with the instream channel Maintain wetland/billabong species and communities	Improves the frequency and extent of flooding in floodplain wetlands and billabongs. Provides water for flood-tolerant vegetation such as River Red Gum Provides wetted habitat for waterbird and frog species who don't necessarily require instream habitat	Overbank *(avoid Oct, Nov if possible)*

It should be noted that not all of the recommendations in these tables are of equal priority for delivery by VEWH and Melbourne Water. Factors such as the feasibility of delivering environmental water, infrastructure constraints, and water availability all have a significant influence on which objectives and reaches are targeted for the annual use of the Yarra River Environmental Entitlement. This is discussed further in Section 6.3.

6.1.1 Management objectives for billabongs - Yering Backswamp case study

Developing management objectives for billabongs will be an ongoing action for Melbourne Water. To illustrate potential management objectives, a case study for Yering Backswamp has been collated from studies and prioritisation assessments completed by Paul Boon (Boon 2009a, b) and SKM (SKM 2012a) (Table 27).

Table 27 : Management objectives and ecological objectives for Yering Backswamp

<table>
<tr><th>Key Value</th><th>Ecological Objectives (Yering Backswamp only)</th><th>Inundation requirement</th></tr>
<tr><td>Fish</td><td>No specific fish objectives</td><td rowspan="7">Historically the swamp would have been filled by regular overbank flooding from the Yarra River (1 in 5 years), and runoff from the hills in the north would have contributed additional water in winter/spring.

The swamp was most likely seasonally wet and dry an annual basis, except during periods of drought. Regulation of the Yarra River and upstream extraction has changed these flows and a 1 in 5 year flood now only occurs 1 in 12 years.

The swamp is currently typically inundated with shallow water (0.5m) for only a few months of the year (<8 months/yr). A diversity of hydrological regimes is required to support the current floristic and structural diversity within the swamp, and the existing wetland EVCs require semi-permanent to permanent inundation.</td></tr>
<tr><td>Vegetation</td><td>Management objectives are likely to be one of two options:
• Allow the new hydrological conditions to remain, with the likely result that the billabong will continue to dry, and Swamp Paperbark will become the dominant vegetation type in the wetland
• Undertake hydrological interventions to prevent the drying-out of the wetland, with the intention to maintain as much as possible of the floristic, structural and habitat diversity of the site.</td></tr>
<tr><td>Macroinvertebrates</td><td>No specific macroinvertebrate objectives</td></tr>
<tr><td>Platypus</td><td>No specific platypus objectives</td></tr>
<tr><td>Frogs</td><td>No specific frog objectives</td></tr>
<tr><td>Birds</td><td>No specific bird objectives</td></tr>
<tr><td>Amenity</td><td>No specific amenity objectives</td></tr>
</table>

Melbourne Water will prepare management objectives for the site, as well as other high value billabongs along the Yarra River through its separate billabong prioritisation and watering program. The EWMP will be updated with these decisions as they become available.

6.1.2 Management objectives for the estuary

Management objectives for the Yarra River estuary were initially provided in the 2005 flows study (SKM 2005a), but were not provided in the 2012 flows study review (SKM 2012d), with SKM acknowledging the need for a separate estuary flows study process. The Yarra River estuary environmental flows study scoping report (Cooling *et al.* 2013) identified a range of knowledge gaps that require addressing in order to conduct such a study, but was not tasked with setting management objectives. Until an estuary flows study is conducted, the management objectives provided in Table 28 may provide an indication of the likely nature of these objectives.

Recommendations for addressing knowledge gaps for the estuary's flow requirements are described in Section 12.

Table 28 : Management objectives previously recommended for the Yarra River estuary

<table>
<tr><th>HWS objectives</th><th>Season</th><th>Ecological objective</th><th>Ecological function</th><th>Key flow component</th></tr>
<tr><td rowspan="3">As per the management objectives for key values specified in Table 23 to Table 26</td><td rowspan="2">Summer / Autumn</td><td rowspan="2">Support ecological processes and provide access to habitat</td><td>Maintains a well oxygenated salt wedge (water quality)</td><td>Low flow</td></tr>
<tr><td>Maintains vertical and longitudinal salinity gradients (water quality)</td><td>Fresh</td></tr>
<tr><td>Winter / Spring</td><td>Support ecological processes and provide</td><td>Maintains a well oxygenated salt wedge (water quality)</td><td>Low flow</td></tr>
</table>

HWS objectives	Season	Ecological objective	Ecological function	Key flow component
		access to habitat	Maintain vertical and longitudinal salinity gradients (water quality)	Fresh
		Support ecological processes and provide access to habitat	Maintains a well oxygenated salt wedge (water quality)	High flow
		Maintain a diverse estuarine fish community composition	Provides cues for spawning and movement	
		Maintain cues for the migration of fish adults and larvae to freshwater reaches		

6.2 Flow recommendations to address the ecological objectives

The specific flow recommendations to address the ecological objectives for the Yarra River's water-dependent values are provided in Appendix F.

6.3 Priorities for flow delivery

Sometimes there is not enough water held in storage for the Yarra Environmental Entitlement to comply with every flow component every year, and Melbourne Water takes into account the antecedent climate conditions, the current condition of key values, and the amount of water held in storage to prioritise releases. The decisions are made by comparing current conditions to historic streamflow data for Reach 2 and Reach 5. Watering actions are prioritised against three scenarios:

1. Protect / Maintain – This scenario applies during dry conditions (where 95% of the time, streamflows are greater)
2. Recover – This scenario applies for average conditions (where 30% of the time, streamflows are greater)
3. Enhance – This scenario applies during wet conditions, represented by the 1992-93 year (where only 5% of the time are streamflows are greater).

Table 29 provides an overview of the expected river conditions and the priority ecological objectives that have been determined for each scenario.

Table 29 : Watering scenarios used to determine the prioritisation of ecological objectives (Source: Melbourne Water (2016b)

Scenario	Description of expected river conditions	Priority ecological objectives
Protect / Maintain (Dry)	• Natural stream flows are low through the whole system and there is a lack of high flows and freshes as the catchment remains dry over the whole system. • There is a risk of poor water quality over the season, but particularly during summer months. Pools in the system will likely stratify, and there may be a need to manage the risk of low dissolved oxygen concentrations in the Dights Falls weirpool with environmental water releases. • The ability to deliver water from storages may be impacted due to minimum operating rules (for example, reserving sufficient water in	Environmental objectives focus on: - • Maintaining water quality (to benefit aquatic species) • Minimising the risk of stratification and low dissolved oxygen in pools on aquatic biota • Maintaining in channel and riparian vegetation extent, structure and composition • Maintaining channel geomorphology and rehabilitating instream habitat • Rehabilitating populations of non-migratory and migratory native fish

Scenario	Description of expected river conditions	Priority ecological objectives
	O'Shannassy Reservoir for firefighting).	• Rehabilitating billabong vegetation
Recover (Average)	• Stream flows in winter are relatively high, meeting flow targets through most of the season. There are some freshes occurring naturally, however the duration and/or magnitude of these natural events may need to be supplemented with environmental water. • There will be a risk of poor water quality over the season, but particularly during summer months. Pools in the system will likely stratify, and there may be a need to manage the risk of low dissolved oxygen concentrations in Dights Falls weirpool with environmental water releases. • O'Shannassy and Maroondah reservoirs will likely spill during spring, but overbank flows along the system are unlikely.	Environmental objectives focus on: • Maintaining water quality (to benefit aquatic species) • Rehabilitating macroinvertebrate communities • Minimising the risk of stratification and low dissolved oxygen in pools on aquatic biota • Maintaining in-channel and riparian vegetation extent, structure and composition • Maintaining channel geomorphology and rehabilitate instream habitat • Rehabilitating populations of non-migratory and migratory native fish • Rehabilitating billabong vegetation
Enhance (Wet)	• Winter and spring flows in the system are relatively high, with natural variability throughout the system. • Natural flows in summer will likely meet all summer freshes and high flows required but environmental water may be required to supplement winter and autumn high flows. • O'Shannassy Reservoir will spill throughout the season. Maroondah Reservoir will likely spill during spring. • Overbank flows in the Yarra floodplain are possible through rainfall and localised flooding. • Billabong watering may occur naturally.	Environmental objectives focus on: • Maintaining water quality (to benefit aquatic species) • Rehabilitating macroinvertebrate communities • Minimising the risk of stratification and low dissolved oxygen in pools on aquatic biota • Maintaining in channel and riparian vegetation extent, structure and composition • Maintaining channel geomorphology and rehabilitate instream habitat • Rehabilitating populations of non-migratory and migratory native fish • Rehabilitating lateral connectivity with billabongs • Rehabilitating billabong vegetation - Naturally engaging low level floodplains in the upper catchment

RISKS, CHALLENGES, AND DEMONSTRATING OUTCOMES

7. Risks

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

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

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

When assessing the risks to water-dependent ecological values for the Yarra 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. Management actions to address these risks are also included, and residual risk is assessed, based on the assumption that risk mitigation actions are successful.

A summary of the results from the Yarra River qualitative risk assessment is shown in Table 30, 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 D.

Table 30 : Risk assessment and management actions

Risk Category	Values Impacted	Likelihood (Almost certain / Likely / Possible / Unlikely / Rare)	Consequence (Negligible / Minor / Moderate / Major / Extreme)	Risk (Low / Medium / High / Extreme)	Residual Risk after Management Actions
RISKS TO ACHIEVING ECOLOGICAL OBJECTIVES					
Further consumptive extraction of surface water, causing an alteration of natural flow regimes	All	Rare	Major	Medium	Medium
Groundwater extractions causing shifts in the surface water/groundwater interface	All	Possible	Minor	Medium	Low
Construction of additional artificial instream structures (e.g. dams, weirs, gauging stations)	All	Unlikely	Major	High	Medium
Recreational fishing	Fish Platypus	Almost Certain	Moderate	High	Medium
Land use change – Urban Development	All	Likely	Major	Extreme	High
Land use change - Farm dams	Fish Platypus Frogs	Almost Certain	Major	Extreme	High
Pest plants and animals: • Carp • Brown Trout • Gambusia • Redfin • Foxes, dogs and cats • Willows	All	Almost certain	Moderate	High	Medium

Risk Category	Values Impacted	Likelihood (Almost certain / Likely / Possible / Unlikely / Rare)	Consequence (Negligible / Minor / Moderate / Major / Extreme)	Risk (Low / Medium / High / Extreme)	Residual Risk after Management Actions
Illegal fishing nets	Platypus Fish Birds	Almost certain	Moderate	High	Medium
Sediment inputs to the estuary	Fish Vegetation	Almost certain	Moderate	High	Medium
Further expansion of irrigation areas within the catchment	All	Unlikely	Major	High	Medium
Stock access and grazing pressure	Vegetation Fish Platypus Amenity	Certain	Moderate	High	Medium
Climate Change	All	Almost certain	Extreme	Extreme	High
RISKS RELATED TO THE DELIVERY OF ENVIRONMENTAL WATER					
Winter high fresh drowns juvenile Platypus	Platypus	Possible	Major	High	Low
Environmental flow releases lead to safety risks to river users	N/A	Rare	Extreme	High	Low
Release volume is insufficient in meeting required flow at target point	All	Possible	Moderate	Medium	Low
Current recommendations on environmental flow are inaccurate	All	Possible	Moderate	Medium	Low
Storage Operator maintenance works affect ability to deliver water	All	Possible	Moderate	Medium	Low

Risk Category	Values Impacted	Likelihood (Almost certain / Likely / Possible / Unlikely / Rare)	Consequence (Negligible / Minor / Moderate / Major / Extreme)	Risk (Low / Medium / High / Extreme)	Residual Risk after Management Actions
Resource Manager cannot deliver required volume or flow rate (outlet/capacity constraints, insufficient storage volume) OR Competing storage operator priorities for flood and fire management do not allow delivery of some events	All	Possible	Moderate	Medium	Low
Releases cause water quality issues (e.g. blackwater, low DO, mobilisation of saline pools, acid-sulphate soils, etc)	All	Possible	Moderate	Medium	Low
Improved conditions for non-native species (e.g. carp)	Fish	Unlikely	Minor	Low	Low
Unable to provide evidence that hydrological target has been met	All	Possible	Minor	Low	Low
Environmental releases do not achieve planned/specified flow targets due to releases being diverted by other users before reaching delivery sites	All	Possible	Moderate	Medium	Low
Environmental releases cause unauthorised inundation of private land, resulting in impacts on landowner activities and assets	Amenity	Unlikely	Major	High	Low
Environmental release interferes with essential Melbourne Water services	N/A	Unlikely	Moderate	Low	Low
Inability to demonstrate outcomes achieved through environmental watering activities lead to a loss of public/political support	All	Likely	Moderate	High	Low
The environmental water account is overdrawn, leading to water not being available as per approved watering statement to complete planned actions	All	Rare	Minor	Low	Low
Community concern over environmental releases under dry	All	Possible	Minor	Low	Low

Risk Category	Values Impacted	Likelihood (Almost certain / Likely / Possible / Unlikely / Rare)	Consequence (Negligible / Minor / Moderate / Major / Extreme)	Risk (Low / Medium / High / Extreme)	Residual Risk after Management Actions
seasonal conditions may lead to a loss of support for environmental watering activities					
Public misperception of the purpose of releases	All	Possible	Moderate	Medium	Low

8. The Challenge of Climate Change

Victoria's climate is changing and will pose a significant challenge for the management of the Yarra River, with climate conditions expected to become hotter and drier. The global average combined land and ocean surface temperature shows a warming of 0.85 [0.65 to 1.06]°C over the period 1880 to 2012 (IPCC 2014), and the local temperature trends in Victoria over a similar period show similar patterns (Grose 2015, Timbal *et al.* 2016). Scientists have observed that climate change can occur as both gradual and step changes. In Victoria it appears that there may have been step changes in climate that occurred in the mid 1970's and again after 1997. These changes have resulted in a reduction in cool season (April to October) rainfall over recent decades, which was particularly evident during the Millennium Drought and which is thought to have continued in many parts of Victoria since the end of the drought (Timbal *et al.* 2016).

Although there are uncertainties associated with climate change predictions, trends for Melbourne have been interpreted from a range of studies focused on climate change impacts (Howe *et al.* 2005, CSIRO 2012, Wales *et al.* 2012, CSIRO and Bureau of Meteorology 2015, Potter *et al.* 2016). These trends are summarised in Table 31.

Table 31 : Climate change threats and trends for Melbourne

Threat	Trend
Drought and reduced rainfall	• The number of annual rainy days is predicted to decrease by 6% by 2030, and 10-19% by 2070, • Reductions in average stream flow of 3-11% by 2020 and 7-35% by 2050 • Up to 50% less runoff into the Yarra, Maribyrnong, Werribee and Bunyip Rivers by 2070
Extreme temperature rise	• Higher average annual temperatures, with an increase of 0.3-1.0°C by 2020, and 0.6-2.5°C by 2050 • An increase in annual number of days above 35°C from 9 days to 10-13 days by 2030, 15-26 days by 2070, and 16-33 days by 2100
Intense rainfall	• An increase rainfall intensity of 0.9% by 2030 and 3.0-5.9% by 2070
Sea level rise	• A rise in sea level of up to 1.1 metres by 2100, which puts a population of approximately 937,000 people at risk from inundation

Changes in rainfall are amplified when translated into changes in catchment runoff and streamflow. Historical changes in the runoff in Victorian streams, particularly over the Millennium Drought, have been well documented. They have been presented in each year's Victorian Water Accounts (e.g. DELWP (2015e)), with the statistical significance of a step change in streamflow being identified in several studies, including the CSIRO Murray-Darling Basin Sustainable Yields project (CSIRO 2008), and by the Bureau of Meteorology at its hydrologic reference stations across Victoria (Bureau of Meteorology 2016).

Figure 33 illustrates the magnitude of changes in streamflow over the Millennium Drought for inflows to Melbourne's main harvesting storages. The inflows over this period were on average around 35% lower than the long-term average, with no single year of inflows above the long-term average.

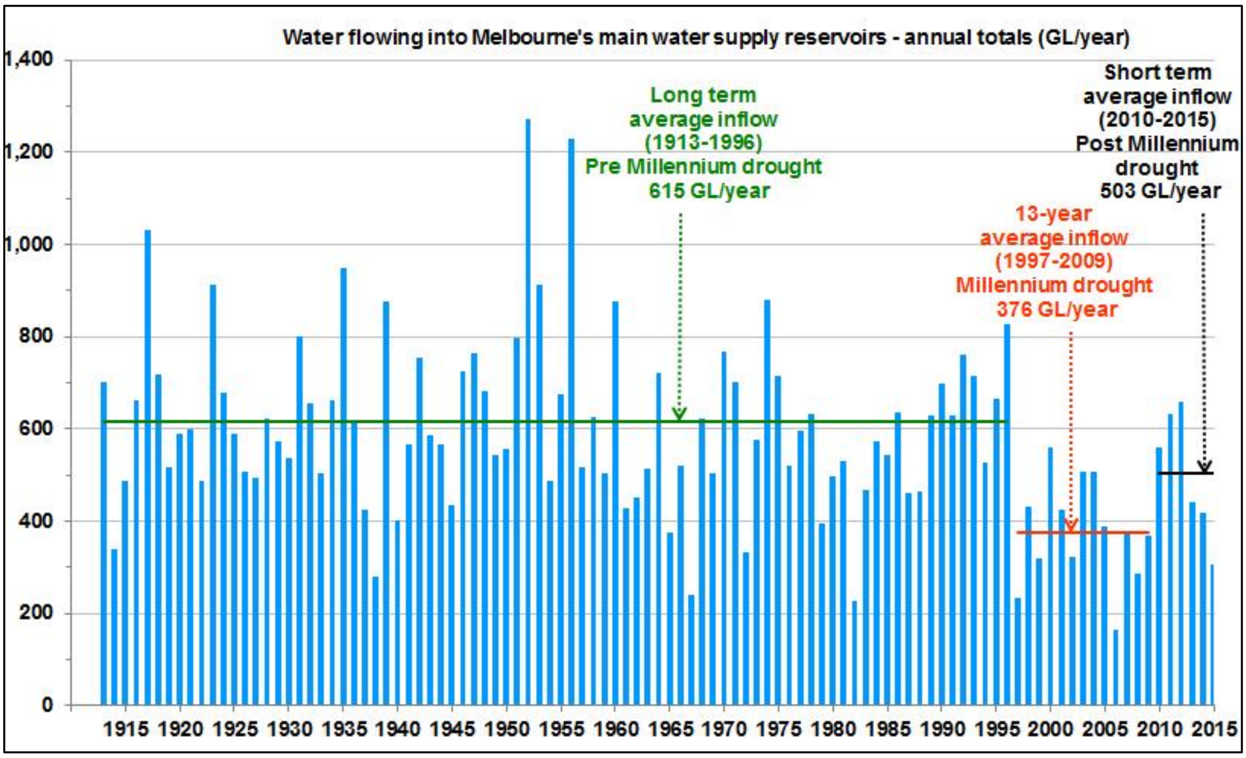

Figure 33 : Annual inflows to Melbourne's main water supply reservoirs (Source:Melbourne Water (2016a))

Medium and high impact climate change scenarios show a decrease in rainfall and runoff across all of Victoria by 2040, with the greatest impacts likely to be seen in western Victoria. However, the low impact climate change scenario actually predicts a small increase in rainfall and runoff across Victoria in 2040 and 2065 (Table 32).

Table 32 : Projected changes in average annual runoff relative to the current climate baseline across all seasons for the Yarra Basin[24])

Average annual runoff (mm) (1975-2014)	Change relative to current climate baseline (%)					
	Year 2040			Year 2065		
Historic	10th percentile (Low impact)	50th percentile (Medium impact)	90th percentile (High impact)	10th percentile (Low impact)	50th percentile (Medium impact)	90th percentile (High impact)
227 mm	+10.0%	-11.0%	-29.2%	+0.8%	-16.4%	-44.3%

8.1 Climate change impacts on Yarra River flows

The impact of climate change on Yarra River flows was assessed for the development of the EWMP, using historical flows data available for Reach 5. The assessment used the current recommended flow regime and applied a flow reduction that matched the projected runoff reductions in Table 32. A number of different climate change flow scenarios were then assessed to see how well the flow regimes would comply with current environmental flow recommendations, using the compliance assessment process described in the Yarra Environmental flows study (SKM 2012d) (Table 33). The climate change flow scenarios included:

- Current streamflow

[24] Projections provided by Melbourne Water, based on Potter *et al*. 2016. Hydroclimate Projects for Victoria at 2040 and 2065, CSIRO, Australia. Modelling should be repeated when Melbourne Water develops agreed short and long term projections for planning purposes.

- 2028 medium impact conditions, with a 5.5% reduction in streamflow[25]
- 2065 medium impact conditions, with a 16% reduction in streamflow
- 2065 high impact conditions, with a 44% reduction in streamflow (worst case scenario).

The analysis found that under current and short term (i.e. 2028) climate change conditions, compliance with flow recommendations remains relatively good in low and medium impact climate years. In high impact (dry) climate years however, there is a significant decrease in compliance. Under longer term climate change scenarios, and especially the worst case '2065_dry' scenario, there is a significant decrease in compliance with flow recommendations, including in wet climate years.

The method used for this analysis is an initial attempt at broadly quantifying the impact of climate change on the achievement of minimum environmental flow recommendations in the Yarra River. The results of this analysis are highly dependent on the assumptions made. Melbourne Water is currently conducting a number of studies using differing methodologies and tools to try to understand the likely impact of climate change on Yarra River streamflows and will continue to refine the assumptions and methodologies to improve the understanding of this impact.

[25] At the time of analysis, suitable short term climate projects for planning purposes were not available, so the 2028 scenario was based on a pro-rata reduction to 2040 in order to provide a short term climate change outlook. It is strongly recommended that short term modelling of climate impacts be repeated once suitable projects are agreed to for both short and long term planning.

Table 33 : Compliance with environmental flow recommendations under current and climate change scenarios and for low impact, medium impact and high impact climate type years for the Yarra River environmental flow Reach 5, noting that environmental flow recommendations differ between wet, average and dry climate years.

		current								2028_medium_CC (-5.5%)							
climate year type	year	Summer low	Summer Fresh	Summer High	winter low	Winter Fresh	Winter High	Small Bankfull	Large bankfull	Summer low	Summer Fresh	Summer High	winter low	Winter Fresh	Winter High	Small Bankfull	Large bankfull
Wet	1964	1.00	0.00	1.00	1.00	1.00	1.00	0.66	1.00	0.66	0.00	1.00	1.00	1.00	1.00	0.66	1.00
Wet	1965	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.93	1.00	1.00	1.00	1.00
Wet	1966	1.00	0.40	0.00	1.00	1.00	1.00	0.00	1.00	0.79	0.40	0.00	0.82	1.00	1.00	0.00	1.00
Avg	1967	1.00	0.67	1.00	0.95	1.00	0.00	1.00		1.00	0.67	1.00	0.93	1.00	0.00	1.00	
Dry	1968	0.48	0.50	0.00	0.93	0.00				0.40	0.50	0.00	0.91	0.00			
Wet	1969	1.00	1.00	1.00	1.00	0.00	0.00	0.33	0.00	0.99	1.00	1.00	0.99	0.00	0.00	0.33	1.00
Avg	1970	1.00	1.00	1.00	1.00	0.50	1.00	1.00		1.00	1.00	1.00	1.00	0.50	1.00	1.00	
Avg	1971	1.00	1.00	1.00	1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00	1.00	1.00	1.00	
Wet	1972	1.00	1.00	0.00	1.00	0.50	1.00	1.00	1.00	1.00	1.00	0.00	1.00	0.50	1.00	1.00	1.00
Avg	1973	0.98	1.00	0.00	1.00	0.00	1.00	0.66		0.96	1.00	0.00	1.00	0.00	1.00	0.50	
Wet	1974	1.00	1.00	1.00	1.00	0.50	0.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	0.00	1.00	1.00
Wet	1975	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00
Avg	1976	1.00	0.50	1.00	1.00	1.00	1.00	1.00		0.98	0.50	1.00	1.00	1.00	1.00	1.00	
Wet	1977	1.00	1.00	0.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	0.00	1.00	0.50	0.00	0.66	1.00
Wet	1978	1.00	0.20	0.00	1.00	1.00	1.00	1.00	1.00	0.90	0.20	0.00	1.00	1.00	1.00	1.00	0.00
Avg	1979	1.00	1.00	0.00	1.00	1.00	0.00	1.00		1.00	1.00	0.00	1.00	1.00	0.00	1.00	
Dry	1980	0.62	0.00	1.00	0.95	0.00				0.53	0.00	1.00	0.93	0.00			
Avg	1981	0.85	0.75	1.00	0.87	1.00	0.00	0.66		0.80	0.75	1.00	0.86	1.00	0.00	0.50	
Dry	1982	0.74	1.00	1.00	0.97	1.00				0.69	0.67	1.00	0.97	1.00			
Dry	1983	0.51	0.00	1.00	0.71	1.00				0.48	0.00	1.00	0.64	1.00			
Avg	1984	0.79	0.50	0.00	0.79	0.50	0.00	1.00		0.71	0.50	0.00	0.74	0.50	0.00	1.00	
Avg	1985	1.00	0.75	1.00	0.89	1.00	1.00	1.00		1.00	0.50	1.00	0.86	1.00	1.00	1.00	
Avg	1986	1.00	1.00	1.00	0.95	1.00	1.00	1.00		1.00	1.00	1.00	0.93	1.00	1.00	1.00	
Avg	1987	1.00	1.00	0.00	1.00	1.00	0.00	1.00		1.00	1.00	0.00	1.00	1.00	0.00	1.00	
Avg	1988	1.00	0.50	1.00	1.00	1.00	1.00	0.66		1.00	0.50	1.00	1.00	1.00	1.00	0.50	
Wet	1989	1.00	1.00	1.00	1.00	0.00	1.00	0.00	1.00	1.00	1.00	1.00	0.98	0.00	1.00	0.00	1.00
Avg	1990	1.00	1.00	0.00	1.00	1.00	1.00	1.00		1.00	1.00	0.00	1.00	1.00	1.00	1.00	
Avg	1991	1.00	1.00	1.00	1.00	1.00	0.00	0.66		1.00	1.00	1.00	1.00	1.00	0.00	1.00	
Wet	1992	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	0.97	1.00	0.00	1.00	0.00
Wet	1993	1.00	1.00	0.00	1.00	0.50	1.00	0.66	1.00	1.00	1.00	0.00	1.00	0.50	1.00	0.66	1.00
Wet	1994	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00
Dry	1995	1.00	0.67	1.00	1.00	0.00				1.00	0.67	1.00	1.00	0.00			
Wet	1996	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Dry	1997	1.00	0.33	1.00	1.00	1.00				1.00	0.33	1.00	1.00	1.00			
Dry	1998	1.00	0.33	0.00	0.99	0.00				0.99	0.33	0.00	0.99	0.00			
Dry	1999	1.00	1.00	1.00	0.94	0.00				1.00	1.00	1.00	0.91	0.00			
Dry	2000	0.97	1.00	1.00	1.00	1.00				0.95	1.00	1.00	1.00	1.00			
Avg	2001	0.81	0.25	1.00	0.99	0.50	0.00	1.00		0.75	0.25	1.00	0.98	0.50	0.00	1.00	
Dry	2002	1.00	0.67	0.00	0.96	0.00				0.95	0.67	0.00	0.93	0.00			
Dry	2003	0.93	0.00	1.00	0.94	0.00				0.90	0.00	1.00	0.92	0.00			
Dry	2004	0.75	0.33	1.00	0.86	0.00				0.64	0.33	1.00	0.86	0.00			
Wet	2005	1.00	0.60	1.00	1.00	0.50	1.00	0.66	1.00	0.88	0.60	1.00	0.90	0.50	1.00	0.66	1.00
Dry	2006	0.69	0.00	0.00	0.85	0.00				0.60	0.00	0.00	0.78	0.00			
Dry	2007	0.19	0.00	1.00	0.63	1.00				0.17	0.00	1.00	0.47	1.00			
Dry	2008	0.49	1.00	1.00	0.71	1.00				0.38	1.00	1.00	0.52	1.00			
Dry	2009	0.51	0.00	1.00	0.60	0.00				0.43	0.00	1.00	0.41	0.00			

		2065_Medium CC (-16%)								2065_dry CC (-44%)							
climate year type	year	Summer low	Summer Fresh	Summer High	winter low	Winter Fresh	Winter High	Small Bankfull	Large bankfull	Summer low	Summer Fresh	Summer High	winter low	Winter Fresh	Winter High	Small Bankfull	Large bankfull
Wet	1964	0.51	0.00	1.00	0.96	0.00	1.00	0.33	1.00	0.22	0.00	1.00	0.75	0.00	1.00	0.00	1.00
Wet	1965	1.00	0.75	0.00	0.92	1.00	1.00	0.66	1.00	0.89	0.75	0.00	0.87	1.00	1.00	0.00	1.00
Wet	1966	0.66	0.00	0.00	0.74	1.00	1.00	0.00	1.00	0.27	0.00	0.00	0.58	0.00	1.00	0.00	1.00
Avg	1967	0.99	0.33	1.00	0.90	1.00	0.00	1.00		0.68	0.67	1.00	0.75	1.00	0.00	0.00	
Dry	1968	0.29	0.50	0.00	0.80	0.00				0.11	0.00	0.00	0.37	0.00			
Wet	1969	0.97	0.60	0.00	0.97	0.00	0.00	0.33	1.00	0.76	0.20	0.00	0.90	0.00	0.00	0.00	1.00
Avg	1970	0.96	0.75	1.00	0.97	0.50	1.00	1.00		0.70	0.75	1.00	0.84	0.00	1.00	0.50	
Avg	1971	1.00	1.00	0.00	1.00	1.00	1.00	1.00		0.91	1.00	0.00	1.00	1.00	1.00	0.50	
Wet	1972	1.00	1.00	0.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	0.00	1.00	0.66	1.00
Avg	1973	0.79	1.00	0.00	0.95	0.00	1.00	0.50		0.43	1.00	0.00	0.39	0.00	1.00	0.00	
Wet	1974	1.00	1.00	1.00	1.00	0.50	0.00	1.00	1.00	0.89	1.00	1.00	1.00	0.00	0.00	0.66	0.00
Wet	1975	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	0.50	1.00
Avg	1976	0.96	0.25	1.00	1.00	1.00	1.00	1.00		0.75	0.25	1.00	0.90	1.00	1.00	0.50	
Wet	1977	1.00	1.00	0.00	1.00	0.50	0.00	0.33	1.00	1.00	1.00	0.00	0.80	0.00	0.00	0.00	1.00
Wet	1978	0.74	0.20	0.00	0.97	1.00	1.00	1.00	0.00	0.26	0.00	0.00	0.85	1.00	1.00	1.00	0.00
Avg	1979	1.00	1.00	0.00	0.99	1.00	0.00	1.00		1.00	1.00	0.00	0.88	1.00	0.00	0.00	
Dry	1980	0.32	0.00	1.00	0.87	0.00				0.07	0.00	1.00	0.60	0.00			
Avg	1981	0.64	0.50	1.00	0.80	1.00	0.00	0.50		0.27	0.25	1.00	0.77	1.00	0.00	0.50	
Dry	1982	0.62	0.67	1.00	0.97	1.00				0.29	0.00	1.00	0.88	1.00			
Dry	1983	0.33	0.00	1.00	0.42	1.00				0.03	0.00	1.00	0.14	1.00			
Avg	1984	0.59	0.50	0.00	0.61	0.50	0.00	1.00		0.22	0.25	0.00	0.50	0.50	0.00	0.00	
Avg	1985	0.93	0.50	1.00	0.80	1.00	0.00	1.00		0.60	0.50	1.00	0.70	1.00	0.00	0.50	
Avg	1986	1.00	1.00	1.00	0.93	1.00	1.00	1.00		0.99	1.00	0.00	0.88	0.00	1.00	0.00	
Avg	1987	1.00	1.00	0.00	1.00	1.00	0.00	1.00		1.00	1.00	0.00	0.99	0.00	0.00	0.00	
Avg	1988	0.88	0.50	1.00	1.00	1.00	1.00	0.50		0.57	0.50	1.00	0.92	0.00	1.00	0.50	
Wet	1989	1.00	1.00	1.00	0.97	0.00	1.00	0.00	1.00	0.99	1.00	1.00	0.86	0.00	1.00	0.00	1.00
Avg	1990	1.00	1.00	0.00	1.00	1.00	1.00	1.00		0.98	1.00	0.00	1.00	1.00	0.00	1.00	
Avg	1991	1.00	0.67	1.00	1.00	1.00	0.00	1.00		0.88	0.00	1.00	1.00	1.00	0.00	0.00	
Wet	1992	1.00	1.00	1.00	0.93	1.00	0.00	1.00	0.00	0.98	1.00	1.00	0.86	1.00	0.00	0.33	0.00
Wet	1993	1.00	1.00	0.00	1.00	0.50	1.00	0.33	1.00	1.00	1.00	0.00	0.98	0.50	1.00	0.66	0.00
Wet	1994	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	0.00	1.00	0.50	0.00	0.33	0.00
Dry	1995	1.00	0.67	1.00	1.00	0.00				0.95	0.67	0.00	0.96	0.00			
Wet	1996	1.00	1.00	1.00	0.99	1.00	0.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	0.00	0.66	1.00
Dry	1997	0.95	1.00	1.00	1.00	1.00				0.49	0.00	1.00	1.00	1.00			
Dry	1998	0.93	0.33	0.00	0.93	0.00				0.74	0.00	0.00	0.46	0.00			
Dry	1999	1.00	1.00	1.00	0.86	0.00				0.81	0.67	1.00	0.59	0.00			
Dry	2000	0.85	1.00	1.00	0.99	1.00				0.61	0.33	1.00	0.72	0.00			
Avg	2001	0.60	0.25	1.00	0.95	0.50	0.00	1.00		0.30	0.25	1.00	0.81	0.50	0.00	0.00	
Dry	2002	0.87	0.67	0.00	0.90	0.00				0.44	0.00	0.00	0.54	0.00			
Dry	2003	0.82	0.00	1.00	0.78	0.00				0.35	0.00	1.00	0.21	0.00			
Dry	2004	0.50	0.00	1.00	0.85	0.00				0.17	0.00	1.00	0.57	0.00			
Wet	2005	0.79	0.40	1.00	0.89	0.50	1.00	0.66	1.00	0.60	0.40	1.00	0.82	0.00	1.00	0.33	1.00
Dry	2006	0.43	0.00	0.00	0.63	0.00				0.08	0.00	0.00	0.31	0.00			
Dry	2007	0.09	0.00	1.00	0.25	1.00				0.02	0.00	1.00	0.01	1.00			
Dry	2008	0.25	1.00	1.00	0.25	1.00				0.04	0.00	1.00	0.09	0.00			
Dry	2009	0.21	0.00	1.00	0.21	0.00				0.04	0.00	1.00	0.05	0.00			

Mostly complies	Greater than	95 %			of time / years / events
Frequently complies	Between	76 &	95 %		of time / years / events
Often complies	Between	51 &	75 %		of time / years / events
Occasionally complies	Between	26 &	50 %		of time / years / events
Rarely complies	Between	5 &	25 %		of time / years / events
Never complies	Between	0 &	5 %		of time / years / events

8.2 Shortfalls and flow recommendations

An assessment of the magnitude of the annual shortfall (the volume of water required to deliver all environmental flow recommendations assuming the river was flow at the minimum passing flow[26]), was also undertaken. Shortfall volumes were calculated for current conditions and climate change scenarios for low flow recommendations and separately for fresh and high flow recommendations. Shortfall volumes were

[26] In calculating shortfall volume the total volume of water required to deliver a recommended flow event was calculated assuming the river was flowing at the minimum passing flow. Furthermore, the volume of water required to achieve ramp up and ramp down recommendations was not included. This means the shortfall volume calculation is likely to have overestimated the actual shortfall because for many events the river would be flowing at a magnitude greater than the minimum passing flow. However, excluding the ramp up and ramp down volumes from the calculation would offset the overestimation to some degree. The analysis and interpretation of climate change impacts on shortfall volumes should be treated as indicative of possible worst case scenarios. Further refinement of the calculation, analysis and interpretation of shortfall volumes and climate change scenarios is required.

not determined for bankfull or overbank flow recommendations because the Environmental Entitlement is not used to deliver these types of flow events. The shortfalls are presented as box plots that show the percentage of time (in years) that a particular shortfall volume is required for wet, average and dry climate year under current and various climate change scenarios (Figure 34). As noted previously, this assessment is an initial attempt at quantifying potential entitlement shortfalls resulting from climate change. Melbourne Water is continuing work to refine these estimates.

The analysis shows that for summer and winter low flows under current conditions there is very little shortfall in delivery of low flow recommendations. This is because low flows are currently delivered as a passing flow requirement. However, during very dry years, and with climate change, there is a decrease in compliance with low flow recommendations and an increase in the volume of water that would need to be released from storages in order to meet low flow recommendations. Under the worst case scenario (2065_dry), a significant volume of water would need to be released just to meet low flow recommendations, particularly in a dry climate year. Notably, in more than 24% of dry climate years the shortfall volume required to meet low flow recommendations would exceed the total volume presently held in the Environmental Entitlement (17 GL/annum) (Figure 35) and in those years there would be no spare entitlement available to deliver any fresh or high flows.

This analysis also shows that under current conditions, the existing Environmental Entitlement is sufficient to deliver all fresh and high flow recommendations in about 40% of years. There is very little difference in the shortfall volumes needed to deliver fresh and high flow recommendations under short term and medium level climate scenarios. However under the long term worst case scenario (2065_dry) there is a significant increase in the volume of water required to deliver fresh and high flow recommendations, and this exceeds the existing Environmental Entitlement volume available in more than 75% of wet, average and dry climate years.

Overall, this analysis indicates that it will become increasingly difficult to meet low flow recommendations and to maintain the current level of compliance with fresh and high flow recommendations with the existing volume of Environmental Entitlement. If it is assumed that the Environmental Entitlement is not required to deliver low flow recommendations (i.e. passing flow requirements), then under the worst case scenario, an increase in the Environmental Entitlement from 17 GL to 25-30 GL/annum is required in order to achieve the same level of compliance with flow recommendations as current conditions. Other studies recently completed by Melbourne Water using different assumptions and methodologies have estimated that the Yarra Environmental Entitlement may need to be expanded from 17 GL to 40 GL over the same time period (GHD 2016). This range of results indicate the importance of continuing to refine the methodologies, tools and assumptions used to estimate climate change impacts.

These findings are of significant concern because the 17 GL/annum entitlement volume has been based on a *minimum* flows recommendation, and is already only able to maintain the current level of compliance in 40% of years. Reducing the ability to meet flow regime requirements, with a volume of water that is essentially only able to support a bare minimum of functions to maintain the current ecological condition of the system, will place a significant stress on a system already considerably flow stressed. This has strong implications for the condition and continuing survival of species and communities in the Yarra River that are vulnerable to changes in the flow regime because of their life history requirements. This risk is discussed further in Section 8.3.

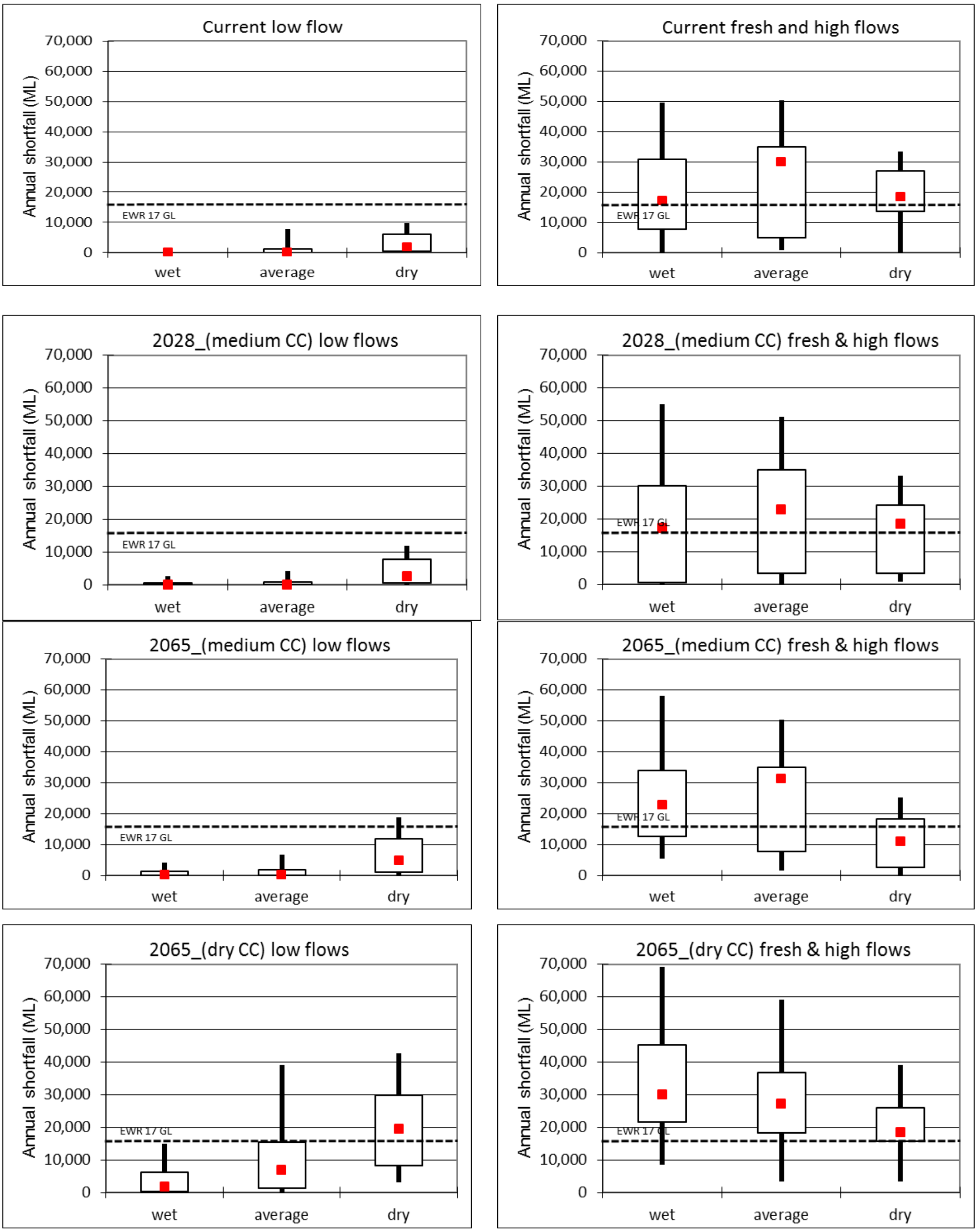

Figure 34 Shortfall volumes required to achieve compliance with summer and winter low flow recommendations and fresh and high flow recommendations in the Yarra River (Reach 5) in wet, average and dry climate years under current and medium and high (dry) impact climate change flow scenarios. The centre of the box marks the median annual shortfall volume, margins of the box shows the 25th and 75th %ile shortfall volume ranges, the whiskers mark the 5th and 95th %ile shortfall volume ranges. The dotted line indicates the volume of the existing Environmental Entitlement (17 GL).

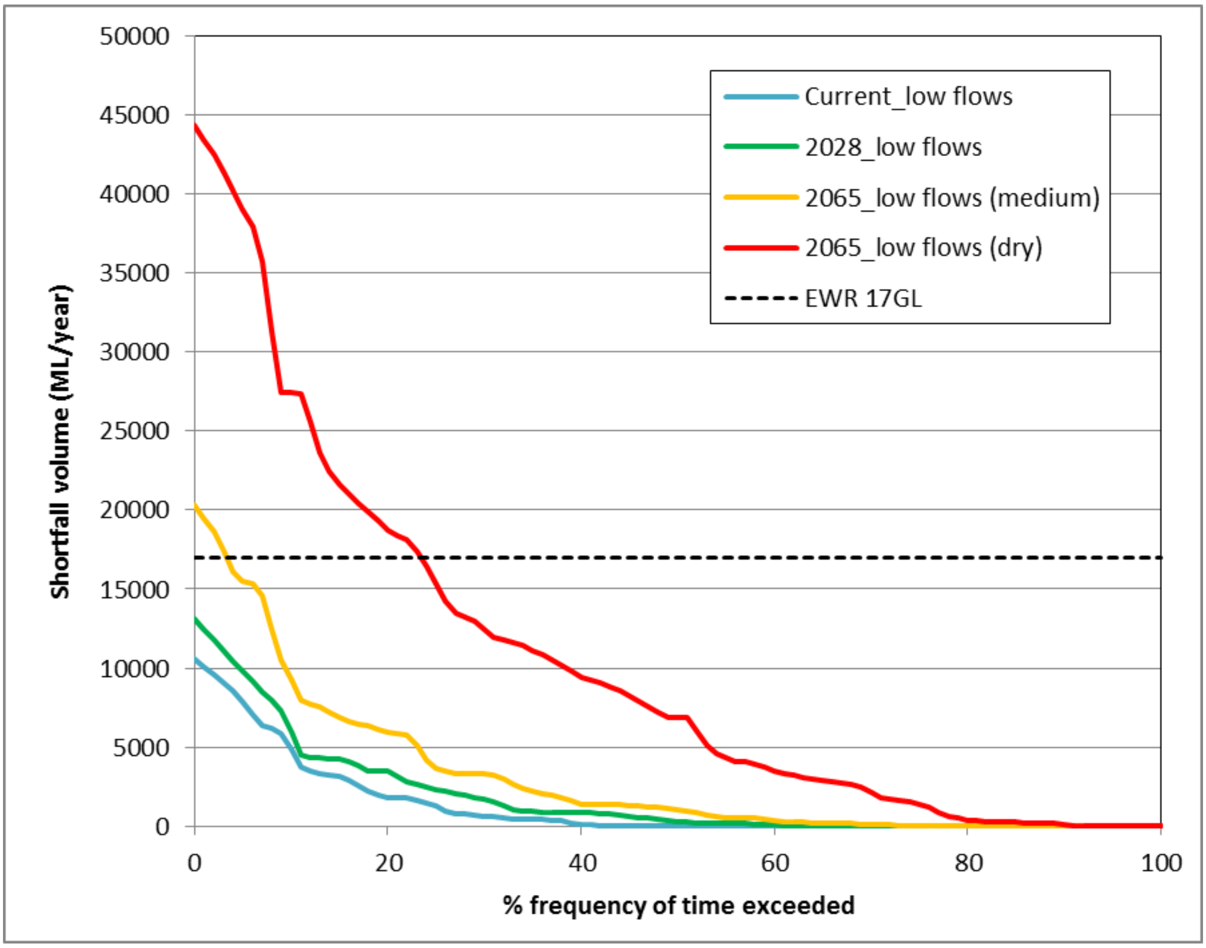

Figure 35 Shortfall volumes required to deliver summer and winter low flow recommendations in the Yarra River (Reach 5) in wet, average and dry climate years under current and climate change flow scenarios. The dotted line indicates the volume of the existing Environmental Entitlement (17 GL).

8.3 The consequences of climate change for the Yarra River

There are significant consequences of climate change for water-dependant environmental values in the Yarra River. To understand these consequences, the vulnerability of a number of key values has been documented and then analysed to understand how their condition is likely to change under future climate change flow scenarios. The vulnerability assessment is based on: life history requirements; sensitivity to environmental flow components; and the predicted ecological response to changes in flow components likely to be impacted by climate change.

The types of ecological responses to climate change are likely to depend on the rate of change and the severity or magnitude of change (Figure 36). Responses can include: changes in behaviour; abundance; and/or geographical range; adaptive micro- and macro-evolution; and under situations where there is a large and/or rapid change, extinction (Huntley *et al.* 2010).

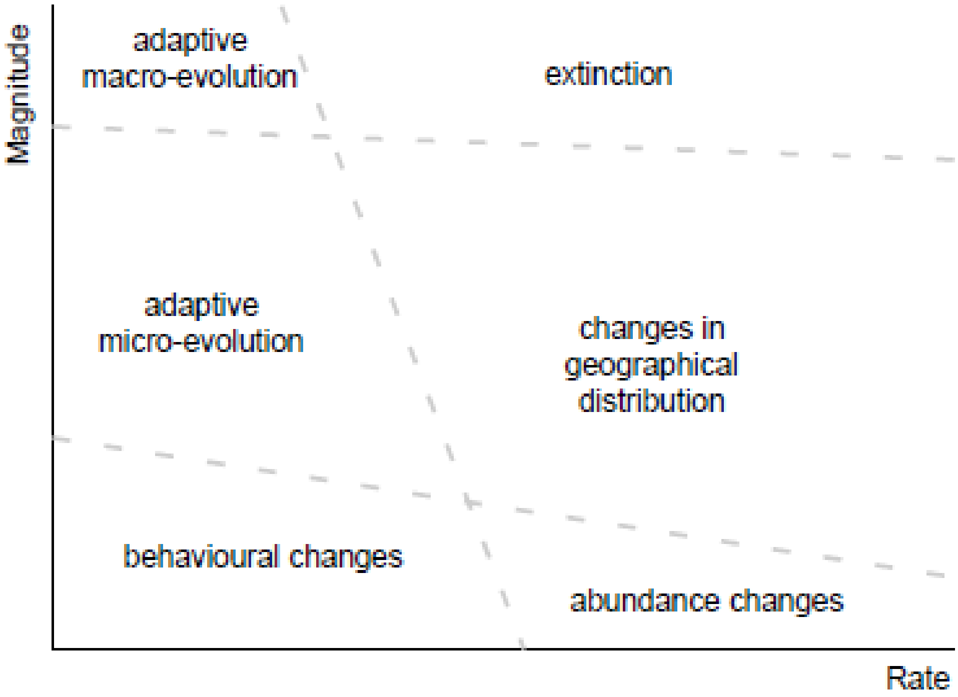

Figure 36 Schematic representation of species' responses to climate change (Source: Huntley *et al.* (2010)).

For the EWMP assessment, the above schematic has been adapted to show how water dependant species, functional groups (i.e. species with similar characteristics), or ecological processes are likely to respond to climate change. The predicted ecological responses have been based on increasing severity of flow reductions (i.e. the loss of high flow events, increasing duration of low flows, and increasing frequency or duration of cease-to-flows) and the duration of the impact (i.e. short term dry conditions, drought and longer term climate change). The key values assessed include:

- Migratory and resident fish
- Platypus
- Frogs
- Waterbirds
- Macroinvertebrates
- Vegetation.

8.4 Fish

Vulnerability plots for migratory fish and resident fish species are shown in Figure 37 and Figure 38. A reduction in bankfull and overbank flows is unlikely to result in a significant impact on riverine fish populations in the short term, but the loss of hydrological connection with the floodplain may have implications for overall river productivity, structure and function, and in the longer term may impact on the quality and quantity of food resources for a range of biota, including fish. Reductions in freshes and high flows that cue migration and spawning behaviours, as well as an overall increase in the duration of low flows, is likely to result in reduced abundance and a reduction in range in the short to medium term, and local extinction in the longer term. If severe drought and climate change results in the development of cease-to-flow conditions in the otherwise perennial sections of the Yarra River, or increases the frequency and duration of cease-to-flows in existing connected intermittent tributaries, then localised extinction could occur more rapidly. Localised extinction of resident fish in the main Yarra River channel is unlikely provided low flows are maintained. However, the loss of migration and spawning cues could result in the local extinction of short-lived flow-sensitive species such as Australian Grayling.

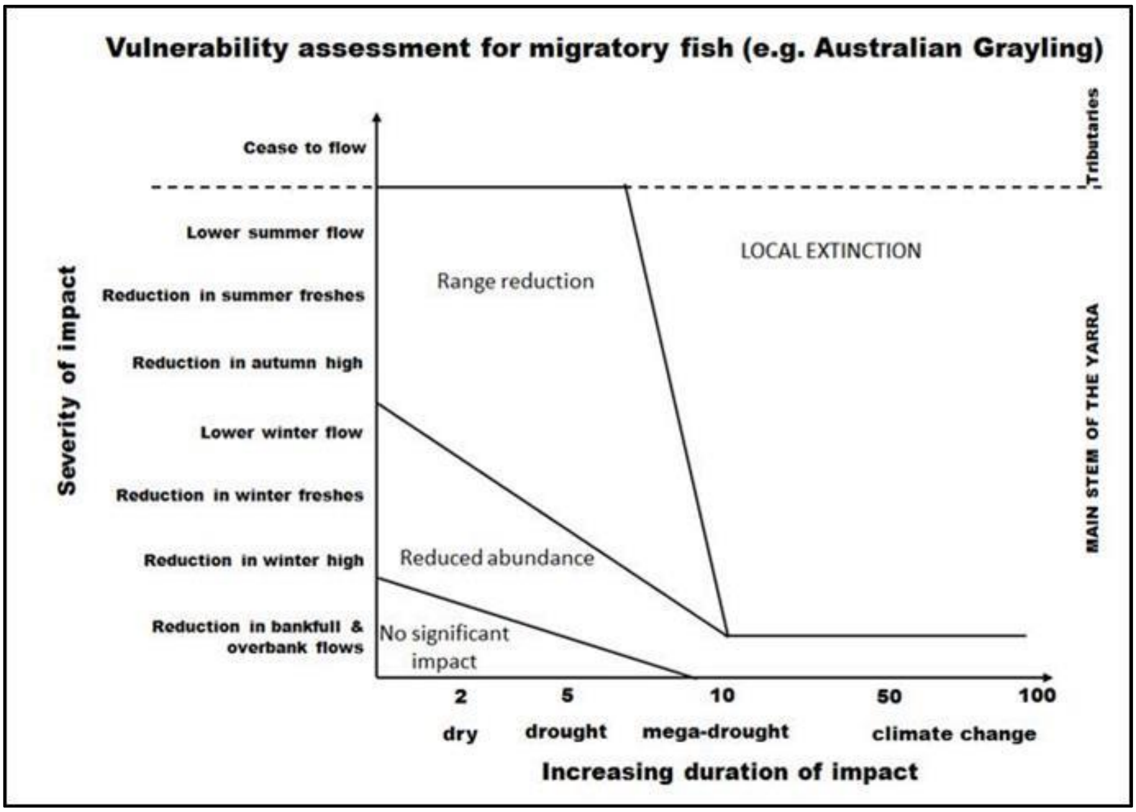

Figure 37 Climate vulnerability assessment for flow sensitive migratory fish (e.g. Australian Grayling)

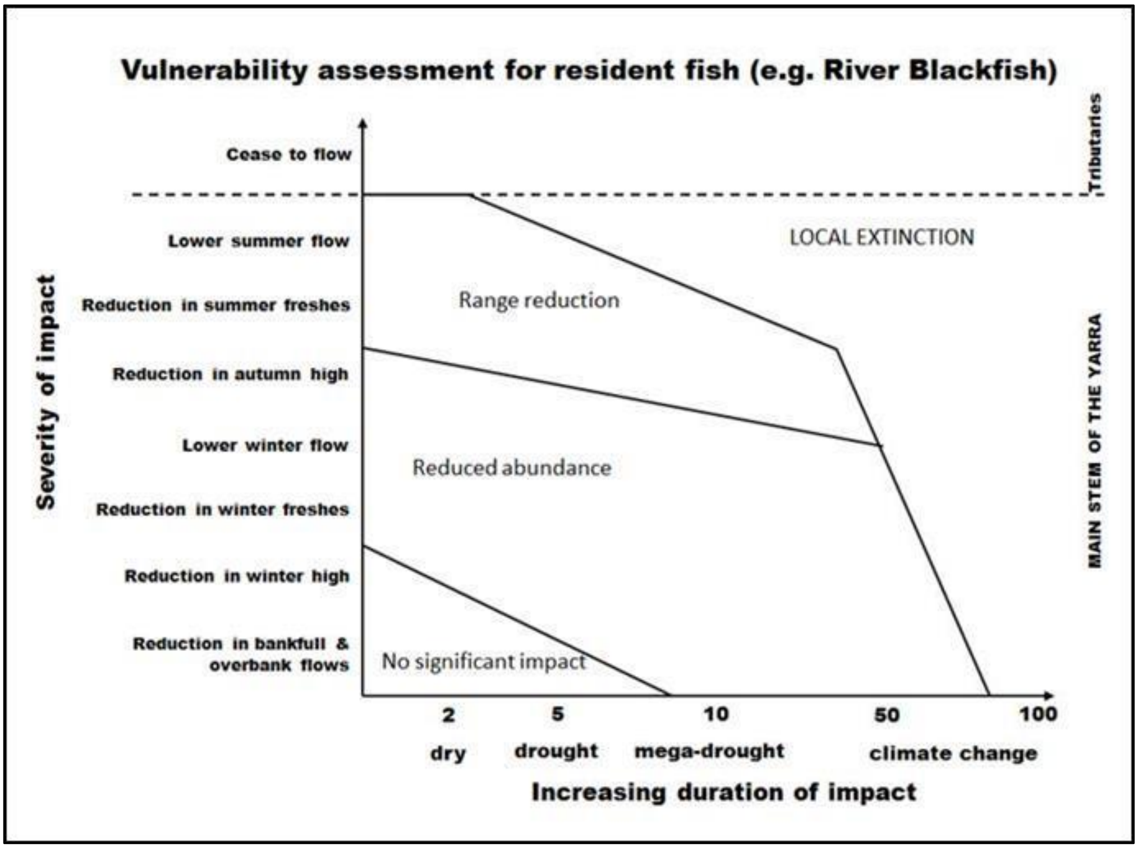

Figure 38 Climate vulnerability assessment for resident fish (e.g. River Blackfish)

A separate analysis of the predicted changes in fish distribution due to climate change by Bond *et al.* (2011) shows that species such as River Blackfish, Macquarie Perch and Australian Grayling could undergo significant range reductions; that Short-finned Eel and some migratory galaxias species show relatively little predicted change in distribution; and that exotic species such as Common Carp and Redfin Perch are predicted to expand their range. The authors indicate that temperature and shifts in flow regime towards increased durations of low flows and cease to flows are primary predictors in determining the likely fish response to climate change. Under climate change River Blackfish is predicted to become locally extinct in the west and north of the Divide and significantly contract in its range south of the Divide. It is predicted to remain within the Yarra Catchment but with a reduced probability of detection (Bond *et al.* 2011).

8.5 Platypus

Platypuses are reliant on the availability of permanent freshwater and riparian habitat; they feed exclusively on aquatic macrophytes and use burrows in stream banks for resting and nesting (Grant 2007). Despite a range of impacts on aquatic and riparian environments, platypuses still persist over much of their historical range (Grant and Temple-Smith 2003), including within the Melbourne area and the Yarra River catchment in particular. However, platypuses are likely to be highly vulnerable to climate change for a range of reasons. Factors contributing to their vulnerability include their dependence on adequate surface water for survival, their characteristically low population density and low reproductive rate, and the fact that female platypus are likely to be out-competed for food by larger (and more aggressive) males and therefore suffer disproportionately high mortality rates when surface water is severely limited (Serena and Williams 2010).

As a consequence, climate change impacts that result in increased duration of low flows and cease to flow events represent significant risks to platypus. Furthermore, warmer temperatures are also likely to represent a significant threat, with recent research suggesting the temperature increases since the 1960s have had a greater impact on platypus than aquatic habitat availability (Klamt *et al.* 2011). The combination of drier conditions and warmer temperatures are hence likely to have compounding effects on platypus through loss of aquatic habitat, reduction in availability of sufficient macroinvertebrate food resources and potential change in composition of food types, and changes to composition of riparian vegetation that may increase exposure of platypuses to higher temperatures. Impacts that result in platypus having to leave the water to travel between isolated pool habitats, or that reduce the amount of cover provided by riparian vegetation are also likely to result in higher levels of predation (Serena and Williams 2010).

Figure 39 summarises the broad response of platypus to drought and climate change induced impacts on stream flow. An increase in cease to flow and increased duration of low flows will over time lead to localised extinction. Increased low flows and a loss of freshes and high flows are likely to lead to reduced abundance and range reductions, mainly due to the impacts that the loss of these flow components will have on food production. In the short term a loss of high flows and overbank flows is unlikely to impact on platypus, but over time, the loss of these flow components will impact on riparian vegetation with consequent impacts on platypus through degradation of riparian habitat, increased exposure to higher temperatures and increased predation.

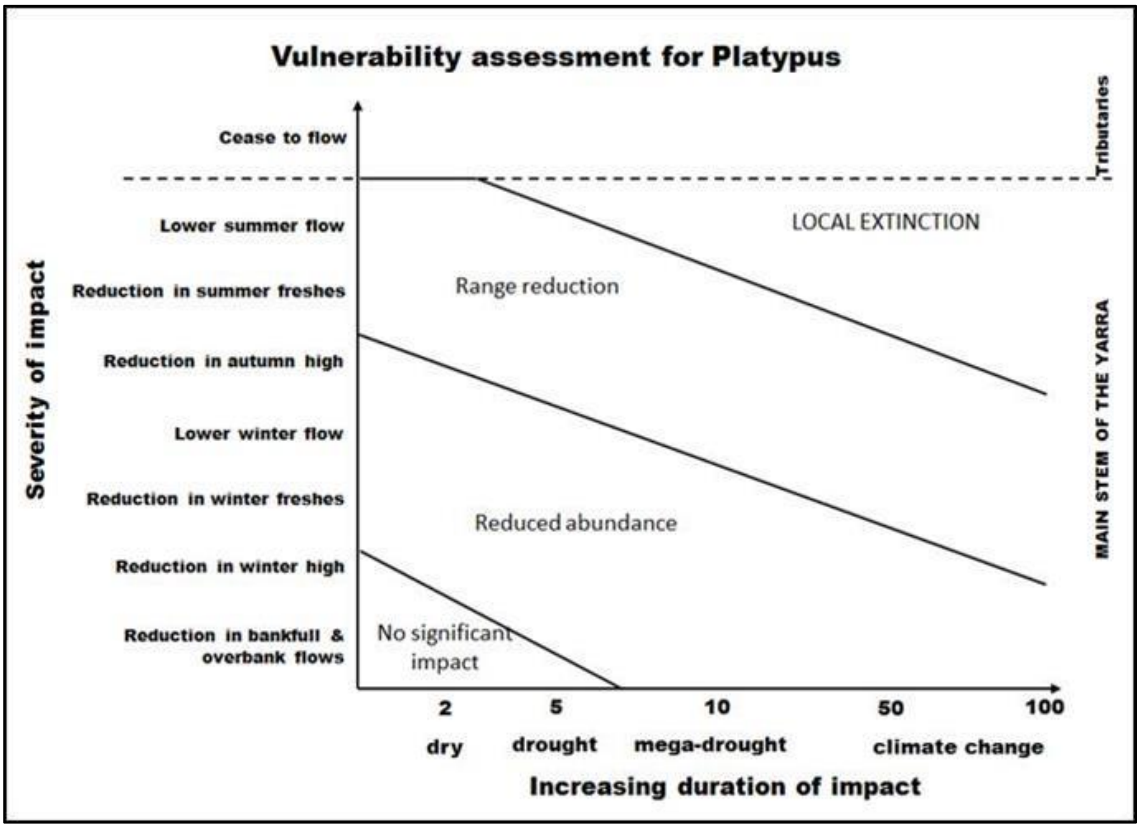

Figure 39 Climate vulnerability assessment for Platypus

8.6 Macroinvertebrates

The response of aquatic macroinvertebrates to climate change is likely to be varied depending on flow and temperature tolerances and preferences (Chessman 2012). At a community composition level, climate change and the consequent drying and warming of aquatic ecosystems will lead to a shift in the composition of macroinvertebrates towards taxa that are tolerant of warmer and drier conditions (Chessman 2013) (Figure 40). This also means a loss of taxa that favour cooler and faster flowing conditions, such as many animals in the Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) orders (often referred to as EPT taxa) (Chessman 2009), which often form a major component of the diet of fish (Chessman 2013) and platypus (Grant 2007).

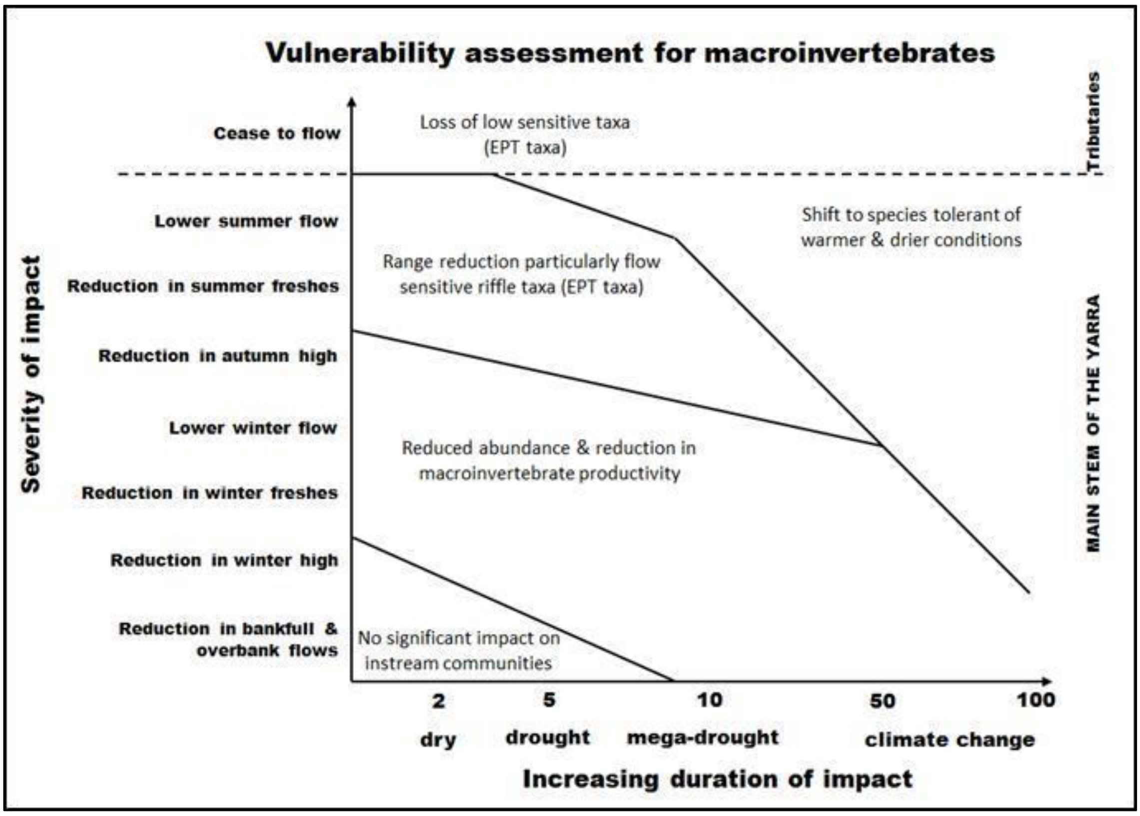

Figure 40 Climate vulnerability assessment for macroinvertebrates

8.7 Frogs

As with the other species described above, climate change impacts on frog species will vary according to their water and temperature tolerances, and specific habitat / hydroperiod (the duration of inundation in wetlands) requirements (Carey and Alexander 2003). There are also a range of indirect impacts, including changes in food availability, disease, UV radiation and species-specific interactions (Blaustein *et al.* 2010)

Figure 41 provides a summary of the general impacts to frogs along the Yarra River in response to the possible flow regimes changes as a result of climate change. An overall drier flow regime is likely to lead to a range reduction and reduced abundance of species that favour within-channel habitats. However, the greater impacts are likely to be to species that prefer riparian and floodplain habitats. In these locations, a reduction in the frequency of bankfull and of overbank flows that also leads to a loss of wetland habitat and reduction in hydroperiod is likely to result in a reduction in range, and in some areas loss, of species that require wetland inundation for breeding. This will particularly be the case if the interval between events that inundate wetlands is longer than the life span of the species in question.

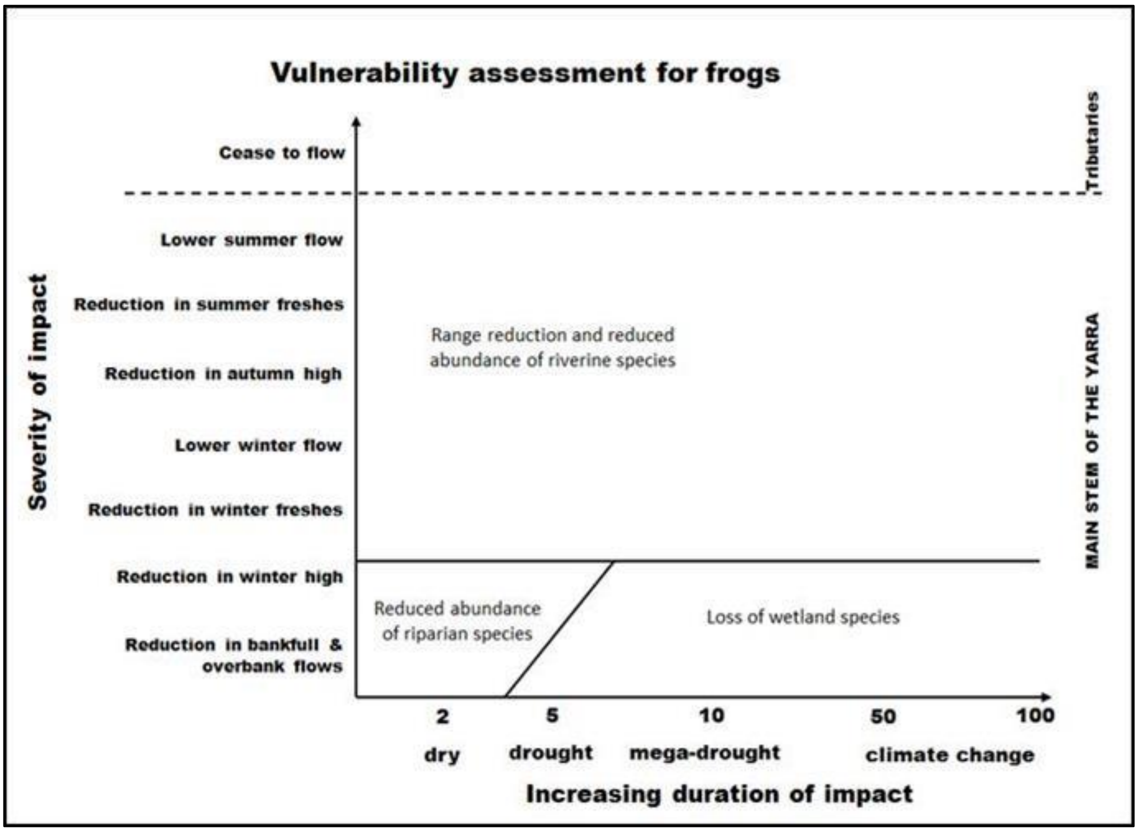

Figure 41 Climate vulnerability assessment for frogs

8.8 Waterbirds

The vulnerability of waterbirds to climate change is likely to be highly variable depending on specific species tolerances and preferences and is most likely to be related to impacts on habitat types and water availability. Figure 42 summarises the possible end points for various waterbird functional groups based on how climate change may impact on the flow regime for the Yarra River. An overall reduction in flow may result in a shift in species composition to opportunistic and invasive species. A reduction in the frequency of overbank flows is likely to result in reduced abundance of species that prefer wetland habitats.

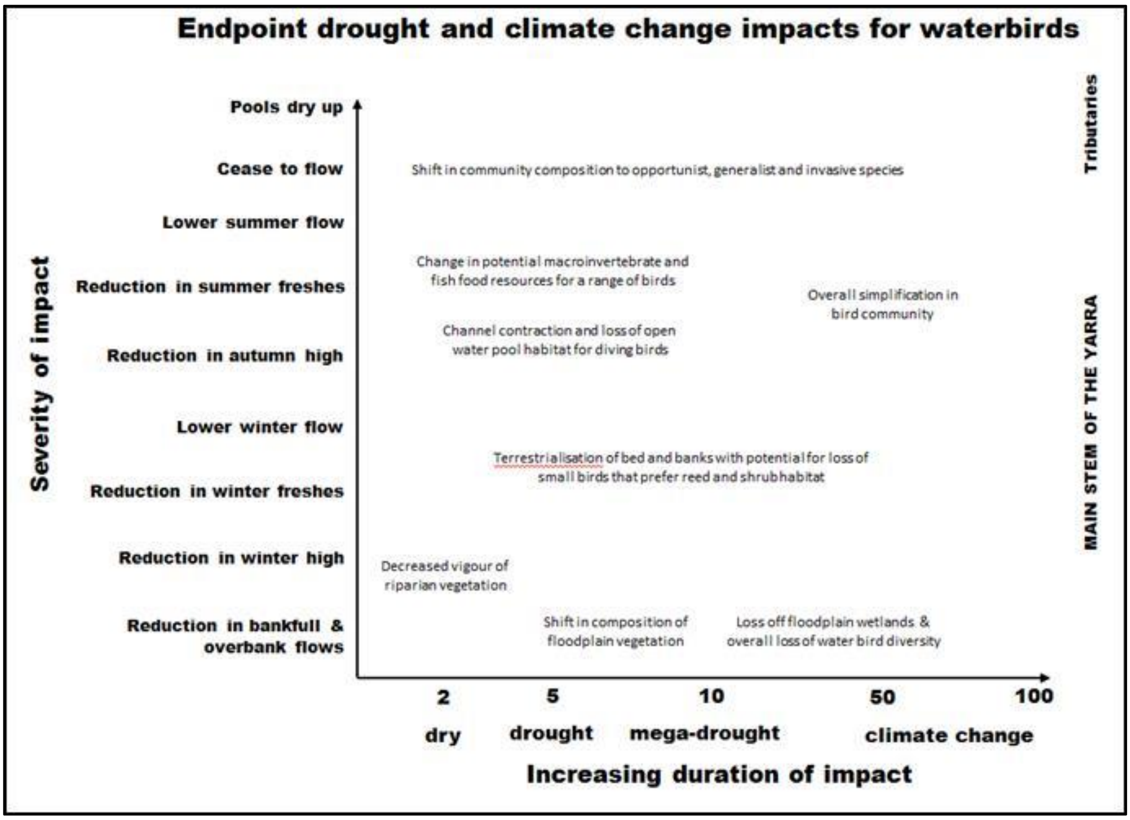

Figure 42 Climate vulnerability assessment for waterbirds

8.9 Vegetation

Figure 43 summarises the potential endpoint responses of water-dependant vegetation to climate change induced changes in flow regime. Reduced in-channel flows and reduced frequency of bankfull and overbank flows means drier conditions in the riparian and floodplain zones, resulting in a shift towards vegetation communities that are more tolerant of dry conditions. Drier floodplains are also likely to result in the loss of some wetland types that will no longer hold water long enough to support water dependant plant communities (Nielsen and Brock 2009). A reduction in in-channel flows, and in particular an increase in the duration of low flows is likely to result in the terrestrialisation of the stream bank, and in severe cases the stream bed (e.g. in response to long durations of cease to flow). Growth of terrestrial vegetation within the channel can then pose significant risks when floods do occur because the vegetation is scoured from the channel and swept downstream, potentially increasing the severity of bed and bank erosion through physical abrasion.

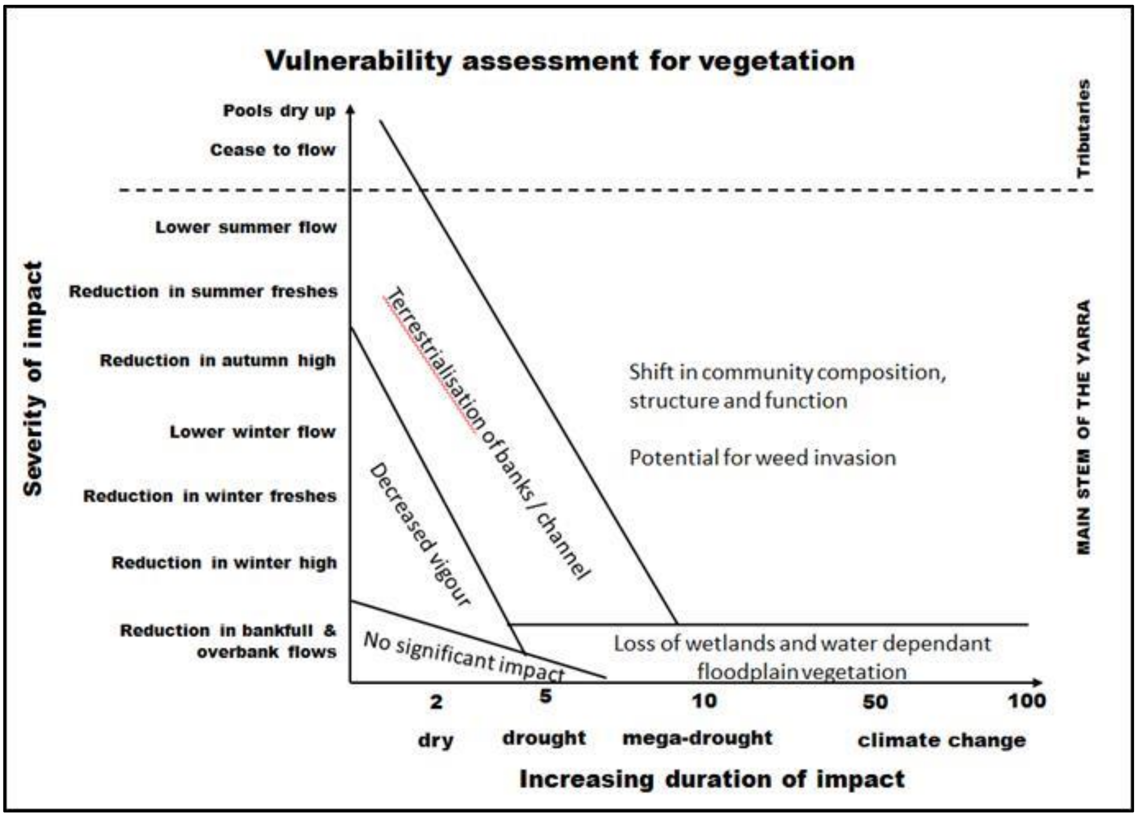

Figure 43 Climate vulnerability assessment for vegetation

8.10 Summary of endpoint outcomes

Figure 44 shows a summary of predicted end points for the range of values assessed for the Yarra River under drought and climate change outlooks. A reduction in the frequency and duration of bankfull and overbank flows will ultimately lead to a reduction in the vigour of riparian and floodplain vegetation and result in a shift towards plants that are tolerant of drier and warmer conditions. Over the medium to long term there will also be a loss of existing wetland/billabong habitat. Over the longer term, the loss of bankfull and overbank flows could also have negative consequences for in-channel food webs because the loss of hydrological connectivity between the river and floodplain/wetlands interrupts the movement of nutrients and organic material that are important food resources for in-stream organisms. Reductions in bankfull flows and freshes will lead to further channel contraction and encroachment of terrestrial vegetation on the river banks. However, a potential increase in high intensity rainfall and flood events could cause significant scour and damage to the channel from time to time.

Within the channel, climate change impacts that result in a reduction in the frequency of fresh flows and an increase in the duration of low flows and cease to flows will over time result in the steady decline in abundance of flow sensitive taxa, including fish, macroinvertebrates, platypus and frogs. Some of these taxa could eventually become locally extinct. For species that are endangered or vulnerable on a regional and/or national basis, this may have serious implications for our ability to protect these species from total extinction.

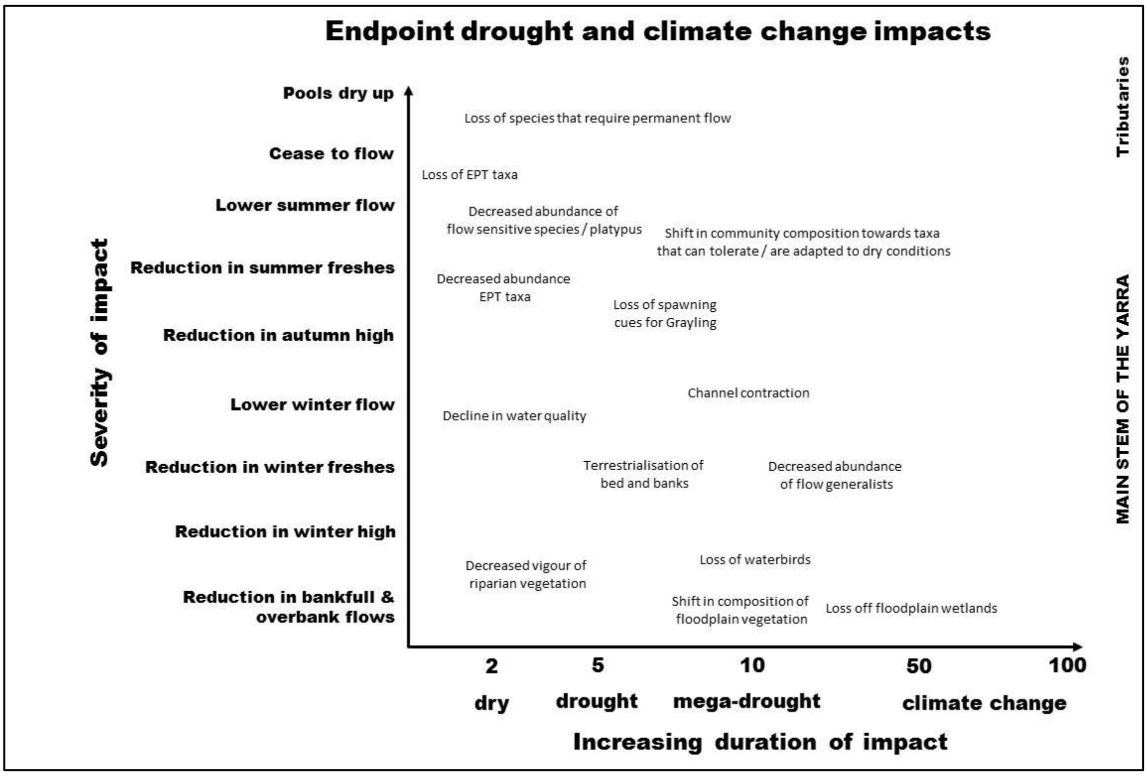

Figure 44 Summary of endpoint drought and climate change outcomes for Yarra River values

8.11 Analysis of flow conditions under current and climate change scenarios

From the vulnerability plots, priority flow components were then determined that would need to be delivered with a high degree of compliance in order to maintain the condition of the ecological value (note that this objective is ‘maintain’ not ‘improve’ condition). For example, resident fish sensitive to increased duration of low flows would need to experience a high degree of compliance with low flow recommendations in order to maintain their condition (under both current and climate change scenarios). If climate change results in a decrease in compliance with low flow recommendations, then the condition of these fish would be expected to deteriorate. The priority of various flow components for each of the values assessed is shown in Table 34. Although some flow components have been rated as lower priority, it is still important that they are delivered, or are allowed to occur naturally, because collectively, all components are required to achieve desired outcomes.

Using the priorities in Table 34 and the previous compliance assessment (see Section 8.1), a time series has been developed to show the overall flow condition in any one year based on the degree to which recommended flows were complied with and weighted towards relevant priority flows components. The condition score is scaled so that 1 indicates perfect conditions (i.e. all relevant flow components were complied with) and 0 indicates poor conditions (i.e. no relevant flow components were complied with). The time series condition scores were determined for current flow conditions and under a range of climate change scenarios, and the current streamflow was scaled downwards as described in Section 8.1. Using this approach it is possible to see how patterns in flow conditions for various values could be expected to change under various climate change scenarios.

Table 34 Flow component priorities for Yarra River values, where 1 = lower priority; 2 = moderate priority; 3 = high priority; and 4 = essential.

Value	Summer low flow	Summer fresh	Autumn high flow	Winter low flow	Winter fresh	Winter high flow	Bankfull	Overbank	Justification for prioritisation
Resident fish	4	3	1	4	2	1	1	1	Weighted for low flows and freshes to maintain access to pool habitat and good water quality
Migratory fish	4	1	4	3	2	4	1	1	Weighted for high flows to trigger migration and spawning
Platypus	4	3	1	4	2	1	1	1	Weighted for low flows and freshes to maintain access to pool habitat, good water quality, and food resources
Macroinvertebrates	4	4	1	4	2	1	1	1	Weighted for low flows and freshes to maintain access to pool habitat and good water quality
Frogs	2	1	1	2	1	1	3	4	Weighted for low flows and overbank flow to maintain instream pool habitat and inundate wetlands
Birds	2	2	2	2	2	3	3	4	Weighted for low flows and overbank flow to maintain in channel vegetation habitats and inundate wetlands
Vegetation	2	1	1	2	2	4	4	4	Weighted for high flows, bankfull and overbank flow to maintain soil moisture in banks and floodplain and inundate wetlands

Figure 45 to Figure 51 show condition scores for all water dependent values. The results show that in the short term (i.e. next 10 to 15 years) the condition of values is likely to be similar to that under current conditions. However, in the long term, especially in dry climate years, condition is expected to deteriorate with climate change.

In order to meet the current management and environmental flow objectives for the Yarra River under a climate change outlook (i.e. maintain the current level of achievement with environmental flow recommendations), an increase in the volume of the Environmental Entitlement will be required.

A project currently being undertaken by researchers at Melbourne University is developing a sophisticated model for predicting ecological responses to environmental flows in the Yarra River. The outcomes of that project were not available to inform this EWMP, however the results will be instrumental in assessing the potential ecological response to climate change and the ability to achieve an agreed level of ecological condition with available environmental water. This model could be used to provide a more accurate analysis of the climate change implications presented herein. However the analyses to-date establishes that with the current Environmental Entitlement it will be difficult to maintain current ecological conditions, let alone improve them, as per Melbourne Water's current Healthy Waterway Strategy objectives.

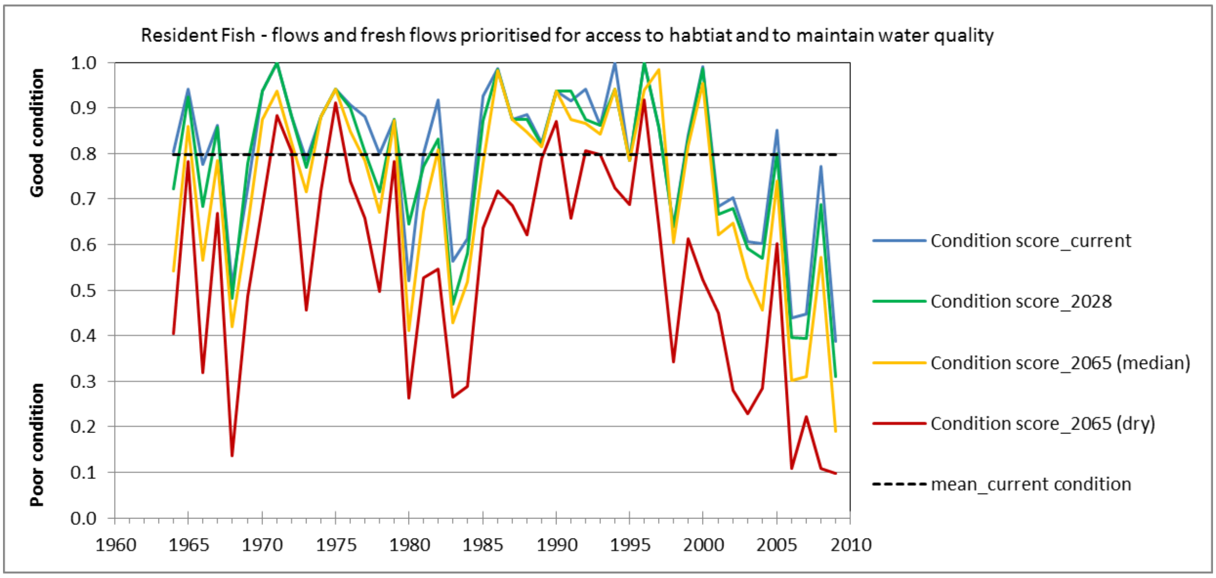

Figure 45 Time series condition scores for resident fish (prioritised for low flows and freshes according to Table 34) under current and climate change scenarios.

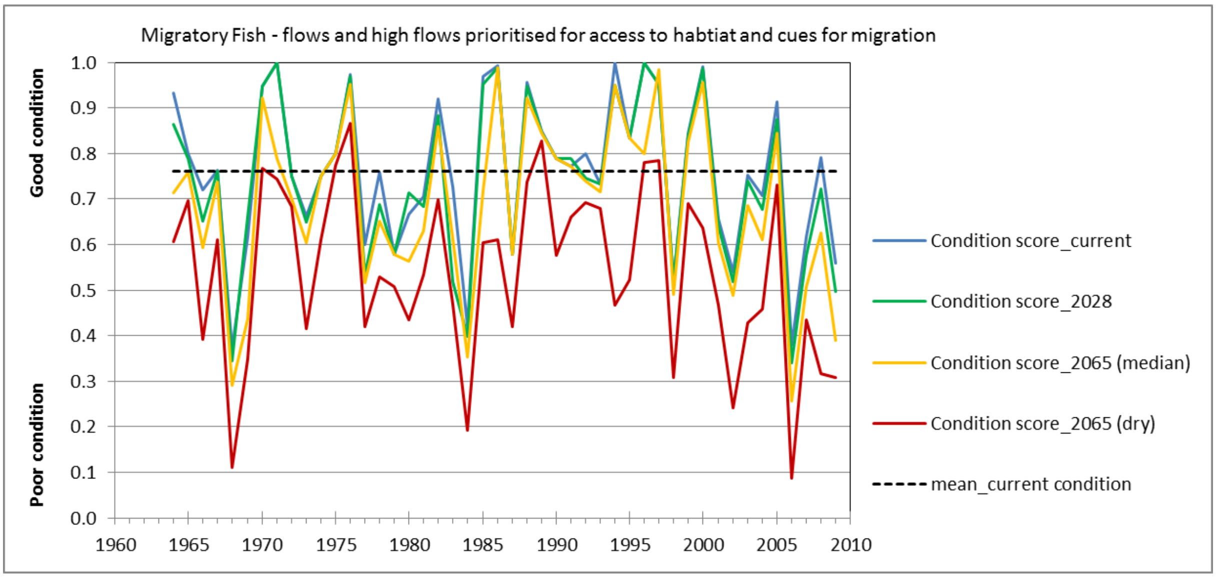

Figure 46 Time series condition scores for migratory fish (prioritised for low flows and high flows according to Table 34) under current and climate change scenarios.

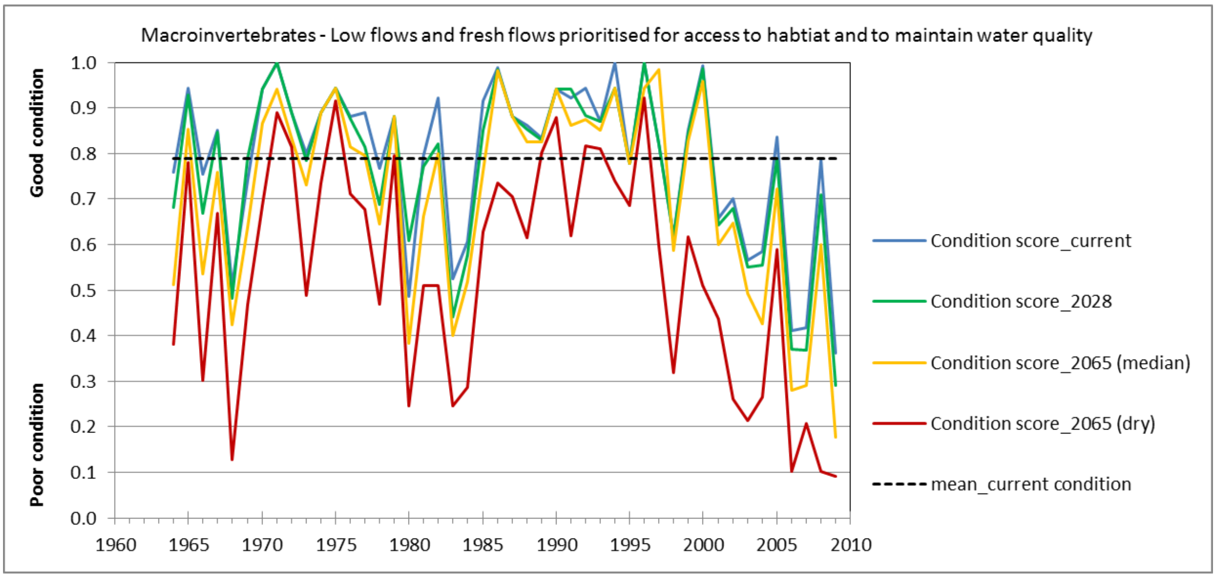

Figure 47 Time series condition scores for macroinvertebrates (prioritised for low flows and freshes to maintain access to habitat and quality of habitat according to Table 34) under current and climate change scenarios.

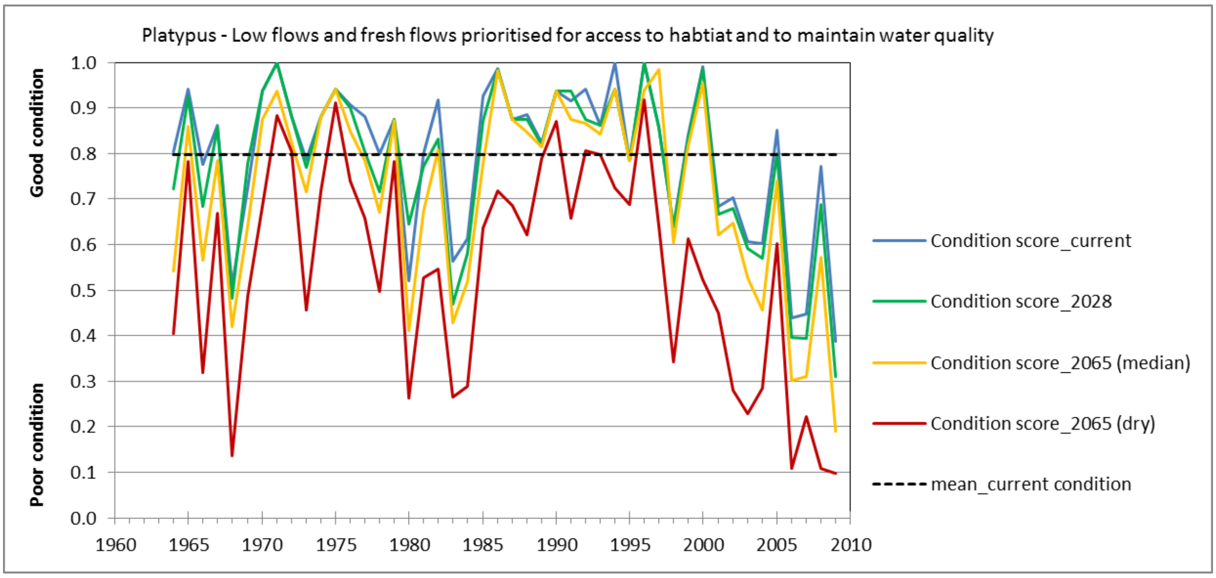

Figure 48 Time series condition scores for platypus (prioritised for low flows and freshes to maintain access to habitat and promote food resources according to Table 34) under current and climate change scenarios.

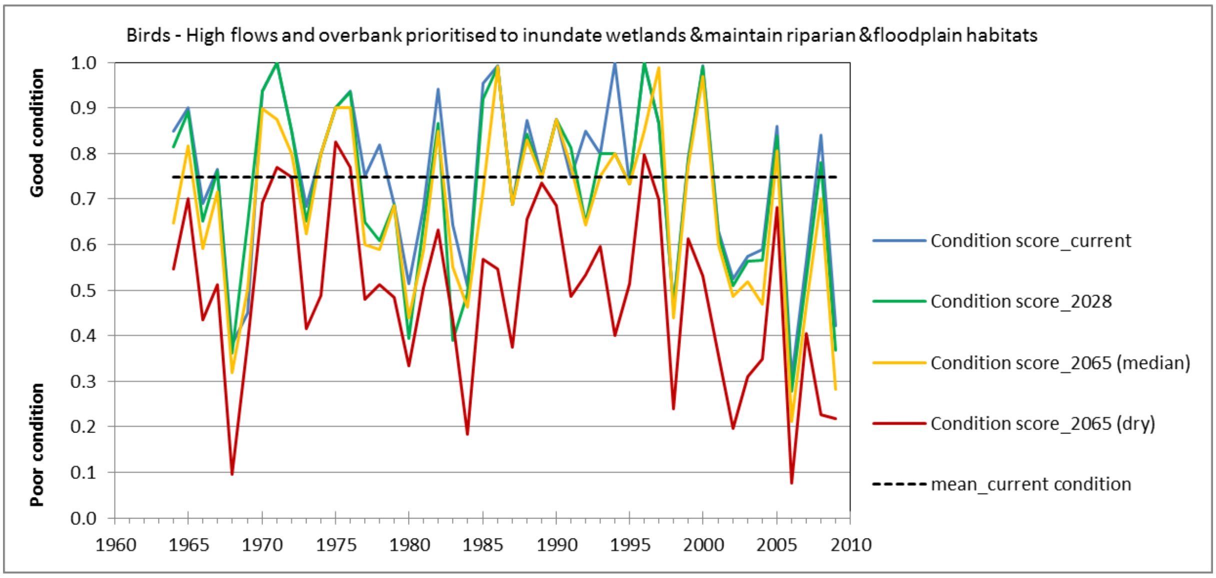

Figure 49 Time series condition scores for birds (prioritised for overbank flows to inundate wetland habitats according to Table 34) under current and climate change scenarios.

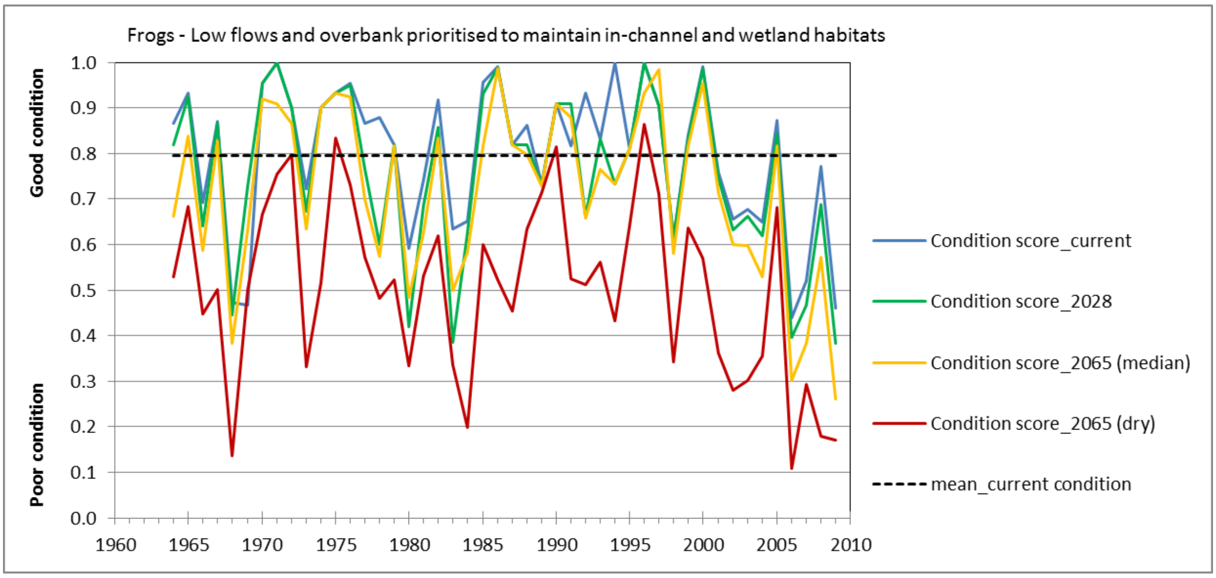

Figure 50 Time series condition scores for frogs (prioritised for low flows to maintain pool habitat and overbank flows to maintain wetland habitats according to Table 34) under current and climate change scenarios.

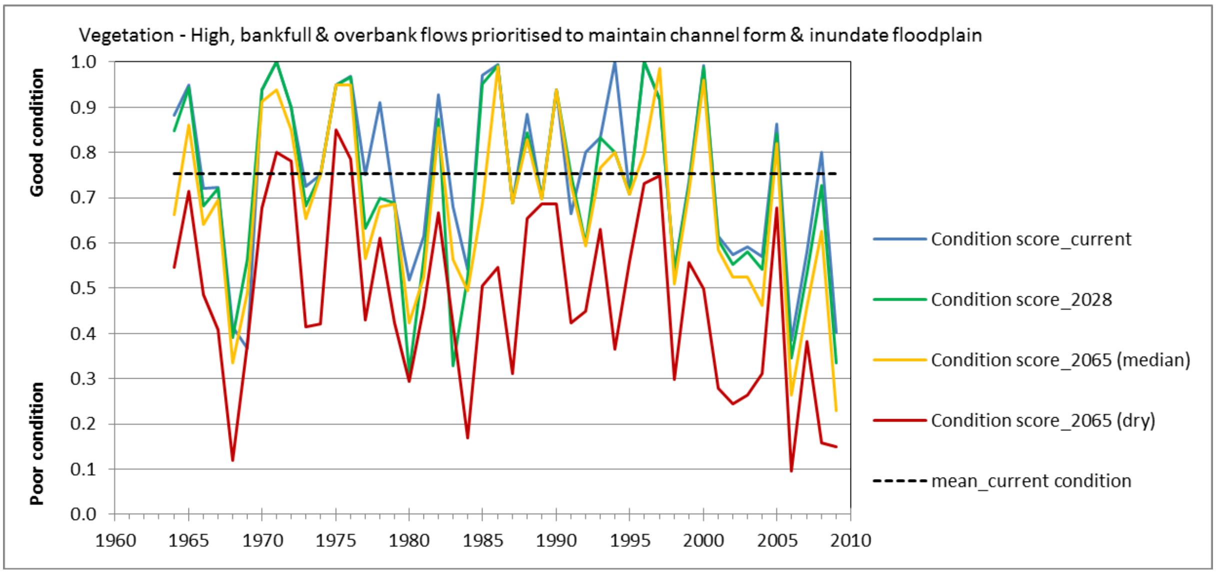

Figure 51 Time series condition scores for vegetation (prioritised for high flows and overbank flows to maintain soil moisture in banks and on the floodplain according to Table 34) under current and climate change scenarios.

9. Delivering Environmental Water

The Yarra Environmental Entitlement volume occupies storage space in the reservoirs that hold Melbourne's water supply. Releases can be made to the Yarra River from a variety of release locations as outlined in Table 35. The harvest of water can also be stopped at certain locations to allow for natural rainfall events to travel along the river to achieve environmental outcomes.

Table 35 : Release locations and target reaches for the Yarra Environmental Entitlement

Storage / Weir	Release location	Target Reaches
Upper Yarra	• Upper Yarra Reservoir valves into reach 1 • Upper Yarra – Silvan Aqueduct into reach 2	Reaches 1-6
Maroondah Reservoir	• Maroondah Reservoir valves into Watts River (reach 8). Delivers into reach 4. • Maroondah Aqueduct at Yering Gorge (reach 5)	Reaches 4-6 Reach 8
O'Shannassy Reservoir	• O'Shannassy Reservoir valves into O'Shannassy River. Delivers into reach 2.	Reaches 2-6
Upper Yarra Tributaries	• Harvest can be stopped at MacMahons Creek, Starvation Creek and Armstrongs Creek weirs. Delivers into reach 2.	Reaches 2- 6
Yering Gorge Pump Station	• Harvest can be stopped at this pump station. Delivers to reach 5 and 6.	Reaches 5 - 6

Decisions about how much water to release from each location are dependent on a range of factors that are unique to each release. The availability of water, streamflows and target streamflows change with each release and therefore the mix of release locations and volumes also needs to change. Close collaboration with the Melbourne Water Service Delivery team allows the flexibility required to meet the delivery needs of each release.

9.1 Delivery constraints

Delivering environmental water to the Yarra River is subject to a number of constraints. These relate to limits on delivery reaches and the volume of water that is available in particular storages. These constraints can create a situation where there is enough water available in the entitlement to achieve a particular event, but it is not actually possible to get all of this water to where it is needed.

The impacts of delivery constraints are greatest in dry years. This is because unregulated flows in the river are lower, and require larger volumes of water to be released to achieve environmental flow targets. This impact can be made worse if there is insufficient water available in some of the smaller storages during dry years. Overcoming these delivery constraints will be an important issue to address in the future to ensure the maximum benefit can be gained from the environmental entitlement. This is particularly important because reduced streamflows resulting from climate change are likely to increase how often the delivery of the entitlement is restricted by delivery constraints.

9.2 Ecological constraints

An investigation into the ecological constraints for delivery in the Yarra system was completed in 2014 (Jacobs 2014). The project reviewed the maximum allowable flows that can be released from Upper Yarra Reservoir and Maroondah Reservoir to meet environmental water objectives in the main stem of the Yarra River. The ecological limits on the volume of water that can be released relate to:

- The need to keep flows low during fish breeding seasons to protect River Blackfish eggs and juveniles that could be killed or washed downstream in high flow events

- Ensuring that disturbance to the bed of the stream is not so excessive that it might kill the macroinvertebrate populations who live there,
- Preserving habitat for fish, platypus and other mobile animals that need to seek refuge from fast flowing water
- Protecting juvenile platypus from accidental drowning while in their nests.

9.2.1 Yarra River estuary

All flows delivered through Reach 6 of the river which ends at Dights Falls will flow through the estuary and into Port Philip Bay. The Yarra River has the largest discharge of any river entering Port Philip Bay and plays an important role in influencing the salinity of the bay (Cooling *et al.* 2013). Environmental flow requirements for the estuary are not well understood currently. The initial environmental flow study for the Yarra (SKM 2005a) studied the estuary but did not make specific flow recommendations. The highly modified nature of the estuary and the volumes of water required to achieve a specific objective are likely to be very large in comparison to the requirements of the freshwater sections of the river. Therefore the estuary has not yet been specifically targeted for releases from the Yarra Environmental Entitlement.

Delivery of specific flow events to the estuary will require further study through mechanisms such as an Estuary Environmental Flow Assessment Method, which will help to understand the water requirements of the estuary. The outcomes of this study would then need to be prioritised for delivery each year as part of the Seasonal Watering Plan process.

9.2.2 Billabong watering

Environmental Entitlement water can be used for watering billabongs along the river. There are two mechanisms through which this can be achieved. One mechanism is to deliver bankfull or overbank flow events that would allow water to run on to the floodplain and fill wetlands. The delivery of bankfull and overbank flows poses a substantial risk of flooding private land, however, and these events are not currently delivered along the Yarra.

The preferred approach is develop specific watering plans for high priority sites and then use delivery infrastructure such as pumps to deliver water to the site. Melbourne Water has undertaken a mapping and prioritisation project to examine all the alluvial wetlands for the Yarra River, defined in this study as billabongs, and prioritised them according to their ecological values, level of threats that exist to these values, and opportunities for providing water to the locations (SKM 2012a). This program examines a range of options for delivering water to priority billabongs, including, but not limited to use of the Environmental Entitlement. This program will be the driver of Melbourne Water's investment in billabong watering activities.

9.3 Infrastructure constraints

The Melbourne Water supply system needs to deliver water to a diverse range of entitlement holders, including consumptive, irrigation and environmental, and to provide public safety services such as firefighting reserves. This can result in conflicting pressures being placed on the system at the same time, resulting in delivery constraints that will impact different entitlement holders at different times. Delivery constraints that impact the environmental entitlement are detailed below.

9.3.1 Maroondah Reservoir

Maroondah Reservoir is a key delivery point for water into the lower Yarra system. The Reservoir is reliant on inflows to fill and is a key water source for Melbourne. It is a low volume reservoir relative to its harvest capacity, meaning that it frequently spills in winter, but has a limited capacity to store water for summer. In the event that inflows to the reservoir are lower than expected, and/or the environmental flow demand is higher than expected, there may be insufficient water available in this reservoir to contribute to environmental flow targets in the lower system.

9.3.2 O'Shannassy Reservoir

Like Maroondah, O'Shannassy Reservoir is entirely reliant on inflows to fill, and it is a very low volume storage compared to its catchment and inflows. It is also subject to a restrictive maximum drawdown rate for dam safety purposes. For this reason, the availability of water in O'Shannassy Reservoir is subject to the overall storage level and its daily inflow (which influences the drawdown rate). This means that there are times when O'Shannassy Reservoir may not be available to assist with the delivery of environmental flow events. In addition, there is a requirement to retain a certain volume of water within O'Shannassy Reservoir for firefighting purposes. This places an additional constraint on the ability to drawdown the storage for environmental releases during summer.

9.4 Overcoming delivery constraints

To maximise the benefits of the Yarra Environmental Entitlement it will be necessary to find ways to overcome the current delivery constraints. This will require innovative solutions and collaboration between entitlement holders in the Yarra system. Options that could be considered include:

- Investing in new environmental entitlement delivery infrastructure
- Utilising existing infrastructure owned by other organisations
- Improving the ability to time environmental releases with rainfall events
- Investigating opportunities to access alternative water supplies to provide environmental flows events
- Substituting irrigation use with recycled water, freeing up irrigation entitlements to be used for environmental purposes
- Optimising the consumptive water supply system to derive additional environmental benefits from this water.

Melbourne Water will continue to explore the feasibility of each of these options with key stakeholders.

10. Demonstrating Outcomes

Carefully designed monitoring and research programs help to judge the robustness of the Yarra River environmental watering program in terms of its ability to meet the management objectives and desired outcomes for key values. These programs will also help to improve work planning and generate new knowledge. The programs cover a range of activities, including:

- Compliance monitoring (such as hydrological monitoring) – To determine if environmental flow release targets have been met
- Short-term event monitoring – To determine if environmental values are responding in the short-term to watering events
- Long-term ecological response monitoring and research – To determine if short-term environmental responses are leading to long-term changes
- Long-term condition/health monitoring – To track trends in the condition of values over time.

10.1 Compliance

Compliance with environmental flow provisions is monitored by Melbourne Water using a series of flow gauges throughout the Yarra catchment (Table 36).

Table 36 : Reaches and their streamflow gauges for monitoring purposes

Reach	Extent	Gauge
Reach 1	Upper Yarra Reservoir to Armstrong Creek junction	Yarra River downstream of Doctors Creek (229103)
Reach 2	Armstrong Creek to Millgrove	Yarra River at Millgrove (229212)
Reach 3	Millgrove to Watts River junction	Yarra River at Yarra Grange (229653)
Reach 4	Watts River to top of Yering Gorge	Yarra River at Yarra Glen (229206)
Reach 5	Top of Yering Gorge to Mullum Mullum Creek	Yarra River at Warrandyte (229200)
Reach 6	Mullum Mullum Creek to Dights Falls	Yarra River at Chandler Highway (229143)
Reach 7	Yarra Estuary (downstream of Dights Falls)	Yarra River at Chandler Highway (229143)
Reach 8	Watts River from Maroondah Reservoir to Yarra River confluence	Watts River at Healesville (229114)
Reach 9	Plenty River from Toorourrong Reservoir to Mernda	Plenty River at Mernda (229216)

These gauges along the river allow monitoring and reporting on the achievement of flow components through releases. As the resource manager, Melbourne Water is required to keep account of the volume of water released from the Environmental Entitlement, which is in accordance with accounting principles that are outlined in the Operating Arrangements for the management of the Yarra River Environmental Entitlement (Melbourne Water and VEWH 2014).

For releases from the Environmental Entitlement (i.e. released from the VEWH's account), accountability for the volume ordered to be released lies with the Melbourne Water Waterway Manager, while accountability for the actual volume released lies with the Melbourne Water Storage Manager. The Storage Manager meters and maintains records of the VEWH's share of system inflows, releases, and changes in storage. This information is provided to the Resource Manager to account for the VEWH's and other entitlement holders shares of water in storage. During environmental water deliveries, the Waterway Manager provides the VEWH with a weekly report, and on the completion of priority watering actions, provides an event summary.

During the development of each year's seasonal watering proposal, Melbourne Water undertakes a review of the previous 12 months to consider:

- How long term flow regimes compare to the recommendations of the flows study

- The degree to which releases from the Environmental Entitlement have met priority watering actions
- Any key issues relating to the management of the Environmental Entitlement from the most recent season.

Melbourne Water has developed a targeted monitoring program to assess the impact of particular flow events in achieving the ecological objectives, and has also developed a Knowledge, Innovation and Research Program to guide its broader monitoring and research requirements in the area of environmental flow delivery.

10.2 Monitoring and research

Within Melbourne Water's Environmental Wates Resources work program, a Knowledge, Innovation and Research Program outlines a number of monitoring and research projects that contribute knowledge about the flow needs of the Yarra River. These are briefly described in Table 37.

Table 37 : Monitoring, research and investigations programs

Monitoring/Research activity	Description
Monitoring of fish migration over Dights Falls fishway	This monitoring is being used to identify evidence of the migration of Australian Grayling, Common Galaxias and Tupong upstream into the freshwater reaches of the river.
Australian Grayling migration and spawning	In recent years Melbourne Water has been investigating the spawning habits of Australian Grayling in both the Yarra and Tarago Rivers. The research is aimed at improving understanding of the conditions required for a spawning event to occur, and to determine if an environmental release can successfully bring about a spawning response. There is currently a limited understanding of what triggers juvenile Australian Grayling to move from estuary to freshwater reaches. Melbourne Water in conjunction with ARI has successfully trialled an otolith[27] analysis technique that may assist in determining the timing of fish moving from estuarine to freshwater conditions. Research using this technique is ongoing. Melbourne Water is also currently investigating combining research and knowledge with catchment management authorities to further its understanding of Australian Grayling from a regional perspective.
Macquarie Perch	The Yarra River population of Macquarie Perch is thought to have undergone low levels of recruitment for several years, and this lack of knowledge about the species' reproductive dynamics makes it difficult to diagnose a cause. A study is underway to help understand recruitment dynamics, undertaking spawning assessments and recruitment surveys to estimate recruitment success under different variables such as location, river discharge and temperature, which are all thought to be significant factors influencing egg numbers. Temperature is thought to have a significant positive influence on Macquarie Perch spawning intensity, while river discharge is thought to have a significant negative influence. Repeating both the spawning assessment and recruitment surveys during years which do not contain high hydrodynamic variability late in the spawning period will help to improve population dynamics knowledge. This is particularly important for the management of environmental water for the purposes of sustaining Macquarie perch in the Yarra River.
Billabong watering outcomes	Melbourne Water will undertake response monitoring for billabongs such as Yering Backswamp, to detect if changes to vegetation communities and billabong condition can

[27] A fish otolith is a calcium carbonate structure of the inner ear, made up of layers of inert tissue. Each year, additional layers are laid down, storing the isotopic signature of the water occupied by the fish. Otoliths can provide a persistent record of movement between rivers and estuaries over the life of diadromous fish.

Monitoring/Research activity	Description
	be directly related to these inundation events
Dights Falls dissolved oxygen levels	Water quality monitoring in the Dights Falls weir pool is being conducted to determine if the delivery of summer fresh events is sufficient to mix this pool and improve the dissolved oxygen concentration throughout the water column. Data collated through the monitoring is being provided by a buoy permanently placed within the weir pool.
Reach 1 High Flow Release monitoring	Reach 1 of the Yarra River has been identified as a constraint to meeting the environmental water requirements of downstream reaches. Channel form and the presence of certain aquatic species limit the amount of water that can be released to this reach without posing a risk. Melbourne Water is monitoring the impact of water deliveries to this reach by monitoring the River Blackfish and macroinvertebrate populations pre and post releases. This information will be used to inform any risk assessment that may be required if Melbourne Water is considering releasing flows above the current recommended ecological constraints in Reach 1.
Optimising seasonal decisions for environmental water use	Melbourne Water has entered into a joint research project with the University of Melbourne and other partners as part of an Australian Research Council (ARC) Linkage Project. The project aims to develop a tool to optimise the use of environmental water, drawing on seasonal forecasts of streamflow and water price, and predicted ecological responses to changing flows. It is expected that the tool will assist in strengthening the effectiveness of parties responsible for managing environmental water. The Yarra River is one case study catchment, along with the Murrumbidgee and Goulburn catchments.
Melbourne Water Urban Platypus Program	Melbourne Water funds the Urban Platypus Program, a yearly monitoring event that surveys platypus populations every spring and autumn within the Greater Melbourne Area. Population abundance, recruitment success and individual animal condition are among a range of factors that are assessed. The program has been running for the past 20 years.
Yarra River flow supporting fish populations in Port Philip Bay	Fresh water inflows to Port Philip Bay from the Yarra River appear to be influencing snapper and sand flathead recruitment. Melbourne Water has established links with researchers in this field and will continue to monitor the research as it develops.

10.3 Evaluating and reviewing the environmental watering program

It is important to interpret and evaluate the monitoring, investigation and research data at regular intervals and translate these into useful actions and improvements to the Yarra River's environmental water management program. Generally, monitoring programs for Environmental Water management in Australia are guided by the following goals:

- The implementation of environmental water management actions is monitored and reported against
- The contribution of environmental flow releases towards the ecological objectives of targeted environmental water regimes are monitored and reported against
- The contribution of the environmental watering program to the achievement of environmental watering outcomes is monitored, evaluated and reported against
- Operational adaptability in environmental water management is supported through a program of monitoring and reporting.

Melbourne Water undertakes its evaluation and review processes according to a framework called the MERI framework, where MERI stands for 'Monitoring', 'Evaluating', 'Reviewing' and 'Improvement'. The MERI framework is used for Melbourne Water's environmental watering program, and establishes the program logic for the Yarra River environmental watering evaluation and review process. The Seasonal Watering Proposal planning process also assists Melbourne Water in tracking the positive and negative impacts and outcomes of environmental flow releases for the Yarra River. This framework provides an important contribution to the adaptive management processes for the Yarra River environmental watering program.

10.4 Complementary actions

Flow-related actions are most effective when they form part of an integrated management approach that also aims to improve habitat quality, address connectivity issues, and reduce direct threats from human activities and pest plants and animals. A range of complementary actions are listed in this section:

- Protect and/or restore native riparian vegetation corridors along stream and river banks and within wetland systems
- Remove willows and other invasive woody weeds from the waterway (while preventing bank erosion and maintaining adequate protective cover for platypus and waterbirds from predators)
- Reduce the adverse impacts of stock access along water courses by working with landowners to fence off waterways and creating off-stream watering points.
- Retain and potentially augment the amount of instream woody habitat (logs and large branches) present in stream and river channels and wetlands
- Melbourne Water is working in collaboration with DELWP and relevant Local Councils to understand and reduce the risks of increasing urban development on the Yarra River, to ensure that the amount of urban stormwater runoff does not increase in catchments subject to substantial urban development, and that stormwater issues are progressively reduced in established urban environments. Melbourne Water is also investigating options for stormwater harvesting and reuse for environmental flows through Water Sensitive Urban Design and integrated water cycle management programs
- Melbourne Water is also working with DELWP to help implement reformed planning controls for the Yarra River. This includes a revised State Planning Policy, which relates to the entire Yarra River corridor, and updated overlay controls within six metropolitan municipalities to manage development along the river between Punt Road, Richmond and Warrandyte. The overlays will be comprised primarily of a Yarra River focused Design and Development Overlay (DDO) to manage built form outcomes, and the use of a ‘whole of river’ corridor Environmental Significance Overlay (ESO) to manage vegetation and environmental outcomes.
- Undertake community education programs to address illegal fishing nets use, and implement an education and involvement program with recreational fishing groups to ensure native fish are released but introduced fish are not released back in to the river
- Through strategies such as Water Sensitive Urban Design (WSUD), control and treat urban stormwater and agricultural runoff as needed before it enters natural water courses to reduce litter and concentrations of sediment and chemical pollutants
- Reduce the impact of introduced predators by implementing control programs for foxes/feral cats and by restoring/maintaining a dense band of plant cover along the edges of waterways to discourage easy access by foxes, dogs and cats, especially in places where water is shallow (seasonally or throughout the year). Undertake community awareness programs to raise dog and cat owners’ understanding of the risks these pets can pose to platypus and waterbirds.

ENGAGEMENT, KNOWLEDGE AND NEXT STEPS

11. Consultation

The consultation and engagement undertaken by Melbourne Water during the development of the Healthy Waterways Strategy has significantly informed this EWMP, particularly in the choice of ecological objectives and key values. As a consequence, the consultation undertaken for the development of the EWMP was able to focus on:

- Ensuring key stakeholders were aware of the EWMP and that they understood its management objectives and priorities, and to elicit
- Discussions and feedback regarding emerging issues such as climate change, cultural values, recreational benefits and urbanisation.

11.1 The EWMP consultation process

In order to develop the EWMP, the following consultation activities were undertaken:

- Identification and documentation of the Yarra River's water-dependent values already assessed through consultation with community and key stakeholders for the Melbourne Water Healthy Waterways Strategy. This drove the engagement process that was needed for the development of the EWMP.
- Identification and documentation of the key stakeholders relevant to the EWMP, via a Stakeholder Engagement Strategy. The strategy was developed in consultation with Melbourne Water Project Manager, and consultation/engagement was undertaken only after the key stakeholders and objectives for engagement were identified, prioritised and endorsed.
- The development and distribution of a one-page project flyer for key stakeholders, describing the project and requesting their involvement. For some stakeholders, this was followed up by telephone and email requests by the Melbourne Water Project Manager, requesting appropriate spokespeople to participate in the consultation process.
- Developing a Discussion Paper, which summarised the information currently known about the key values, their general flow requirements, and their management objectives. A Vision Statement was also developed as part of the Discussion Paper, and was used to help drive consultation discussions regarding the high level intent and purpose of providing environmental flows to the Yarra River.
- Undertaking consultation with the Yarra River Environmental Flows Advisory Group, which includes participants from:
  - Nillumbik Shire Council, Yarra City Council, Shire of Yarra Ranges, Manningham City Council and Banyule City Council
  - DELWP
  - VR Fish
  - Yarra River Keepers Association
  - Kew Golf Club
  - Native Fish Australia
  - Environment Victoria

  - Parks Victoria
  - Environment Protection Authority Victoria.
- Consultation with the Yarra River Environmental Flows Advisory Group included the following activities:
  - Circulating the contents of the Draft Discussion Paper for review and feedback, and then presenting an overview of the Paper to a meeting with the Advisory Group
  - Circulating the proposed Vision Statement for comment
  - Facilitating a review and feedback process regarding the draft and final versions of the EWMP, including preparing a Consultation Paper as summary of the Technical Synthesis.
- Presenting the Discussion Paper to the Melbourne Water facilitated Bulk Entitlement Management Committee (BEMC). The membership of the BEMC includes representatives from each of the three Melbourne retail water companies, Melbourne Water, DELWP, and a representative from each of the other bulk entitlement holders in the Melbourne supply system. Consultation was held to:
  - Provide an overview of the project and garner feedback regarding the management objectives and intent of the EWMP
  - Facilitating a review and feedback process regarding the draft and final versions of the EWMP
- Conducting two days of site visits, with attendance by members of the Yarra River Environmental Flows Advisory Group, Local Government and Melbourne Water Waterways and Land Officers, to visit key sites along the River and discuss the key values and issues that should be included for discussion in the EWMP.
- Consulting directly with Environment Victoria and the Yarra Riverkeeper regarding emerging issues, key values and appropriate management objectives for the Yarra River environmental flows, and to explore their feedback regarding the contents of the Discussion Paper
- Consulting with Melbourne Water staff responsible for the operational management of the Melbourne Headworks system, to understand system operations and constraints.
- Liaising with and attending a number of workshops facilitated by a Melbourne University led ARC Linkage Grant project investigating decision-support tools for the Yarra River environmental flows program (managed by Dr Avril Horne), including consultation with a technical reference group engaged to assist in this project.
- Consulting with Local Government Project Managers and Parks Victoria regarding the ecological values and management objectives for both the main stem of the River and its billabongs
- Consulting with the Victorian Environmental Water Holder and Environment Victoria regarding emerging issues affecting the Yarra River, appropriate communications and engagement strategies, and cultural values management.
- Attending a Wurundjeri eel trap site visit to discuss the EWMP development process with the Traditional Owners of the Yarra River, and to begin the consultation process regarding the management of water-dependent cultural values. Further consultation with the Wurundjeri regarding the Yarra River’s key values is being pursued through a separate project for Melbourne Water, which seeks to identify, document and provide flow recommendations for water-dependent cultural values.
- Consulting with members of the Yarra River Ministerial Advisory Committee, to explore emerging issues and synergies in the programs.

Stakeholder feedback and Melbourne Water responses regarding the draft EWMP are included in Appendix G.

A copy of the Consultation Paper is available from Melbourne Water.

11.2 Future communications and engagement

A Yarra River environmental watering program Communications and Engagement Strategy has been developed to support the implementation of the EWMP and the ongoing management of the Yarra River

Environmental Entitlement by Melbourne Water. This Strategy will be treated as a 'live' document by Melbourne Water, updated when and as needed to ensure that two-way communications and engagement remains appropriate, tailored and effective. As emerging issues become known, the Strategy will also be reviewed to ensure that key stakeholders with influence on and/or interest in these issues are appropriately engaged with.

12. Knowledge Gaps and Recommendations

A considerable amount of knowledge has assisted in the determination of the environmental flow regime for the Yarra River. However, because the science of environmental flows is relatively new, this knowledge base is incomplete. The 2005 and 2012 environmental flows studies recommended minimum flow requirements for the Yarra and while these studies have advanced our scientific knowledge of the Yarra, there remain large gaps in our understanding of the river's species and their flow requirements, as well as the associated ecological processes. The environmental objectives developed for the studies were necessarily limited by this knowledge gap.

It is important that future advances in knowledge or methodology are incorporated into the data and evidence base used to manage environmental flows for the Yarra River. A range of knowledge gaps are discussed briefly below.

12.1 Estuary

A preliminary review of flow requirements for the estuary was undertaken by SKM for the 2005 Yarra River flows study, and a scoping study completed in 2013 (Cooling *et al.* 2013), but no full flows study has been conducted. Despite the known positive links between river discharge and coastal ecosystems, and the fact that a significant proportion of Australia's total fisheries harvest is derived from estuarine and inshore waters, there still exists a common perception that "water going to the sea is wasted" (Bunn *et al.* 1998). There is little information available on the consequences of flow regulation in headwater areas for coastal ecosystems, but there are suggestions that it could be significant. Strong positive correlations have been observed between Snapper and Sand Flathead recruitment in Port Phillip Bay and discharge from the Yarra River for example, and further research is required to investigate these causal mechanisms and to develop predictive models using existing catch and flow data.

The 2005 flows study included some general flow recommendations for the Yarra Estuary, which were based on the assumption that a flow regime that meets all of the environmental objectives for the freshwater reaches of the Yarra River would also probably meet the requirements of the estuary. A dedicated study to assess environmental flow requirements for the Yarra estuary using the Estuary Environmental Flows Assessment Method for Victoria (EEFAM) would help improve the understanding of the flow requirements in the estuary. To contribute to this knowledge:

- Melbourne Water has developed a tool to prioritise its estuaries for further investigation based on their ecological and social values and vulnerabilities (Lloyd et al. 2013) and the management tools available to manage the flow regime (GHD 2014). The Yarra estuary has been assessed in this context as being of high priority for further action
- The development of a 3-D hydrodynamic model for the Yarra estuary has been completed (Bruce and Hipsey 2013, Bruce et al. 2015) since the initial SKM investigation in 2005 to improve the understanding of the flow needs of the estuary

Achievement of suitable dissolved oxygen concentrations in the estuary will be an important flow-related objective in providing improved habitat conditions for biota in the estuary (Coleman et al. 2011). Another important flow-related objective will be managing the hydraulic thresholds that control bed sediment remobilisation (which might impact contaminant levels), and the hydraulic thresholds that determine if sediment will be deposited or eroded from benches that can be colonised by instream plants under suitable conditions. The hydrology of the estuary is highly modified from natural, and all flow components (high, medium and low flows) will potentially have important roles in maintaining estuary health, and will thus require further investigation.

12.2 Platypus

The current understanding of the flow requirements of platypus in the Yarra River system needs improvement. It will be particularly important to improve understanding of the existing platypus population, including its resilience and appropriate condition/response assumptions for different water availability scenarios under climate change. Surveys of platypus abundance and distribution through Melbourne Water's annual Urban Platypus Program (MWUPP) will also assist in improving this knowledge. The surveys, held every spring and autumn, identify threats to the species, insights into the steps to mitigate these threats and monitor the response of platypus to river health works. An innovative new application being trialled by Melbourne University, CESAR and Melbourne Water for the MWUPP is the analysis of environmental DNA samples (eDNA) to detect the presence and relative abundance of platypus throughout the Melbourne area (Jacobs *et al.* 2016).This technique analyses genetic material collected not through targeted methods such as trapping, but extractions from bulk environmental samples such as water (Barnes and Turner 2016).

A number of key knowledge gaps and research priorities were identified during a recent Technical Review of knowledge regarding platypus flow requirements, finding that it will be important to develop a better understanding of how to develop an effective network of platypus drought refuges, and how best to manage populations deemed to be at risk due to small population size and/or the isolated nature of their habitat (Jacobs *et al.* 2016). These recommendations included assessing how platypus usage and carrying capacity can be increased at existing drought refuge sites, as well as assessing the distribution and size (surface area, mean and maximum depth when filled) of potential platypus drought refuge sites along normally reliable water courses that are expected to stop flowing and potentially dry up completely during extended periods of drought. Further knowledge will also be important regarding assessing where these drought refuge sites are most needed in the Yarra catchment, to avoid local population extinctions. The identification of the critical barriers to platypus migration in the catchment will also be important, as will assessing the range of management actions that can best contribute to conserving any isolated platypus populations deemed to be at risk (Jacobs *et al.* 2016).

12.3 Waterbirds and frogs

Very little is known of the environmental flow requirements of waterbirds and frogs in the Yarra catchment. For example, flow requirements for frog species such as Growling Grass Frog are not well known for the population of the Yarra catchment, particularly regarding the extent of dependence this species may, or may not have, on flows from the main stem of the river or its connected floodplains.

The dependence of waterbirds on the Yarra River is also poorly understood. This work will necessarily be a long term strategy for Melbourne Water given the current paucity of data on species and community abundance and distribution over time. Understanding the impacts of climate change on migratory bird species within the catchment will be particularly important given a number of these species are protected under international covenants and are endangered on a global basis. Conducting surveys and habitat profiling will assist Melbourne Water to understand the relationship between inundation events and use of the river, including the antecedent conditions that are favourable for breeding.

12.4 Amenity and recreation

Given the priority that people place on the Yarra River's amenity values, it will be important to be able to link amenity values with flow requirements where they are known. Melbourne Water is undertaking significant work to determine what aspects of amenity can be managed by the provision of flows and how outcomes for amenity objectives can best be monitored and measured. Melbourne Water's Strategic Asset Management Plans, as well as the next revision of the Healthy Waterways Strategy, will be further investigating this issue, and as new methodologies are developed through these strategies, this information will also inform future revisions of the EWMP. The Healthy Waterways Strategy is due for revision in 2017-18.

12.5 Water-dependent cultural values

Currently there is very little knowledge available for non-Aboriginal waterway managers to help ensure that water-dependent cultural values are protected and managed appropriately and sensitively in Australia. Melbourne Water and the Victorian Environmental Water Holder have begun a collaborative project with the Wurundjeri to determine the water-dependent cultural values of the Yarra River, and to assess the likely flow requirements of these values, with a view to being able to provide co-beneficial watering of these values where they do not contradict ecological objectives. This project is one of the first of its kind in Australia, and the findings of the project will inform Melbourne Water's annual environmental flow planning processes, as well as VEWH's seasonal watering strategies. Collaborative management of the Yarra River between Aboriginal and non-Aboriginal people will likely highlight a wide range of knowledge gaps and weaknesses. It is recommended that future versions of the EWMP, as well as other strategic management documents, are regularly updated to reflect the increasing knowledge base of practitioners.

12.6 Groundwater

Targeted hydrogeological assessments (even in the broadest sense), particularly if coordinated with hydrological and ecological survey and monitoring, would improve the understanding of the role of groundwater in the Yarra catchment. In this way, dramatic changes in contributions from (and to) groundwater can be better accounted for in the environmental flow recommendations.

12.7 Drought risk

Paleoclimate proxy records provide an insight into past climate variability prior to the start of historical rainfall records. Paleoclimate records indicate that the time period over which we have rainfall records has been relatively wet in eastern Australia, and that prolonged dry periods much longer than the Millennium Drought have occurred over the past thousand years. For water resources planning, this reinforces the need to consider the possibility of conditions that are drier than those observed in the historical record, and that climate change is likely to further add to this need (Tozer *et al.* 2016).

Paleoclimate data indicate that droughts similar to and longer than those over the instrumental climate record have occurred on a regular basis in Australia's past over the last 2700 years. For example, six mega-droughts that persisted for longer than 10 years occurred in the period 1000-1320 AD, including a 39 year drought from AD 1174-1212. While there are some uncertainties about whether current influences on Australian climate have been stationary over previous millennia, it can be inferred from these paleoclimate reconstructions that climate variability from the historical record represents only a fraction of the climate variability which has been observed over the last few thousand years. Although a 39 year drought is unlikely, a drought longer than the Millennium Drought is plausible (Tozer *et al.* 2016).

The development and use of Paleoclimate proxy records suitable for application for environmental water resource management and planning have to date largely rested within the academic community. Risks to the flow regime of the Yarra River may be far greater than currently estimated based on an understanding of paleoclimate data. Melbourne Water is exploring these risks through an ARC linkage project that is examining the likelihood of mega droughts and its impacts on water resources, using the Yarra as a case study. The results of this will become available in three years, and are aiming to assess the likelihood of mega drought occurrence and severity.

12.8 Billabong watering

The environmental flow requirements of billabongs connected to the Yarra River are not well known. Information regarding the flow requirements of the species and communities present within these wetlands is poor, and there remains an incomplete understanding of the connectivity between the river, the floodplain and the billabongs. A future review of the environmental flow requirements for the Yarra River should include an analysis of LIDAR information to identify potential barriers to natural flow paths and to determine commence to fill levels for a range of its connected floodplain wetlands and billabongs. This information could be used to identify areas for on-ground work to re-instate natural flow paths and to help set realistic flow targets.

It is important that management objectives are determined for the priority billabongs because this will help to determine their preferred hydrological regimes. Once management objectives have been set for billabongs, the water requirements needed to achieve site objectives can be determined. Furthermore:

- Significant knowledge gaps exist around the hydrology of billabongs and their connectivity with groundwater and the Yarra River. This knowledge is critical given the need to understand and quantify the interaction and flow of water between these sources and potential impacts on water quality, billabong hydrology and ecosystem health.

- The complex mosaic of topographical relief at small scales also poses a challenge to manipulating or managing the water regime at billabongs. Without this knowledge the movement of water throughout a site is largely unknown, however can be comfortably predicted with site LiDAR data and additional survey points obtained during the field assessment. This information could also be used to approximate the volume of the main basins of these wetlands.
- Cultural heritage information is also lacking for most billabongs. A cultural heritage survey could be undertaken to determine the historic cultural significance of the priority billabongs.
- Threatened species surveys may also contribute to the overall understanding of the billabongs and their significance.

13. Securing the Ecological Health of Flow-dependent Values in the Yarra River

The delivery of appropriate environmental flows is just one aspect of securing the health of flow-dependent values in the Yarra River. In addition to delivering environmental flows, a range of complementary actions are needed to assist in achieving the objectives of the EWMP. In some cases, failure to deliver complementary actions will limit the benefits of delivering environmental flows. Complementary actions include riparian vegetation rehabilitation, addressing catchment sources of sediment and pollution, and undertaking pest plant and animal eradication/control programs.

Melbourne Water is also working with key stakeholders to address the emerging issue of urbanisation. 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. Melbourne Water is working in collaboration with land developers and State and Local government agencies to understand and reduce the risks of increasing urban development within the Yarra catchment. For example, Melbourne Water is working with key agencies in the Northern Growth Corridor to develop stormwater capture and treatment options, which will help to reduce the impact of flow regime alterations and sedimentation issues within the catchment.

Melbourne Water is directing significant effort towards better managing the risks that climate change poses to the Yarra River and its catchment. Programs to understand and improve the resilience of water-dependent environmental values are being implemented, with the aim of improving the ability of Melbourne Water to protect the Yarra River's values, particularly during times of drought. Melbourne Water's seasonal watering plans for the Yarra River will take in to consideration monitoring data and the relative vulnerabilities and sensitivities of high value species to climate change stressors, and will adapt flow releases accordingly.

A key threat is that climate change will significantly reduce the flows available for the river. Adaptive management, sourcing alternative supplies of water, and monitoring of current water availability will assist Melbourne Water in further understanding water availability and sustainable diversion limits for the Yarra catchment. While a cap has been placed on extractions in the Yarra catchment, Melbourne Water will actively seek opportunities to participate in reviews of the sustainability of this cap, and to improve its effectiveness under the impacts of climate change. Melbourne Water is also investigating options to improve environmental flows for the Yarra River through Integrated Water Cycle Management Plans, and is working to identify alternative sources of water that may reduce our reliance on extractions from the Yarra River for consumptive purposes. Water Sensitive Urban Design programs will also explore options for harvesting stormwater to augment environmental flows.

While a great deal has been learned about the relationship between flows and the condition of water-dependent values within the Yarra River, there remains many knowledge gaps and uncertainties. It will take a concerted and collaborative effort to protect these values, particularly because we know already that there is not enough water to provide for all of the flow components that are important to maintain their ecological functioning and health. Melbourne Water will continue to work with scientists, technical experts and other key stakeholders to determine how the 17GL Environmental Entitlement can best be delivered to the Yarra River. In light of the current poor condition and flow stress of the river, it is an imperative for Melbourne Water to identify and implement options to address these issues, to protect and restore the values of the river that people love and appreciate.

14. Next Steps

This EWMP provides the overarching strategy for the management of environmental water and protection of water-dependent values in the Yarra for the next ten years. It will provide the basis of annual planning for the management of the entitlement, most notably providing the direction for future Seasonal Watering Proposals and the development of Melbourne Water's environmental water annual work program.

Figure 52 shows the contribution of EWMP information towards the annual seasonal planning processes for both Melbourne Water and VEWH. The numbers in brackets associated with each of the EWMP topics correspond to key seasonal watering proposal considerations.

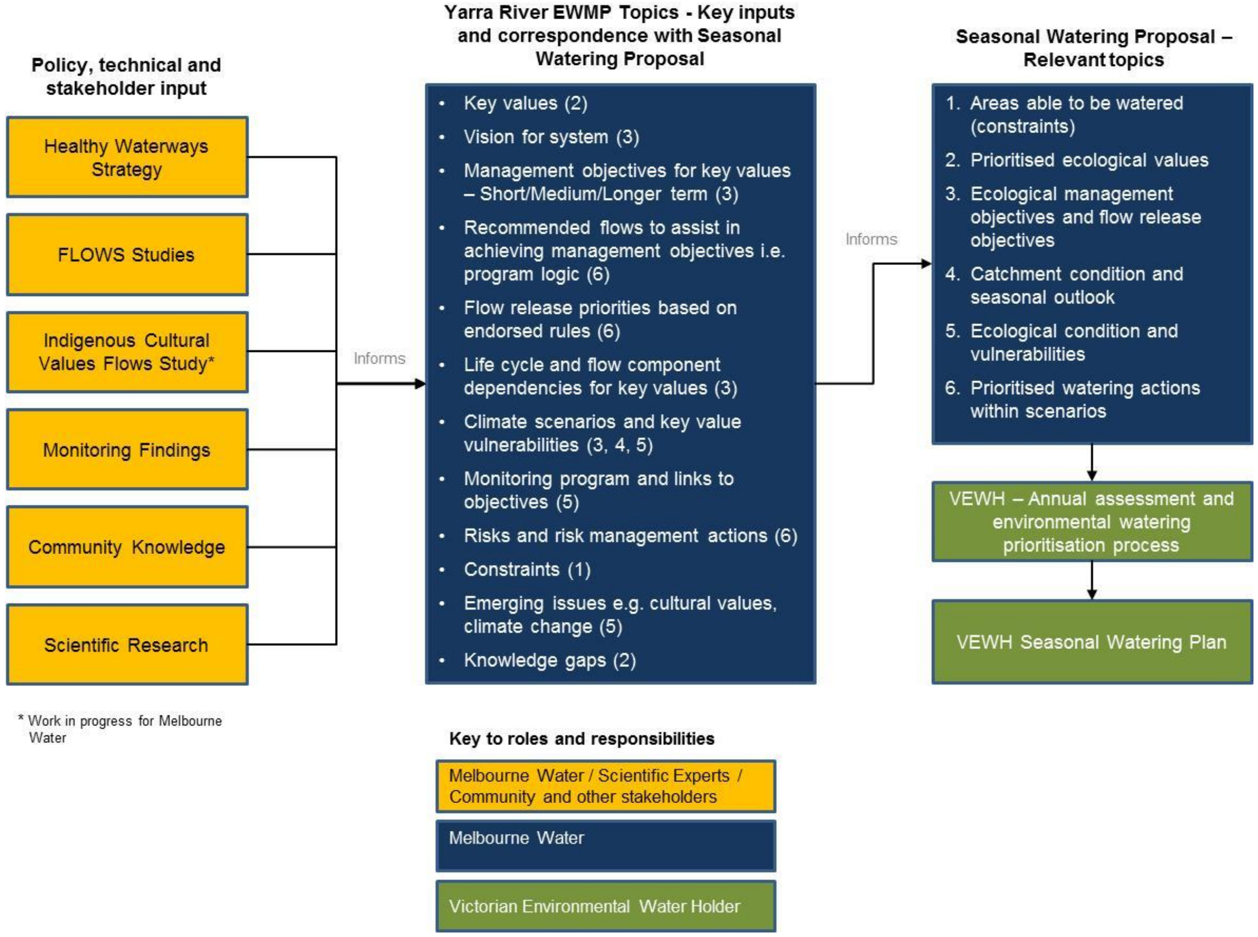

Figure 52 : The contribution of EWMP information to Seasonal Watering Proposal content

This EWMP will also be used to inform the review of technical information underpinning the Yarra Environmental Entitlement, including for the upcoming review of the environmental flows study in 2017-18.

The EWMP will also provide the basis of future inputs to Melbourne Water strategic documents, including the review of the current Healthy Waterways Strategy, which is due for completion in 2017/18. In addition to internal strategies, the EWMP will allow Melbourne Water to advocate for improved outcomes for water dependent values in the Yarra through State Government policy reviews and strategies, such as the Yarra River Protection Ministerial Advisory Committee review of opportunities to improve the oversight and management of the Yarra River, and possible future reviews of the Central Region Sustainable Water Strategy.

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Appendix A. Flora and Fauna

A.1 Flora

A.1.1 Bioregional EVCs and conservation status (Source: DELWP (2015c)

Bioregion	Ecological Vegetation Class (EVC)	Bioregional Conservation Status
Gippsland Plain	EVC 9 Coastal Saltmarsh Aggregate	LC
	EVC 56 Floodplain Riparian Woodland	E
	EVC 126 Swampy Riparian Complex	E
	EVC 53 Riparian Scrubs or Swampy Scrubs and Woodlands	E
	EVC 656 Brackish wetland	E
	EVC 636 Brackish Lake Aggregate	E
	EVC 3 Damp Sands Herb-rich Woodland	V
	EVC 934 Brackish grassland*	E
	EVC 140 Mangrove Shrubland	LC
	EVC 641 Riparian Woodland	E
Highlands – Southern Fall	EVC 18 Riparian Forest	LC
	EVC 29 Damp Forest	LC
	EVC 45 Shrubby Foothill Forest	LC
	EVC 30 Wet Forest	LC
	EVC 56 Floodplain Riparian Woodland	E
	EVC 126 Swampy Riparian Complex	E
Victorian Volcanic Plains	EVC 125 Plains Grassy Woodland	E
	EVC 56 Floodplain Riparian Woodland	E
	EVC 132 Plains Grassland	E
	EVC 68 Creekline Grassy Woodland	E
	EVC 895 Escarpment Shrubland	E
	EVC 292 Red Gum Swamp	E
Conservation Status: *E = Endangered* *LC = Least concern* *V = Vulnerable*		

A.1.2 Threatened plant species in the Yarra catchment (Source: SKM (2012c))

Common name	Scientific Name	AROTS	VROTS	Water Dependency	Habitat
YARRA RIVER					
Smooth Nardoo	*Marsile a mutica*		k	H	Floodplains, bogs or swamps

Common name	Scientific Name	AROTS	VROTS	Water Dependency	Habitat
Oval Fork-fern	*Tmesipteris ovata*		r		
Small Fork-fern	*Tmesipteris parva*		r		
Tall Club-sedge	*Bolboschoenus fluviatilis*		k	H	Swamps, seasonal creek lines
Green-top Sedge	*Carex chlorantha*		k	H	Swamps
Veiled Fringe-sedge	*Fimbristylis velata*		r	H	Occasional on drying mud beside lakes and rivers in seasonally wet depressions
Tufted Club-sedge	*Isolepis wakefieldiana*		r		
Wine-lipped Spider-orchid	*Caladenia oenochila*		v		
Fertile Finger-orchid	*Caladenia prolata*		v		
Large White Spider-orchid	*Caladenia venusta*		r		
Slender Beard-orchid	*Calochilus gracillimus*		k		
Naked Beard-orchid	*Calochilus imberbis*		r		
Fringed Helmet-orchid	*Corybas fimbriatus*		r		
Swamp Diuris	*Diuris palustris*		v		
Silurian Leek-orchid	*Prasophyllum pyriforme s.s.*		*e*		
Red-tip Greenhood	*Pterostylis sp. aff. Parviflora (Southern Victoria)*		r		
Woodland Plume-orchid	*Pterostylis sp. aff. Plumose (Woodland)*		r		
Silurian Striped Greenhood	*Pterostylis sp. aff. Striata* (Silurian)		k		
Pale Grass-lily	*Caesia parviflora* var. *minor*		e		
Matted Flax-lily	*Dianella amoena*	E	e		
Arching Flax-lily	*Dianella sp. aff. Longifolia* (Benambra)		v		
Veined Spear-grass	*Austrostipa rudis* subsp. *australis*		r		
Wetland Blown-grass	*Lachnagrostis filiformis* var. 2		k		
Nunniong Everlasting	*Ozothamnus rogersianus*		r		
Smooth Groundsel	*Senecio glabrescens*		r		
Forest Bitter-cress	*Cardamine papillata*		v		
Slender Bitter-cress	*Cardamine tenuifolia*		k		
Basalt Peppercress	*Lepidium hyssopifolium*	E	e		
Native Peppercress	*Lepidium pseudohyssopifolium*		k	H	Floodplain
Swamp Water-starwort	*Callitriche palustris*		k	H	Grows on shallow still water and mud

Common name	Scientific Name	AROTS	VROTS	Water Dependency	Habitat
Hypsela	*Hypsela tridens*		k		
Stalked Guinea-flower	*Hibbertia pedunculata*		r		
River Leafless Bossiaea	*Bossiaea riparia*		r		
Slender Tick-trefoil	*Desmodium varians*		k		
Austral Cranesbill	*Geranium solanderi* var. *solanderi s.s.*		v		
Pale-flower Cranesbill	*Geranium* sp. 3		r		
Sticky Wattle	*Acacia howittii*		r		
Dandenong Range Cinnamon Wattle	*Acacia leprosa* (Dandenong Range variant)		r		
Southern Varnish Wattle	*Acacia verniciflua* (southern variant)		k		
Spotted Gum	*Corymbia maculata*		v		
Studley Park Gum	*Eucalyptus* X *studleyensis*		e		
Buxton Gum	*Eucalyptus crenulata*	E	e		
Green Scentbark	*Eucalyptus fulgens*		r		
Melbourne Yellow-gum	*Eucalyptus leucoxylon* subsp. *Connate*		v		
Yarra Gum	*Eucalyptus yarraensis*		r		
Yarra Burgan	*Kunzea leptospermoides*		k		
Giant Honey-myrtle	*Melaleuca armillaris* subsp. *Armillaris*		r		
Fluffy-fruit Wood-sorrel	*Oxalis thompsoniae*		k		
Velvet Apple-berry	*Billardiera scandens* var. *brachyantha*		r		
Rosemary Grevillea	*Grevillea rosmarinifolia* subsp. *Rosmarinifolia*		r		
Striped Pomaderis	*Pomaderris pilifera*		r		
Round-leaf Pomaderris	*Pomaderris vacciniifolia*		v		Endemic in moist forest scrubs
Powelltown Correa	*Correa reflexa* var. *Lobata*		r		
Notched Leionema	*Leionema bilobum*		r		
Coast Tobacco	*Nicotiana maritima*		e		
Austral Tobacco	*Nicotiana suaveolens*		r		
Slender Stylewort	*Levenhookia sonderi*		r		
Poison Rice-flower	*Pimelea pauciflora*		r		
WATTS RIVER					
Bristly Shield-fern	*Lastreopsis hispida*		r		Grows in wet forests
Jungle Bristle-fern	*Cephalomanes caudatum*		r		
Summer Spider-orchid	*Caladenia flavovirens*		r		
Narrow-lip Spider-orchid	*Caladenia leptochila*		k		
Mountain Bird-orchid	*Chiloglottis jeanesii*		r		

Common name	Scientific Name	AROTS	VROTS	Water Dependency	Habitat
Spurred Helmet-orchid	*Corybas aconitiflorus*		r		
Fringed Helmet-orchid	*Corybas fimbriatus*		r		
Wiry Bossiaea	*Bossiaea cordigera*				
Dwarf Silver Wattle	*Acacia nano-dealbata*		r		
Green Scentbark	*Eucalyptus fulgens*		r		
Long Pink-bells	*Tetratheca stenoCarpa*		r		
AROTS (Australian Rare or Threatened Species) ***E =*** *Endangered in Australia*					
VROTS (Victorian Rare of Threatened Species) ***e =*** *Endangered in Victoria* ***r =*** *Rare in Victoria but not considered otherwise threatened* ***k =*** *Poorly known and suspected, but not definitely known, to belong to any of categories x, e, v or r within Victoria.* ***v*** *= Vulnerable in Victoria*					
Water dependency ***H*** *Hydrophyte - A plant that is adapted to morphologically and/or physiologically to grow in water or very wet environments.*					

A.1.3 Plant species of conservation significance for the Yarra estuary (Source: Arundel and Barton (2007))

Common Name	Scientific Name	VROTS	FFG	EPBC
Venus-hair Fern	*Adiantum capillus-veneris*	e	L	
Branching Groundsel	*Senecio cunninghamii var. cunninghamii*	r		
Basalt Peppercress	*Lepidium hyssopifolium*	e	L	E
Swamp Water-starwort	*Callitriche palustris*	k		
Coast Saltwort	*Salsola tragus subsp. pontica*	r		
Tiny Arrowgrass	*Triglochin minutissima*	r		
Prickly Arrowgrass	*Triglochin mucronata*	r		
Buxton Gum	*Eucalyptus crenulata*	e	L	E
Southern Blue-gum	*Eucalyptus globulus subsp. globulus*	r		
Melbourne Yellow-gum	*Eucalyptus leucoxylon subsp. connata*	v		
Studley Park Gum	*Eucalyptus X studleyensis*	e		
Giant Honey-myrtle	*Melaleuca armillaris subsp. armillaris*	r		
Purple Diuris	*Diuris punctata var. punctata*	v	L	
Pale Grass-lily	*Caesia parviflora* var. *minor*	k		
Matted Flax-lily	*Dianella amoena*	e		E
Austral Tobacco	*Nicotiana suaveolens*	r		
Grey Mangrove	*Avicennia marina subsp.*	r		

Common Name	Scientific Name	VROTS	FFG	EPBC
	australasica			

VROTS (Victorian Rare of Threatened Species)
e = Endangered in Victoria
r = Rare in Victoria but not considered otherwise threatened
k = Poorly known and suspected, but not definitely known, to belong to any of categories x, e, v or r within Victoria.
v = Vulnerable in Victoria

FFG
L = Listed

EPBC
E = Endangered

A.2 Fauna

A.2.1 Birds

Scientific Name	Common Name	FFG	Vic Advisory	EPBC	Treaty	Origin
Puffinus gavia	Fluttering Shearwater					
Morus serrator	Australasian Gannet					
Pelagodroma marina	White-faced Storm-Petrel		Vulnerable			
Pterodroma lessonii	White-headed Petrel					
Sterna hirundo	Common Tern				CAMBA, JAMBA, ROKAMBA	
Fulmarus glacialoides	Southern Fulmar					
Puffinus huttoni	Hutton's Shearwater					
Puffinus tenuirostris	Short-tailed Shearwater				JAMBA, ROKAMBA	
Stercorarius skua	Great Skua					
Eolophus roseicapilla	Galah					
Platycercus elegans	Crimson Rosella					
Phaps chalcoptera	Common Bronzewing					
Hirundapus caudacutus	White-throated Needletail		Vulnerable		CAMBA, JAMBA, ROKAMBA	
Streptopelia chinensis	Spotted Turtle-Dove					Introduced
Anas castanea	Chestnut Teal					
Porphyrio porphyrio	Purple Swamphen					
Cacomantis variolosus	Brush Cuckoo					
Ninox novaeseelandiae	Southern Boobook					
Callocephalon fimbriatum	Gang-gang Cockatoo					
Chenonetta jubata	Australian Wood Duck					

Scientific Name	Common Name	FFG	Vic Advisory	EPBC	Treaty	Origin
Egretta novaehollandiae	White-faced Heron					
Accipiter cirrhocephalus	Collared Sparrowhawk					
Accipiter fasciatus	Brown Goshawk					
Ardea pacifica	White-necked Heron					
Apus pacificus	Fork-tailed Swift				CAMBA, JAMBA, ROKAMBA	
Platycercus eximius	Eastern Rosella					
Falco cenchroides	Nankeen Kestrel					
Cacatua galerita	Sulphur-crested Cockatoo					
Threskiornis molucca	Australian White Ibis					
Anas superciliosa	Pacific Black Duck					
Poliocephalus poliocephalus	Hoary-headed Grebe					
Cuculus pallidus	Pallid Cuckoo					
Cacomantis flabelliformis	Fan-tailed Cuckoo					
Platalea flavipes	Yellow-billed Spoonbill					
Lewinia pectoralis pectoralis	Lewin's Rail	Listed	Vulnerable			
Trichoglossus haematodus	Rainbow Lorikeet					
Microcarbo melanoleucos	Little Pied Cormorant					
Dacelo novaeguineae	Laughing Kookaburra					
Gallinago hardwickii	Latham's Snipe		Near threatened		BONNA2H, CAMBA, JAMBA, ROKAMBA	
Lophocroa leadbeateri	Major Mitchell's Cockatoo	Listed	Vulnerable			
Accipiter novaehollandiae novaehollandiae	Grey Goshawk	Listed	Vulnerable			
Fulica atra	Eurasian Coot					
Anas gracilis	Grey Teal					
Chrysococcyx lucidus	Shining Bronze-Cuckoo					
Calyptorhynchus funereus	Yellow-tailed Black-Cockatoo					
Phalacrocorax sulcirostris	Little Black Cormorant					
Podargus strigoides	Tawny Frogmouth					
Ninox strenua	Powerful Owl	Listed	Vulnerable			
Anas rhynchotis	Australasian Shoveler		Vulnerable			
Hieraaetus morphnoides	Little Eagle					

Scientific Name	Common Name	FFG	Vic Advisory	EPBC	Treaty	Origin
Todiramphus sanctus	Sacred Kingfisher					
Phalacrocorax carbo	Great Cormorant					
Menura novaehollandiae	Superb Lyrebird					
Psephotus haematonotus	Red-rumped Parrot					
Circus approximans	Swamp Harrier					
Falco longipennis	Australian Hobby					
Chrysococcyx basalis	Horsfield's Bronze-Cuckoo					
Columba livia	Rock Dove					Introduced
Elanus axillaris	Black-shouldered Kite					
Anhinga novaehollandiae	Darter					
Ardea modesta	Eastern Great Egret	Listed	Vulnerable		CAMBA, JAMBA	
Gallinula tenebrosa	Dusky Moorhen					
Falco berigora	Brown Falcon					
Anas platyrhynchos	Northern Mallard					Introduced
Platalea regia	Royal Spoonbill		Near threatened			
Aythya australis	Hardhead		Vulnerable			
Nycticorax caledonicus hillii	Nankeen Night Heron		Near threatened			
Threskiornis spinicollis	Straw-necked Ibis					
Pelecanus conspicillatus	Australian Pelican					
Alisterus scapularis	Australian King-Parrot					
Glossopsitta concinna	Musk Lorikeet					
Eurostopodus mystacalis	White-throated Nightjar					
Phalacrocorax varius	Pied Cormorant		Near threatened			
Tachybaptus novaehollandiae	Australasian Grebe					
Eurystomus orientalis	Dollarbird					
Aquila audax	Wedge-tailed Eagle					
Aegotheles cristatus	Australian Owlet-nightjar					
Cygnus atratus	Black Swan					
Glossopsitta porphyrocephala	Purple-crowned Lorikeet					
Ocyphaps lophotes	Crested Pigeon					
Alcedo azurea	Azure Kingfisher		Near threatened			
Glossopsitta pusilla	Little Lorikeet					

Scientific Name	Common Name	FFG	Vic Advisory	EPBC	Treaty	Origin
Phaps elegans	Brush Bronzewing					
Coturnix pectoralis	Stubble Quail					
Tadorna tadornoides	Australian Shelduck					
Polytelis anthopeplus monarchoides	Regent Parrot	Listed	Vulnerable	Vulnerable		
Porzana pusilla palustris	Baillon's Crake	Listed	Vulnerable			
Haliastur sphenurus	Whistling Kite					
Cacatua sanguinea	Little Corella					
Turnix varia	Painted Button-quail					
Columba leucomela	White-headed Pigeon					
Tyto javanica	Pacific Barn Owl					
Ardea ibis	Cattle Egret				CAMBA, JAMBA	
Cacatua tenuirostris	Long-billed Corella					
Falco peregrinus	Peregrine Falcon					
Trichoglossus chlorolepidotus	Scaly-breasted Lorikeet					
Podiceps cristatus	Great Crested Grebe					
Nymphicus hollandicus	Cockatiel					
Biziura lobata	Musk Duck		Vulnerable			
Falco subniger	Black Falcon		Vulnerable			
Ardea intermedia	Intermediate Egret	Listed	Endangered			
Eudynamys orientalis	Eastern Koel					
Anseranas semipalmata	Magpie Goose	Listed	Near threatened			
Malacorhynchus membranaceus	Pink-eared Duck					
Egretta garzetta nigripes	Little Egret	Listed	Endangered			
Botaurus poiciloptilus	Australasian Bittern	Listed	Endangered	Endangered		
Tyto tenebricosa tenebricosa	Sooty Owl	Listed	Vulnerable			
Geopelia striata	Peaceful Dove					
Gallirallus philippensis	Buff-banded Rail					
Coturnix ypsilophora australis	Brown Quail					
Pedionomus torquatus	Plains-wanderer	Listed	Critically endangered	Vulnerable		
Neophema chrysostoma	Blue-winged Parrot					
Merops ornatus	Rainbow Bee-eater				JAMBA	

Scientific Name	Common Name	FFG	Vic Advisory	EPBC	Treaty	Origin
Porzana tabuensis	Spotless Crake					
Dromaius novaehollandiae	Emu		Near threatened			
Oxyura australis	Blue-billed Duck	Listed	Endangered			
Melopsittacus undulatus	Budgerigar					
Lathamus discolor	Swift Parrot	Listed	Endangered	Endangered		
Barnardius zonarius zonarius	Australian Ringneck					
Platycercus elegans flaveolus	Yellow Rosella					
Callipepla californicus	California Quail					Doubt that it has ever been established in Victoria
Geopelia humeralis	Bar-shouldered Dove					
Burhinus grallarius	Bush Stone-curlew	Listed	Endangered			
Ptilinopus superbus	Superb Fruit-Dove					
Porzana fluminea	Australian Spotted Crake					
Cereopsis novaehollandiae	Cape Barren Goose					
Haliaeetus leucogaster	White-bellied Sea-Eagle	Listed	Vulnerable		CAMBA	
Pavo cristatus	Indian Peafowl					Introduced
Chalcophaps indica	Emerald Dove					
Leucosarcia melanoleuca	Wonga Pigeon					
Circus assimilis	Spotted Harrier		Near threatened			
Lophoictinia isura	Square-tailed Kite	Listed	Vulnerable			
Falco hypoleucos	Grey Falcon	Listed	Endangered			
Barnardius zonarius barnardi	Mallee Ringneck					
Psittacula krameri	Indian Ringneck Parrot					Introduced but doubt it ever established a population in Victoria
Ninox connivens connivens	Barking Owl	Listed	Endangered			
Ixobrychus minutus dubius	Little Bittern	Listed	Endangered			
Platycercus icterotis	Western Rosella					
Coturnix chinensis victoriae	King Quail	Listed	Endangered			
Plegadis falcinellus	Glossy Ibis		Near threatened		BONNA2S, CAMBA	
Dendrocygna eytoni	Plumed Whistling-Duck					

Scientific Name	Common Name	FFG	Vic Advisory	EPBC	Treaty	Origin
Neophema pulchella	Turquoise Parrot	Listed	Near threatened			
Rostratula australis	Australian Painted Snipe	Listed	Critically endangered	Vulnerable	CAMBA	
Todiramphus macleayii	Forest Kingfisher					
Ardeotis australis	Australian Bustard	Listed	Critically endangered			
Polytelis swainsonii	Superb Parrot	Listed	Endangered	Vulnerable		
Grus rubicunda	Brolga	Listed	Vulnerable			
Gallinula ventralis	Black-tailed Native-hen					
Geopelia cuneata	Diamond Dove	Listed	Near threatened			
Tyto novaehollandiae novaehollandiae	Masked Owl	Listed	Endangered			
Chrysococcyx osculans	Black-eared Cuckoo		Near threatened			
Dendrocygna arcuata	Wandering Whistling-Duck					
ord. Anseriformes fam. Anatidae	Ducks, Geese, Swans					
ord. Podicipediformes fam. Podicipedidae	Grebes					
Anser anser	Domestic Goose					
Platycercus adscitus	Pale-headed Rosella					
Platycercus sp.	Rosella species					
Stictonetta naevosa	Freckled Duck	Listed	Endangered			
Anas spp.	Unidentified Ducks					
Todiramphus pyrropygia pyrropygia	Red-backed Kingfisher		Near threatened			
Elanus scriptus	Letter-winged Kite					
Rhipidura leucophrys	Willie Wagtail					
Malurus cyaneus	Superb Fairy-wren					
Neochmia temporalis	Red-browed Finch					
Lichenostomus leucotis	White-eared Honeyeater					
Acanthiza pusilla	Brown Thornbill					
Strepera graculina	Pied Currawong					
Turdus merula	Common Blackbird					Introduced
Sturnus vulgaris	Common Starling					Introduced
Petrochelidon neoxena	Welcome Swallow					
Sericornis frontalis	White-browed Scrubwren					

Scientific Name	Common Name	FFG	Vic Advisory	EPBC	Treaty	Origin
Acridotheres tristis	Common Myna					Introduced
Acanthiza lineata	Striated Thornbill					
Cracticus torquatus	Grey Butcherbird					
Eopsaltria australis	Eastern Yellow Robin					
Turdus philomelos	Song Thrush					Introduced
Phylidonyris novaehollandiae	New Holland Honeyeater					
Lichenostomus chrysops	Yellow-faced Honeyeater					
Zosterops lateralis	Silvereye					
Corvus mellori	Little Raven					
Coracina novaehollandiae	Black-faced Cuckoo-shrike					
Falcunculus frontatus	Crested Shrike-tit					
Manorina melanocephala	Noisy Miner					
Grallina cyanoleuca	Magpie-lark					
Carduelis carduelis	European Goldfinch					
Pardalotus striatus	Striated Pardalote					
Colluricincla harmonica	Grey Shrike-thrush					
Manorina melanophrys	Bell Miner					
Artamus cyanopterus	Dusky Woodswallow					
Rhipidura albiscarpa	Grey Fantail					
Cormobates leucophaeus	White-throated Treecreeper					
Lichenostomus penicillatus	White-plumed Honeyeater					
Anthochaera carunculata	Red Wattlebird					
Passer montanus	Eurasian Tree Sparrow					Introduced
Corvus coronoides	Australian Raven					
Strepera versicolor	Grey Currawong					
Acanthorhynchus tenuirostris	Eastern Spinebill					
Dicaeum hirundinaceum	Mistletoebird					
Gymnorhina tibicen	Australian Magpie					
Psophodes olivaceus	Eastern Whipbird					
Phylidonyris pyrrhoptera	Crescent Honeyeater					
Anthus novaeseelandiae	Australasian Pipit					
Oriolus sagittatus	Olive-backed Oriole					

Scientific Name	Common Name	FFG	Vic Advisory	EPBC	Treaty	Origin
Passer domesticus	House Sparrow					Introduced
Daphoenositta chrysoptera	Varied Sittella					
Petroica phoenicea	Flame Robin					
Pachycephala pectoralis	Golden Whistler					
Acanthiza nana	Yellow Thornbill					
Cisticola exilis	Golden-headed Cisticola					
Climacteris picumnus victoriae	Brown Treecreeper (south-eastern ssp.)		Near threatened			
Lichenostomus melanops	Yellow-tufted Honeyeater					
Myiagra inquieta	Restless Flycatcher					
Carduelis chloris	European Greenfinch					Introduced
Pardalotus punctatus	Spotted Pardalote					
Pachycephala rufiventris	Rufous Whistler					
Acanthiza chrysorrhoa	Yellow-rumped Thornbill					
Climacteris erythrops	Red-browed Treecreeper					
Petroica boodang	Scarlet Robin					
Alauda arvensis	European Skylark					Introduced
Taeniopygia guttata	Zebra Finch					
Cincloramphus cruralis	Brown Songlark					
Artamus personatus	Masked Woodswallow					
Myiagra cyanoleuca	Satin Flycatcher				BONNA2H	
Anthochaera phrygia	Regent Honeyeater	Listed	Critically endangered	Endangered		
Acanthiza reguloides	Buff-rumped Thornbill					
Zoothera lunulata	Bassian Thrush					
Petroica rosea	Rose Robin					
Ptilonorhynchus violaceus	Satin Bowerbird					
Lichenostomus fuscus	Fuscous Honeyeater					
fam. Corvidae gen. Corvus	Ravens and Crows					
Meliphaga lewinii	Lewin's Honeyeater					
Melithreptus brevirostris	Brown-headed Honeyeater					
Melithreptus lunatus	White-naped Honeyeater					
Anthochaera chrysoptera	Little Wattlebird					

Scientific Name	Common Name	FFG	Vic Advisory	EPBC	Treaty	Origin
Microeca fascinans	Jacky Winter					
Lalage sueurii	White-winged Triller					
Pycnoptilus floccosus	Pilotbird					
Coracina tenuirostris	Common Cicadabird					
Petrochelidon nigricans	Tree Martin					
Petrochelidon ariel	Fairy Martin					
Corcorax melanorhamphos	White-winged Chough					
Smicrornis brevirostris	Weebill					
Myiagra rubecula	Leaden Flycatcher					
Acrocephalus stentoreus	Clamorous Reed Warbler				BONNA2H	
Cincloramphus mathewsi	Rufous Songlark					
Petroica rodinogaster	Pink Robin					
Rhipidura rufifrons	Rufous Fantail				BONNA2H	
Philemon corniculatus	Noisy Friarbird					
Artamus superciliosus	White-browed Woodswallow					
Chthonicola sagittatus	Speckled Warbler	Listed	Vulnerable			
Pachycephala olivacea	Olive Whistler					
Mirafra javanica	Horsfield's Bushlark					
Megalurus gramineus	Little Grassbird					
Stagonopleura bella	Beautiful Firetail					
Lichenostomus melanops cassidix	Helmeted Honeyeater	Listed	Critically endangered	Endangered		
Pomatostomus temporalis temporalis	Grey-crowned Babbler	Listed	Endangered			
Sericornis magnirostris	Large-billed Scrubwren					
Pycnonotus jocosus	Red-whiskered Bulbul					Introduced
Phylidonyris melanops	Tawny-crowned Honeyeater					
Melithreptus gularis	Black-chinned Honeyeater					
Epthianura albifrons	White-fronted Chat					
Cinclosoma punctatum	Spotted Quail-thrush		Near threatened			
Stipiturus malachurus	Southern Emu-wren					
Melanodryas cucullata cucullata	Hooded Robin	Listed	Near threatened			

Scientific Name	Common Name	FFG	Vic Advisory	EPBC	Treaty	Origin
Artamus leucorynchus	White-breasted Woodswallow					
Gerygone fusca	Western Gerygone					
Lonchura castaneothorax	Chestnut-breasted Mannikin					Introduced
Pycnonotus cafer	Red-vented Bulbul					Introduced
Petroica goodenovii	Red-capped Robin					
Acanthagenys rufogularis	Spiny-cheeked Honeyeater					
Grantiella picta	Painted Honeyeater	Listed	Vulnerable			
Lichenostomus virescens	Singing Honeyeater					
Philemon citreogularis	Little Friarbird					
Coracina papuensis	White-bellied Cuckoo-shrike					
Myzomela sanguinolenta	Scarlet Honeyeater					
Calamanthus pyrrhopygius	Chestnut-rumped Heathwren	Listed	Vulnerable			
Stagonopleura guttata	Diamond Firetail	Listed	Near threatened			
Neochmia ruficauda	Star Finch					Doubt that it has ever been established in Victoria
Monarcha melanopsis	Black-faced Monarch				BONNA2H	
Lichenostomus ornatus	Yellow-plumed Honeyeater					
Calamanthus fuliginosus	Striated Fieldwren					
Gerygone olivacea	White-throated Gerygone					
Dicrurus bracteatus	Spangled Drongo					
Epthianura tricolor	Crimson Chat					
Gerygone mouki	Brown Gerygone					
Phylidonyris albifrons	White-fronted Honeyeater					
Pachycephala inornata	Gilbert's Whistler					
Vanellus miles	Masked Lapwing					
Chroicocephalus novaehollandiae	Silver Gull					
Elseyornis melanops	Black-fronted Dotterel					
Vanellus tricolor	Banded Lapwing					
Thalasseus bergii	Crested Tern					
Calidris canutus	Red Knot		Endangered		BONNA2H CAMBA, JAMBA,	

Scientific Name	Common Name	FFG	Vic Advisory	EPBC	Treaty	Origin
					ROKAMBA	
Himantopus himantopus	Black-winged Stilt					
Calidris ferruginea	Curlew Sandpiper		Endangered		BONNA2H CAMBA, JAMBA, ROKAMBA	
Calidris ruficollis	Red-necked Stint				BONNA2H CAMBA, JAMBA, ROKAMBA	
Tringa stagnatilis	Marsh Sandpiper		Vulnerable		BONNA2H CAMBA, JAMBA, ROKAMBA	
Larus pacificus pacificus	Pacific Gull		Near threatened			
Erythrogonys cinctus	Red-kneed Dotterel					
Actitis hypoleucos	Common Sandpiper		Vulnerable		BONNA2H CAMBA, JAMBA, ROKAMBA	
Recurvirostra novaehollandiae	Red-necked Avocet					
Calidris acuminata	Sharp-tailed Sandpiper				BONNA2H CAMBA, JAMBA, ROKAMBA	
Limosa lapponica	Bar-tailed Godwit				BONNA2H CAMBA, JAMBA, ROKAMBA	
Chlidonias hybridus javanicus	Whiskered Tern		Near threatened			
Charadrius bicinctus	Double-banded Plover				BONNA2H	
Hydroprogne caspia	Caspian Tern	Listed	Near threatened		CAMBA,JAMBA	
Sternula nereis nereis	Fairy Tern	Listed	Endangered	Vulnerable		
Charadrius ruficapillus	Red-capped Plover					
Arenaria interpres	Ruddy Turnstone		Vulnerable		BONNA2H CAMBA, JAMBA, ROKAMBA	
Pluvialis fulva	Pacific Golden Plover		Vulnerable		BONNA2H CAMBA, JAMBA, ROKAMBA	
ord. Charadriiformes fam. Charadriidae	Plovers, Dotterels and Lapwings					
ord. Ciconiiformes fam. Ardeidae	Heron					

A.2.2 Fish

A.2.2.1 Freshwater species (Source: SKM 2005c)

		Conservation Status			Relevant reach from flows studies								
Common name	**Scientific name**	**EPBC**	**FFG**	**Migrat-ory**	**R 1**	**R 2**	**R 3**	**R 4**	**R 5**	**R 6**	**R 7**	**R 8**	**R 9**
Native freshwater													
Australian Grayling*	*Prototroctes maraena*	Vul	L	Diad.			✓	~	✓	✓	✓		
Australian Smelt	*Retropinna semoni*			Res.		~	✓	✓	✓	✓	✓	✓	
Broad-finned Galaxias	*Galaxias brevipinnis*			Diad.					✓	✓	✓	✓	
Common Galaxias*	*Galaxias maculatus*			Diad.		✓	~	✓	✓	✓	✓	✓	✓
Flat-headed Gudgeon	*Philypnodon grandiceps*			Res.						✓	✓		
Mountain Galaxias	*Galaxias olidus*			Res.	~	✓	✓					✓	✓
Pouched Lamprey	*Geotria australis*			Diad.		✓	✓	✓	~	✓	✓	✓	
River Blackfish*	*Gadopsis mamoratus*			Res.	✓	✓	✓	~	✓	✓		✓	✓
Short-finned Eel	*Anguilla australis*			Diad.	✓	✓	✓	✓	✓	✓	✓	✓	✓
Short-headed Lamprey	*Mordacia mordax*			Diad.	✓	✓	✓	✓	✓	✓	✓	✓	
Small Mouthed Hardyhead	*Atherinosoma microstoma*			Res.			✓					✓	
Southern Pygmy Perch	*Nannoperca australis*			Res.			✓	✓				✓	✓
Spotted Galaxias*	*Galaxias truttaceus*			Diad.		✓	~	~	~	✓	✓		
Tupong*	*Pseudaphritis urvillii*			Diad.						✓	✓		
Native freshwater, but translocated													
Australian Bass	*Macquaria novemaculeata*			Diad.					✓	✓	✓		
Freshwater Catfish	*Tandanus tandanus*		L	Res.					✓	✓			
Murray Cod	*Maccullochella peelii peelii*	End	L	Pot.			✓	✓	✓	✓	✓		
Macquarie Perch	*Macquaria australasica*	End	L	Pot.				✓	✓	✓	✓	✓	
Golden perch	*Macquaria ambigua*	Vul		Pot.						✓	✓		
Exotic species													
Brown Trout	*Salmo trutta*				✓	✓	✓	✓	✓	✓	✓	✓	✓
Carp	*Cyprinus Carpio*						✓	✓	✓	✓	✓	✓	
Eastern Gambusia	*Gambusia holbrooki*					✓	✓	✓	✓	✓	✓	✓	✓

		Conservation Status			Relevant reach from flows studies								
Common name	**Scientific name**	**EPBC**	**FFG**	**Migrat-ory**	**R 1**	**R 2**	**R 3**	**R 4**	**R 5**	**R 6**	**R 7**	**R 8**	**R 9**
Goldfish	*Carassius auratus*						✓	✓	✓	✓	✓	✓	✓
Oriental Weatherloach	*Misgurnus anguillicaudatus*				✓	~	~	✓	✓	✓		✓	
Rainbow Trout	*Oncorhynchus mykiss*				~	✓	✓	~	~	✓	~		
Redfin	*Perca fluviatilis*				~	~	✓	✓	✓	✓	✓	✓	✓
Roach	*Rutilus rutilus*				✓	✓	✓	✓	✓	✓	✓	✓	

Conservation status

End	Endangered
Cr	Critically endangered
Vul	Vulnerable
L	Listed

* Native species listed in the SEPP schedule F7 waters of the Yarra Catchment

Migratory Definitions

Diad. - Diadromous	Fish that migrate between the freshwater and the sea either as larvae or adults.
Est. - Estuarine	Fish that prefer an estuarine or brackish environment.
Pot. - Potamodromous	Fish that migrate large distances within freshwater.
Res. - Resident	Fish that require passage only within the local freshwater environs.

Record

✓	Recorded in surveys
~	Likely to occur given recorded distribution

A.2.2.2 Estuary species (Source: SKM 2005c)

			Conservation Status		
Common Name	**Scientific Name**	**Migratory**	**EPBC**	**Vic Advisory**	**FFG**
Native Fish					
Australian Grayling	*Prototroctes maraena*	Diad.	Vul		L
Australian Smelt	*Retropinna semoni*	Res.			
Broad-finned Galaxias	*Galaxias brevipinnis*	Diad.			
Mountain Galaxias	*Galaxias olidus*	Res.			
Pouched Lamprey	*Geotria australis*	Diad.			
Short-finned Eel	*Anguilla australis*	Diad.			
Small-mouthed Hardyhead	*Atherinosoma microstoma*	Res.			

Common Name	Scientific Name	Migratory	Conservation Status		
			EPBC	Vic Advisory	FFG
Spotted Galaxias	*Galaxias truttaceus*	Diad.			
Tupong	*Pseudaphritis urvillii*	Diad.			
Australian Bass	*Macquaria novemaculeata*	Diad.			
Murray Cod	*Maccullochella peelii peelii*	Pot.	End		L
Macquarie Perch	*Macquaria australasica*	Pot.	End		L
Golden Perch	*Macquaria ambigua*	Pot.		Vul	
Australian Anchovy	*Engraulis australis*	Est.			
Black Bream	*Acanthopagrus butcheri*	Est.			
Black Sole	*Snyapturn nigra*	Est.			
Bridled Goby	*Arenigobius bifrenatus*	Est.			
Estuary Perch	*Macquaria colonorum*	Est.			
Flat-tail Mullet	*Liza argentea*	Est.			
Greenback Flounder	*Rhombosolea tapirina*	Est.			
Half-bridled Goby	*Arenigobius frenatus*	Est.			
Mulloway	*Argyrosomus hololepodotus*	Est.			
Sand Flathead	*Playtcephalus bassensis*	Est.			
Sea Mullet	*Mugil cephalus*	Est.			
Smooth Toadfish	*Terracetenos glaber*	Est.			
Australian Mudfish	*Neochanna cleaveri*	Diad.			L
Three-barred Porcupinefish	*Dicotylichthys punctulatus*	Est.			
Exotic Fish					
Brown trout	*Salmo trutta*	Res.			
Carp	*Cyprinus carpio*	Res.			
Goldfish	*Carassius auratus*	Res.			
Eastern Gambusia	*Gambusia holbrooki*	Res.			
Oriental Weatherloach	*Misgurnus anguillicaudatus*	Res.			
Rainbow Trout	*Oncorhynchus mykiss*	Res.			
Redfin	*Perca fluviatilis*	Res.			
Roach	*Rutilus rutilus*	Res.			

Conservation status	
End	*Endangered*
Cr	*Critically endangered*
Vul	*Vulnerable*
L	*Listed*
Migratory Definitions	

Common Name	Scientific Name	Migratory	Conservation Status EPBC	Vic Advisory	FFG

Diad. - Diadromous	*Fish that migrate between the freshwater and the sea either as larvae or adults.*
Est. - Estuarine	*Fish that prefer an estuarine or brackish environment.*
Pot. - Potamodromous	*Fish that migrate large distances within freshwater.*
Res. - Resident	*Fish that require passage only within the local environs.*

A.2.3 Amphibians

Scientific Name	Common Name	FFG	Vic Advisory	EPBC
Limnodynastes tasmaniensis	Spotted Marsh Frog (race unknown)			
Litoria ewingii	Southern Brown Tree Frog			
Geocrinia victoriana	Victorian Smooth Froglet			
Pseudophryne semimarmorata	Southern Toadlet		Vulnerable	
Crinia signifera	Common Froglet			
Litoria peronii	Peron's Tree Frog			
Litoria raniformis	Growling Grass Frog	Listed	Endangered	Vulnerable
Limnodynastes peronii	Striped Marsh Frog			
Limnodynastes dumerilii insularis	Pobblebonk Frog			
Pseudophryne bibronii	Brown Toadlet	Listed	Endangered	
Litoria verreauxii verreauxii	Verreaux's Tree Frog			
Neobatrachus sudellae	Common Spadefoot Toad			
Limnodynastes dumerilii	Southern Bullfrog (ssp. unknown)			
Litoria verreauxii (ssp. unknown)	Unknown Tree Frog			
Litoria ewingii SOUTHERN	Southern Brown Tree Frog SOUTHERN			
Litoria fallax	Eastern Dwarf Tree Frog			
Litoria ewingii GROUP	Litoria ewingii GROUP			
Limnodynastes tasmaniensis SCR	Spotted Marsh Frog SCR			
Limnodynastes dumerilii dumerilii	Pobblebonk Frog			
Litoria lesueuri	Lesueur's Frog			

A.2.4 Invertebrates

Scientific Name	Common Name	FFG	Vic Advisory	EPBC
Paralucia pyrodiscus lucida	Eltham Copper	Listed	Endangered	
Boeckella nyoraensis	Calanoid copepod		Data deficient	
Spathula gourbaultae	Planarian		Data deficient	
supf. Scirtoidea fam. Eucinetidae	Plate-thigh beetles			
supf. Tabanoidea fam. Athericidae	Water Snipe-flies			

Scientific Name	Common Name	FFG	Vic Advisory	EPBC
Ceratopogonidae EPA sp. 12	Biting Midges			
Thaumatoperla robusta			Data deficient	
Riekoperla darlingtoni	Mt Donna Buang Wingless Stonefly	Listed		
Hemiphlebia mirabilis	Ancient Greenling	Listed		
Thaumatoperla alpina	Alpine Stonefly	Listed	Vulnerable	Endangered
Plectrotarsus gravenhorstii			Vulnerable	
Berosus queenslandicus				
Tipulidae SRV sp. 17				
subo. Crassiclitellata supf. Megascolecoidea	Earthworms			
Tipulidae SRV sp. 4				
Berosus veronicae				
fam. Chironomidae subf. Orthocladiinae	Non-biting midge			
fam. Baetidae gen. Genus 2				
Aphilorheithrus stepheni				
Tipulidae SRV sp. 25				
fam. Caenidae gen. Caenid Genus C				
Tipulidae SRV sp. 18				
fam. Chironomidae subf. Tanypodinae	Non-biting midge			
fam. Polycentropodidae gen. Genus I				
supo. Exopterygota ord. Plecoptera	Stoneflies			
fam. Hydrobiosidae gen. Apsilochorema				
subf. Chironominae trib. Chironomini	Non-biting Midge			
supo. Amphiesmenoptera ord. Trichoptera	Caddisflies			
supf. Caraboidea fam. Gyrinidae	Whirligig Beetles			
info. Ptychopteromorph fam. Tanyderidae	Primitive crane flies			
Tipulidae SRV sp. 33				
supf. Leptoperloidea fam. Gripopterygidae	Stoneflies			
fam. Calamoceratidae gen. Anisocentropus				
supf. Tipuloidea fam. Tipulidae	Crane Flies			
Cherax destructor destructor	Common Yabby			
Engaeus affinis	Central Highlands Burrowing Crayfish			
Engaeus cunicularius	Granular Burrowing Crayfish			
Euastacus yarraensis	Southern Victorian Spiny Crayfish			
Engaeus tuberculatus	Tubercle Burrowing Crayfish		Endangered	
Engaeus quadrimanus	Lowland Burrowing Crayfish			
Engaeus curvisuturus	Curve-tail Burrowing Crayfish	Listed	Endangered	
Engaeus hemicirratulus	Gippsland Burrowing Crayfish		Endangered	

Scientific Name	Common Name	FFG	Vic Advisory	EPBC
Paratya australiensis	Freshwater Shrimp			
fam. Parastacidae gen. Engaeus	Burrowing Crayfish			
Euastacus kershawi	Gippsland Spiny Crayfish	Rejected		
Euastacus woiwuru	Central Highlands Spiny Crayfish			
supf. Unionoidea fam. Hyriidae	Freshwater Mussels			
supf. Parastacoidea fam. Parastacidae	Freshwater Crayfishes			
fam. Parastacidae gen. Euastacus	Spiny Crayfish			
fam. Palaemonidae gen. Macrobrachium	River Prawns			
Engaeus sericatus	Hairy Burrowing Crayfish		Vulnerable	

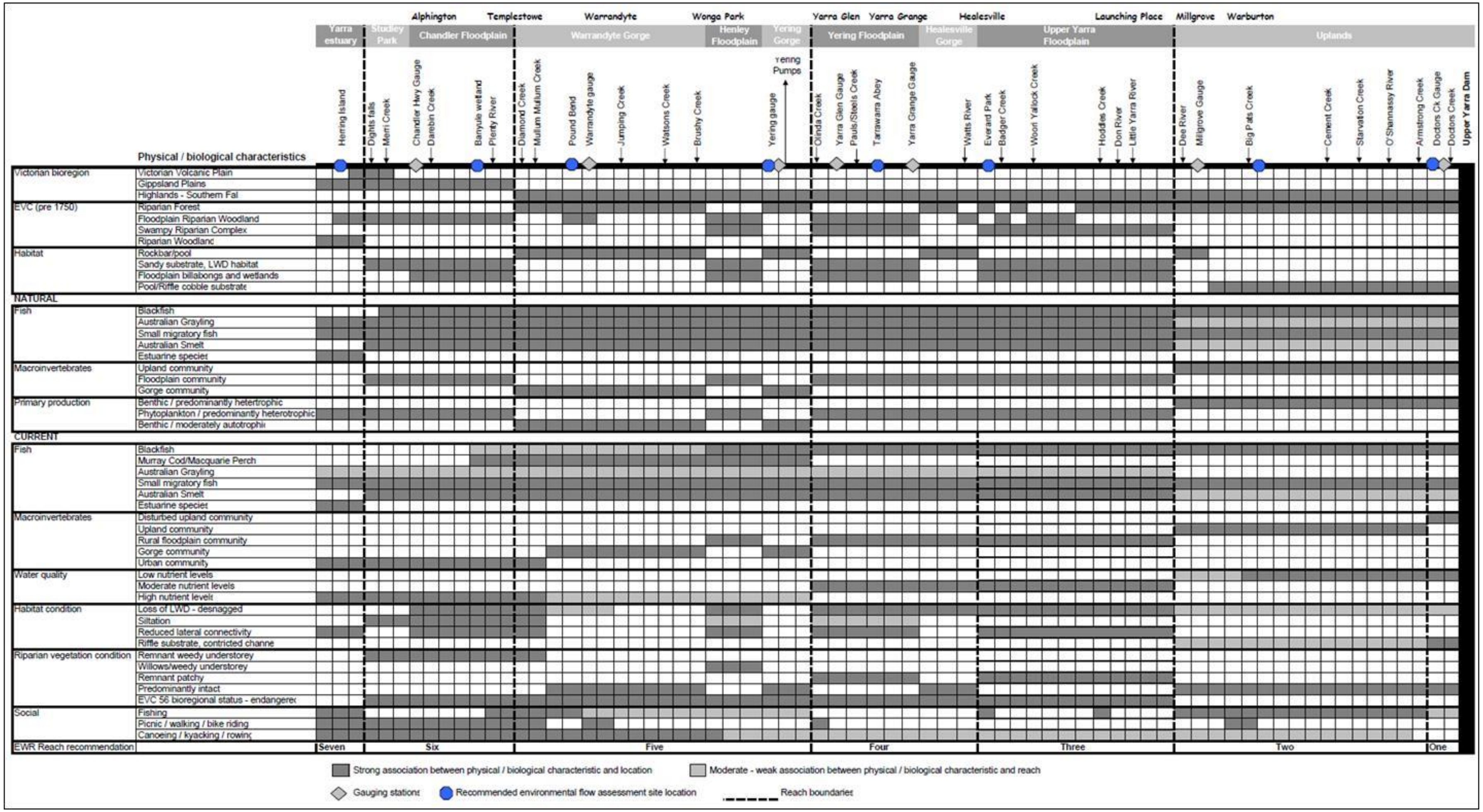
A.2.5 Mammal species

Scientific Name	Common Name	FFG	Vic Advisory	EPBC	Origin
Antechinus agilis	Agile Antechinus				
fam. Dasyuridae gen. Antechinus	Antechinus				
fam. Peramelidae gen. Bandicoot	Bandicoots				
supo. Laurasiatheria ord. Chiroptera	Bats				
Rattus rattus	Black Rat				Introduced
Wallabia bicolor	Black Wallaby				
Tursiops truncatus	Bottlenose Dolphin				
fam. Vespertilionidae gen. Scotorepens	Broad-nosed bats				
Mastacomys fuscus mordicus	Broad-toothed Rat	Listed	Endangered		
Rattus norvegicus	Brown Rat				Introduced
fam. Phalangeridae gen. Trichosurus	Brushtail Possums				
Phascogale tapoatafa	Brush-tailed Phascogale	Listed	Vulnerable		
Rattus fuscipes	Bush Rat				
Felis catus	Cat				Introduced
Chalinolobus morio	Chocolate Wattled Bat				
Miniopterus schreibersii GROUP	Common Bent-wing Bat	Listed			
Trichosurus vulpecula	Common Brushtail Possum				
Delphinus delphis	Common Dolphin				
Sminthopsis murina murina	Common Dunnart		Vulnerable		
Pseudocheirus peregrinus	Common Ringtail Possum				
Vombatus ursinus	Common Wombat				
Canis lupus dingo	Dingo	Listed	Data deficient		
Canis lupus	Dingo & Dog (feral)				

Scientific Name	Common Name	FFG	Vic Advisory	EPBC	Origin
Canis lupus familiaris	Dog				Introduced
Antechinus swainsonii	Dusky Antechinus				
Perameles gunnii	Eastern Barred Bandicoot	Listed	Extinct in the Wild	Endangered	
Scotorepens orion	Eastern Broad-nosed Bat				
Falsistrellus tasmaniensis	Eastern False Pipistrelle				
Mormopterus sp. 2	Eastern Freetail Bat				
Macropus giganteus	Eastern Grey Kangaroo				
Sciurus carolinensis	Eastern Grey Squirrel				Introduced
Rhinolophus megaphyllus megaphyllus	Eastern Horseshoe Bat	Listed	Vulnerable		
Cercartetus nanus	Eastern Pygmy-possum	Rejected	Near threatened		
Dasyurus viverrinus	Eastern Quoll	Listed	Regionally extinct		
Lepus europeaus	European Hare				Introduced
Oryctolagus cuniculus	European Rabbit				Introduced
Acrobates pygmaeus	Feathertail Glider				
Mustela furo	Ferret				Introduced
fam. Molossidae gen. Mormopterus	Free-tailed Bats				
Capra hircus	Goat (feral)				Introduced
Nyctophilus gouldi	Gould's Long-eared Bat				
Chalinolobus gouldii	Gould's Wattled Bat				
Petauroides volans	Greater Glider		Vulnerable		
Pteropus poliocephalus	Grey-headed Flying-fox	Listed	Vulnerable	Vulnerable	
fam. Vespertilionidae gen. Eptesicus	House Bats				
Mus musculus	House Mouse				Introduced
fam. Macropodidae gen. Macropus	Kangaroo				
Phascolarctos cinereus	Koala				
Vespadelus darlingtoni	Large Forest Bat				
Gymnobelideus leadbeateri	Leadbeater's Possum	Listed	Endangered	Endangered	
Nyctophilus geoffroyi	Lesser Long-eared Bat				
Vespadelus vulturnus	Little Forest Bat				
Pteropus scapulatus	Little Red Flying-fox				
fam. Vespertilionidae gen. Nyctophilus	Long-eared bats				
Perameles nasuta	Long-nosed Bandicoot				
Trichosurus cunninghami	Mountain Brushtail Possum				
Sus scrofa	Pig (feral)				Introduced

Scientific Name	Common Name	FFG	Vic Advisory	EPBC	Origin
Ornithorhynchus anatinus	Platypus				
gen. Rattus	Rats				
Cervus elaphus	Red Deer				Introduced
Vulpes vulpes	Red Fox				Introduced
Cervus unicolor	Sambar				Introduced
Tachyglossus aculeatus	Short-beaked Echidna				
Pseudomys fumeus	Smoky Mouse	Listed	Endangered	Endangered	
Isoodon obesulus obesulus	Southern Brown Bandicoot	Listed	Near threatened	Endangered	
Vespadelus regulus	Southern Forest Bat				
Myotis macropus	Southern Myotis		Near threatened		
Dasyurus maculatus maculatus	Spot-tailed Quoll	Listed	Endangered	Endangered	
Petaurus breviceps	Sugar Glider				
Rattus lutreolus	Swamp Rat				
Misc Target taxa not found	Target taxa not found				
gen. Pseudomys	unidentified Pseudomys				
fam. Dasyuridae gen. Sminthopsis	unidentified Sminthopsis				
Hydromys chrysogaster	Water Rat				
fam. Vespertilionidae gen. Chalinolobus	Wattled and Pied bats				
Sminthopsis leucopus	White-footed Dunnart	Listed	Near threatened		
Tadarida australis	White-striped Freetail Bat				
Petaurus australis	Yellow-bellied Glider				
Saccolaimus flaviventris	Yellow-bellied Sheathtail Bat	Listed	Data deficient		

Appendix B. Reach Characteristics



Appendix C. Flow Duration Curves

Hydrological information for the Yarra River and its tributaries is based on data derived from a Yarra Headworks REALM model, covering the period from May 1963 to December 2010 for reaches 1 to 6 and 8 (SKM 2012c). Data for the hydrological modelling for Reach 9 is derived from a previous Yarra Headworks REALM model, covering the period from 1965 to 2012.

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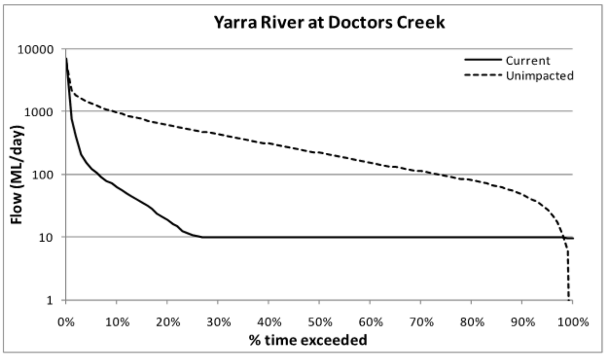

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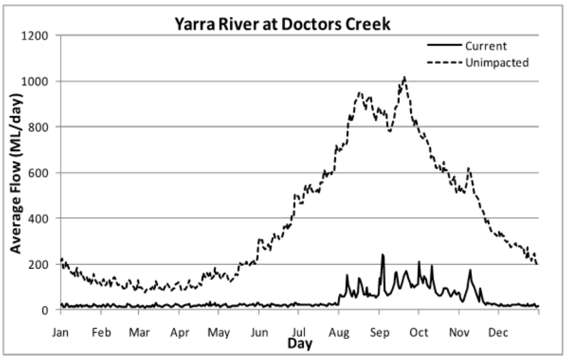

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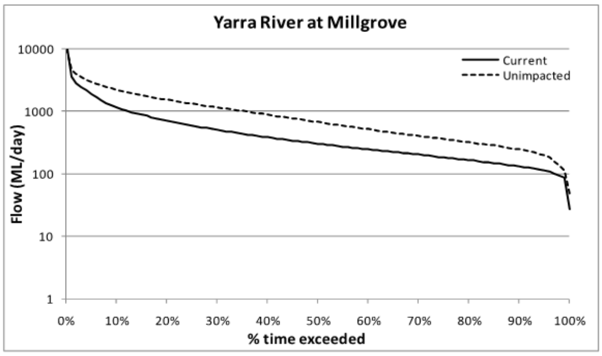

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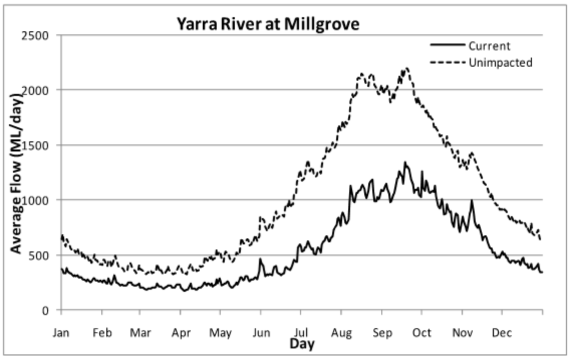

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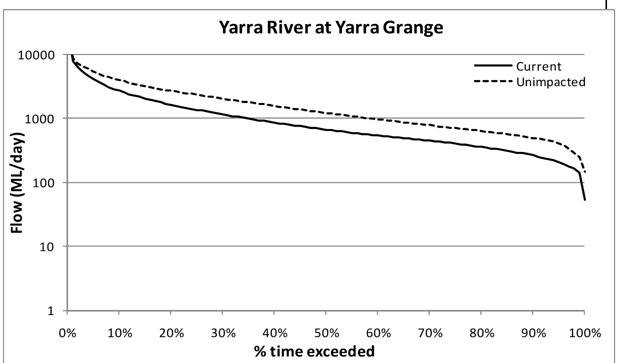

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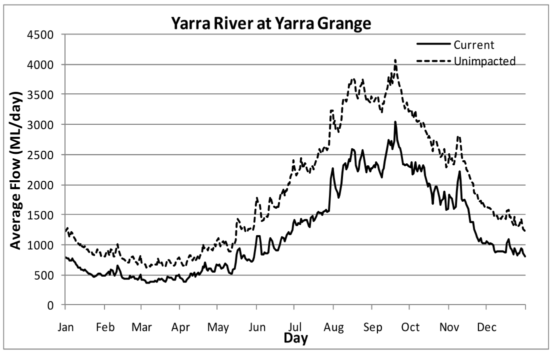

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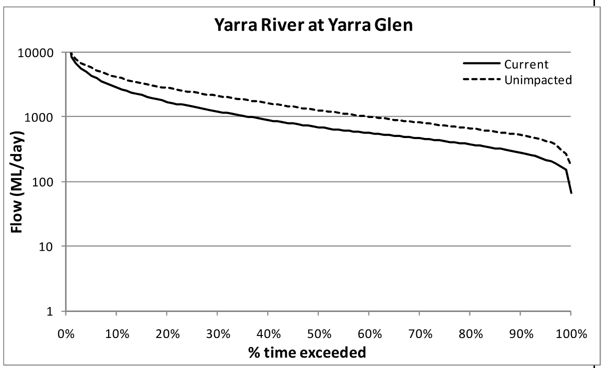
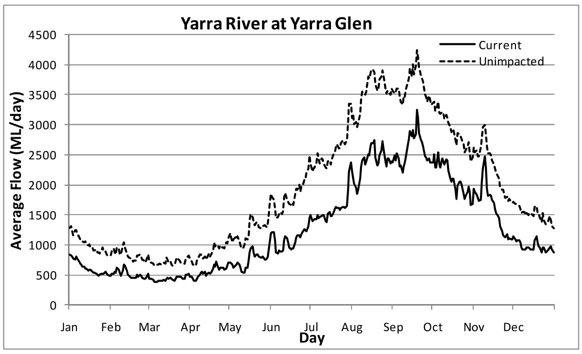
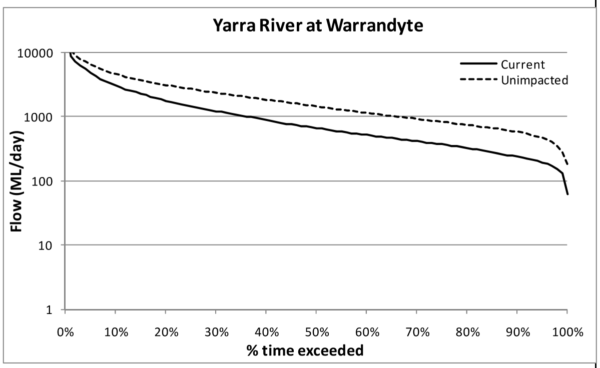
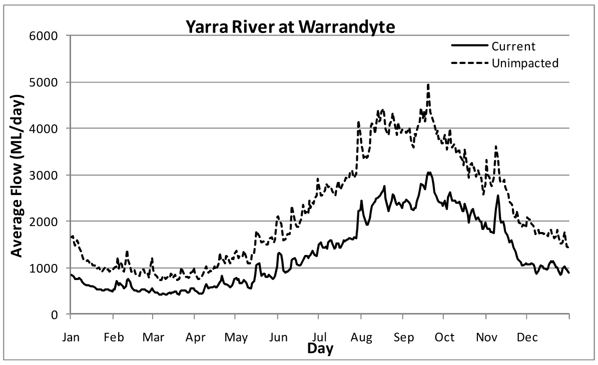
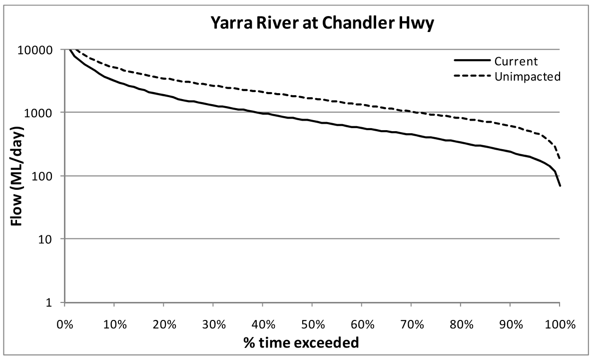
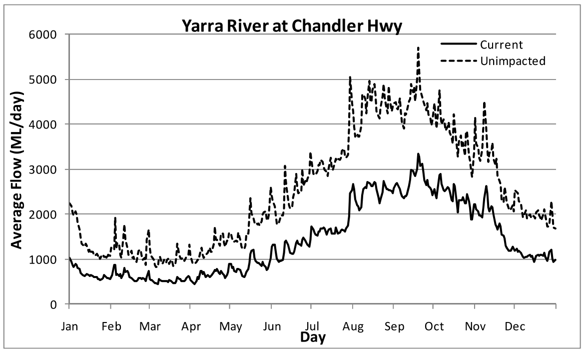
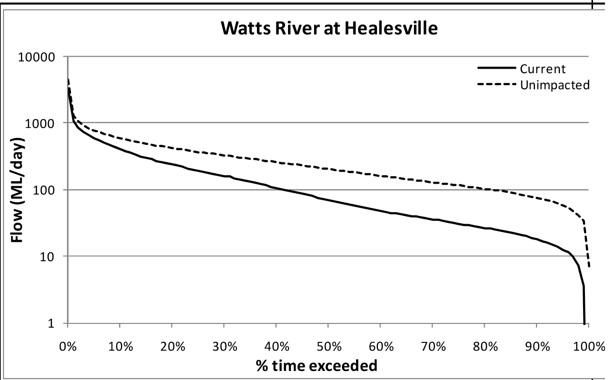
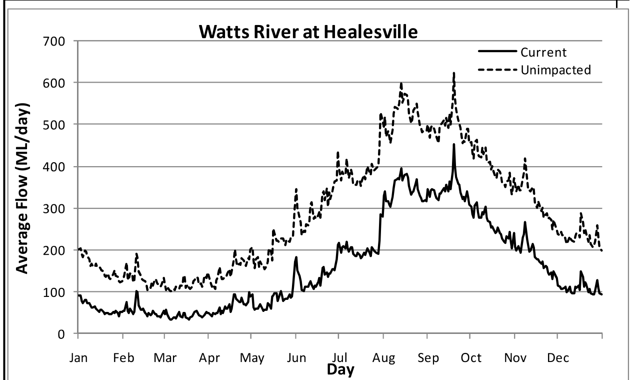
Flow Duration Curves for unimpacted and current flows	Unimpacted and current average daily flow
 Reach 4	 Reach 4
 Reach 5	 Reach 5
 Reach 6	 Reach 6
 Reach 8	 Reach 8

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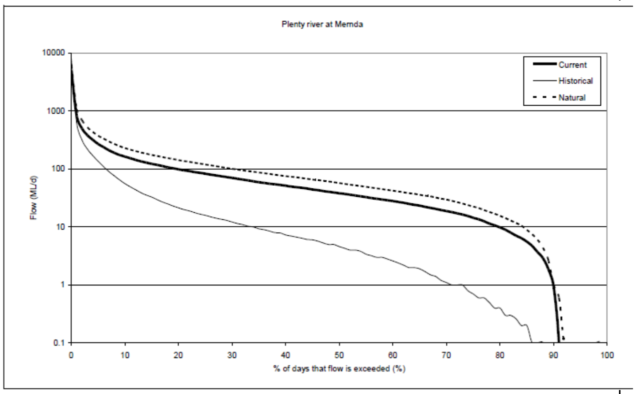
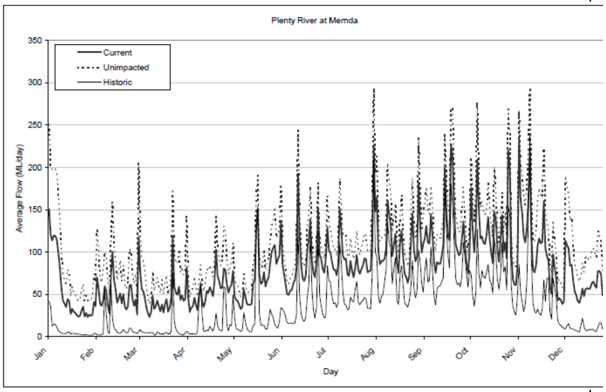
<tr><td>
</td><td>
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<tr><td>Reach 9[28]</td><td>Reach 9</td></tr>
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28 [28] Hydrological modelling for Reach 9 was completed for the original 2005 Yarra River flows study (SKM 2005c), but not for the 2012 flow study review (SKM 2012c)

Appendix D. Detailed Risk Assessment Findings

Key to risk table

	CONSEQUENCE				
LIKELIHOOD	**Negligible**	**Minor**	**Moderate**	**Major**	**Extreme**
Almost certain	Low	Medium	High	Extreme	Extreme
Likely	Low	Medium	High	Extreme	Extreme
Possible	Low	Medium	Medium	High	Extreme
Unlikely	Low	Low	Medium	High	Extreme
Rare	Low	Low	Low	Medium	High

Key to likelihood categories

RATING	DESCRIPTION
Almost certain	The event is expected to occur in most circumstances
Likely	The event will probably occur in most circumstances
Possible	The event might occur
Unlikely	The event could occur at some time
Rare	Event may occur only in exceptional circumstances

Risk Category	Impact of the Risk Occurring	Water-Dependent Ecological Values Impacted	Likelihood (Almost certain / Likely / Possible / Unlikely / Rare)	Consequence (Negligible / Minor / Moderate / Major / Extreme)	Risk (Low / Medium / High / Extreme)	Management Actions	Residual Risk after Management Actions
RISKS 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 Yarra 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 main channel, floodplains and billabongs ○ Loss of breeding and migration cues for native fauna ○ Riparian zone and floodplain	All	Rare	Major	Medium	• A cap has been placed on surface water extractions in the Yarra catchment, preventing extraction over and above limits set through water entitlements. The total volume of water entitlements is currently 400,000 ML/year • 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.	Medium

Risk Category	Impact of the Risk Occurring	Water-Dependent Ecological Values Impacted	Likelihood (Almost certain / Likely / Possible / Unlikely / Rare)	Consequence (Negligible / Minor / Moderate / Major / Extreme)	Risk (Low / Medium / High / Extreme)	Management Actions	Residual Risk after Management Actions
	degradation through altered flow patterns ○ Increased habitat for invasive species ○ Further changes to the hydrology of estuary, altering salt wedge dynamics ○ Loss or disruption of ecological functions ○ Increased bank erosion and changes to channel geomorphology.						
Groundwater extractions causing shifts in the surface water/groundwater interface	• Groundwater extraction may reduce habitat availability for groundwater dependent ecosystems	All	Possible	Minor	Medium	• A cap on the volume of groundwater extractions 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. • Melbourne Water is also investigating options to improve environmental flows in the Yarra	Low

Risk Category	Impact of the Risk Occurring	Water-Dependent Ecological Values Impacted	Likelihood (Almost certain / Likely / Possible / Unlikely / Rare)	Consequence (Negligible / Minor / Moderate / Major / Extreme)	Risk (Low / Medium / High / Extreme)	Management Actions	Residual Risk after Management Actions
						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 Yarra River. • Residual risk calculations assume that the consequences are reduced to 'Moderate' following intervention actions.	
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 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 for aspects of their lifecycle) • Disruptions to sediment and nutrient transport processes • Loss of hydrodynamic diversity,	All	Unlikely	Major	High	• 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. • Melbourne Water will work with 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	Medium

Risk Category	Impact of the Risk Occurring	Water-Dependent Ecological Values Impacted	Likelihood (Almost certain / Likely / Possible / Unlikely / Rare)	Consequence (Negligible / Minor / Moderate / Major / Extreme)	Risk (Low / Medium / High / Extreme)	Management Actions	Residual Risk after Management Actions
	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 Yarra catchment.					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 • Residual risk is calculated based on the assumption that management actions reduce the consequence to 'Moderate'	
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 can already be considerably reduced.	Fish	Almost Certain	Moderate	High	• In partnership with VRFish, Melbourne Water will develop and implement an education and involvement program with recreational fishing groups to ensure native fish are released but introduced fish are not released back in to the river. • Residual risk has assumed that the likelihood is reduced to 'Possible' following intervention	Medium

Risk Category	Impact of the Risk Occurring	Water-Dependent Ecological Values Impacted	Likelihood (Almost certain / Likely / Possible / Unlikely / Rare)	Consequence (Negligible / Minor / Moderate / Major / Extreme)	Risk (Low / Medium / High / Extreme)	Management Actions	Residual Risk after Management Actions
						actions.	
Land use change – Urban Development	Different land uses have different impacts on environmental flows and the stream health of the Yarra 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: • Recreational or commercial activities near urban centres disturbing bird behaviour, causing them to stop feeding or breeding • Sewage effluent and septic tank discharges affecting water quality • Industrial discharges decreasing	Vegetation Geomorphology Fish Platypus	Likely	Major	Extreme	• 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, and relevant Local Councils to understand and reduce the risks of increasing urban development on the Yarra River • Melbourne Water is also	High

Risk Category	Impact of the Risk Occurring	Water-Dependent Ecological Values Impacted	Likelihood (Almost certain / Likely / Possible / Unlikely / Rare)	Consequence (Negligible / Minor / Moderate / Major / Extreme)	Risk (Low / Medium / High / Extreme)	Management Actions	Residual Risk after Management Actions
	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 Yarra River and Estuary • Increasing salinity downstream (Note: this is also associated with soil erosion and irrigation drainage flows (Ecological Associates 2005a)					investigating options for stormwater harvesting and reuse for environmental flows through Water Sensitive Urban Design and integrated water cycle management programs • Residual risk is assessed assuming that the consequences of urban development can be ameliorated to 'Moderate' through management actions	
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 South-Eastern Australia; the months where temperatures are usually the highest and rainfall and streamflows are at their lowest.	Fish	Almost Certain	Major	Extreme	• 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	High

Risk Category	Impact of the Risk Occurring	Water-Dependent Ecological Values Impacted	Likelihood (Almost certain / Likely / Possible / Unlikely / Rare)	Consequence (Negligible / Minor / Moderate / Major / Extreme)	Risk (Low / Medium / High / Extreme)	Management Actions	Residual Risk after Management Actions
						catchment. • Residual risk is calculated based on the assumption that interventions reduce the consequences of farms dams to 'Moderate' based on improvements in managing catchment water allocation processes.	
Pest plants and animals: • Carp • Brown Trout • Gambusia • Redfin • Foxes, dogs and cats • Willows	• 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	All	Almost certain	Moderate	High	• 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	Medium

Risk Category	Impact of the Risk Occurring	Water-Dependent Ecological Values Impacted	Likelihood (Almost certain / Likely / Possible / Unlikely / Rare)	Consequence (Negligible / Minor / Moderate / Major / Extreme)	Risk (Low / Medium / High / Extreme)	Management Actions	Residual Risk after Management Actions
	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)					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'.	
Illegal fishing nets	Illegal fishing nets cause preventable animal mortality.	Platypus Fish Birds	Almost certain	Moderate	High	• A vigorous community education campaign, particularly targeting school 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.	Medium
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	Fish Vegetation	Almost certain	Moderate	High	• 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	Medium

Risk Category	Impact of the Risk Occurring	Water-Dependent Ecological Values Impacted	Likelihood (Almost certain / Likely / Possible / Unlikely / Rare)	Consequence (Negligible / Minor / Moderate / Major / Extreme)	Risk (Low / Medium / High / Extreme)	Management Actions	Residual Risk after Management Actions
	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 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)					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 to 'Possible' following management interventions.	
Further expansion of irrigation areas within	• The expansion of irrigated agriculture within the Yarra catchment may	All	Unlikely	Major	High	• Adaptive management, sourcing alternative supplies of water	Medium

Risk Category	Impact of the Risk Occurring	Water-Dependent Ecological Values Impacted	Likelihood (Almost certain / Likely / Possible / Unlikely / Rare)	Consequence (Negligible / Minor / Moderate / Major / Extreme)	Risk (Low / Medium / High / Extreme)	Management Actions	Residual Risk after Management Actions
the catchment	increase consumptive surface water and groundwater demands on the system, reducing the availability of water for environmental flows.					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.	
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 Amenity	Certain	Moderate	High	• 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.	Medium
Climate Change	• Climate change will reduce water availability within the Yarra catchment, and alter flow regimes through changes to the temporal and volumetric patterns of seasonal	All	Almost certain	Extreme	Extreme	• Management actions will focus on understanding the nature of the risks that climate change poses to the biodiversity and ecosystem services of the Yarra	High

Risk Category	Impact of the Risk Occurring	Water-Dependent Ecological Values Impacted	Likelihood (Almost certain / Likely / Possible / Unlikely / Rare)	Consequence (Negligible / Minor / Moderate / Major / Extreme)	Risk (Low / Medium / High / Extreme)	Management Actions	Residual Risk after Management Actions
	rainfall. • Impacts on the Yarra 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					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 Yarra River Environmental Entitlement.	
RISKS RELATED TO THE DELIVERY OF ENVIRONMENTAL WATER							
High flow releases	Winter high fresh drowns juvenile Platypus	Platypus	Possible	Major	High	• Deliver winter high fresh in August to trigger females to select or construct nursery burrows higher up the river bank	Low

Risk Category	Impact of the Risk Occurring	Water-Dependent Ecological Values Impacted	Likelihood (Almost certain / Likely / Possible / Unlikely / Rare)	Consequence (Negligible / Minor / Moderate / Major / Extreme)	Risk (Low / Medium / High / Extreme)	Management Actions	Residual Risk after Management Actions
All releases	Environmental flow releases lead to safety risks to river users	N/A	Rare	Extreme	High	• Release plans to include controlled/gradual increases in flow rates. • Undertake appropriate communications actions to alert users, especially for high use sites and high use periods	Low
All releases	Release volume is insufficient in meeting required flow at target point	All	Possible	Moderate	Medium	• To date, orders have generally been slightly higher than required to ensure compliance. • Close communication with storage operators and monitoring of losses is increasing the required body of knowledge	Low
Evidence base	Current recommendations on environmental flow are inaccurate	All	Possible	Moderate	Medium	• 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	Possible	Moderate	Medium	• Undertake early planning and communications with Storage Operator to minimise likelihood of constraints and enable scheduling of maintenance	L

Risk Category	Impact of the Risk Occurring	Water-Dependent Ecological Values Impacted	Likelihood (Almost certain / Likely / Possible / Unlikely / Rare)	Consequence (Negligible / Minor / Moderate / Major / Extreme)	Risk (Low / Medium / High / Extreme)	Management Actions	Residual Risk after Management Actions
						outside of high demand periods.	
Operational	Resource Manager cannot deliver required volume or flow rate (outlet/capacity constraints, insufficient storage volume) Completing storage operator priorities for flood and fire management do not allow delivery of some events	All	Possible	Moderate	Medium	• Undertake early planning and communications with Storage Operator to minimise likelihood of constraints and enable scheduling of maintenance outside of high demand periods. • Coordination with storage manager has avoided this in the past by changed scheduling of delivery.	Low
Impact of releases	Releases cause water quality issues (e.g. blackwater, low DO, mobilisation of saline pools, acid-sulphate soils, etc)	All	Possible	Moderate	Medium	• Monitor water quality in the lead up to and during events and adjust release plans as necessary based on data provided by Storage Operator • Undertake research to identify risk factors and triggers	Low
Impact of releases	Improved conditions for non-native species (e.g. carp)	Fish	Unlikely	Minor	Low	• No effective mitigation actions currently possible	Low
Operational	Unable to provide evidence that hydrological target has been met	All	Possible	Minor	Low	• Stream flow gauging is adequate.	Low
Operational	Environmental releases do not achieve planned/specified flow targets due to releases being diverted by other users before reaching delivery sites	All	Possible	Moderate	Medium	• Ensure diversions field staff are aware of planned events and are managing compliance with orders by all users • Ensure diversions field staff are	Low

Risk Category	Impact of the Risk Occurring	Water-Dependent Ecological Values Impacted	Likelihood (Almost certain / Likely / Possible / Unlikely / Rare)	Consequence (Negligible / Minor / Moderate / Major / Extreme)	Risk (Low / Medium / High / Extreme)	Management Actions	Residual Risk after Management Actions
						aware of planned events and are managing compliance with orders by all users.	
Operational	Environmental releases cause unauthorised inundation of private land, resulting in impacts on landowner activities and assets	Amenity	Unlikely	Major	High	• Development of release plans designed ot avoid overbank flows • Monitoring of events and adjustment of releases to avoid overbank flows	Low
Operational	Environmental release interferes with essential Melbourne Water services	N/A	Unlikely	Moderate	Low	• 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
Operational	Inability to demonstrate outcomes achieved through environmental watering activities lead to a loss of public/political support	All	Likely	Modearte	High	• Monitor flow deliveries and share / communicate outcomes. • Communicate benefits of environmental watering to the broader community • Undertake investigations and research into flow relationships across multiple systems and translate into improved knowledge	Low

Risk Category	Impact of the Risk Occurring	Water-Dependent Ecological Values Impacted	Likelihood (Almost certain / Likely / Possible / Unlikely / Rare)	Consequence (Negligible / Minor / Moderate / Major / Extreme)	Risk (Low / Medium / High / Extreme)	Management Actions	Residual Risk after Management Actions
Operational	The environmental water account is overdrawn, leading to water not being available as per approved watering statement to complete planned actions	All	Rare	Minor	Low	• Monitor account balances and undertake regular communications with waterway manager as part of portfolio management activities	Low
Operational	Community concern over environmental releases under dry seasonal conditions may lead to a loss of support for environmental watering activities	All	Possible	Minor	Low	• Communicate benefits of environmental watering ot the boarder community and provide information on water entitlements framework	Low
Evidence base	Public misperception of the purpose of releases	All	Possible	Moderate	Medium	• An email list of interested parties has been created and updates on planned watering occur regularly. • Interest from agencies and public enquiries indicates a reasonably widespread level of community interest and support. • VEWH has a communications strategy to promote the benefits of environmental watering	Low

Appendix E. Detailed Flow Recommendations

Flow recommendations are based on the recommendations provided by SKM (2012). Note that recommendations for Reach 7 (the estuary) have not been provided. The volume (ML/day), duration (days) and number (per year / season) are specified for each flow component in wet, average and dry climate years.

An '×' indicates flow components that are not expected to occur under the specified climate conditions.

Table 38 : Summary of flow recommendations for the Yarra River

Season	Flow	Climate		Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 8
Summer / Autumn										
Dec - May	Low flow	All	Volume	10 *	80 *	150 *	200 *	200 *	>300 ^	>10 *
Dec - May	Fresh	Wet / Average	Volume	60 *	350 *	450 *	450 *	750	750 *	80 *
			Duration	≥1	≥3	≥3	≥3	2	≥2	≥2
			Number	≥4	≥2	≥2	≥2	Wet 5 Ave 4	≥3	≥4
		Dry	Volume	60	350	450	450	750	750	80 *
			Duration	4	3	3	3	2	2	≥2
			Number	1	2	2	2	3	3	≥4
Apr - May	High	Wet / Average	Volume	×	560 *	900-1100 #	900-1100 #	1300 #	1300 #	×
			Duration		≥7	7-14	7-14	7-14	≥7	
			Number		1	1	1	1	1	
		Dry	Volume	×	560	900-1100 #	900-1100 #	1300 #	1300 #	×
			Duration		≥7	7-14	7-14	7-14	7	
			Number		1	≥1 in 3 yrs	≥1 in 3 yrs	≥1 in 3 yrs	≥1 in 3 yrs	
Winter / Spring										
Jun - Nov	Low flow	Wet / Average	Volume	10 *	>350	>350	>350	>350 (median 750)	>350 (median 750)	80 *
		Dry	Volume	10 *	>200 (Median 350)	>350 (Aug – Nov)	>350 (Aug – Nov)	>350 (median 600)	>350 (median 600)	80 *
Jun - Sep (Jun – Nov Reach 8)	Fresh	Wet / Average / Dry	Volume	100 *	700 *	1800 *	2000 *	2500 *	2500 *	180 *
			Duration	≥2	≥7	≥7	≥7	≥7	≥7	≥2
			Number	≥3	≥2	≥2	≥2	≥2	≥2	Wet 4-5 Ave 3-4 Dry 2-3

Season	Flow	Climate		Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 8
Jun - Nov	High	Wet / Average	Volume	300	700	1800	2000	2500	2500	×
			Duration	3	14	14	14	14	14	
			Number	1 in 2 years (Jun – Sep)	1 (Sep)	1 (Oct – Nov)	1 (Oct – Nov)	1 (Oct – Nov)	1 (Oct – Nov)	
		Dry	Volume	300	×	×	×	×	×	×
			Duration	3						
			Number	1 in 2 years (Jun – Sep)						
Not Oct - Nov	Bankfull	Wet	Volume	1100	2700	4000	5000	5000	13000	1000
			Duration	3	2	2	2	2	1-2	2
			Number	1 in 10 years	1 in 2 years	1	2-3	2-3	1 in 2 years	1 in 2 years
		Average	Volume			4000	5000	5000	13000	1000
			Duration			2	2	2	1-2	2
			Number			1	1-2	1-2	1 in 2 years	1 in 2 years
		Dry	Volume			×	×	×	×	×
Not Oct - Nov	Overbank	Wet and/or Average years only	Volume	×	×	9000	10000	14000	21500	×
			Duration			2	1-2	1-2	1-2	
			Number			1 in 2 years	1 in 2 years	1 in 2 years	1 in 4 years	

* Minimum delivered flow, allow tributary inflows to provide variation on top of stated flow

^ Low flow needs to be >450 ML/day between Dec – Feb if flow is being used to keep Dights Falls Weir Pool mixed

Larger flows should be passed if they occur

Appendix F. Explanation of Condition Ratings

Value	Rating	Explanation
Fish	Very high	Almost all native species that have been recorded in the catchment present. Native species greatly outnumber exotics
	High	Most native species that have been recorded in the catchment present. Native species outnumber exotics.
	Moderate	About half the expected species present. Significant proportion of exotic species recorded.
	Low	Large proportion of expected species not recorded. Exotic species likely to dominate. Poor diversity and abundance.
	Very low	Most expected species not recorded. Exotic species dominate. Very poor diversity and abundance.
Platypus	Very high	Platypus abundant.
	High	Platypus very common.
	Moderate	Platypus common.
	Low	Platypus present in low numbers.
	Very Low	Platypus present in very low numbers.
Frogs	Very high	Almost all species present.
	High	Most species present.
	Moderate	About half the expected species present.
	Low	Significant proportion of the expected species not recorded. Poor diversity.
	Very low	Few of expected species recorded. Very poor diversity.
Macroinvertebrates	Very high	Excellent state of stream water quality.
	High	Healthy state of stream water quality.
	Moderate	Mild pollution.
	Low	Moderate pollution.
	Very low	Severe pollution.
Birds	Very high	Almost all expected streamside and wetland species recorded.
	High	Most expected streamside and wetland species recorded.
	Moderate	About half the expected streamside and wetland species recorded.
	Low	Poor diversity, most expected streamside and wetland species not recorded. Low abundance.
	Very low	Very poor diversity, most expected streamside and wetland species not recorded. Low abundance.

Value	Rating	Explanation
Vegetation	Very high	Vegetation largely same as the reference condition (Index of Stream Condition). Waterway largely vegetated along and out from waterway onto floodplain.
	High	Vegetation largely the same as reference condition although species may be missing and some weed invasion present. Waterway is vegetated along and out onto floodplain although some gaps exist.
	Moderate	Vegetation resembles reference condition although species may be missing and weeds present. Gaps along and out from the waterway onto the floodplain.
	Low	Vegetation may have some components of reference community but has exotic species and fragmented.
	Very low	Fragmented and degraded vegetation.
Amenity	Very high	High level of satisfaction with amenity, appropriate facilities and good visitation.
	High	High satisfaction with amenity but not widely known for amenity in the region.
	Moderate	Moderate satisfaction with amenity but opportunity to improve satisfaction through improved waterway condition or awareness.
	Low	Low satisfaction but with concerted effort (maintenance and/or improved condition) may change.
	Very low	Low satisfaction, poor facilities, poor condition.

Appendix G. Response to Stakeholder Feedback

G.1 Melbourne Water response to feedback on Consultation Paper and Technical Synthesis

Comment	Who	Response
Could/should rakali be included alongside platypus. I suspect what benefits platypus benefits the Rakali.	Yarra River Keeper (Andrew Kelly)	The Rakali (*Hydromys chrysogaster*), also known as the Australian Water-Rat and the largest of Australia's rodents, has not yet been considered by environmental flows studies for the Yarra River, and its flow requirements are currently not well known. The animal occupies habitat in the vicinity of permanent water, and surveys for Platypus in the Melbourne region frequently also detect Rakali [29]. Evidence suggests that the urbanised waterways around Melbourne support substantial populations of Rakali[30]. While little research has been done as yet on the flow requirements of Rakali, the co-habitation of many waterways with Platypus suggests that the species may have similar flow needs. Rakali will be included for analysis in the next review of the flow requirements of the Yarra River in 2017/18.
We need to compare not only to long term trends but to a model of the hydrology of the river in 1835.	Yarra River Keeper	No hydrological model of the river prior to 1835 exists, and given the condition and landscape of the River's catchment has been significantly and permanently changed since European occupation and river regulation, it would be very difficult and expensive to develop such a model. This type of comparison would also be relatively meaningless because the objective of providing environmental water is not to return the Yarra River and its wetlands to their pre-European condition given the extensive changes to the system. Rather, environmental flows are used to help improve the condition of the values of the Yarra River by providing water that meets their specific environmental requirements. Melbourne Water is working in partnership with university researchers to better understand the hydrological changes of the Melbourne region using paleoclimate data, particularly the frequency and severity of drought events, but this work is unlikely to provide a greater understanding of the timing, frequency or duration of low, middle and high flow events at the more granular scale. This work will however, provide Melbourne Water with a greater understanding of the macro-scale climate scenarios that the river has experienced over time. This will assist in risk management and planning for environmental flows.
The threatened Grey-Headed Flying Fox chooses to live on the	Yarra River Keeper	Noted. The Yarra River Environmental Flows Study (which the Environmental Entitlement and Seasonal Watering Plan

[29] Williams, G.A. & Serena, M. (2004) Distribution and Status of Australian Water-Rats (*Hydromys chrysogaster*) in the Melbourne Metropolitan Region. Information obtained from Platypus Surveys, 1995-2003. A report to Melbourne Water

[30] Williams, G.A. & Serena, M. (2004)

Comment	Who	Response
river. I am guessing because it is cooler. Flows and maintenance of riverside veg will help the flying foxes.		are based upon), includes an assessment of the flow requirements of riparian vegetation for the purpose of maintaining and improving its condition. Achieving this objective will have positive impacts for the fauna and flora species and communities (both terrestrial and aquatic), that are dependent on riparian vegetation for habitat, food sources and shelter, including the Grey-Headed Flying Fox.
Will flows contribute to lowland Leadbeater's Possum and Helmeted Honeyeater habitat in the Yellingbo Conservation Corridor?	Yarra River Keeper	Yellingbo Conservation Corridor is known for providing Leadbeater's Possum and Helmeted Honeyeater habitat, and is located within an unregulated area of the Yarra Valley - the Woori Yallock catchment. This catchment rises on the eastern slopes of the Dandenong Ranges, with Woori Yallock Creek flowing north to join the Yarra River. Because the catchment is unregulated, it is not possible to provide water to it from the Yarra River Environmental Entitlement (which can only be released from regulated sections of the system). Water sharing arrangements for the Woori Yallock catchment are managed under a Stream Flow Management Plan[31], and are based on an Environmental Flows Study for the catchment[32]. This study considers the flow requirements of the mid Woori Yallock Creek, where the Yellingbo Conservation Corridor is located.
The water plan makes a deal of getting shared benefits from flows - Can we talk about the benefits to kayakers etc, especially if they are informed of flows. Also the hundreds of rowers out on the river on a summer morning are dependent on adequate flows. Should there be a program of ensuring that kayakers can safely paddle the upper Yarra by re-locating (not removing large woody debris)?	Yarra River Keeper	In line with the commitments specified in *Water for Victoria – Water Plan 2016,* Melbourne Water has obligations to explicitly consider shared benefits when conducting water planning exercises. In developing the Seasonal Watering Proposal for the Yarra River for 2017/18, shared benefits will be considered in planning for environmental flow releases. This will include incorporation of the findings of consultation with key recreational user groups such as kayakers, canoers and rowers. Section 2.9 of the Technical Synthesis has been modified to include a discussion of the keen non-motorised boat users community of the river. The removal of large woody debris is not within the scope of management responsibilities for the Environmental Water Entitlement. Relocating this type of habitat is also unlikely to be supported as it would be contrary to the objectives within the Melbourne Water Healthy Waterway Strategy, and is likely to have significant impacts on sediment retention and movement processes within the waterway.
Can summer freshes have identified benefits for bushfire control - keeping riverine veg wet? Planisphere have done a lot of work on the visual amenity of the naturalistic landscape of	Yarra River Keeper	**Bushfire control** Where there is well-managed riparian vegetation with limited grass and weed growth and low slopes, and under a Low to Moderate Fire Danger Rating, bushfires may be difficult to ignite within the riparian zone, and may only burn very

[31] *Water Act 1989* Woori Yallock Creek Water Supply Protection Area Stream Flow Management Plan 2012
[32] SKM (2005) Environmental flow determination for Woori Yallock Creek

Comment	Who	Response
the lower river and natural landscape in the middle and upper Yarra. For example the 2005 report for DELWP and the recent work for Yarra Council (a prelude to the introduction of the mandatory height and setbacks along the Yarra Council section of the river.		slowly and at a low intensity. However, as the amount of riparian land is limited, compared with other land uses within most catchments, riparian land can be expected to have only a limited influence on bushfire spread at a landscape scale[33]. Fire behaviour is very complex, and can be dependent on many different factors, such as: fuel type, size, quantity and arrangement; fuel moisture content; and slope, aspect, wind and temperature[34]. Using environmental flows to manage riparian vegetation for bushfire risk mitigation would be extremely difficult given the large number of factors that are considered in predicting fire behaviour. **Visual amenity** The Technical Synthesis section of the EWMP includes discussion in Section 4.1. of the analysis undertaken by Planisphere regarding visual amenity and corridor planning controls.
Can we make more of the benefit to cyclists - the 1000 or so who cycle down the river each weekday morning and up the river each weekday evening?	Yarra River Keeper	In line with the *Water for Victoria – Water Plan 2016,* all water managers have new obligations to explicitly consider the shared benefits of the provision of water in their water planning exercises. In developing up the Yarra River Seasonal Watering Proposal for 2017/18, shared benefits will be considered by Melbourne Water when planning for environmental flow releases.
Tying flows in with other actions that can substitute for flows - planting of trees to shade water, removal of weirs, tunnels and other constraints on fish migrations, use of stormwater to sustain natural wetlands (also slowing flows and improving the quality of the water).	Yarra River Keeper	This already is picked up in the recommendations section for complementary works in the Yarra River Environmental Flows Study, and is also considered as part of the Melbourne Water Healthy Waterways Strategy. An overview is provided in Section 10.4 of the Technical Synthesis.
Can we narrow the channel of the river back to its original form where it has been artificially widened?	Yarra River Keeper	The purpose of the environmental watering program for the Yarra River is not to try to return the river and its wetlands to their pre-European condition and/or form. Rather, it is used to ensure the values currently dependent on the River are improved by providing water that meets their specific environmental requirements. Options to change the river channel to reconnect parts of the floodplain may be considered at some point in the future, but this is beyond the scope of the current EWMP given the current policy requirement to not provide overbank flows. For example, improving connections to billabongs by lowering the Yarra River bank in specific areas to increase the frequency of overbank flows to water larger areas of floodplain and billabongs is under consideration. Any

[33] DEPI and CFA (2012) Riparian land and bushfire risk. Resource Document
[34] DEPI & CFA (2012) – As above

Comment	Who	Response
		changes to the waterway channel needs to be assessed for possible flooding implications through detailed hydrological modelling and stakeholder consultation processes.
Artificial reefs beneath the water in Docklands?	Yarra River Keeper	This is a great idea, but is outside the scope of the Yarra River EWMP, which is only able to consider and plan for environmental flow releases. This would be considered a complementary action. Parks Victoria manage the estuary (where Docklands is located) and the idea would need their consultation and approval if it was to be further explored.
Where is the sediment going when we scour it out to improve habitat? Is it just filling in the next pool, hollow or hole? Is there a net benefit or is the problem just being moved around? How will the flow releases reshape the channel? Are they in parts contributing to the erosion of the river? Are they contributing to turbidity? Are there slugs of gravel that will be influenced by flows? How can flows be used to promote instream veg that will collect sediment and reduce turbidity? Does rapid wetting and then drying of banks under climate change scenarios increase erosions?	Yarra River Keeper	The pattern of sediment deposition and movement along a waterway is related to riverbank and instream erosion patterns, catchment land use and sediment inputs, rainfall patterns, geomorphology and hydrology[35]. Sediment movement downstream fulfils an important physical and ecological function for a river, creating disturbances and mosaics of changing habitats, which help to drive ecosystem processes and biodiversity. In systems impacted by regulation and dams, diversions, and/or channelisation and levees, sediment abundance and movement can be greatly impacted. Where sediment movement is significantly reduced, either through less of it being present in a system, or through fewer opportunities for flow events that can move it, biodiversity is decreased[36]. Major sediment movement generally occurs through large flood events, and the Environmental Entitlement is not of a sufficient size to enable releases that could influence this type of movement within the Yarra River. Although a significant amount of sediment is being captured and held in storages on the Yarra River system, there is still an issue with sediment within the Yarra River building up in certain areas and not able to move downstream, decreasing habitat availability and variety in those reaches where it is 'stuck'. More work is needed to understand the impact that climate change will have on streamflow within the Yarra catchment and the subsequent impacts on bank wetting and drying patterns and erosion potential. More work is also needed to understand the impacts of urbanisation on the system, which is likely to increase the amount of sediment input into the Yarra system because of flashier and higher velocity rainfall in the upper catchment areas, further compounding the issue of climate change.
The penguins at St Kilda depend on fresh water flows from the Yarra - as they eat the pilchards in the plume.	Yarra River Keeper	Acknowledged. The discussion in Section 2.4 of the Technical Synthesis has been updated to include a brief case study of the relationship between Yarra River flows and foraging behaviour for Little Penguin.

[35] Yarnell Sarah M., Petts Geoffrey E., Schmidt John C., Whipple Alison A., Beller Erin E., Dahm Clifford N., Goodwin Peter, Viers. Functional Flows in Modified Riverscapes: Hydrographs, Habitats and Opportunities. Joshua H. BioScience. 2015 65(10). p.963

[36] Yarnell et al (2015)

Comment	Who	Response
I note that the condition of the Lower Yarra for frogs is rated very high. I have seen that quoted elsewhere but I need some convincing that it is an accurate assessment?	Yarra River Keeper	Acknowledged. This value is based on the number of wetlands/billabongs in this part of the catchment (rather than just the main stem waterways) where frogs are known to exist, and a measure of the ratio of native species recorded as present in the areas versus expected to be present. The system for rating the condition of the key values of the Yarra River is currently being reviewed as part of the process for updating the Healthy Waterways Strategy.
Obviously the aspect of demonstrating the benefits of the EW allocation is critical, and then sharing the benefits broadly to ensure the community / govt recognise the importance. Who's responsibility is it to 'promote' awareness and benefits of the Yarra Environmental Entitlement Could this be given more support by MW or others?	Michaela Skett (Coordinator Environmental Sustainability) Boroondara Council	Acknowledged. The responsibility for raising awareness, understanding and support for the objectives and benefits of the Yarra River Environmental Entitlement sits with a range of organisations. In particular, the Victorian Environmental Water holder, Melbourne Water, and the Department of Environment, Land, Water and Planning have primary responsibilities for communicating the policy, objectives, planned releases and outcomes of environmental flow releases. A comprehensive communications strategy is managed by VEWH to support the environmental watering program for Victoria, and a communications and engagement strategy has also been prepared to support the implementation of this EWMP, specifically focusing on the Yarra River environmental watering program.
On p16m the paragraph under Ecological constraints that begins 'The maximum flow recommendations….' Is quite hard to follow/interpret. I know you spoke to it at the workshop, but I have read the paragraph a few times before the meeting and still wasn't really clear what it was saying. Perhaps a further review/edit for clarity would help to understand what you are trying to say here.	Boroondara Council	Acknowledged. This has been re-worded in the Executive Summary and Technical Synthesis sections of the EWMP to provide further clarity. The revised wording is as follows: "The maximum flow recommendations for the Yarra River immediately below the Upper Yarra Reservoir (Reach 1) and the Watts River below Maroondah Reservoir (Reach 7) have created an ecological conflict for Melbourne Water. This is because these flows need to be lower during fish breeding season to prevent damage to and/or sweeping away of eggs and to protect habitat availability, but must at the same time be large enough to meet high priority flow objectives in reaches further downstream. Melbourne Water has acknowledged and assessed these conflicts and is implementing a program of flow release testing and monitoring to determine the maximum amount of flows that can be released while minimising ecological risk where potential conflicts occur."
On page 20, the last sentence isn't quite right I don't think. Overly confident/absolute? Certainly more entitlement will <u>help</u> protect condition of values but 'likely to maintain current…' seems dubious given the climate change impacts that you have	Boroondara Council	Acknowledged. **Protection of condition** Melbourne Water's EWMP Consultation Paper must keep the current wording in order to provide an accurate record of what was sent to key stakeholders for review. However, we have reviewed the relevant sections within the EWMP Technical Synthesis (Executive Summary and Section 8.3),

Comment	Who	Response
spoken about over the medium to long term will decrease water in the Yarra and related factors that even optimal flows wouldn't avoid eg changes to ecological communities / species due to temperature / heat stress etc. In the longer term, the high level ecological objectives (p 13) will need to focus on ecological 'function', as 'composition' of vegetation will change as a consequence of climate change.		and have provided more clarity in the text so readers are aware that the focus of the discussion is on compliance with flow recommendations and the likely associated impacts on values, for example: "In order to meet the current management and environmental flow objectives under a climate change outlook (i.e. maintain the current level of achievement with environmental flow recommendations), an increase in the volume of the Environmental Entitlement will be required" (Executive Summary) We have also noted in the text that: "A range of priority flow components will need to be delivered with a high degree of compliance *to help maintain* (our emphasis) the current condition of Yarra River values." **Ecological function** While much of the study of biodiversity in recent decades has been inspired by concern over the loss of species richness, of increasing concern is the loss of the ecological functions of the species involved[37]. This is because ecological function, the measurable aspect of an organism or community that reflects what it is doing, how it interacts with other organisms and its environment and the resources it uses, can sometimes be a better predictor of ecosystem functioning than species richness and/or species composition alone[38]. As our knowledge of ecological functions of the different species and communities dependent on the Yarra River increases, this will be incorporated into reviews of the environmental flows study and management objectives will be adjusted accordingly. The Yarra River Flows Study is due to be reviewed in 2017-18 and an assessment of the current values, the role they play in the ecosystem, and their flow requirements will be undertaken during that process.
In the section on p 24, other complementary actions include protective land use development controls (DDO and ESO) along waterways (underway for the Yarra), stronger WSUD controls in Vic Planning Framework (opportunity), and improvements in building regulations (increasing water efficiency, need for harvesting etc) (again, an opportunity). Could flesh this out a little more	Boroondara Council	Acknowledged. **DDO and ESO planning complementary actions** The work being undertaken by Melbourne Water, local government and DELWP to improve Yarra River corridor planning controls is discussed in Section 4.1.2 of the Technical Synthesis, but we have strengthened this section to include a discussion of the ESO and DDO work that is currently underway. We have also updated the Complementary Actions sections of the Executive Summary and Technical Synthesis sections (Section 10.4) of the EWMP to include mention of these actions. **WSUD**

[37] Cadotte, M.W., Carscadden, K., and Mirotchnick, N. (2011) Beyond species: functional diversity and the maintenance of ecological processes and services. Journal of Applied Ecology 2011, 48, 1079–1087
[38] Cadotte et al. (2011)

Comment	Who	Response
		Melbourne Water advocates for improved stormwater management across Melbourne's urban areas, including the Yarra River catchment. Notably, Melbourne Water assisted in the development of Clause 56 of the Victorian Planning Provisions. This clause describes the stormwater management objectives within the Victorian Planning Framework that residential subdivisions need to meet. These objectives are designed to reduce the harm to our waterways, bays and ocean by implementing sustainable urban water management, including water sensitive urban design (WSUD). Melbourne Water will continue to work with key planning agencies to strengthen the WSUD controls in the Victorian Planning Framework. **Building regulations** Building regulations are not within Melbourne Water's areas of responsibility, instead this falls within the EPA and local government council responsibility. An area where Melbourne Water has greater influence is in regards to flooding overlays, because Melbourne Water is the drainage and floodplain manager for the Greater Melbourne area. Melbourne Water provides guidelines for development in areas that have a flood or land subject to inundation overlay within the planning scheme. The primary purpose of these overlays is for flood risk protection of built assets. The Yarra River Protection Ministerial Advisory Committee is developing interim planning controls to guide development, and Melbourne Water is participating in this process. A key focus for these controls is the environmental health of the waterway. Please see http://www.dtpli.vic.gov.au/planning/plans-and-policies/waterways-planning/yarra-river-planning for more information.
Regarding the values, just a thought (which might come up in the cultural values discussions with Wirundjeri) if presence/ abundance of Eels might be a value worth understanding / protecting. May have already been considered/dismissed for some reason???	Boroondara Council	The cultural value of Eels for the Wurundjeri and their potential flow requirements was provided as a case study within the Technical Synthesis section of the EWMP (Section 2.8.2).

PART THREE – FACT SHEETS

The summary fact sheets contained in this final section aim to provide the reader with a consolidated overview of the current condition, management objectives and threats facing each key value within the Yarra River. The fact sheets outline:

- The importance of each value and their current condition within the Yarra catchment
- The key threats to each value
- Management objectives from the Healthy Waterways Strategy as well as the more detailed ecological management objectives recommended through environmental flows studies
- An overview of why providing environmental flows is important, and a discussion of the possible implications if the recommended environmental flow regime is not achieved
- Emerging issues, particularly the potential implications of climate change.