Healthy Waterways Strategy

Resource Document

Supporting the development of the Strategy

Contents

List of Figures and Tables

Acknowledgement of Country

We acknowledge and respect Traditional Owners and Aboriginal communities and organisations.

We recognise the diversity of their cultures and the deep connections they have with the region's lands and waters.

We value partnerships with them for the health of people and Country.

We pay our respects to Elders past and present, and we acknowledge and recognise the primacy of Traditional Owners' obligations, rights and responsibilities to use and care for their traditional lands and waters..

Contributors

The Resource Document has relied on a significant body of knowledge inputs from many (30+) knowledge domains in which influence waterway health. Rivers, estuaries and wetlands, their key ecological values, supporting environmental conditions, key drivers and threats, how they are measured, assessed and modelled are all specialist areas of expertise.

Many Melbourne Water and Melbourne University staff were involved in developing the scientific methods that are summarised in this document. We would like to acknowledge their key contributions. These people include Melbourne Water staff Sharyn Rossrakesh, Trish Grant, Simone Wilkie, Dr Belinda Lovell, Dr Rhys Coleman, Andrew Grant, Dr William Steele, Dr Al Danger, Michelle Dickson, Michelle Ezzy, Sarah Gaskill, Leigh Smith, Karen White, and Melbourne University staff Dr Yung En Chee, Associate Professor Chris Walsh, Professor Tim Fletcher, Professor Vincent Pettigrove, Simon Sharp and Daniel MacMahon who together, with the help of many others, contributed to developing the methods used to derive the Healthy Waterways Strategy. A list of the lead authors for each chapter is provided in Appendix 1.

We also acknowledge the critical contribution that was fostered by the development of Melbourne Water Melbourne University Research Practice Partnership and the CAPIM (now A3P) partnership. Some of the work that is described in this document is the result of many years of research and the development of models and methods that have integrated data collected over many decades.

We acknowledge the Healthy Waterway Strategy Science Panel for their considered advice throughout the development of the Healthy Waterways Strategy. Membership: Dr Jane Doolan/Professor Ian Rutherford (Chairs), Dr Rhys Coleman, Dr Belinda Hatt, Dr David Jones, Dr Randall Lee, Dr Kay Morris, Professor Vin Pettigrove, Dr Simon Treadwell, Associate Professor Chris Walsh, Dr Yung En Chee, Dr Fiona Warry, Michelle Dickson and Dr Paul Reich.

We also acknowledge our committed service providers who supported the development of the thinking and approach for a number of the values and conditions.

Executive Summary

This Resource document describes the methods, approaches, assumptions, limitations and knowledge gaps in the science that informed the development of the *Healthy Waterways Strategy* (HWS) for the Port Phillip and Westernport region. It sits alongside the *Healthy Waterways Strategy 2018* (HWS 2018), five Co-Designed Catchment Programs, the 'Engagement and Collaboration Summary' and the *Monitoring, Evaluation, Reporting and Improvement (MERI) Plan* to form the full scope of the region's HWS documents.

The science underpinning the HWS 2018 clearly indicates that climate change and urban growth are significant challenges to maintaining and improving waterway health outcomes in the Melbourne region.

The HWS 2018 marks a significant development in the management of Melbourne's waterways. Previous waterway management strategies have primarily focused on activities that were delivered or influenced by Melbourne Water. This strategy takes a more holistic approach, describing the needs of the waterways and the full range of management options that can be employed by a variety of agencies, businesses and the community to achieve a shared long-term vision for healthy and valued waterways in the region. Additionally, the strategy adopts a unified approach by bringing together rivers, wetlands and estuaries with explicit place-based stormwater targets. While the available information to assess conditions and establish targets has not always been equal for all asset classes, developing a unified approach for the first time and outlining a strategy that enables all levels of the community to contribute to achieving strategy objectives is a significant improvement.

The HWS 2018 has focused on setting targets for outcomes, allowing flexibility for how these will be achieved, whereas the previous strategy set targets on activities and was not explicit about the outcomes to be achieved. This strategy recognises uncertainty with respect to climate change and population growth, and was designed to allow adaptation along the way to achieve desired outcomes.

Long-term investment by Melbourne Water in applied research and monitoring of waterways, and utilisation of data since the beginning of the 1970s, have enabled Melbourne Water to develop a science-based HWS. The methodology reported in the Resource document is the culmination of these research programs to date. The reported methodologies have been robustly and independently tested by an advisory Science Panel and Liveability Directions Panel.

The research and scientific modelling described in the Resource document identified the current conditions and the environmental and social values of individual waterways across the region. The likely impacts of climate change and human activity on waterway conditions over the next 50 years were modelled or estimated, with management options tested against desired outcomes.

The scientific expertise, data and modelling that have been relied upon consisted of:

- habitat suitability models (HSMs)
- conceptual models

- literature and data review
- specialist expert opinions
- statistical analyses
- aquatic value identification and risk assessments (AVIRAs)
- community perceptions as expressed in waterways survey.

The science in this Resource document has stimulated a collaborative culture in Melbourne's region that values knowledge and information and leveraged these to create a transformational HWS. Going forward, it is essential to recognise the connection of Traditional Owners to the waterways and the significant value and importance of their knowledge to sustainable management of these important assets.

To address key gaps and adequately assess the performance and risks of the 2018 Strategy, sustained investment in science and data relating to the waterways is required to understand the impacts of changing climate, urbanisation and population growth. Such investment is vital for adaptive and collective waterway management to be effective. Melbourne Water has a lead role in ensuring that our decision-making is informed by science and supports the co-delivery with our partners of the HWS. The MERI Plan is a significant addition to the HWS in providing a framework that guides the continual improvement of key tasks.

A strong, vibrant and resourced scientific community of practice has and will remain the linchpin of responsive and adaptive management of Melbourne's waterways into the future. Continued investment in monitoring and addressing knowledge gaps will support the improvement and refinement of efforts into the future. Fostered collaborations between researchers, planners, policymakers, on-the-ground practitioners, Traditional Owners and local communities enable a better and shared understanding and responsive adaptation to our shared challenge. Only through coordinated investment and data and knowledge sharing among this community of practice will we have the best chance of effectively delivering the HWS.

Abbreviations

AVIRA – Aquatic Value Identification Risk Assessment
DELWP – Department of Environment, Land, Water and Planning
DIWA - Directory of Important Wetlands in Australia
EPA – Environmental Protection Authority, Victoria
HSM – Habitat Suitability Model
HWS Healthy Waterways Strategy
IEC – Index of Estuary Condition
ISC – Index of Stream Condition
IWC – Index of Wetland Condition
KV – Key Values
LWD – Large Woody Debris
MERI – Monitoring, Evaluation, Review and Improvement Plan
MEP – Monitoring and Evaluation Plan
PO – Performance Objectives
RPO – Regional performance objectives
SEPP – State Environment Protection Policy
SHW – Seasonal Herbaceous Wetland
SoBS – Site of Biodiversity Significance
WQI – Water Quality Index

1 Introduction

1.1 Purpose

The purpose of the Resource Document is to provide a reference guide for technical aspects of the Healthy Waterways Strategy 2018 (HWS 2018 or the Strategy). The methods, approaches, assumptions and limitations in the science relevant to the development of the Healthy Waterways Strategy are described. Explicitly documenting how the HWS was constructed will vastly improve and expedite future strategy development, both for Melbourne Water, but also for others developing similar strategies.

This Resource document sits alongside other key documents to inform the full scope of reporting of the HWS 2018:

Healthy Waterways Strategy 2018

The Strategy is the overarching planning document for the management of rivers, wetlands and estuaries in the Port Phillip and Westernport region aiming to ensure their value to the community is protected and improved. This document provides methodological context for the Strategy, outlines the collaborative approach for its development, and summarises the performance objectives for the five major catchments and describes a set of region-wide enabling performance objectives.

Co-Designed Catchment Programs

The Co-designed Catchment Programs support the HWS 2018 by providing an adaptive program for managing waterways in each of the five catchments. These programs provide specific details of 10-year outcomes required in each of the local sub-catchments and are written in alignment with the overarching Strategy. Their delivery will enable successful implementation of the Strategy and therefore contribute to long-term, 50-year outcomes.

These programs will be reviewed and updated over the 10-year life of the Strategy to reflect changes in catchment condition, progress of works, and to respond flexibly to emerging opportunities or challenges.

This document describes how the available data and information on values and conditions was brought together and summarised to sub-catchment scale. It also provides information on how and why performance objectives were set.

Collaborative design report

This summary contains a record of the engagement activities, workshops, collaborative efforts and working groups such as the Social Actions Working Group (SAWG) formed through co-design and feedback that have shaped the Healthy Waterways Strategy.

MERI Plan

The Monitoring Evaluation and Reporting Improvement (MERI) Plan outlines monitoring, and reporting requirements for all the Regional and Sub-catchment Performance Objectives in the Strategy and the Co-designed catchment programs. It also articulates the governance and adaptive review process that will guide the continuous improvement of the Strategy over its life. The MERI Plan comprises the MERI Framework and a four Monitoring and Evaluation Plans (MEP's). The MERI Framework provides the high-level overarching principles, governance structure, reporting time frames, program logic and high level key evaluation questions which will guide data collection, evaluation and reporting. The detailed monitoring and evaluation plans (MEPs) for each of the three ecosystem types – rivers, wetlands and estuaries provide greater detail on how values, conditions and performance objectives will be monitored, reported and evaluated over time. An additional MEP for the region-wide performance objectives will focus on tracking, reporting and evaluating progress of the regional performance objectives. The MERI Plan will span the full 10 years of the Strategy implementation, adapt over time as we improve and provide an end of strategy review to guide a refresh of the strategy in 2028. This resource document provides the evidence base and starting point for the development of the MERI Plan. Some of the gaps in knowledge and information described in this document will be addressed through the MERI Plan and MEP's.

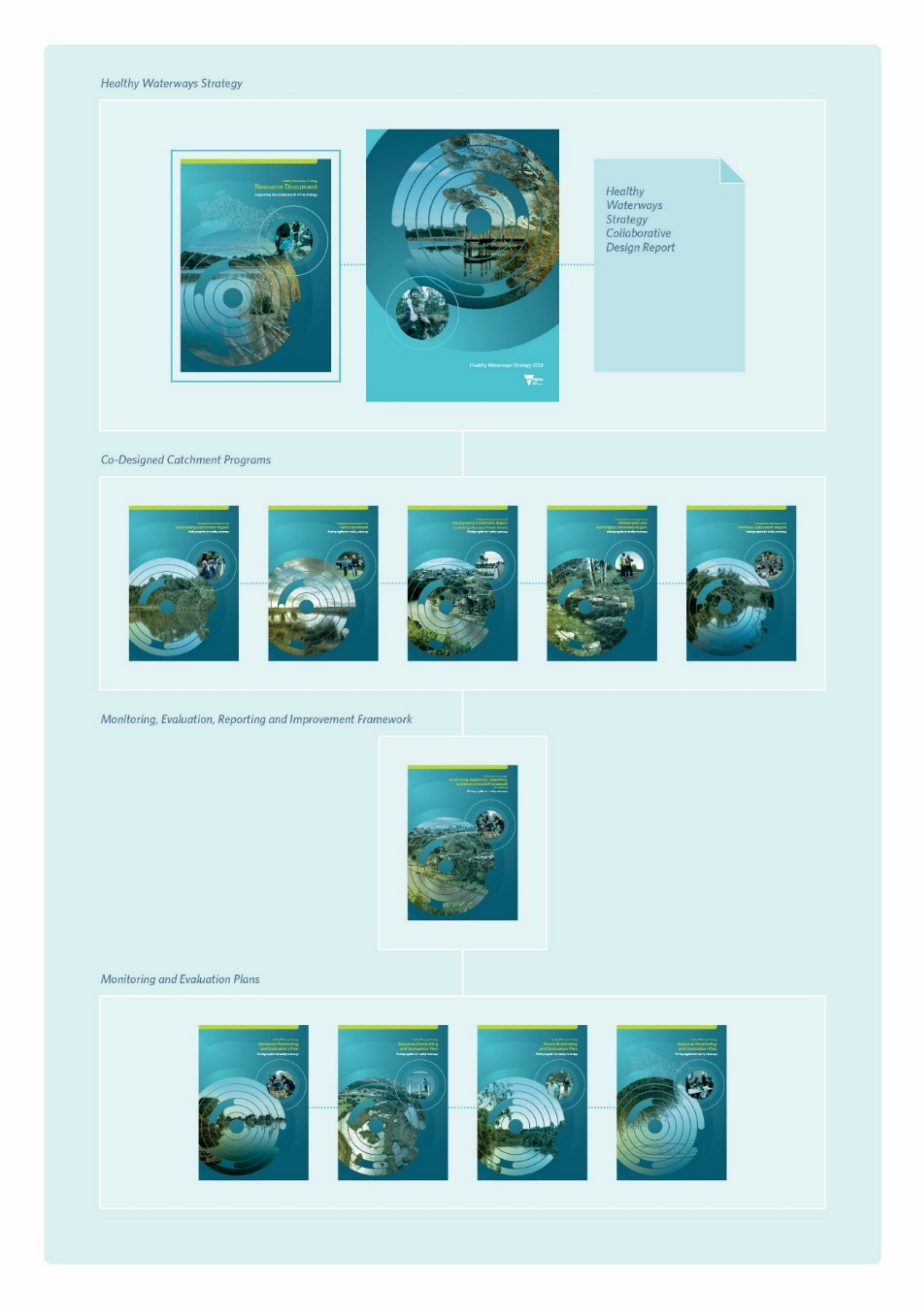


Figure 1. Healthy Waterways Strategy document library. The Resource Document is part of a suite of resources that support the development, implementation and monitoring and evaluation of the strategy.

1.2 Navigating the Resource Document

The resource document is made up of several parts and is structured to allow the reader to focus on the sections of interest.

Section	Why read this section?
1. Overview of scientific approach	To have an overview of approach taken to define current condition of environmental values and their supporting conditions. To understand what scenarios were used to determine future trajectory of values and supporting conditions.
2. River values (vegetation, riparian birds, frogs, platypus, fish, macroinvertebrates, amenity, community connection and recreation) 4. Estuarine values (bird, fish, vegetation, amenity, community connection, recreation) 6. Wetland values (vegetation, birds, frogs, fish, amenity, communication connection, recreation)	To understand: • what data and metrics were used to determine current condition of values • the assumptions were applied to current and future scenarios for target setting • the priority conditions, threats and management interventions for each value • key assumptions and limitations of approach along with links to key resources.
3. River conditions (stormwater, water for environment, vegetation, extent, vegetation quality, water quality, instream connectivity, physical form, access, litter, participation) 5. Estuarine conditions (flow regime, tidal exchange, longitudinal extent, connectivity, water quality) 7. Wetland conditions (water regime, wetland habitat form, wetland buffer, vegetation, water quality)	To understand: • what data and metrics were used to determine current state of conditions • the assumptions were applied to current and future scenarios for target setting • how performance objectives were developed • the priority conditions, threats and management interventions for each condition • key assumptions and limitations of approach along with links to key resources.
8. Benefits to the Bays	To understand how the performance objectives provide benefits to Port Phillip Bay and Westernport Bay.
9. Appendices	To access additional information and data

1.3 Collaborative design approach

The HWS 2018 was developed using a collaborative design process underpinned by science and research, an overview of which is provided in Part B of the Strategy. This document provides the detail of the methods and assumptions based on the science and research applied to strategy development. The Healthy Waterways Strategy Collaborative Design Report (Melbourne Water 2019) provides the detailed method for the co-design process.

The Strategy provides the rationale for how, over the 10-year implementation period, the shorter-term outcomes (performance objectives) collectively contribute to waterway conditions to support key waterway values. This ultimately contributes to the regional and catchment vision and goals as articulated in HWS 2018 (Figure 2).

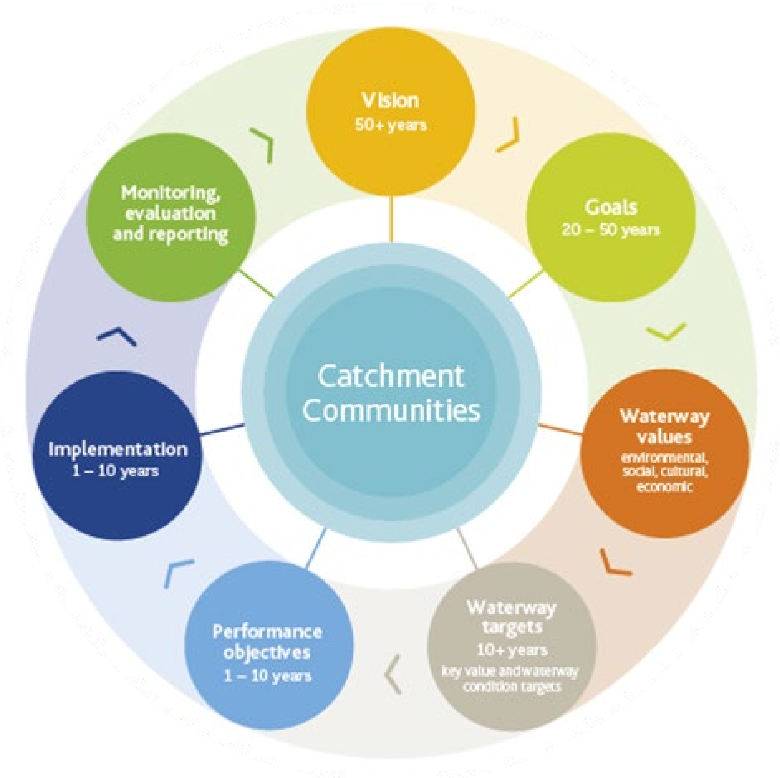


Figure 2. Diagram of HWS 2018 development approach

The collaborative process involved the community in determining what the strategy should be aiming for. This has broadened the scope of HWS 2018 to speak to actions to be co-delivered by all agencies, partners and community to protect and enhance waterways.

The collaborative design process also involved the community and stakeholders contributing their local, lived in experience about the status of the key values and the conditions required to support them and the potential threats under the current vs target trajectory. This ensured that local knowledge and expertise was used alongside decision support tools and expert scientific knowledge to develop targets and performance objectives for the strategy.

For example, the overlap between outputs through collaboration and science was generally strong. In the Maribyrnong catchment, there was 60-80 per cent alignment of stormwater and revegetation priorities between local knowledge and analysis outputs (Melbourne Water 2018). Figure 3 illustrates how the process helped to identify the 'sweet spot' – where science and local knowledge overlapped.

Figure 3. Alignment of collective knowledge and science produced the targets and performance objectives

The Science Panel advised on the ecological and environmental aspects of the Healthy Waterways Strategy. The Science Panel comprised experts encompassing skills and knowledge across a wide range of scientific disciplines in waterways. They provided a forum for key ideas and approaches to be tested, reviewed and improved, and for limitations to be identified, assumptions tested and agreed. The Science Panel and provided guidance on approach to developing robust targets and performance objectives for the Healthy Waterways Strategy.

The Liveability Directions Panel advised on the framework for describing social values especially the "Community Connection" value which reflects the role of waterways in connecting people to place and to each other and represents "social capital". It captures experiences such as engaging and learning from nature amongst others. the social value aspects of the Healthy Waterways Strategy.

During the co-design process, the Social Actions Working Group (SAWG), a sub-group of co-design collaborators, was formed to allow more detailed discussion of the proposed Social Value Framework, including program logics and potential value condition targets and performance objectives. The group was made up of interested representatives from Councils and the community.

1.4 Scope of the Strategy

The geographical scope of HWS 2018 includes the Melbourne region's five major catchments; Werribee, Maribyrnong, Yarra, Dandenong and Westernport. Within the catchments, waterways form a complex and interconnected drainage network of rivers, wetlands and estuaries, which collectively gather water from the landscape; ultimately connecting into Port Phillip Bay, Western Port or Bass Strait (Figure 4).

The Port Phillip and Westernport region covers a total catchment area of almost 13,000 square kilometres, containing more than 25,000 kilometres of rivers and creeks, 33 estuaries and in excess of 14,000 natural wetlands.

For management purposes, the five catchments are divided into 69 sub-catchments that reflect the drainage of smaller creeks and tributaries into the larger river systems.

Figure 4. The geographical scope of HWS 2018

Waterways

Throughout this Strategy, the term 'waterways' refers collectively to rivers, wetlands and estuaries.

Rivers – refers to rivers, streams, creeks, and smaller tributaries, including the water, bed, banks, and adjacent land (known as riparian land).

Wetlands – areas, whether natural, modified or artificial, subject to permanent or temporary inundation, that hold static or very slow moving water and develop, or have the potential to develop, biota adapted to inundation and the aquatic environment. They may be fresh or saline. swamps Examples include, billabongs, seasonal herbaceous wetlands and coastal wetlands,.

Estuaries – where a river meets the sea, including the lower section of a river that experiences tidal flows where fresh water and saline (salty) water mix together. For this Strategy, the definition of an estuary is that it must be at least 1 kilometre in length or have a lagoon greater than 300 metres in length. The downstream extent of an estuary is where the banks of the river end and the waterway meets the bay or ocean.

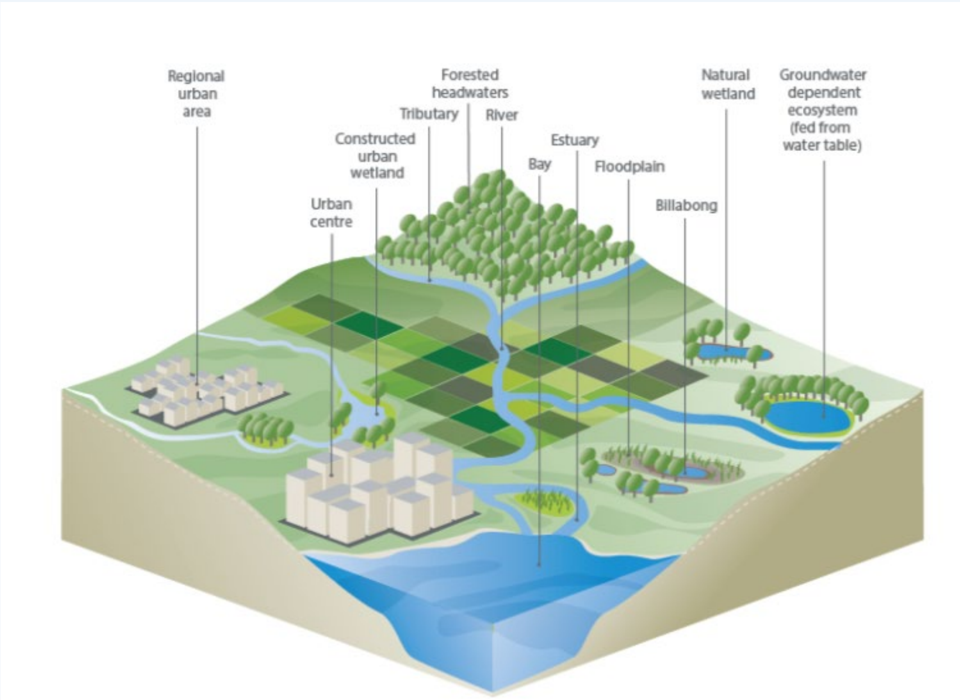


Figure 5. Elements of the waterway system

The Healthy Waterway Strategy is the overarching document for the management of waterways in the region to ensure their value to the community is protected and improved. The **value** of waterways is collectively shaped from the four main benefits they provide; environmental, cultural, social and economic.

- *Environmentally*, waterways provide habitat for plants and animals, and are critically important in sustaining much of our region's native biodiversity.
- *Socially*, waterways are important for our wellbeing. They provide places to escape the busy urban landscape, to bird watch, to fish for food, to actively commute, to meet with friends and family, to exercise and connect with nature. They provide cool and shady spaces during hot weather, and water for swimming and boating.
- *Culturally*, they are places of memories, spiritual connection and ancestral history.
- *Economically*, waterways provide benefits, through provision of drinking water for towns and cities, water for livestock and irrigation for crops, and pleasant places for travel, tourism, hospitality purposes and convenient boat mooring.

The Strategy also refers to **key values**, which are a subset of the waterway values. The key values were chosen as representative measures for all waterway values. Not all features of waterways can be effectively assessed and tracked so nine key values were chosen by science and collaborative teams on the basis of their importance to the community, ability to represent broader water value and data availability. The nine key values used throughout the Strategy are:

For each of the key values, a method to estimate their current status and future trajectory has been developed to make the best use of the available data and tools. These methods are expected to evolve over time with improved monitoring techniques and analysis methods.

How have the key values evolved?

Through the implementation of previous river health strategies (Melbourne Water's Regional River Health Strategy 2005 and its Addendum in 2008 and the Healthy Waterways Strategy 2013), Melbourne Water developed an increased understanding of the importance of waterway values to the community (Melbourne Water 2013).

The research and consultation through Melbourne Water's community perceptions data and feedback to inform the 2013 Healthy Waterways Strategy told us that key values such as birds, fish, frogs, macroinvertebrates, platypus and vegetation were more tangible to the community than river health indictors (such as water quality, physical form etc.). Amenity was also a key value important to the community, as well as being a value that Melbourne Water had the ability to influence with its investment in on-ground works.

These key values were the main reason why the community wanted to protect and improve waterways. These seven key values were selected based on their importance to the community, data availability to assess their status, and ability to represent a range of values found in rivers, estuaries and wetlands (Melbourne Water 2013).

Whilst these values remain the basis of our strategy, the HWS 2018 has expanded to include a wider range of social values as well as economic and cultural values. This aligns with directions taken from the Victoria Waterway Management Strategy (DEPI 2013). Additionally, the strategy has expanded to consider the combined effort of all agencies, partners and the community in protecting and enhancing our regions waterways, not just what is able to be achieved by Melbourne Water.

Cultural and economic values

The Strategy outlines cultural and economic waterway values performance objectives at the regional level. The reason for this is that they are currently not well understood or documented at the catchment level, certainly not as well as social and environmental values. Data, methodologies and the knowledge collective to better understand these values needs to be further developed so that catchment-specific targets and performance objectives can be developed for both Aboriginal and other cultural values and economic values in the future.

The performance objectives in the Strategy for cultural values represents a commitment to working with Traditional Owners and Aboriginal Victorians to protect and promote their cultural and historical connections with waterways. Refer to page 64 in the HWS 2018 for further information.

The performance objectives for economic values commit to the exploration and development of environmental accounts. Refer to page 65 in the HWS 2018 for further information.

Waterway **condition** describes the overall state of features and processes that underpin functioning waterway ecosystems. By maintaining or improving waterway condition the environmental, social, cultural and economic values that waterways provide can be preserved for both current and future generations (DEPI 2013). Waterway condition is measured by assessing a range of biological and physical factors. Rivers, wetlands and estuaries have different sets of conditions that support their key values. An example of the conditions that support river key values is shown in Figure 6.

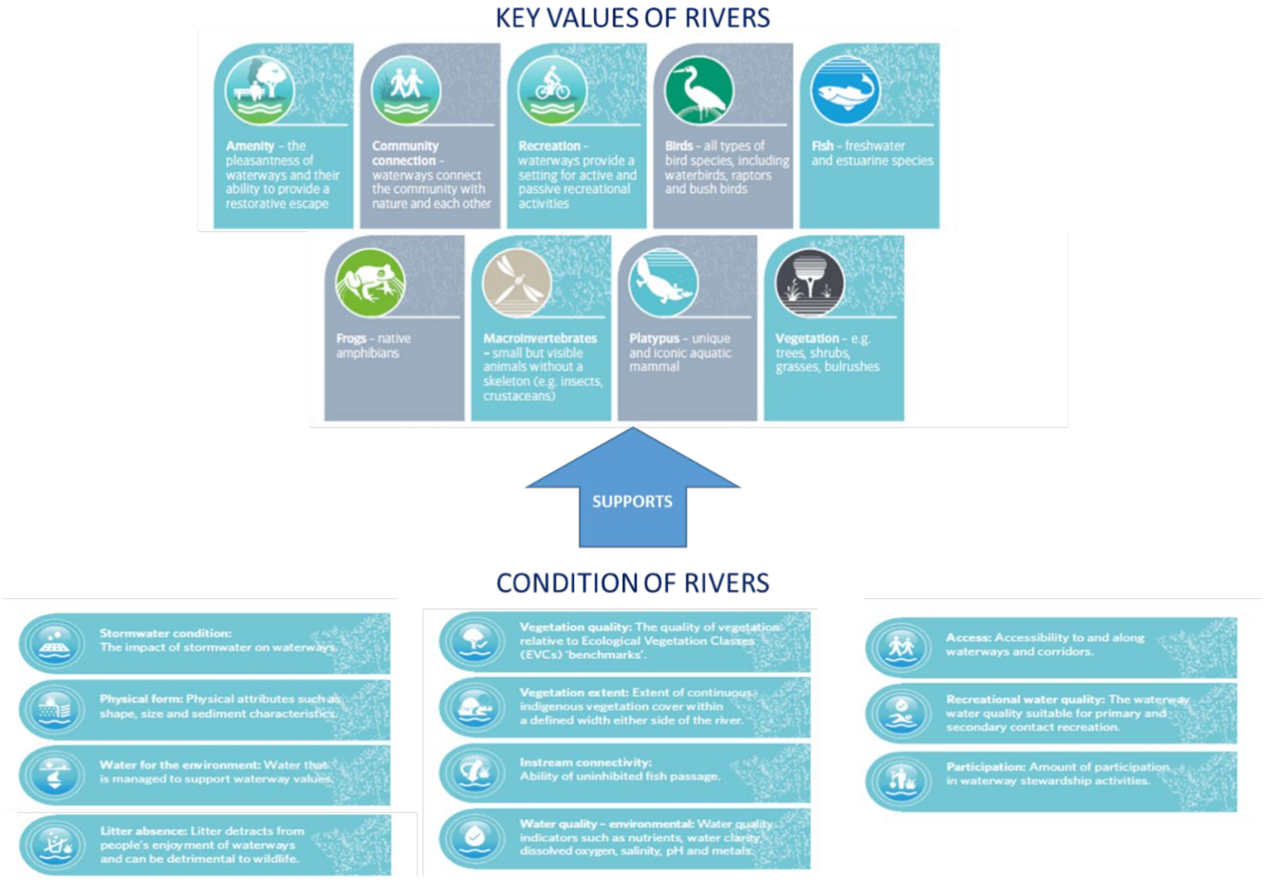


Figure 6. Relationship between the physical conditions and features of rivers that support their key values.

The **current state** of key values and the conditions that support them are measured by a series of metrics outlined in Appendix 2 and Appendix 3 respectively and the results are reported at a high level in the HWS 2018. More specific detail at the sub-catchment scale is provided in each of the Co-designed Catchment Programs (Melbourne Water 2018).

Improving the state of the key values and the conditions that supports them helps to progress against the catchment goals and vision. **Targets** have been set to quantify the amount of improvement that is required to meet the catchment goals and vision within a set timeframe.

Targets in the HWS 2018 have been set for key values and the conditions that support them in:

- Rivers and creeks
- Wetlands
- Estuaries and bays

The process by which targets were set is outlined in Section 1.5.

The short term (one to ten year quantitative steps) by which targets can be achieved are described by **performance objectives**. Performance objectives provide prioritised short-term, tangible outcomes which indicate progress towards long-term outcomes (i.e. change in key value state).

They prioritise the areas of land that are to be revegetated, or fish barriers that need to be removed or modified. The terminology 'performance objectives' is aligned with the requirements of the State of Victoria Yarra River Protection (*Wilip-gin Birrarung Murron*) Act (2017).

Performance objectives:

- are outcome-based, and not actions
- enable a partnership approach
- are quantitative, measurable and achievable in 10 years
- inform short-term management aims through annual planning processes
- describe where they link to environmental conditions
- are underpinned by transparent and best available information and knowledge
- are able to be assessed without needing to measure waterway values and condition outcomes on every asset.

The relationships between these different concepts; key values, conditions, targets, and performance objectives is demonstrated in the program logic for the Strategy (

Box **1**).

The status of the key values, current conditions, targets and performance objectives were developed for rivers, wetlands and estuaries separately as each asset type used different approaches based on data availability and tools.

Box 1. Program Logic

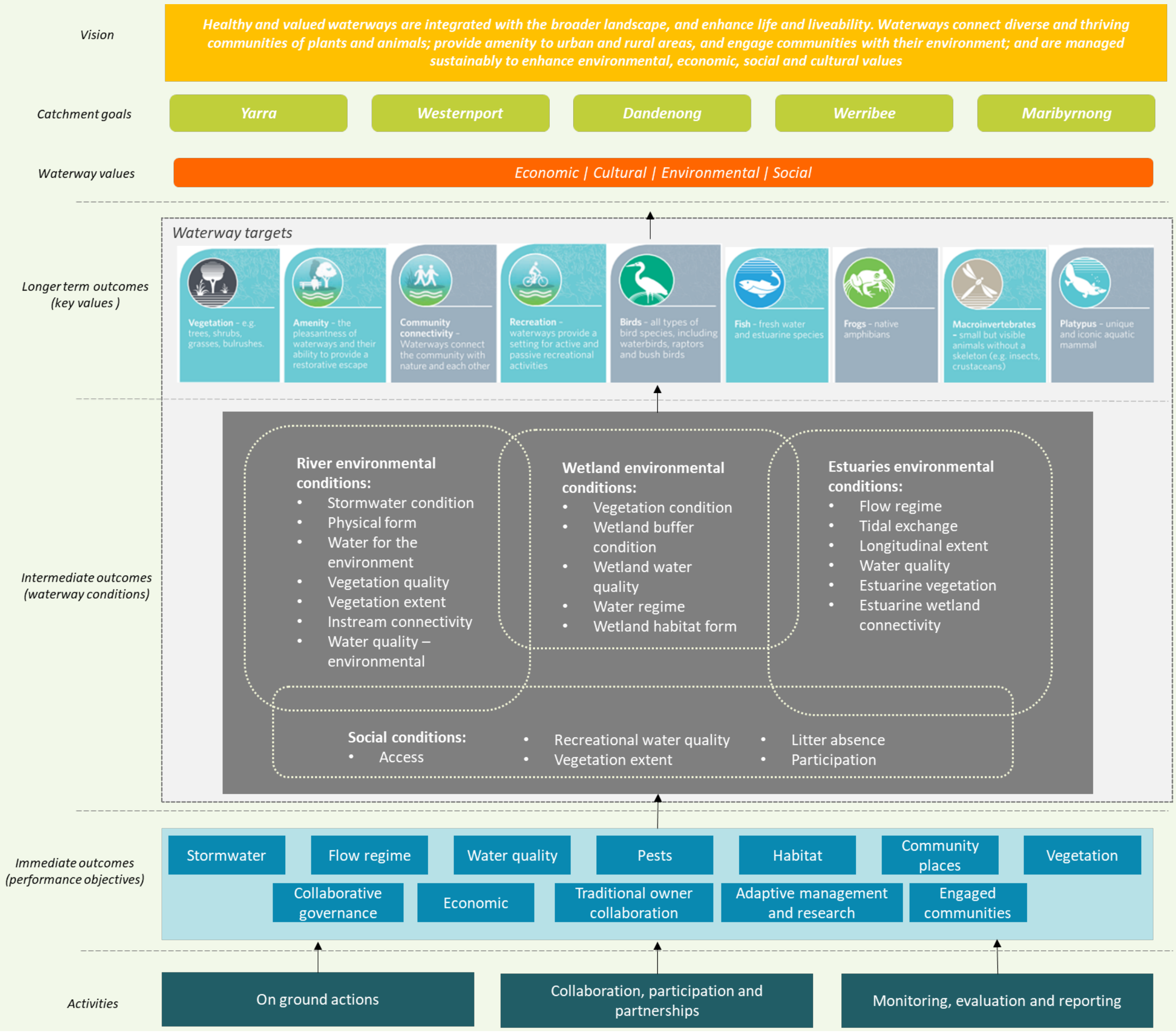
Program logic is an approach commonly used in natural resource management that uses a diagram to demonstrate the rationale for a program, including the relationships between actions, targets, goals and ultimately how the vision is expected to be achieved.

It provides the rationale for how, over the 10-year implementation period of the Strategy, the shorter-term outcomes (performance objectives) collectively contribute to either maintaining or improving the waterway conditions, in turn maintaining or improving the status of the key waterway values, and ultimately contributing to the regional and catchment visions and goals for waterways.

The overarching Strategy program logic recognizes that management activities and outcomes occur over a range of timeframes. It covers:

- Aspirational long-term regional vision and catchment goals: (50+ years)
- Longer term outcomes - key values targets (~ 20+ years)
- Intermediate outcomes - waterway condition targets (~10+ years)
- Immediate outcomes– performance objectives (1-10 years)
- Activities – on-ground actions, partnerships, governance, tracking performance

The program logic for the HWS 2018 is illustrated below.



1.5 Overview of the Values and target setting approach

Targets have been developed in the Strategy for waterway key values and the conditions that support them. The targets provide quantitative measures of progress towards the qualitative goals and vision within the program logic approach (see Box **1**).

The targets are set for different timescales in reference to the period of time it can take for a measurable change to occur and be detected. For example, targets for key values are set for 10 – 50 years reflecting the timescale required to achieve outcomes. This is because the conditions that support the key values need to change first, hence why targets for conditions are set at 10+ years. Performance objectives represent interim measures that guide activities and indicate progress towards improving waterway conditions (target), hence why the timescale is 1 – 10 years (Figure 7).

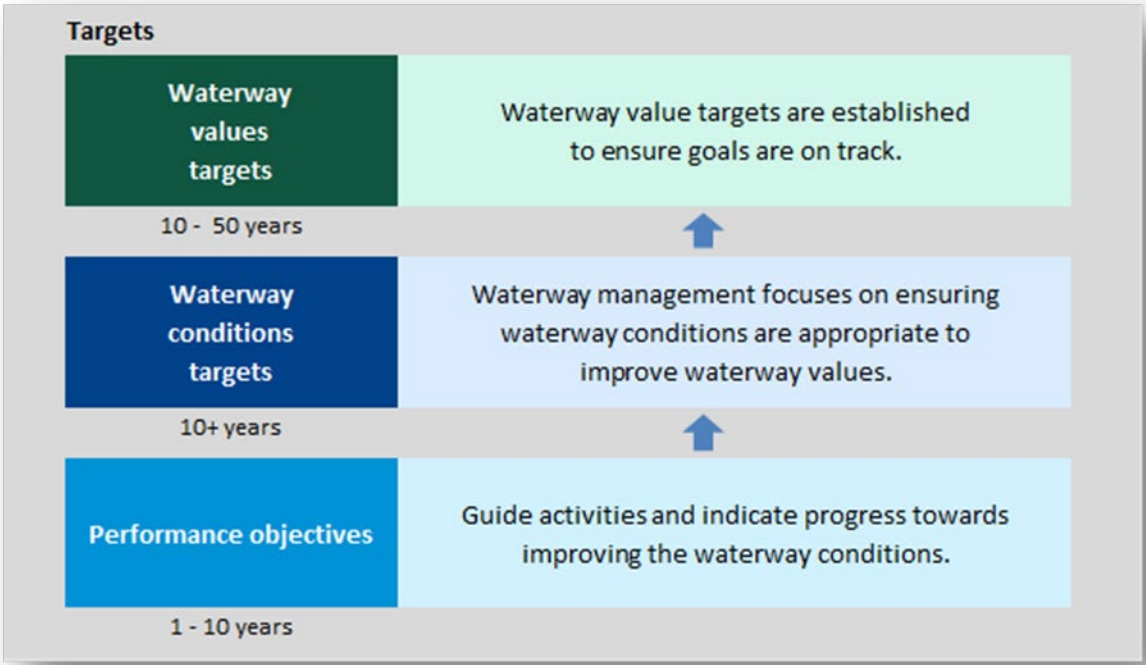


Figure 7. Hierarchy of targets in the Strategy

To set targets, the relationship between key values and the conditions that support them needs to be documented. Our understanding of condition and/or threats to key values and the conditions that support them varies greatly. For in-stream values like fish, platypus and macroinvertebrates, we have a reasonably mature understanding of what environmental conditions support improvement in value and what processes are key threats. For others (e.g. cultural, economic and social values, wetlands and estuaries) we have a less mature understanding.

This was highlighted in the Waterway Science Conceptual Models project (Alluvium 2017) which documented scientific understanding and expert opinion of the relationships between environmental conditions (e.g. water quality and flow regime) and key environmental values (e.g. fish, frogs, birds, macroinvertebrates, platypus and vegetation).

The conceptual models provide information about the important relationships, with reference to landscape context, and other contextual factors (or drivers) including urban growth and climate change, and potential management levers. This information was used assist stakeholders during the co-design process with understanding other aspects of environmental condition (e.g. water regime, water quality) that are most (or least) important to support a key value, and broadly what management responses might be applicable to protect and restore environmental conditions and key environmental values.

In the Strategy, conceptual models have been used to document what is known about the relationships between:

- Key values and conditions that support them
- Threats to conditions (and therefore to key values)
- Effectiveness of management actions to improve conditions
- The likely response to the status of key values

This information has been used to help stakeholders to understand what conditions support the key values and which management levels are most applicable to drive long term outcomes for the key values.

The conceptual models have also been used to refine the Habitat Suitability models and filter the analysis for Zonation (see below). The conceptual model for each key value is displayed in their respective section in this document. A detailed description of the method and assumptions in developing the conceptual models is provided in Alluvium (2017).

Key to setting targets was understanding current status of key values and conditions, their current trajectory (decline, maintain or improve) and the threats to current status. The approach to determining this differed according to our knowledge and understanding of key values (based on the conceptual models). Three distinct methods were used to develop targets for the Strategy.

1. Habitat Suitability Models (hereafter HSM) were used where we had adequate data and confidence in data interpretation. This was supported by Zonation, a prioritisation tool.
2. Aquatic Values Identification and Risk Assessment (hereafter AVIRA) was utilised where insufficient data created less confidence in interpretation.
3. A hybrid data driven approach was used for birds and frogs.

An overview of these are provided below (Table 1 and Boxes 2- 5) with specific information related to how these tools were applied to the key values and conditions outlined in their respective sections.

Table 1. Approaches used for target setting.

Steps	Key values for wetlands (Vegetation, birds, frogs, fish and amenity, community connection and recreation)	Key values for estuaries (Vegetation, birds, fish and amenity, community connection and recreation)	Key values for rivers			
			Fish, platypus, macroinverte-brates	Vegetation	Frogs and birds	Amenity, community connection and recreation
Key value status	Aquatic Value Identification Risk Assessment (AVIRA)	Aquatic Value Identification Risk Assessment (AVIRA)	Habitat Suitability Models (HSM)	Spatial data and expert opinion	Spatial data	Community perceptions of waterways
Threat analysis	AVIRA and expert opinion	AVIRA and expert opinion	HSM models and data	Data and expert opinion	Expert opinion	Data and conceptual models
Current trajectory for waterway conditions and key values	AVIRA and expert opinion	AVIRA and expert opinion	HSM models and expert opinion	Data and expert opinion	Expert opinion	Data, conceptual models and collaboration
Long-term targets for conditions and values	AVIRA and expert opinion	AVIRA and expert opinion	HSM Zonation and expert opinion	Existing targets and Zonation	Expert opinion and data analysis	Conceptual models and collaboration
10-year performance objectives	Risk-based AVIRA	Risk-based AVIRA	Zonation and internal experts	Risk-based	Cross checking with Zonation and review of existing *Healthy Waterways Strategy* priority areas	Conceptual models and collaboration

Box 2: Habitat Suitability Models

Habitat Suitability Models (HSM's) are spatially-explicit quantitative models that help prioritisation of management actions in the Strategy.

A HSM is used to predict the probability of a family or species presence or absence at a particular location. Environmental characteristics like temperature, streamside vegetation width, mean annual flow and Attenuated Imperviousness are important inputs to the model that explain predicted presence or absence.

HSM development had additional benefits of being able to iterate various condition scenarios (e.g. Current, Forecast Future under Business as Usual and long term setting) for instream key values.

With respect to the Strategy development process, the macroinvertebrate, fish and platypus HSMs were used to:

1. Illustrate where instream taxa occur in the landscape;
2. Develop indices/summary measures to represent the biodiversity value of macroinvertebrates and fish;
3. Illustrate and assess the impacts on patterns of habitat suitability of instream taxa arising from different scenarios of land-use and climate change (see Section 2);
4. Develop a biodiversity priority rank map for the streams in the Melbourne region using the conservation planning software tool, Zonation sensu (Moilanen, Leathwick et al. 2008); and
5. Develop a quantitative action prioritization map again, using Zonation (sensu (Moilanen et al., 2014; Moilanen, Leathwick, & Quinn, 2011); see Section 3).

HSM's were developed for 52 macroinvertebrate families, 13 native fish species, and platypus.

Models were used to explore the likely outcomes of stream biodiversity responses against different climatic and land-use scenarios resulting from climate change and urbanisation and also mitigating actions such as riparian revegetation, stormwater management and the removal of fish barriers.

The power of HSM lies in the ability to use existing data to extrapolate predictions to un-sampled locations (Figure 8).

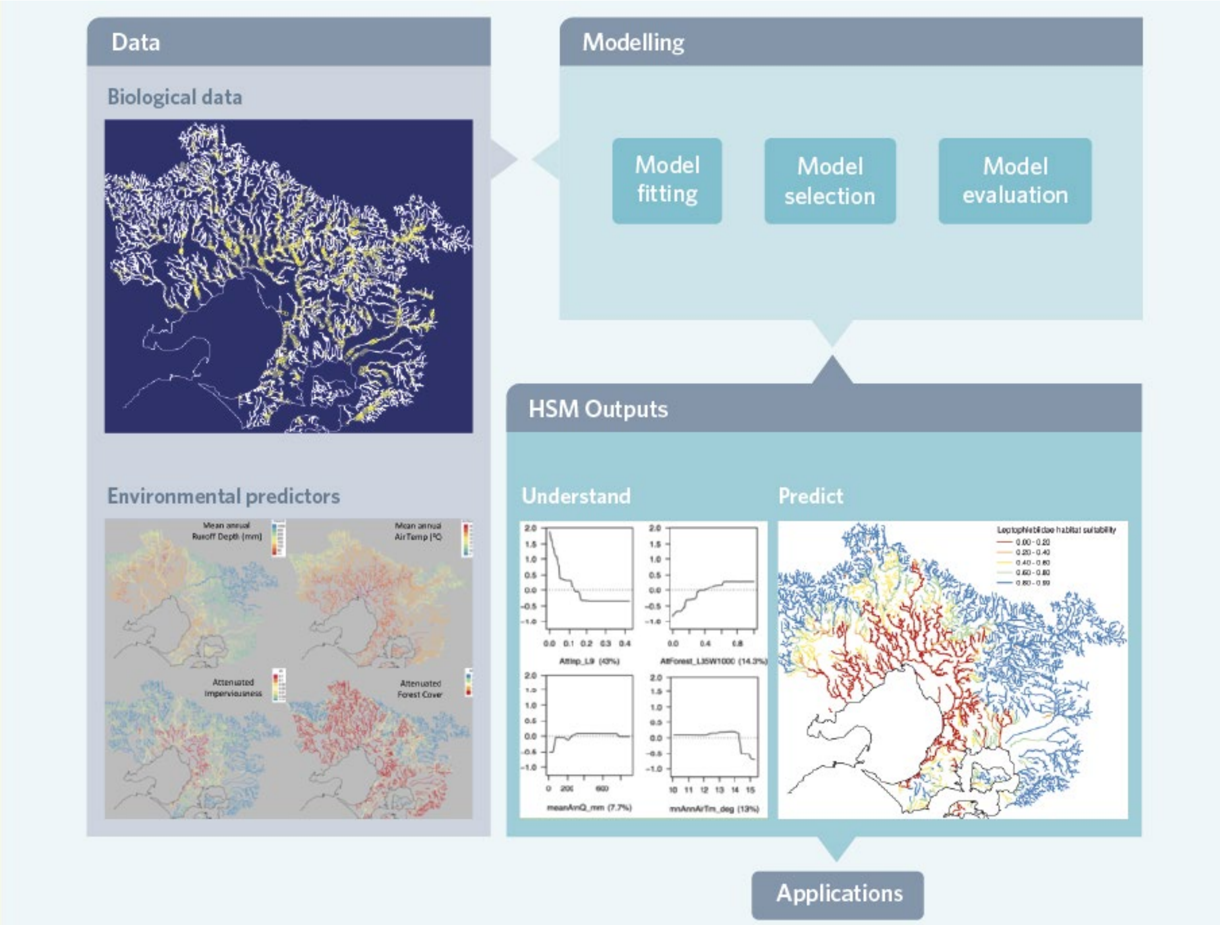


Figure 8. Overview of the steps in the habitat suitability modelling process

Box 3. Zonation

Zonation was the spatial prioritisation tool used to focus where investment could be made in order to achieve best outcomes at lowest cost – in a reproducible and robust fashion. Zonation allows spatial prioritisation of management works simultaneously for many species, ecological communities or ecosystem types to support persistence. It uses three principals:

1. Representativeness - representing the full variety of biodiversity in the study area
2. Irreplaceability - prioritising unique or rare species occurrences without which we would fail to achieve *representativeness*
3. Complementarity - ensuring that the selection of additional sites complements or adds new species rather than duplicating the species present in sites already selected

The tool iteratively removes the least valuable planning units from the landscape while minimizing marginal loss of conservation value and accounting for connectivity needs and taxa/species weights. This process connects landscape structures, with increasingly important areas of species habitats (or distributions) remaining last. The Zonation solution is a ranked list of spatial priorities across the study area that is easy to visualise and interpret.

It can visualised in a two-step process:

1. Optimal action for each reach in the MW area (Figure 9). See for the optimal actions which include:
- SQ: Status Quo, RV20: Riparian Revegetation to 20 m width,
- SW2: treat all *future* impervious cover such that Attenuated Imperviousness is maintained at 2016 levels,
- SW1: treat all *existing* and *future* impervious cover such that Attenuated Imperviousness is effectively zero,
- RV20_SW2: Riparian Revegetation to 20 m width *and* treat all *future* impervious cover such that Attenuated Imperviousness is maintained at 2016 levels,
- RV20_SW1: Riparian Revegetation to 20 m width *and* treat all *existing* and *future* impervious cover such that Attenuated Imperviousness is effectively zero.

2. Prioritisation of management actions. Figure 10 shows the priority for management actions across all waterways in the region where orange lines represent low priority and purple lines represent high priority for investment.

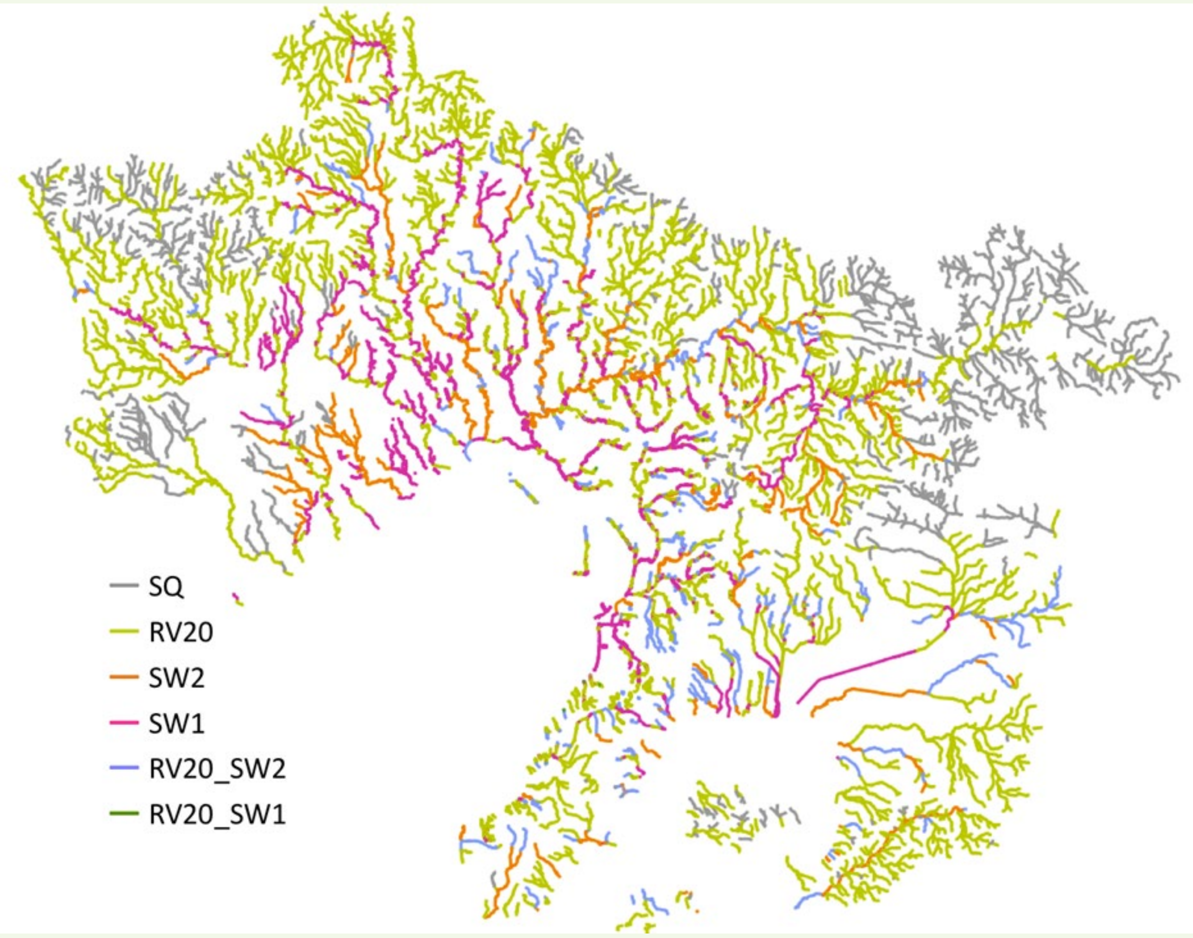


Figure 9. The 'optimal' action 'applied' at each of the 8,233 reaches in the MW region after identifying the most cost-effective action and including the various customisations.
Refer to text above for description of the actions in the map legend.

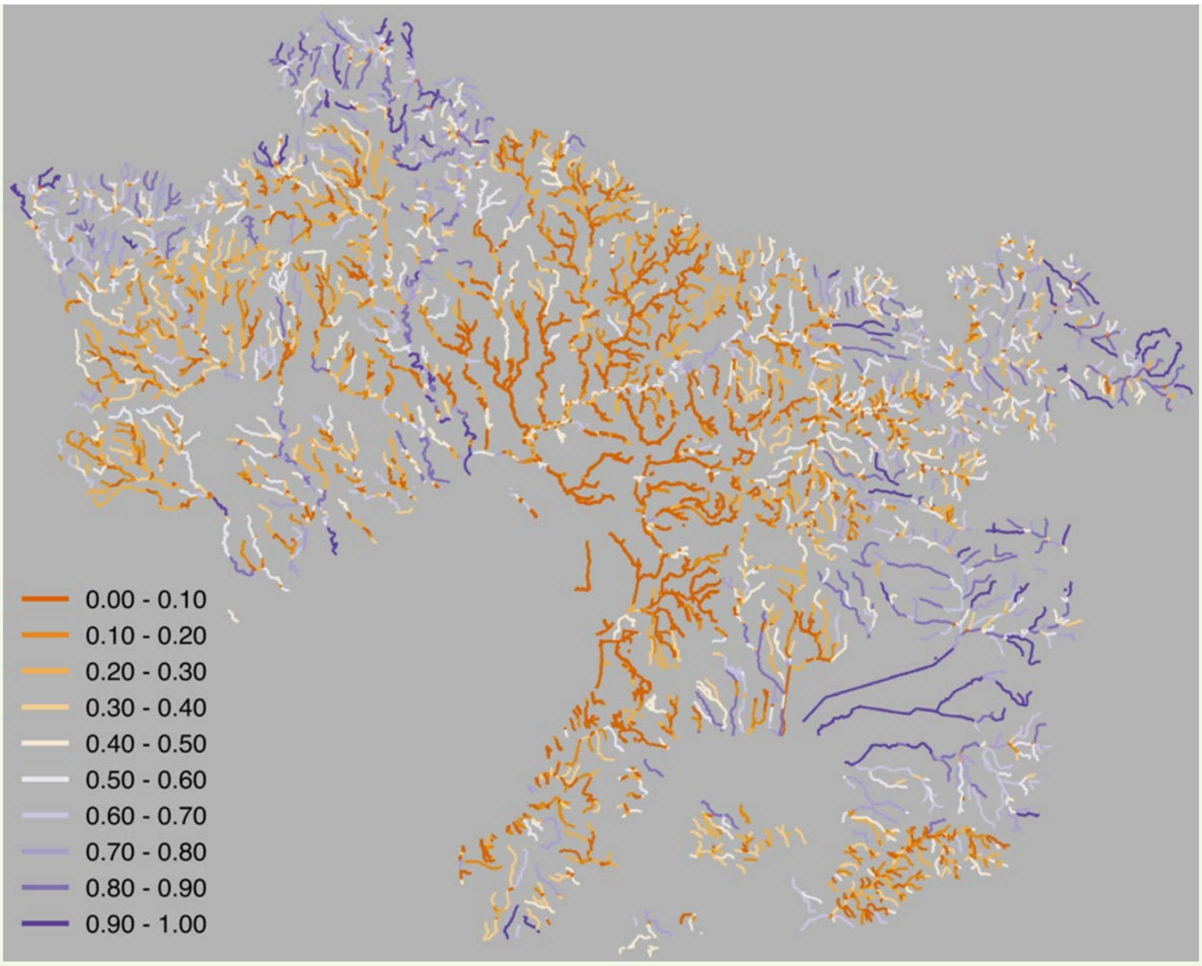


Figure 10. The initial output of continuous ranking of spatial priorities (0 = lowest prioritisation 1 = highest prioritisation) produced by Zonation.

Box 4. Aquatic Value Identification and Risk Assessment database

The Aquatic Values Identification and Risk Assessment (AVIRA) database tool uses an asset based approach that focuses on reducing the threat to a particular asset such as rivers, wetlands and estuaries (DELWP 2015). It also directs investment towards high value areas (rather than in areas in poor condition) and provides the basis for identifying priorities for investment.

AVIRA was developed for DELWP by Riverness to assist Victoria's catchment management authorities in developing their regional waterways strategies. The AVIRA database contains information about the values and threats associated with selected assets using information from monitoring programs such as the Index of wetland Condition (IWC), Index of Stream Condition and Index of Estuary condition. In the Melbourne region, there are gaps in the data associated with these monitoring programs so supplementary information is used in some cases.

The AVIRA framework considers environmental, social and economic values for each waterway asset type (rivers, estuaries and wetlands) and using a consistent process as outlined in the AVIRA manual (DELWP 2015) and assigns a score to the value based on metrics that includes both descriptive and numerical values. The broad threats to the values are identified using a similar metric approach followed by an assessment of the level of risk those threats pose. The level of risk is determined by a matrix of threat score vs value score and this also guides appropriate management response (Figure 11).

		Value Score						
		0	1	2	3	4	5	No Data
Threat Score	No Data	NR No Priority Action	VL No Priority Action	L Fill Data Gap	M Fill Data Gap	H Fill Data Gap	VH Fill Data Gap	VH Fill Data Gap
	5	NR No Priority Action	VL No Priority Action	L Investigate	M Investigate	H Reduce Threat	VH Reduce Threat	VH Fill Data Gap
	4	NR No Priority Action	NR No Priority Action	VL Investigate	L Investigate	M Reduce Threat	H Reduce Threat	H Fill Data Gap
	3	NR No Priority Action	NR No Priority Action	NR No Priority Action	VL Investigate	L Reduce Threat	M Reduce Threat	M Fill Data Gap
	2	NR No Priority Action	NR No Priority Action	NR No Priority Action	NR No Priority Action	VL Protect	L Protect	L Fill Data Gap
	1	NR No Priority Action	NR No Priority Action	NR No Priority Action	NR No Priority Action	NR No Priority Action	VL Protect	VL No Priority Action
	0	NR No Priority Action	NR No Priority Action	NR No Priority Action	NR No Priority Action	NR No Priority Action	NR No Priority Action	NR No Priority Action

Figure 11. Risk level and management response for existing threats (DELWP 2015).

Box 5. Hybrid approach

A hybrid data driven approach was used for birds and frogs due to HSM's and AVIRA being unsuitable frameworks with which to apply the available data sets to determine value and condition. The approach centred on using the spatial datasets and applying a framework of bespoke metrics to determine value status supplemented with expert opinion. Further information is provided in the bird and frog values sections in this document.

Scenarios

To understand how improving waterway values might contribute to long-term targets, two planning scenarios (or trajectories) were prepared and tested for each waterway – Current Trajectory (also referred to as Business as Usual (BAU) trajectory) and long term targets (target Trajectory). The scenarios estimate the likely waterway outcomes with two different levels of management effort, policy and climate variables. These trajectories demonstrate that a step-change in waterway management is required over the next 10 years, to prevent broad scale loss of waterway values.

Many assumptions have been built into the scenario planning, including that climate change predictions will affect our waterways (in line with the principles outlined in the Climate Change Act (2017) and that the current urban growth boundary will reach 'ultimate' development within the next 50 years.

Current trajectory

This scenario represents the expected change in waterway health if current programs and approaches continue, otherwise referred to as the 'business as usual' approach.

This scenario indicates a worsening of key values across the majority of the region's waterways' key values.

A key learning from this scenario is that even with the extensive existing effort and resources contributed by waterway managers, agencies and community, it will be extremely difficult to maintain all the waterway values everywhere. This knowledge provides a definitive call to action, and confirms that aligned, increased and collaborative efforts will be required over the next 10 years.

Target trajectory

This scenario represents what can be achieved with an increase in coordinated, collaborative and prioritised effort. It is the scenario that the Strategy partners have agreed is required. Maintaining, and where possible improving, waterway health is what the HWS 2018 proposes to achieve. This 'target trajectory' includes assumptions on policy allowing increased standards for stormwater management, increased resources for waterway management, willingness to take collaborative actions, and that it is feasible to establish continuous vegetation buffers along the majority of waterways.

Assessment and modelling of the scenarios was undertaken at a range of different scales for key values and conditions for each waterway type. The reason for this is that, for example, platypus, fish and macroinvertebrates in streams were assessed for 8000+ reaches, which was informed by stormwater condition assessed from 16,346 sub-catchments. In comparison, birds and frogs for streams were assessed at the scale of 69 sub-catchments, informed by extensive monitoring records from multiple sites across each sub-catchment.

Although data is available at a range of scales for conditions and values, all reporting in the Strategy has been provided at:

- Rivers: Catchment (5) and sub-catchment scale (69 sub-catchments), with the exception of Amenity, Community Connection and Recreation which are reported at catchment scale.
- Wetlands: Catchment (5) and individually/complexes (81)
- Estuaries: Catchment (5) and individually (30)

Setting targets for the strategy was a top down - bottom up approach. Collaborative workshops were used to develop goals and actions for each of the 5 catchments and from this tools and data were used to help prioritise actions and set SMART targets for each of the environmental values and conditions.

To set meaningful long term key value targets, an understanding of the current trajectory of each value was required. The main drivers in this region which, under current policies will be a major threat to waterway health, are climate change and urbanisation. The quantitative models developed for instream values in particular are able to predict changes to condition based on these threats and have been very useful in both demonstrating the future impact as well as predicting the level of effort required to overcome these pressures. The power of these trajectories is in communicating the outcome if actions to address the impacts are not undertaken (Figure 12).

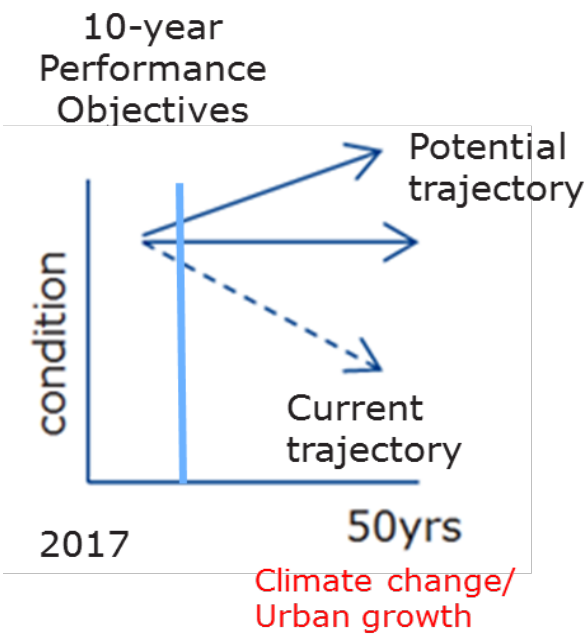


Figure 12. Diagram depicting current and potential trajectories.

1.6 References

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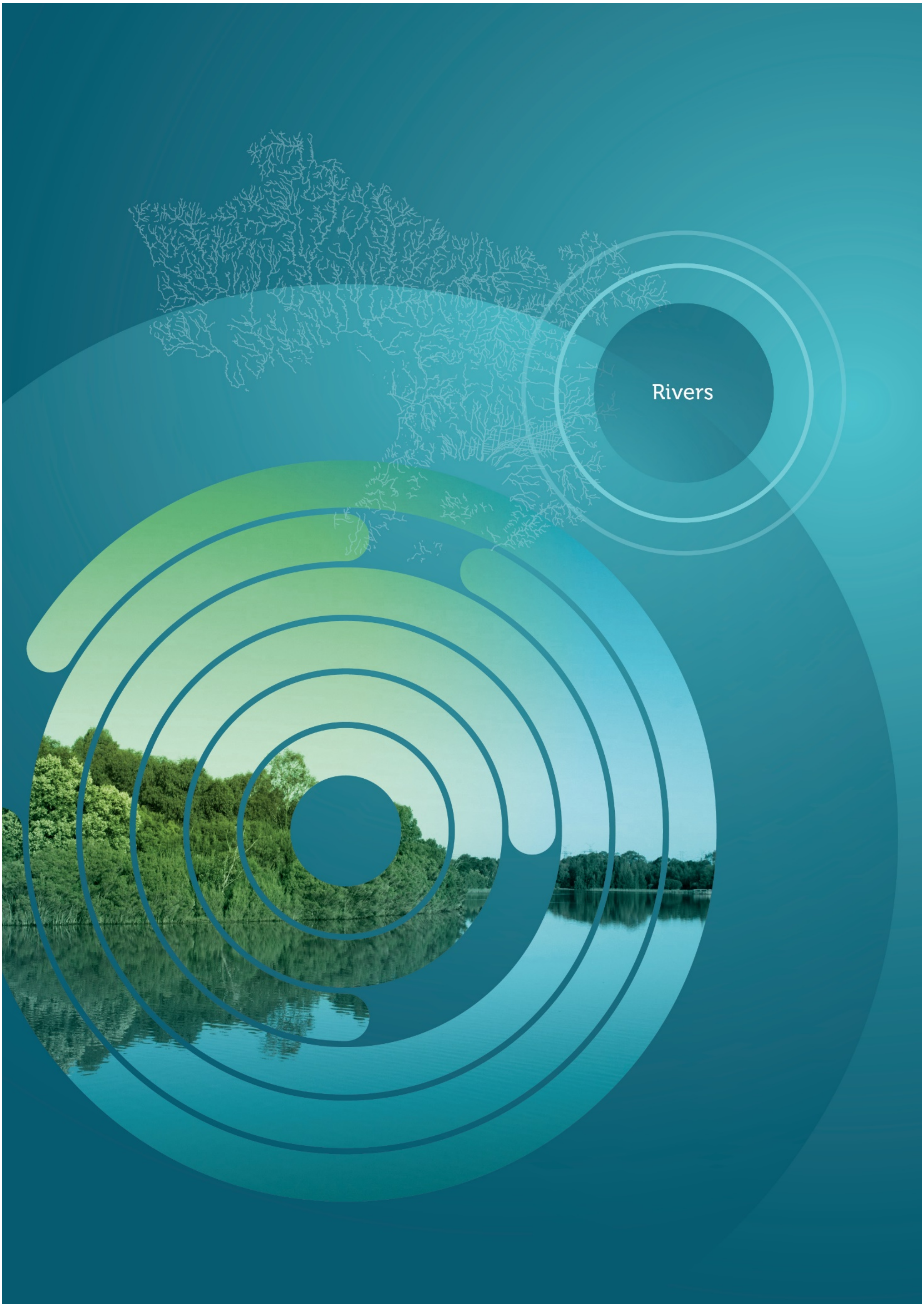
Rivers

2 River Values

The term rivers refers to rivers, creeks, and smaller tributaries, including the water, bed, banks, and adjacent land (known as riparian land). Rivers can vary in size and can contain water all year around or can periodically dry out. Many of the region's 25,000 kilometres of rivers are highly modified from their natural state due to human intervention. Despite this, modified rivers still provide connections across the landscape, habitat for wildlife and are highly valued and extensively used by local communities.

The rivers in the region are located in five major catchments; Werribee, Maribyrnong, Yarra, Dandenong and Westernport & Peninsula. These catchments are divided into sub-catchments and sometimes reaches to provide a scale appropriate to measure change in key values.

A summary of the key environmental values in rivers and their corresponding environmental conditions referred to in this document is provided in Figure 13.

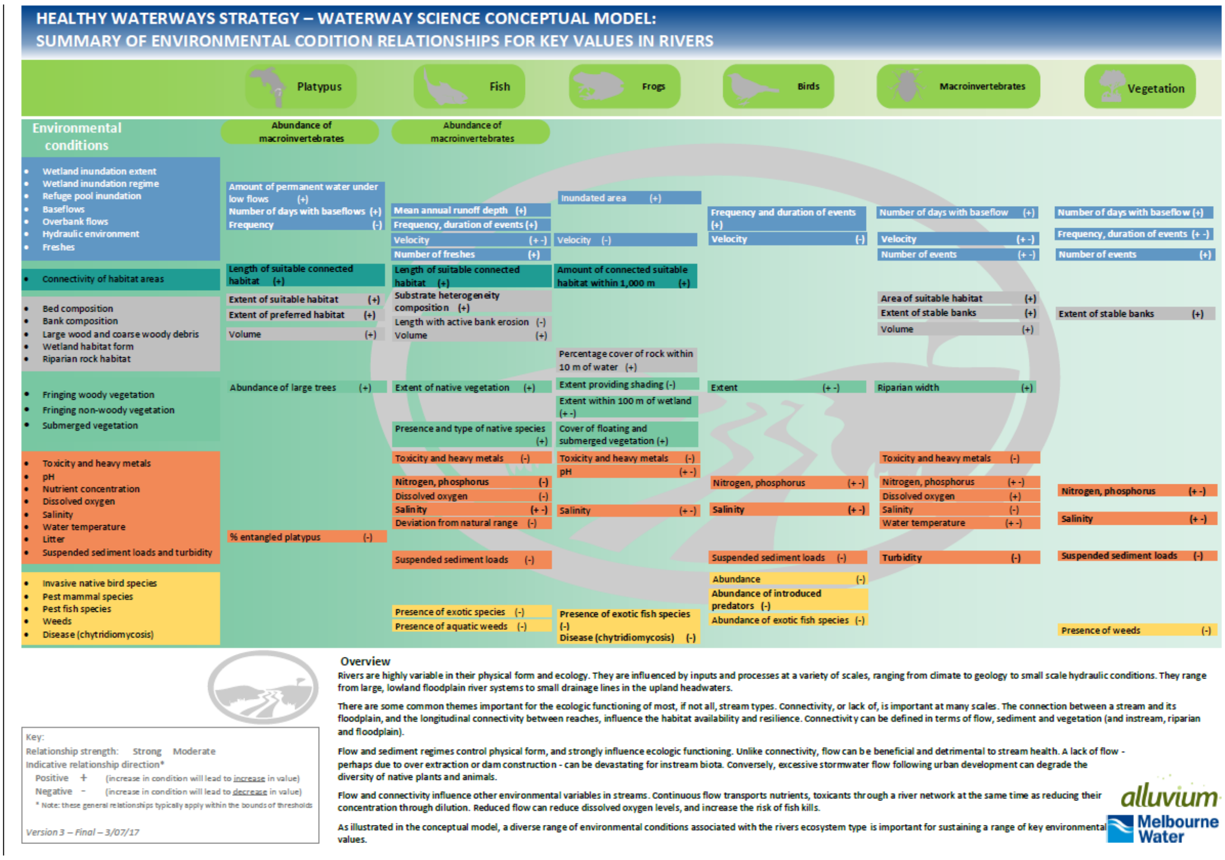

Figure 13. Summary of environmental values and the condition relationships for rivers (Alluvium 2017).

A range of approaches and tools were used at different scales for the key values to establish current state and set 50 year targets for the Strategy. Details of the method for each key value is described in the sections below.

2.1 Vegetation

2.1.1 Defining our Vegetation Value

Riparian and aquatic vegetation are important components of a healthy, functioning waterway. Vegetation provides a number of functions important to river health including:

- bank stabilisation and erosion control (including coasts)
- improvement to water quality through buffering and natural filtering
- shade and regulation of water temperature
- shelter and provision of habitat and connectivity for wildlife and pathways of gene-flow through the landscape
- provision of organic matter fundamental in the food chain of waterway ecosystems.

The HWS 2018 identifies vegetation as a key value as well as a supporting condition for other key values (e.g. birds, macroinvertebrates etc). The notion of vegetation as a value describes it's worth or merit, which is based on a belief system that society holds. For example, native vegetation has value due to sensory, aesthetic, landscape connection and naturalness perceptions. Vegetation as a condition describes the quantity state of a value and is based on empirical facts that can be observed and tested (e.g. extent and quality).

A conceptual model for vegetation as a key value was developed representative of the current scientific understanding at the time of development (Alluvium 2017). The model documents and describes the relationships between environmental conditions and vegetation key environmental value, including relevance to rivers, estuaries and wetlands, and with reference to landscape context, land use, urban growth and climate change (Figure 14).

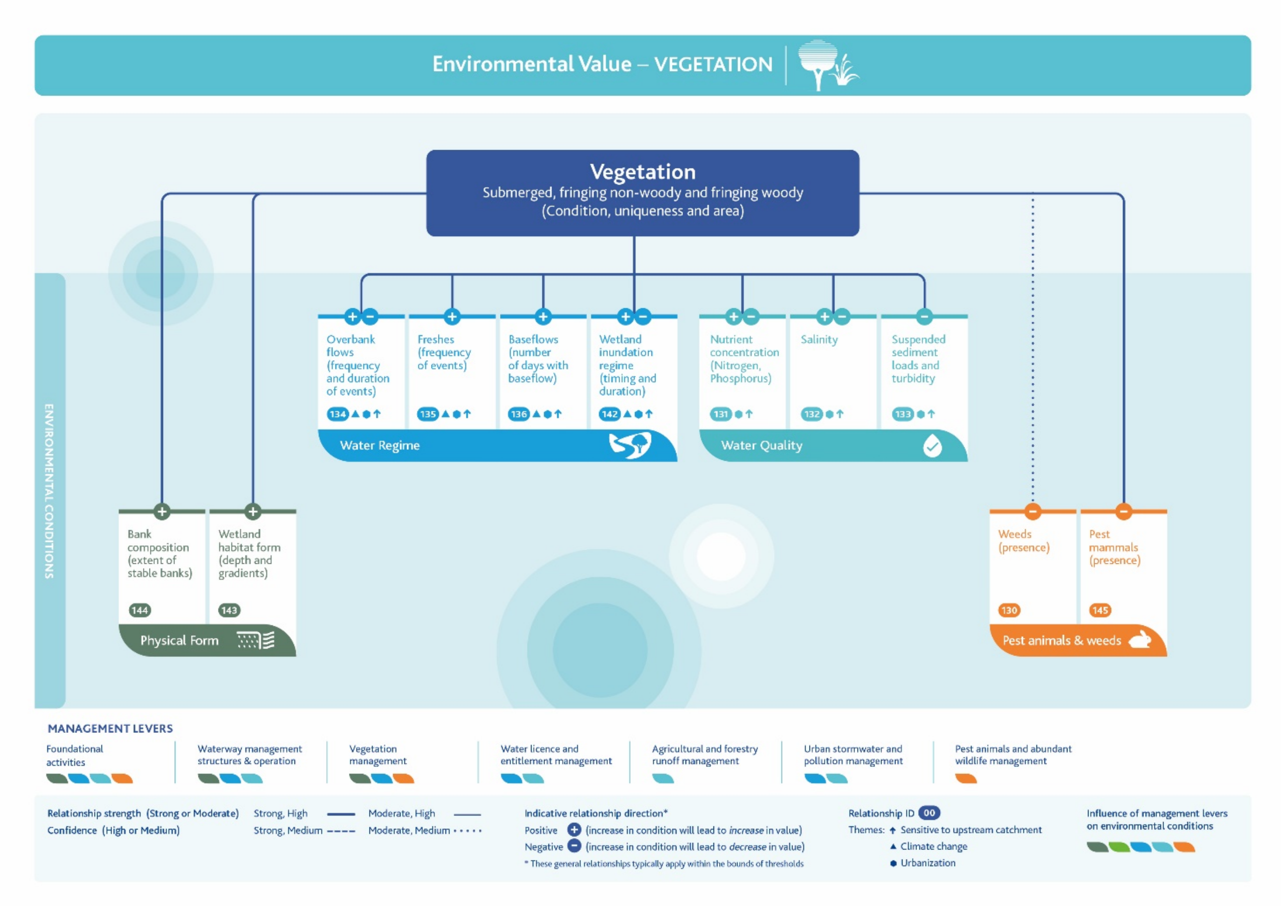

Figure 14. Conceptual model for vegetation as a key value (Alluvium, 2017)

2.1.2 *Available data and condition metric used for vegetation*

Vegetation data

A Melbourne Water Working Group worked alongside vegetation experts from GHD to oversee the vegetation value and condition metrics developed for the Strategy. Based on a review of the approach used in the previous HWS, vegetation value was more clearly defined in the Strategy using measures of naturalness and uniqueness (GHD 2018).

Vegetation data used to measure naturalness and uniqueness exists in several forms which are listed below.

Bioregions: Bioregions are a landscape based approach to classifying the land surface using a range of environmental attributes such as climate, geomorphology, lithology and vegetation. Assessments of native vegetation are routinely undertaken in a bioregional context. There are 28 bioregions within Victoria and 7 within the Port Phillip and Westernport region.

Ecological Vegetation Classes (EVCs) are aggregations of floristic communities that are defined by a combination of floristics, life form, position in the landscape and an inferred fidelity to particular environments.

Victorian Biodiversity Atlas (VBA) The VBA is a foundation dataset of flora and fauna species that feeds into some of the many biodiversity tools used in decision making. It includes bio conservation status.

The conservation status of vegetation in Victoria is classified by Bioregional Conservation Status and is included on DELWP's 'NatureKit' system (DELWP 2017). Threatened vegetation communities may also be listed under the Victorian *Flora and Fauna Guarantee Act (1988)* and the Commonwealth Flora and Fauna Guarantee Act 1988.

Rarity refers to the conservation status of waterway dependent vegetation communities and their component flora and fauna (DELWP 2015). The State government database "Actions for Biodiversity Conservation (ABC) assigns management priority to sites with threatened species. Primary sources of plant species' conservation status are DELWP's Advisory list (DEPI 2014) and the Victorian Biodiversity Atlas (DELWP 2017). Both sources include species recognised or legally protected in Victoria or nationally.

Vegetation Visions: Prior to the last HWS a number of data layers for waterways were created known as the Waterway Visions (see
Box **6**) The Vegetation Visions (2009) covered the majority of main waterways across the region but many gaps existed, particularly in the west and far south east. During the preparation of the HWS 2018 the Vegetation Visions were updated to include data that had been collected over the life of the intervening period and to fill some of the gaps in the data where possible.

Box 6: The Melbourne Water 2030 Visions

The Healthy Waterways Visions were developed between 2009 and 2013 and were tools of the Healthy Waterways Strategy (Melbourne Water 2013) to communicated Melbourne Water's longer term aims for the form and function of waterways in the Port Phillip and Westernport region by 2020.

The visions were created to convey an agreed and consistent outcome for waterways to the broad audience involved in managing waterways across agencies, industry and the community. The visions cover 'major waterways' in the Port Phillip and Westernport region (approx. 5500km) and consider six characteristics of a healthy waterway: stream form, riparian vegetation (quality and species), flow, water quality, waterway corridor and fauna.

Development of the Vegetation Quality Visions

The Vegetation Quality Visions were the first Vision developed in 2009. The vegetation quality vision is designed to indicate the riparian vegetation quality that can be achieved and maintained along Melbourne Water's waterways assuming current levels of revegetation and maintenance are continued. For each vegetation quality level, the following characteristics are described:
- Vegetation structure
- Species composition
- Instream vegetation

- Vegetation continuity and connectivity
- Weediness
- Regeneration
- Typical land use setting
- Suitable weed and vegetation management techniques to achieve the vision

Descriptions of vegetation quality levels and a comparison table are available (see 2.1.6)

The vegetation quality visions can be used in conjunction with other resources to ensure the desired outcomes of a range of potential projects are consistent with the intended vision.

The 2009 and potential (2030) vegetation quality levels were determined via a series of workshops with representatives from River Health, Capital, Maintenance and Minor Capital, Stream Frontage assessors and independent experts. The waterways were rated from 1 (very low) to 5 (very high) for both current (2009) and potential (2030) vegetation quality using the following ratings:

1. Very Low Riparian vegetation is highly modified, predominantly comprising exotic species.

2. Low Riparian vegetation is highly modified, fragmented and meets social and amenity requirements

3. Medium Riparian zone consists of fragmented relevant EVC vegetation.

4. High Riparian vegetation is relatively intact with structural elements present with high connectivity.

5. Very High Riparian vegetation is intact with all structural components present and very high connectivity

More detailed information is provided to describe and support definition of these ratings. (see section 2.1.6)

Inventory data Melbourne Water has conducted many detailed vegetation surveys for a variety of purposes including areas planned for development, condition information for initiation of capital projects or other management strategies etc. A standard data collection process has recently been established to enable this data to be stored centrally and accessed spatially. This data has been used in the updating of the vegetation visions. This data was not specifically used in the HWS – other than as supporting information for determining broad weed threat ratings at a sub-catchment scale.

ISC The Index of Stream Condition is a statewide condition monitoring assessment which was undertaken in 1999, 2004 and then again in 2010. The Streamside Zone sub-index is a useful indicator of riparian vegetation condition. It measures characteristics of the woody vegetation within 40 metres of the river's edge, including width, fragmentation, overhang, cover of trees and shrubs, structure, large trees and weeds. Unfortunately the coverage of this monitoring within the Port Phillip and Westernport region is patchy, meaning it does not provide a comprehensive overview.

Vegetation extent data refer to veg extent section on available data. Due to timing – extent data was only available for Maribyrnong catchment. A region wide data set now exists and updated value scores could be developed. Riparian evergreen vegetation >2m tall was mapped throughout the region for 2009 and 2016.

The data used to define the current status of vegetation value was EVCs including the conservation status, individual records of rare or threatened species, the vegetation vision data and vegetation extent data. This information was brought together into the vegetation conditions metric as outlined below.

Vegetation condition metric

Two vegetation measures were combined to form the overall Vegetation Value Condition metric; Uniqueness and Naturalness. Uniqueness is a qualitative indicator consisting of a score of rarity based on known benchmarks such as EPBC listing etc, while naturalness is a quantitative indicator that consists of two components; Vegetation Extent and Vegetation Quality (GHD 2018) (Figure 15). Methods to quantify these are outlined below.

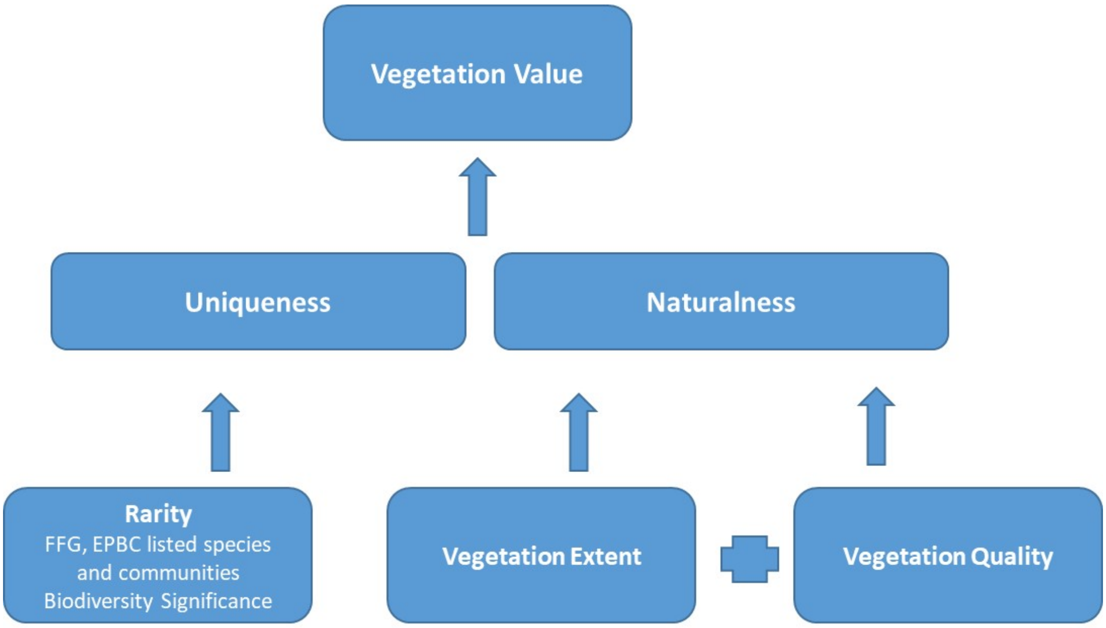

Figure 15. Framework for the vegetation value metric

Uniqueness is defined as rarity and consisted of the bioregional conservation status of the vegetation community and/or occurrence of rare or threatened species.

The criteria for determining uniqueness is displayed in Table 2. A maximum score of 5 can be achieved if all 3 categories are triggered within the reach. Table 3 then assigns a value measure to the cumulative score.

Table 2. Uniqueness criteria for vegetation value scoring.

Score	Uniqueness criteria (based on 200m buffer)
2	Bioregional conservation status endangered or vulnerable
2	Listed species EPBC or FFG
1	BCS depleted or low

Table 3. Uniqueness value scoring and categorisation

Uniqueness Value category	Cumulative score
Very low	1
Low	2
Medium	3
High	4
Very High	5

Stateside datasets (eg VBA) were used to determine the uniqueness scores for each reach based on a 200m buffer along the waterways.

Naturalness was defined by a combination of vegetation quality and extent. Data was generated for these two indicators at the reach scale. The reaches were based on the Melbourne Water reach asset dataset. Reaches vary in length but are on average about 1km.

Vegetation Quality: Melbourne Water's vegetation 2009 vegetation visions was the main source of data used to describe vegetation quality. (see section X for a description of this dataset) Essentially it provides a score based on vegetation structure, species composition and weediness.

Vegetation extent: Ideally this metric would be based around the extent of cover of remaining native vegetation – using EVCs as a benchmark. However due to time limitations a simple canopy cover assessment was undertaken using existing data. The methods to derive canopy cover data are described in section 3.3.1This data was used to determine the percentage of the reach which contained canopy cover within the 200m buffer. The following categories were used (see Table 4):

Table 4. Vegetation extent scoring

Amount of canopy cover within a 200m buffer from the centreline	Category	Score
80-100%	Very High	5
60-80%	High	4
40-60%	Medium	3
20-40%	Low	2
0-20%	Very Low	1

Naturalness ratings were then calculated by combining the vegetation quality and vegetation extent ratings using a lookup table that rated naturalness of vegetation from very low to very high (Table 5).

Table 5. Vegetation naturalness rating

Naturalness		Vegetation Extent					
		Very Low	Low	Medium	High	Very High	No Data
Vegetaion Quality	Very Low	Very Low	Very Low	Very Low	Very Low	Low	Very Low
	Low	Very Low	Low	Low	Low	Medium	Low
	Medium	Low	Medium	Medium	Medium	High	Medium
	High	Medium	High	High	High	High	High
	Very High	High	Very High	Very High	Very High	Very High	Very High
	No Data	Very Low	Low	Medium	High	Very High	

Uniqueness and Naturalness ratings were combined using a look up table to determine the overall Vegetation value state (Table 6).

Table 6. Look-up table for calculating vegetation value based on naturalness and uniqueness scores

Vegetation Value		Uniqueness					
		Very Low	Low	Medium	High	Very High	No Data
Naturalness	Very Low	Very Low	Low	Low	Medium	High	Very Low
	Low	Low	Low	Low	Medium	High	Low
	Medium	Medium	Medium	Medium	Medium	High	Medium
	High	Medium	Medium	High	High	Very High	High
	Very High	High	High	High	Very High	Very High	Very High
	No Data	Very Low	Very Low	Low	Medium	High	

2.1.3 Setting vegetation scenarios

Current state

Using the above methodology, vegetation value data (from very low to very high) was mapped at the reach scale and provided as information to the co-design workshops and stored on the HWS website as background information.

For the Strategy and the purpose of deriving trajectories and targets, the value data was averaged to the sub-catchment scale – using a length weighted average.

Forecast current trajectory under a 'business as usual' scenario

A long term 'business as usual' trajectory was based on rules and assumptions around the likely impacts of significant future threats like climate change, urbanisation and invasive plants and animals. It was based on expert opinion which drew on existing studies into climate change impacts (e.g. South West Climate Change Portal ((2014), (CSIRO 2016) and future urbanisation predictions (see HSMs). Further assumptions are outlined in the vegetation environmental conditions sections.

Long term target setting trajectory

Long-term targets for vegetation value were based on the vegetation condition targets set for vegetation quality and vegetation extent. The methods for these are described within the environmental condition sections 3.3 and 3.4.

2.1.4 Priority conditions, threats and management interventions

Priority conditions

The main two long term condition targets and associated 10 year performance objectives which drive the long term vegetation value targets are:

- Vegetation Extent (describes the length and width of riparian buffers along waterways)
- Vegetation Quality (Melbourne Water Vegetation Vision data - describes the quality of vegetation along waterways – with an aspect of patch size/extent embedded in the method)

The approach to developing long term targets and associated 10 year performance objectives for these environmental conditions is detailed in sections 3.3 and 3.4.

Priority vegetation threats

Threats to riparian vegetation were identified through a review of Melbourne Water HWS Conceptual Models (Alluvium 2017) and AVIRA (DELWP 2015) riparian vegetation threats. AVIRA categorises the association between a specific threat and values as either high, medium or low. This approach provides a screening process for the associated risk analysis method in AVIRA. To define threats to vegetation we were only interested in high association threats as they are more likely to pose a risk to vegetation. The high association threats were reviewed in workshops with Melbourne Water staff 8 February 2018. Identified high association threats are:

- Pest Plants can significantly alter vegetation structure and species composition of native vegetation communities
- Pest Animals including deer, rabbits and other species impact vegetation through grazing, trampling and other disturbance factors
- Stream Flows impact riparian vegetation in a number of ways including impacts to flow regime where components such as low flows, bank full and over bank flows reduce vegetation disturbance, recruitment impacts species composition and structure. Flows from urban areas alter the natural flow regime resulting in unnaturally high flows for a short period after rainfall events impacting natural channel processes and scouring.
- Urbanisation impacts riparian vegetation through loss of habitat from urban encroachment, use of waterway corridors for infrastructure with vegetation removed in accordance with planning requirements.
- Bed and Bank Instability can result in physical loss of riparian vegetation through bank slumping and erosion processes.
- Livestock access through uncontrolled management of riparian areas alters vegetation structure and composition through grazing of vegetation, physical trampling (of vegetation and introduction of weed species) and contributing to bed and bank instability
- Recreational access from unauthorised access of walkers, mountain bikes, trail bikes and 4WD vehicles impacts vegetation through disturbance, loss of habitat, trampling, introduction of weed species and long term can alter the structure and composition of vegetation communities
- Vegetation width where the width of the riparian zone is reduced will impact the natural extent of vegetation communities impacting its ecosystem function and services they provide.
- Water Quality (salinity) from changed landuse practices increases soil and water salinity (secondary salinity) altering community composition favouring more salt tolerant species.
- Climate Change impacts riparian vegetation through increased average and summer temperatures and reduced rainfall. Impacts maybe direct (temperature and rainfall) or associated with reduced stream flows and more frequent extreme events
- Extreme Events (fire, flood, temperature) are closely associated with climate change and are predicted to increase in severity and frequency as the impacts of climate change increase.

Priority management interventions for vegetation

The main interventions that can be employed to protect or improve vegetation values include:

- Revegetation
- Pest plant and animal control
- Stock exclusion fencing
- Mitigating impacts of urbanisation (eg through WSUD)
- Improving flow regimes
- Erosion control

2.1.5 Key assumptions and improvement opportunities

A key assumption was made that a minimum vegetation quality rating of 3 is required to provide adequate riparian and instream habitat for other values. This assumption is based on a level 3 quality having at least reasonable over and mid story vegetation of a suitable type which is going to provide many of habitat requirements of aquatic fauna and ecosystem functions such as shade, contributions of organic matter and large woody debris etc.

Significant knowledge gaps were identified in headwater streams where data and knowledge of vegetation quality was limited. These areas were identified through querying the data, comparing it to the headwater streams layer and sense checking and prioritising with on-ground staff. Where these existed an additional performance objective was included eg *"Improve understanding of the extent, composition and condition of high and very high quality vegetation, and effectively monitor and manage both values and threats."*

Improvement opportunities for riparian vegetation data and monitoring will be developed through the HWS MERI Framework and the associated Rivers Monitoring and Evaluation Plan (MEP).

2.1.6 Further Resources

Melbourne Water Vegetation quality visions http://inflo/inflo/cs.exe/link/10692363

2.1.7 References

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2.2 Riparian Birds

2.2.1 Defining the Riparian Bird Value

The 2013 *Healthy Waterways Strategy* (Melbourne Water 2013) separated the community's Bird Value into "wetland birds" and "riparian birds". The 2018 HWS defines the community value of riparian birds to be the pleasure these bring through their colour, calls, flight and other behaviours. Ecosystem functions, such as pollination, seed dispersal and regulation of some insect populations are important but probably not recognised by most residents. Therefore, the riparian bird value is taken to be native species richness and abundance. This incorporates underlying factors such as the need for persistent populations that are resilient and self-sustaining in the long-term through drought, storm, flood, fire, epidemics and climate change.

A conceptual model for birds as a key value was developed representing our scientific understanding at the time of the Strategy development (Alluvium 2017). The model documents and describes the relationships between environmental conditions and bird communities, including relevance to rivers, estuaries and wetlands, and with reference to landscape context, land use, urban growth and climate change (Figure 16).

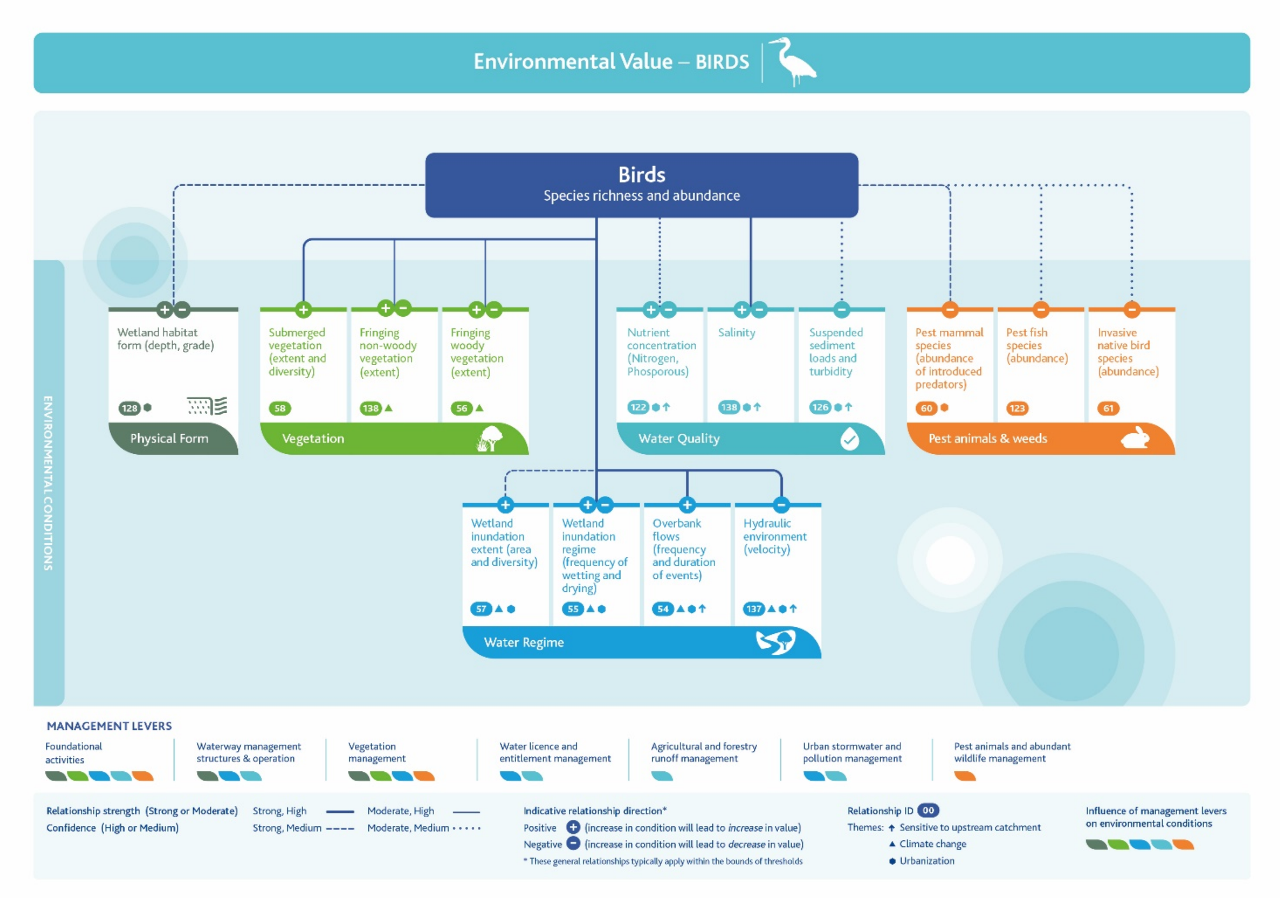

Figure 16. Conceptual model for bird key values (Alluvium, 2017)

Analysis and some modelling of Birdlife Australia's extensive bird data set was used to derive a list of expected riparian species for each of our major catchments (AECOM 2012a).

2.2.2 Available data and condition metric used for riparian birds

Riparian bird data

Melbourne Water works with Birdlife Australia to ensure over 200 sites in our region are visited by birdwatchers trained to report the results of their bird surveys. Birdlife Australia recruit teams of volunteer birdwatchers for nominated sites, produce training materials and collate and audit their data before sending this to Melbourne Water.

In the past five years there have been close to 10,000 standardised surveys at 235 sites by trained volunteers. Through Birdlife Australia, access is provided to the entire regional bird count database (not just Melbourne Water surveys). The August 2017 database held 1,918,893 species' records from 135,116 surveys dating from 26 August 1951 to 8 August 2017.

Riparian bird condition metric

There are several possible conditions metrics, or indictors, for riparian bird communities, Table 7 lists those considered.

Table 7. Review of potential metrics for riparian bird communities.

Candidate indicator	How considered in 2013 Healthy Waterways Strategy
1. Breeding success	UNSUITABLE. Lack of robust data on true breeding success (i.e. young raised successfully to adulthood where they join the breeding population).
2. Abundance of individuals	UNSUITABLE. We had limited surveys with quantitative count data, and wished to be able to include the previous 'Bird Atlas' data which are almost entirely presence/absence.
2b. Relative abundance of individuals among species (e.g. proportion of total bird population not of the most abundant species, or proportion of total birds counted that were native species)	UNSUITABLE. While attractive this indicator requires quantitative count data. It is certainly likely to be useful at site scale, where we have quantitative count data, to evaluate works effectiveness.
3. Species richness	SUITABLE. Analysis of bird data by Jamie Mathew (AECOM) shows simple species richness (corrected for survey effort, or number of surveys, affecting the species accumulation curve) was a useful indicator. (AECOM, 2012a, 2012b)
3b. Species richness weighted by reporting rate to include some measure of abundance	SELECTED. But, in addition, a recent paper suggests we might include a function for species' average size to improve the accuracy of reporting rates.(Lee and Barnard, 2016)
4. Persistence of threatened species	We considered including a weighting for threatened species presence. But, at the time the metric was being developed for the 2013 HWS,

Candidate indicator	How considered in 2013 Healthy Waterways Strategy
	this was considered to be taking the bird value beyond Melbourne Water's authorised scope. Including a weighting for threatened species of bird will be investigated.
5. Landscape species	UNSUITABLE. We investigated this option with Andrew Hamer (ARCUE) (Hamer, Ainley and Hipler, 2010).
6. Keystone species	NOT CONSIDERED. Some work in Perth, using Swamp Harrier as indicator of wetland health, was noted but not pursued.
7. Indicator species	Briefly considered selecting indicator species, such as Azure Kingfisher and Eastern Yellow Robin but thought to be too restrictive due to (a) survey effort required and (b) limiting on-ground managers' options and opportunities.
8. Functional diversity – foraging guilds	UNSUITABLE. We investigated this option with Kerryn Herman (Birdlife Australia) but found little reliable response from bird communities to management levers (Herman, 2015).
9. Functional diversity using 'response guilds' as established in work initiated by Croonquist *et al*.	Not properly assessed (Bishop and Myers, 2005; Brooks & Croonquist, 1990; Croonquist & Brooks, 1991; Croonquist & Brooks,1993).
10. Phylogenetic diversity	NOT CONSIDERED (Sebastián-González, & Green, 2016).

The best condition metric would be based upon quantitative count data. But by using presence/absence data many more bird surveys are included than would otherwise be possible. It was only from 1998 onwards that Birdlife Australia surveys regularly record bird numbers counted, rather than simple species lists. A metric based upon species richness allows Melbourne Water to use the vast mass of bird survey data gathered across the Region through the first Birdlife Australia atlas during the 1970s and 1980s.

Utilising only the species presence/absence information from surveys avoids problems of observer skills and bias; and detectability issues related to wind and weather at the time of a survey. Volunteer birdwatchers are generally competent at identifying species. But their accuracy when estimating numbers of birds actually present in vegetated riparian areas will be highly variable according to their skill and experience. Therefore, the riparian bird metric in the Strategy is based on species' presence/absence information.

A list of riparian species of bird was generated from assessment of the entire Birdlife Australia database for the Port Phillip and Westernport Region and modified in light of expert opinion. Preliminary analyses by Jamie Mathew (AECOM 2012) show that species richness using this restricted list of species does correlate to some extent with stream condition (as defined by ISC scores).

The riparian bird community condition score can only be calculated for areas having at least 40 relevant bird surveys since species accumulation curves suggest that 40 surveys are required to record more than 90% of bird species present (AECOM 2012a).

An important consideration in deriving our condition metric was to ensure it would be of use to on-ground managers. Therefore, the reporting rate of each species is considered as a measure of frequency of use of a site. The reporting rate is simply the proportion of surveys at any site during which a species was recorded. Including the reporting rate allows site managers to improve riparian bird condition score by increasing bird usage of a site, and not only by attracting additional species.

The procedure to calculate the riparian bird metric is:

(a) Bird surveys from 1 January 1998 were selected from Birdlife Australia's Bird Atlas data for the Region because this is when the second Australian bird atlas project started (Barrett *et al*. 2003) and when there was a great increase in bird survey records. It was also when bird survey methods were standardised to some extent and fits in well with the start of ISC data collection.

(b) Surveys with certain search type codes (any code other than 1,2 or 5) were removed from the data set. This is to ensure anecdotal and non-standardised surveys are excluded, and that all survey data included are accurate to within hundreds of metres.[1]

(c) Surveys centred on a point within 250 m of a waterway or wetland were then selected. Waterways included all designated waterways and all drains other than concreted ones. The waterway centre line was buffered using:

- DR_Natural Waterways Centreline
- Natural Waterways above MW limit
- DR_Channel_Centreline – but with RC (reinforced concrete), BSPTCH (bluestone pitchers), RCBST (reinforced concrete and bluestone), CONC (unreinforced concrete), CONCRCK, ETHCNC (earthy and concrete) and CONCBS (concrete and bluestone) deleted.

Wetlands included were those in MWWetlands_NoWways:

- Sewage ponds
- DST (sediment traps)
- DUL (urban lakes)
- DWL (wetlands)
- WH (storage dams)
- Natural wetlands >1 ha

[1] Type 1 survey: 20 minute search of a 2 ha area
Type 2 survey: area search within a 500 m radius
Type 5 survey: fixed-route search (designed and generally applied to surveys of wetlands but also used for certain stream reaches).

NB: Westernport is included in the natural wetlands layer but the bay was excluded, other than wetlands above high tide level.

This resulted in 412,121 selected records.

(d) The selected data were used to determine the proportion of surveys during which each of the expected species was recorded, and multiplied each species by this proportion. The expected species list per catchment is defined in a 2012 AECOM report. Thus an expected riparian species recorded during 50% of surveys in an area contributes a score of 0.5. Another species, recorded on 10% of surveys, contributes only 0.1.

(e) The expected riparian species' scores were then summed to obtain the 'raw' sub-index for the selected area over the selected time period.

$$SI\ riparian\ birds = \sum_{n=113}^{1} \left(\frac{n1}{n}\right), \left(\frac{n2}{n}\right), \left(\frac{n3}{n}\right) \dots \left(\frac{n113}{n}\right)$$

The raw scores were normalised to generate a score between 0 and 1. The raw score was divided by a quarter of the number of expected species (which varies between basins). This normalisation was devised after 'gaming' the raw scores against our knowledge of the maximum scores achieved for sub-catchments of known condition.

(f) Finally the resulting score was allocated to one of five categories for the final sub-index reflecting a sigmoidal response as outlined in Table 8.

Table 8. Riparian bird condition metric description.

Key Value	Description	Very low	low	Moderate	high	Very high
Birds	The summed reporting rate of riparian species expected in that catchment (from minimum of 40 appropriate surveys)	Very few of the expected species are recorded and these in only low numbers 0.00 to 0.10	Few of the expected riparian bird species are recorded 0.11 to 0.30	Most expected species occur but some of these are only infrequently recorded over a year 0.31 to 0.70	Many expected species are recorded often. 0.71 to 0.90	Almost all expected species are frequently recorded 0.91 to 1.0

2.2.3 Setting bird scenarios

Current riparian bird state

Example condition scores calculated for present (i.e. 2012 to 2017 inclusive) by sub-catchment are shown in Table 9.

Table 9. Example of current (2012-17) riparian bird condition assessment of sub-catchments.

Catchment	Sub-catchment	No. Surveys	Raw Score	Normalised Score	Current Score
Dandenong	Bayside	96	25.70	0.82	High
	Blind Creek	125	15.26	0.48	Moderate
	Dandenong Creek Upper	29	13.10	0.42	Insufficient data
Maribyrnong	Boyd Creek	2	10.50	0.45	Insufficient data
	Moonee Ponds Creek	283	14.71	0.63	Moderate
	Steele Creek	9	7.00	0.30	Insufficient data
Werribee	Cherry Main Drain	27	23.26	0.69	Insufficient data
	Kororoit Creek Lower	314	15.91	0.47	Moderate
	Kororoit Creek Upper	2	9.50	0.28	Insufficient data
	Little River Lower	998	7.09	0.21	Low
	Werribee River Lower	121	22.55	0.67	Moderate
	Werribee River Middle	38	16.50	0.49	Insufficient data
	Werribee River Upper	7	13.43	0.40	Insufficient data
Westernport	Bass River	32	14.41	0.44	Insufficient data
	Bunyip Lower	10	13.60	0.42	Insufficient data
	Bunyip River Middle & Upper	98	17.99	0.55	Moderate
	Mornington Peninsula South-Eastern Creeks	195	26.37	0.81	High
Yarra	Brushy Creek	10	6.20	0.16	Insufficient data
	Darebin Creek	99	16.16	0.42	Moderate
	Diamond Creek (Rural)	177	9.56	0.25	Low
	Merri Creek (Rural & Forested)	105	16.14	0.42	Moderate
	Merri Creek (Urban)	148	17.33	0.45	Moderate
	Plenty River Upper	223	11.35	0.30	Low
	Woori Yallock Creek	156	15.35	0.40	Moderate

Forecast current bird trajectory under a 'business as usual' scenario

As the Habitat Suitability Model used for other key values such as platypus and fish was not available for birds at the time of the Strategy development, a hybrid data and expert elicitation approach was used to forecast future bird condition.

Riparian bird scores were calculated for sub-catchments using our metric and presented in a January 2018 survey sent to ~85 people identified as having knowledge of birds in the Port Phillip region. Experts were asked whether the scores presented were a reasonably accurate depiction of the heath of riparian bird communities.

To determine the most likely future trajectory of riparian communities, this survey asked experts for their forecast for riparian bird condition ~20 years ahead, when planned urban growth is in place and climate change effects will be apparent, assuming current policies and levels of investment in the management of our waterways. The spatial scale used in this survey was the 'system', a coarse subdivision of the Port Phillip and Westernport catchment developed for the 2013 Healthy Waterways Strategy. Systems are smaller than Catchments but larger areas than the sub-catchments used in the present Strategy.

The forecast trajectory was downwards for most Systems although, surprisingly, the expert elicitation suggested some areas might improve under current investment futures with better targeted works (Table 10).

Table 10. Expert opinion on future condition of systems under a 'business as usual' scenario.

Catchment		No. Surveys	Score	Categorgial Score	CC and Urbanisation
Dandenong	Dandenong	3942	0.66	High	Moderate
Maribyrnong	Lower Maribyrnong	86	0.51	Moderate	Low
	Upper Maribyrnong	205	0.55	Moderate	Moderate
Weribee	Cherry, Kororoit, Laverton, Skeleton	514	0.53	Moderate	Low
	Werribee and Littler River Lowlands	1581	0.27	Low	Low
	Werribee and Little River Middle and Upper	125	0.46	Moderate	Low
Westernport	Cardinia	505	0.47	Moderate	Low
	French and Phillip Islands	307	0.54	Moderate	High
	Lower Bunyip, Lang Lang and Bass	55	0.42	Moderate	Low
	Monrnington Peninsula	588	0.7	High	Moderate
	Upper Bunyip and Tarago	117	0.54	Moderate	High
Yarra	Lower Yarra	2646	0.38	Low	Very Low
	Middle Yarra	1098	0.38	Low	Moderate
	Upper Yarra	56	0.44	Moderate	High

Long term target setting

The expert survey was not intended or designed to determine achievable long-term scores for riparian birds. Such targets are difficult to quantify when we do not have a set timeframe to work within, or know the budgets and investment likely to be invested. Estimating long-term targets is especially difficult when climate change effects are occurring faster than all modelled predictions, and the population growth of Melbourne is outstripping all planning estimates.

Nevertheless, when long-term "targets" (estimates) were required for riparian bird value at some point in the future after indeterminate investment results from our survey were considered the best available guide. Forecast scores for Systems were used as the possible long-term outcome for sub-catchments within the system. The 'best possible' scores for systems was used (see Table 9). The higher of the two outcomes predicted by experts was taken as the best possible outcome.

2.2.4 Priority conditions, threats and management interventions

Priority conditions

There are a number of conditions that influence birds as a value and the interaction between those conditions and others that relate to the wider environment are complex. Some of the more influential conditions which drive the long term bird value targets (which in turn drive other key values) are:

- Vegetation Extent (describes the length and width of riparian buffers along waterways)
- Vegetation condition (describes the quality of vegetation along waterways – with an aspect of patch size/extent embedded in the method)

It should be noted that these were prioritised for the purposes of the Strategy and that habitats for birds are influenced by a variety of factors. The approach to developing long term targets and associated 10 year performance objectives for these environmental conditions is detailed in sections 3.3 and 3.4.

Priority bird threats

Garnett & Crowley (2000) list key threats to Australian birds as:

- Introduced predators
- Pollution (marine or terrestrial)
- Inappropriate fire regime
- Habitat loss, fragmentation and/or degradation
- Lack of nesting sites
- Water extraction
- Recreational disturbance
- Grazing
- Weeds

The January 2018 survey of regional bird experts asked respondents to identify the key threats to bird communities, and also the most effective management responses. Survey answers supported the previous listing of threats and reinforced confidence in the bird conceptual model (Figure 16).

Key threats to riparian bird communities, as ranked by survey responses, are shown in Table 11. The priority management interventions for birds are shown in Table 12.

Table 11. Ranked threats to regional bird communities.

Threat	Score (n = 33)
Riparian habitat loss and fragmentation	**12.19**
Riparian habitat degradation	**11.14**
Introduced predators (e.g. cats and foxes)	**10.95**
Disturbance from recreational and other human activities	**9.82**
Loss of hollow-bearing trees	9.44
Water extraction and changed hydrological regimes as a result of human activities	**9.31**
Removal of woody debris from (terrestrial) riparian habitat	9.08
Weeds altering riparian habitat	8.07
Grazing by stock	7.42
Pollutants in water	7.18

Priority management interventions for birds

Table 12. Ranked management interventions for regional bird communities

Management action	Score
Revegetation of corridors to link habitat patches.	20.04
Planning controls to preserve set-backs and areas of native vegetation.	19.73
Revegetation to increase depth of riparian zone.	19.38
Cat and/or fox control.	19.35
Stock exclusion fencing.	18.27
Controlling human (and dog) access or disturbance.	17.40
Promoting natural regeneration of vegetation (as opposed to revegetation).	16.42
Woody weed removal.	16.40
Further research (e.g. riparian bird responses to management and climate change).	16.33
Reinstating meanders or billabongs.	16.21

Zonation using Habitat Suitability Models for aquatic macroinvertebrate families, native fish, and platypus was the primary means of identifying priority reaches for works. The identification of priority reaches for habitat improvement works for riparian birds was only considered where there was no overlap with Zonation-derived priority reaches because it was assumed that works to improve habitat for in-stream values would also benefit riparian birds. But high priority reaches as defined through Zonation were seen to miss some important frog and bird habitat areas. An example of a gap in the Zonation prioritisation is the lower Plenty River which Zonation did not highlight as a priority but where riparian bird values are high and there is potential to protect or improve riparian habitat for bird.

A simple spatial assessment was devised, to identify possible gaps. The 16,346 stream reaches used in Zonation were taken as the spatial scale for this assessment.

The Melbourne Water Vegetation Visions (see Box 6) were found to be too limited in coverage to be useful, as many reaches had not been assessed at the time these data were required to inform the riparian bird habitat assessment. Therefore, for each reach's catchment the percent cover of native vegetation was calculated from DELWP mapping (Vegetation_CurrentEVC GIS file dated 2014. native vegetation extent) and the mean Greenprint score (Jacobs 2015) was determined (native vegetation condition). Note that this is a different method to what was included in the Habitat Suitability models (see Section 2.4)

For each reach both values were scored. For mean native vegetation condition:

- >50.0 = "protect", with a priority ranking of 2
- 25.0 to 49.9 = "improve", with a priority ranking of 1

- <25.0 = "maintain", with a priority ranking of 1.

For native vegetation extent:

- 66.7% to 100.0% = "protect", with a priority ranking of 2
- 20.0% to 66.6% = "improve", with a priority ranking of 1
- Less than 20% cover = "maintain", with a priority ranking of 1.

This was informed by work by Andrew Bennett and others which showed once a catchment fell below a threshold of 30% native vegetation cover there was a sharp decline in bird species richness and abundance (e.g. Radford et al. 2004)

The two priority rankings for reaches were then summed to generate an overall priority ranking, from 6 to 2. Reaches with scores of 5 and 6 were identified as priority areas for measures to improve or protect riparian bird habitat.

2.2.5 Key assumptions and improvement opportunities

- See sections above for assumptions

Some of improvement opportunities to progress for the Strategy:

- Reporting rate - It might be useful to include a weighting for threatened species to focus site managers' attention on attracting, or sustaining, populations of these species. This will be investigated further.
- Improvement opportunities for bird data and monitoring will be developed through the HWS MERI Framework and the associated Rivers Monitoring and Evaluation Plan (MEP).

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2.3 Frogs

2.3.1 Defining the Frog value

The 2013 *Healthy Waterways Strategy* (Melbourne Water 2013) introduced frogs as a key value of rivers, streams and wetlands following community consultation.

However, the exact nature of the value of frogs to the community was not defined. Most people in the community are unlikely to know what species of frog occur in their local areas, or recognise frog calls over those of some insects and birds. It seems unlikely the public value frogs because of their ecosystem function, or for any economic value. During the Millennium Drought there was some discussion about how people—particularly those in rural areas—missed the sound of frogs calling, and how this absence contributed to feelings of depression or anxiety about the future. Therefore it seems that frogs are valued as some intuitive, or natural, indicator of the condition of landscapes with water. From this the Strategy identifies the frog value to be the presence, abundance and variety of frogs (abundance and species richness), which incorporates underlying factors such as the availability of suitable breeding habitat and adequate ongoing breeding success for persistent populations that are resilient and self-sustaining.

This definition of the frog value immediately raises the question of non-native and introduced species. While the community is unlikely to see Cane Toads moving into the region as a positive, the arrival of Eastern Dwarf Tree Frog (*Litoria fallax)* has seemingly been accepted. The current position is that south-eastern mainland Australian species of frog that arrive through natural expansion (e.g. in response to climate change) or even through 'unintentional' human assistance might add to the frog species richness of the Region (e.g. Eastern Dwarf Tree Frog). However, other species would not add to the frog value, especially when these have the potential to become over-abundant and pest animals (e.g. Cane Toad (*Rhinella marina*), Asian Black-spined Toad (*Duttaphrynus melanostictus*), or even another invasive amphibian the Smooth Newt (*Lissotriton vulgaris*)).

A conceptual model for frog as a key value was developed representative of the current scientific understanding at the time of development (Alluvium 2017). The model documents and describes the relationships between environmental conditions and frog key environmental value, including relevance to rivers and wetlands, and with reference to landscape context, land use, urban growth and climate change (Figure 17).

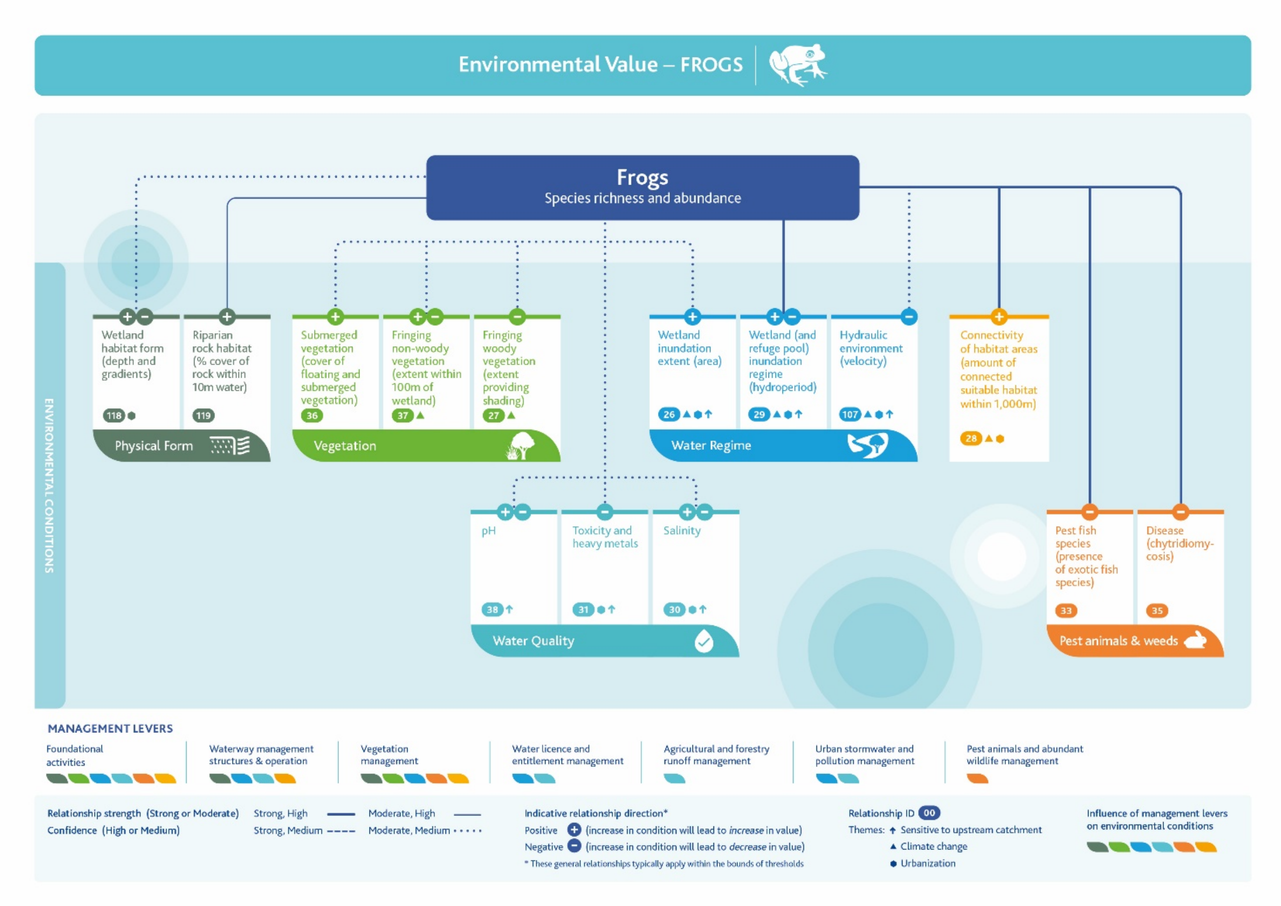

Figure 17. Conceptual model for frog value (Alluvium, 2017)

2.3.2 *Available data and condition metric for frogs*

Frog data

Regional frog data comprise records from the Victorian Biodiversity Atlas (VBA: which we believe are duplicated in the Atlas of Living Australia, or ALA); Melbourne Water Frog Census; and records of consultants and academics.

During the preparation of the 2013 *Healthy Waterways Strategy*, confidence in the frog value results was constrained by the very limited data which were patchily distributed across the region (many consultant surveys targeted land about to be developed). Based on 23,000 observations of frogs from 1960 to 2013, up to 20 species of frog are recorded within the region (Table 13), although the validity of Dendy's Toadlet (*Pseudophryne dendyi*) records in our region has been questioned.

Table 13. Frog species recorded in the Port Phillip and Westernport Region and their conservation status.

Scientific Name	Common Name(s)	IUCN Red List	EPBC Act	FFG Act	VROT
Crinia parinsignifera	Eastern Sign-bearing Froglet (Plains Froglet)	LC			
Crinia signifera	Eastern Common Froglet	LC			
Geocrinia laevis	Smooth Froglet				
Geocrinia victoriana	Victorian Smooth Froglet (Eastern Smooth Froglet)	LC			
Limnodynastes dorsalis	Western Banjo Frog				
Limnodynastes dumerilii	Eastern Banjo Frog (Southern Bullfrog)	LC			
Limnodynastes peronii	Striped Marsh Frog (Brown-striped Frog)	LC			
Limnodynastes tasmaniensis	Spotted Marsh Frog (Spotted Grass Frog)	LC			
Litoria ewingii	(Southern) Brown Tree Frog	LC			
Litoria fallax	Eastern Dwarf Tree Frog	LC			
Litoria lesueuri	Rocky River Frog (Lesueur's Frog)	LC			
Litoria paraewingi	Plains Brown Tree Frog (Victorian Frog)	LC			
Litoria peronii	Peron's Tree Frog	LC			
Litoria raniformis	Growling Grass Frog (Southern Bell Frog)	EN	VU	Listed	EN
Litoria verreauxii	Whistling Tree Frog (Verreaux's Tree Frog)	LC		Listed	
Neobatrachus sudelli	Common Spadefoot Toad (Sudell's Frog)	LC			
Paracrinia haswelli	Red-groined Froglet (Haswell’s Froglet)	LC			
Pseudophryne bibroni	Brown Toadlet (Bibron’s Toadlet)	NT		Listed	EN
Pseudophryne dendyi	Dendy's Toadlet	LC			
Pseudophryne semimarmorata	Southern Toadlet	LC			VU

Subsequent to the 2013 HWS, a concentrated effort on the Frog Census program, leading to the release of a smart phone app in time for spring 2016, has seen an increase in frog records collected by community members. Although these are still presence-only data. biased towards densely populated areas of our region, there were 637 records submitted to Frog Census for September to November 2016, compared to 250 records for the entire 2015/16 year. Targeted studies (particularly focussed on the endangered Growling Grass Frog (*Litoria raniformis)* but including frog community research commissioned by Melbourne Water) have also seen an increase in regional frog data. The dataset as of March 2019 has 33,240 observations from 1960.

Frog condition metric

Recent detailed analysis by Ecology & Heritage Partners with Symbolix has refined the frog value metric used in the 2013 Healthy Waterways Strategy. New, data-driven predicted Species Richness Models have been developed for each system (see below). All data from 1960 are included in this modelling but an 'aging' function is applied to increase the relative weight of data collected after 1980. The condition metric is still essentially a measure of observed/ expected species, but a more robust and defensible list of 'expected' species, based upon data, and survey effort is now taken into account. Thus if one has only a few surveys across a sub-catchment, the number of expected species is reduced to reflect the 'species accumulation curve' whereby the more one surveys the more species are recorded, at a diminishing rate of accumulation (Ecology & Heritage Partners 2017).

Generating Species Richness Models for catchments

1. For each month of data for each sub-catchment, species richness was calculated as a proportion of the maximum species richness for the catchment. Thus if seven species were recorded in one month in a catchment with a maximum observed species richness of 14, a value of 0.5 was assigned.
2. A generalised linear model was fitted to the data to express the proportional species richness as a function of the number of observations and the catchment.
    a. The model included a year weight, so that more recent observations carried a higher weight than older observations.
    b. The best model was of the form ***logit(*S_p*) ~ log(*N_{obs}*) * catchment*** where:
        i. S_p is the species richness divided by the maximum possible species richness for the catchment, and
        ii. N_{obs} is the number of observations for the time period.
    c. The weight was derived from a normal distribution function, centred on 1987 (after this date there was increased consistent data). Year was transformed as $Y' = (Year—1987)/5$ which allowed us to fit a normal distribution with mean of zero and standard deviation of one.
        a. Variations on this weight (including no weight) were also trialled. The model and score results were robust to changes in this weight but the one chosen gave the best model residuals.

Generating a condition score for sub-catchments

For the six-year period 2012-2017 a frog value score was generated using the following approach:

1. For each observation within each sub-catchment species richness S_p was calculated as a proportion of the maximum species

2. The model was used to predict the expected (proportional) species richness (***E***) over the six-year period for each sub-catchment.
3. The difference between the actual proportional species richness (***Obs***) and expected (***E***) for every observation was calculated. The definition of ***deviance = Obs-E***
4. The value score is a number between 0 and 1 using the distribution of ***deviance*** values across all sub-catchments. For each sub-catchment the score is the percentile of the deviance distribution. This score represents a robust statistical quantity that is readily interpretable, i.e.
   a. The sub-catchment with the largest positive deviance (between actual and expected species richness) has a score of 1.
   b. The sub-catchment with the most negative deviance (between actual and expected species richness) has a score of 0.
   c. A condition score of 0.9 means that the sub-catchment in question has an observed value that is better than the expected and the difference is better than 90% of other sub-catchments.

Notable changes among species recorded

A Science Panel discussion of the frog value (8 February 2017) raised concerns about our limited ability to influence frog condition scores in a measurable way using current thinking about value metrics. External factors, particularly drought and urban development, have far greater effects on large-scale metrics than any site-focussed management intervention. Therefore, the Panel advised against setting targets for frogs at landscape scales, and that the Strategy should focus on maintaining populations at specific sites. For this, key information to track is when individual species of frog 'drop out' of an area.

Consequently, Ecology & Heritage Partners with Symbolix prepared an analysis of regional frog data showing the last year in which species were recorded in each sub-catchment. This reveals worrying patterns of disappearance of some species of frog and also management areas of concern. For example Taylor's sub-catchment demonstrates an overall loss of frog species in recent years. The Common Spadefoot Toad (*Neobatrachus sudelli*) and both *Pseudophryne* species have apparently disappeared from the Maribyrnong catchment.

2.3.3 Setting frog scenarios

Current state of frog communities

Frog value scores were calculated for each catchment for the period 2012-2017. Scores were then converted into one of five simple categories: from 1 = very low condition to 5 = very high reflecting a sigmoidal response (Table 14 and Table 15) (refer to
Box **7**).

Table 14. Condition metric for frogs

Key Value	Very low	Low	Moderate	high	Very high
Frog	Very few of the expected species are recorded and these in only low numbers 0.00 to 0.10	Few of the expected frog species are recorded 0.11 to 0.30	Most expected species occur but some of these are only infrequently recorded over a year 0.31 to 0.70	Many expected species are recorded often. 0.71 to 0.90	Almost all expected species are frequently recorded 0.91 to 1.0

Box 7: Changing the approach for assigning the condition rating

Alluvium (2011) for the Healthy Waterways Strategy 2013 used categories of unequal scores to reflect likely near exponential response curve of frogs to improving environmental conditions:

Condition rating	Score (SR)
Very high	0.801- 1.00
High	0.701- 0.80
Moderate	0.601- 0.70
Low	0.401- 0.60
Very low	0.0- 0.40

Condition score categories be also be calculated using equal intervals. But, since this assumes a linear response, equal interval categories are not really appropriate. Scores were reduced to simple categories reflecting a sigmoidal response, as this was thought to be most likely.

Very high = 0.91 to 1.00

High = 0.71 to 0.90

Moderate = 0.31 to 0.70

Low = 0.11 to 0.30

Very low = 0.00 to 0.10

The graphs below show the different responses being assumed in each decision on how to simplify scores into categories.

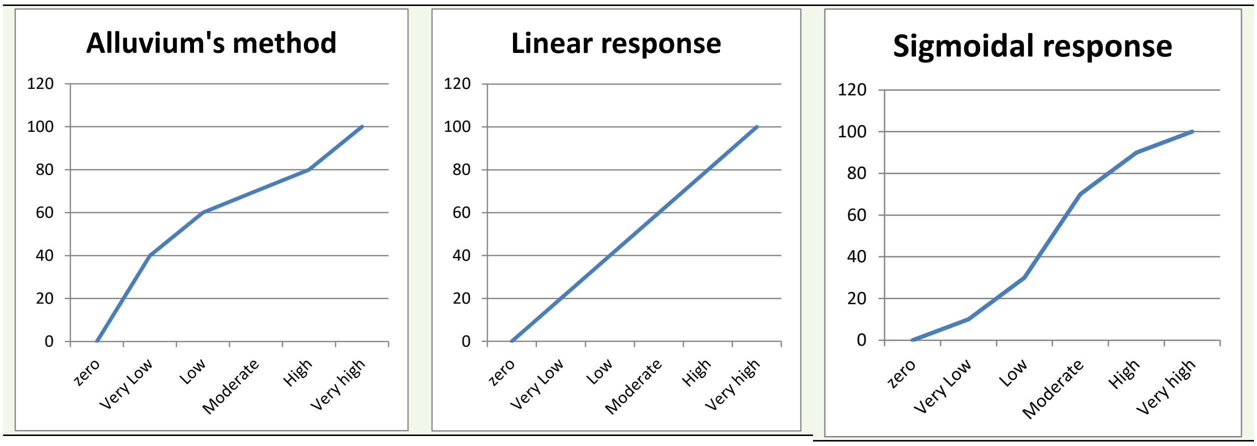

Table 15. Example of (2012 to 2017) frog condition scores for selected sub-catchments (derived by Symbolix).

Catchment	Sub-catchment	Exp species richness	Obs species richness	No. obs.[2]	Condition score	Category
Maribyrnong	Steele Creek	15	3	24	0.00	Very low
Werribee	Lollypop Creek	15	5	79	0.06	Very low
Dandenong	Blind Creek	14	1	2	0.07	Very low
Yarra	Diamond Creek (Rural)	17	8	150	0.08	Very low
Yarra	Koonung Creek	17	3	8	0.16	Low
Werribee	Laverton Creek	15	3	15	0.17	Low
Yarra	Woori Yallock Creek	17	7	43	0.40	Moderate
Westernport	Bunyip River Middle and Upper	16	5	19	0.43	Moderate
Werribee	Werribee River Lower	15	6	40	0.59	Moderate
Yarra	Yarra River Middle	17	6	16	0.70	Moderate
Werribee	Little River Upper	15	2	2	0.79	High
Maribyrnong	Emu Creek	15	7	18	0.87	High
Yarra	Little Yarra River and Hoddles Creek	17	6	10	0.89	High
Yarra	Plenty River (Source)	17	6	8	0.94	Very high
Yarra	Watsons Creek	17	8	17	0.96	Very high

[2] The number of observations provides an indication of the level of confidence in the data

Forecast current frog trajectory under business as usual scenario

As the Habitat Suitability Model used for other key values such as platypus and fish was not available for frogs at the time of the Strategy development, the hybrid data and expert elicitation approach was used to forecast future frog condition.

To determine the most likely future trajectory of frog communities, a survey was sent in January 2018 to ~76 people identified as having knowledge of frogs in the Port Philip Region. The survey asked for their forecast for frog condition scores around 20 years ahead, when planned urban growth is in place and climate change effects will be apparent, assuming current policies and levels of investment in the management of our waterways. The trajectory forecast was downwards for most Systems (Table 16).

Table 16. Comparison of current (2012-17) and projected future frog community conditions scores by system.

Catchment	System	Current Condition Estimate	Estimated future condition w/BAU (n=28, confidence 52/100
Dandenong	Dandenong	Moderate	Moderate
Maribyrnong	Lower Maribyrnong	Very Low	Very Low
	Upper Maribyrnong	Very Low	Low
Werribee	Cherry, Kororoit, Laverton, Skeleton	Low	Low
	Werribee and Littler River Lowlands	Very Low	Very Low
	Werribee and Little River Middle and Upper	High	Low/Moderate
Westernport	Cardinia	Moderate	Low
	French and Phillip Islands	Moderate	Moderate
	Lower Bunyip, Lang Lang and Bass	Moderate	Moderate
	Mornington Peninsula	Very High	Moderate
	Upper Bunyip and Tarago	High	Moderate
Yarra	Lower Yarra	Very Low	Low/Very Low
	Middle Yarra	Low	Low
	Upper Yarra	High	Moderate

Long term target setting trajectory

Long term targets for frogs were set on the basis to maintain current condition. In the instances where the future condition under BAU was predicted to be higher than the current condition, then the higher of the two was chosen as the target.

2.3.4 Priority conditions, threats and management interventions

Priority conditions

The priority conditions that drive the frog value include:

- Hydrology
- Water Quality
- Habitat

The threats and management interventions for frogs are summarised in Table 17.

Table 17. Suggested management interventions to promote frog communities.

Significant threat	Management options	Comments on spatial considerations
Habitat loss (vegetation and water).	Planning controls to protect riparian lands retaining some value. Revegetation of riparian buffers to improve depth and connect habitat nodes. Exclude stock.	Zonation using fish, Platypus and aquatic macroinvertebrates should identify reaches needing riparian vegetation improvement. Need to prioritise areas supporting declining species, such as the *Pseudophryne* species. Threatened species (Growling Grass Frog) habitat is identified through the Melbourne Strategic Assessment and habitat offsets prescribed. 'Soft' non-woody and non-tree vegetation needs to be included in revegetation.
Water extraction and changed hydrological regimes.	Environmental flow releases. Watering floodplains depressions.	Environmental Flows Team identify flow-stressed streams to prioritise and target. Hydrological changes to 'wet' floodplain depressions are largely wetland actions.
Declining water quality because of chemical pollutants.	Revegetation of riparian buffers. Stormwater disconnection. Monitoring to identify sources of pollution, which can then be addressed.	Zonation using fish, Platypus and aquatic macroinvertebrates should identify reaches needing improved stormwater disconnection.
Chytrid fungus and other pathogens.	Monitoring and research.	Region-wide problem.

Introduced fishes (*Gambusia* and carp).	Research.	Region-wide problem.

Zonation, using Habitat Suitability Models for aquatic macroinvertebrate Families, some native species of fish, and Platypus was the primary means of identifying priority reaches for works (see below). The identification of priority reaches for habitat improvement works for frogs was only specified when there was no existing overlap with Zonation-derived priorities for in-stream values.

Initially a simplistic, spatial assessment was undertaken scoring sub-catchments 1 (= yes) or 0 (= no) for each of the following factors:

- Current frog condition scores are High or Very High.
- Predicted decline in frog condition score is two or more levels, e.g. from High to Low or Very Low.
- Presence of either *Pseudophryne* species since 2000.
- Presence of a 'Frog Priority Area' under the 2013 Healthy Waterways Strategy (since this suggests works to enhance frog habitat will have been planned).
- Location of a co-design target addressing a frog threat, e.g. improving water quality in Arundel Creek.

This simple assessment was seen as a 'filter' to ensure the outputs of Zonation were not the only input to spatial prioritisation of management interventions, and that key habitat areas for frogs would be included. (see 2.3.6 Further Resources)

The simple assessment produced a range of scores for each sub-catchment. These scores can be 'cut' into any category useful for prioritisation. Figure 18 shows one categorisation of sub-catchments into three priorities. The nomenclature was intended simply to communicate that some areas have a higher priority for protecting or improving frog habitat than others.

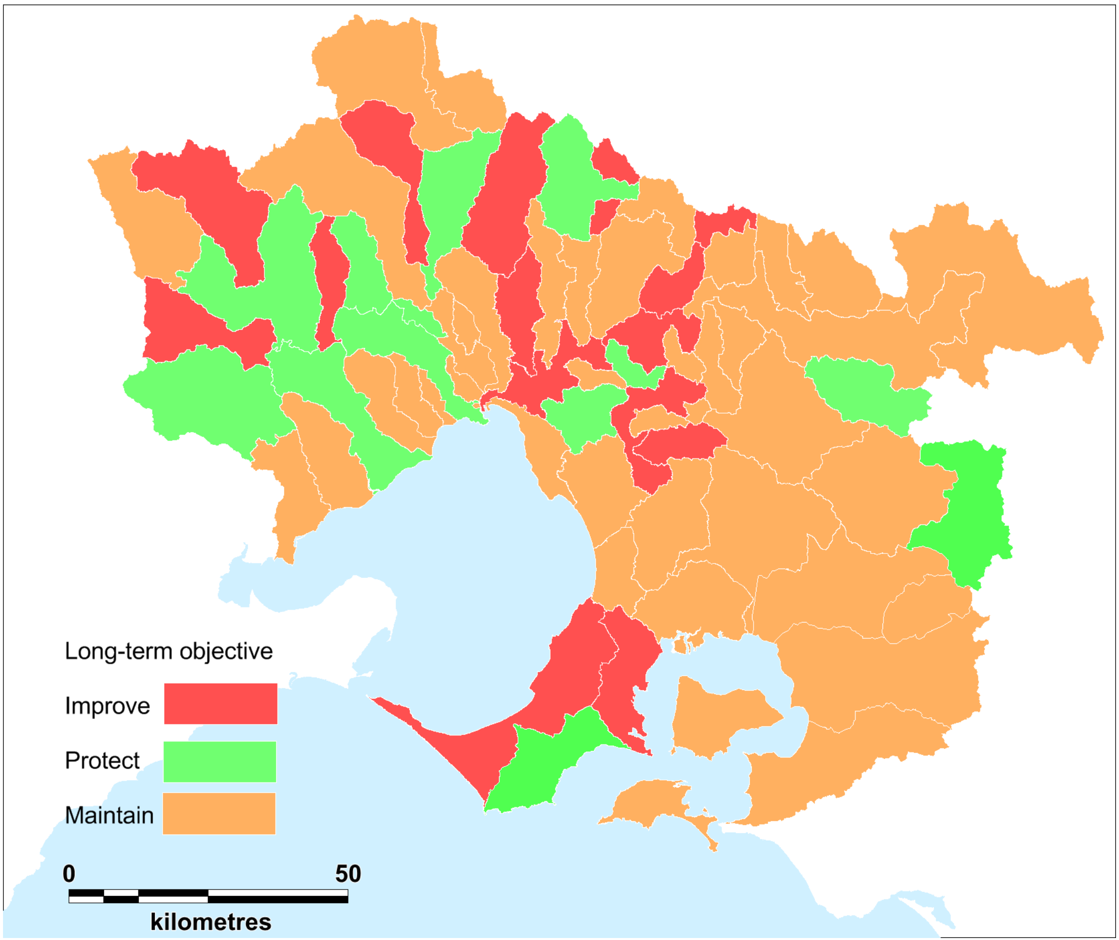

Figure 18. Preliminary assessment to identify and rank important areas for frog management intervention.

2.3.5 Key assumptions and improvement opportunities

The following key assumptions were made at the time of developing the Strategy:

- Our records provide an accurate picture of frog species' distribution and monitoring is sufficient to detect changes in frog community.
- Vegetation and water management will have positive effects on native species of frog and lead to greater persistence of species in modified environments than would otherwise be the case.
- On-ground works can counteract the effects of climate change.

Some of the improvement opportunities to be progressed over time for the Strategy:

- Explore opportunity to include frogs in the Habitat Suitability Models
- Utilise eDNA to obtain more accurate frog presence and absence data for a wider range of sites.

Improvement opportunities will be developed through the HWS MERI framework and the associated Rivers Monitoring and Evaluation Plan (MEP).

2.3.6 Further Resources

HWS Frog Key Value analysis - HWS2018_Frog_Key_Value_workings.xlsx
http://inflo/inflo/cs.exe/properties/41785009

2.3.7 References

Alluvium (2010a) Waterways Trajectories: Frogs. Report (P10050_R08V02) prepared for Melbourne Water by Alluvium Consulting, Melbourne. http://inflo/inflo/cs.exe/open/22123615

Alluvium (2011a) Frog Data Analysis — Priority Areas. Draft report prepared for Melbourne Water by Alluvium Consulting, Melbourne. http://inflo/inflo/cs.exe/open/22124932

Alluvium (2011b) Proposing Long Term Outcomes for the Healthy Waterways Strategy. Draft report prepared for Melbourne Water by Alluvium Consulting, Melbourne. http://inflo/inflo/cs.exe/open/22124817

Alluvium (2017) Healthy Waterways Strategy Waterway Science Conceptual Models. Report prepared for Melbourne Water by Alluvium Consulting Australia, Melbourne.

DEWHA (2010) Listed Key Threatening Processes. Department of the Environment, Water, Heritage and the Arts, Canberra; , accessed 16 April 2010 <http://www.environment.gov.au/cgibin/sprat/public/publicgetkeythreats.pl>

DSE (2009) Flora and Fauna Guarantee Act 1988, Processes List. Department of Sustainability and Environment, Melbourne; , accessed 16 April 2010 <http://www.dpi.vic.gov.au/DSE/nrenpa.nsf/LinkView/EADA0F1874AF9CF24A2567C1001020A388BBA5581CF9D859CA256BB300271BDB>

Ecology & Heritage Partners (2017) Review of Data and Condition Metric for Healthy Waterway Strategy Frog Value. Report prepared for Melbourne Water by Ecology & Heritage Partners, Melbourne. http://inflo/inflo/cs.exe/open/41196690

Ecology Australia (2017) Frog Conceptual Models: Modelling and Final Report. Report prepared for Melbourne Water by Ecology Australia Pty Ltd, Melbourne. http://inflo/inflo/cs.exe/open/37882850

Ecology Australia (2017d) Modelling of frog communities and contaminants at constructed wetlands in the Port Phillip and Western Port region, Victoria. Report prepared for Melbourne Water by Ecology Australia Pty Ltd, Fairfield, Victoria. http://inflo/inflo/cs.exe/properties/40449074

Melbourne Water (2013) *Healthy Waterways Strategy*. Melbourne Water, Melbourne.

Morton, S., Sheppard, A. & Lonsdale, M. (eds) (2014) *Biodiversity: Science and Solutions for Australia*. CSIRO Publishing, Melbourne.

Tyler, M.J. (1997) *The Action Plan for Australian Frogs*. Wildlife Australia, Canberra.

2.4 Platypus, fish and macroinvertebrates

2.4.1 Defining our platypus, fish and macroinvertebrate values

Platypus, fish and macroinvertebrates were used in the 2013 HWS as key values and the decision to carry them forward was decided very early in the strategy process. Apart from some small changes to condition metrics the values are described in a very similar way.

The platypus is identified as a key value in recognition of the vital role they play in aquatic ecosystems as an apex predator and the high level of community interest around this unique native species. A conceptual model for platypus as a key value was developed representative of the current scientific understanding at the time of strategy development (Alluvium, 2017). The model documents and describes the relationships between environmental conditions and platypus key value, including relevance to rivers and wetlands, and with reference to landscape context, land use, urban growth and climate change (Figure 19).

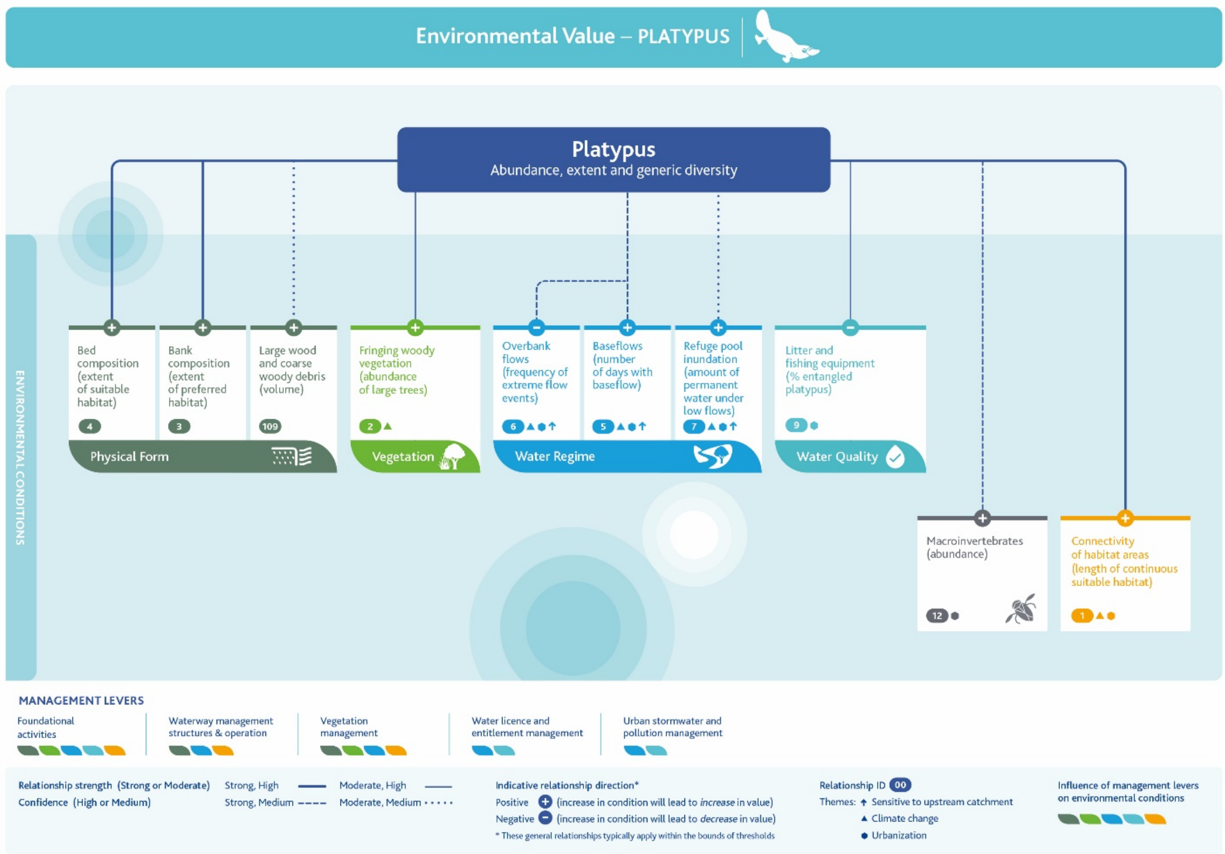

Figure 19. Platypus conceptual model (Alluvium, 2017).

Fish play an important role in waterways; they are usually near the top of the aquatic food chain and also provide food for people and some birds. Their key value recognition is also due to species such as Macquarie perch, Murray cod and river blackfish being highly valued for their recreational value by the fishing community. A conceptual model for fish as a key value was developed representative of the current scientific understanding at the time of strategy development (Alluvium, 2017) (Figure 20).

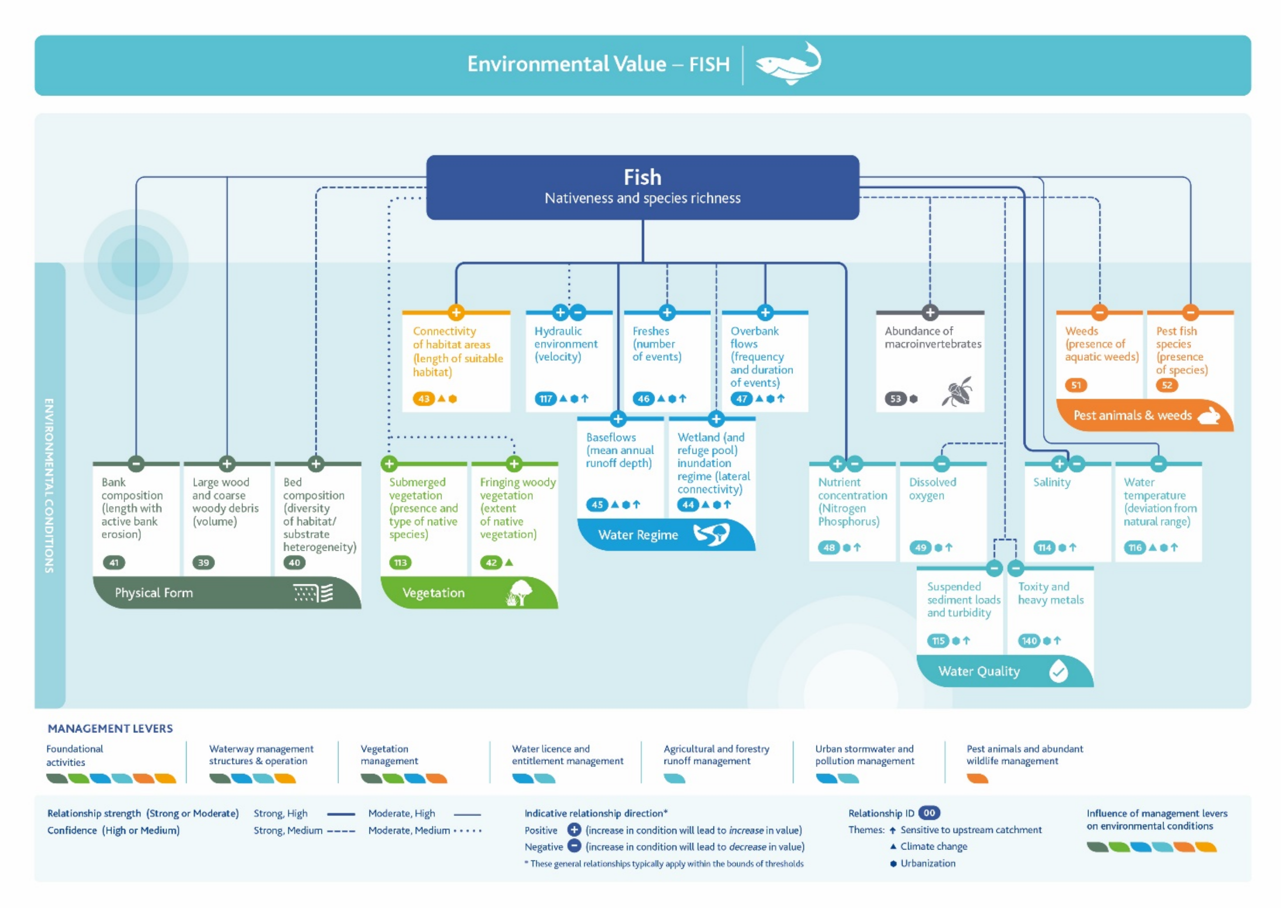

Figure 20. Fish conceptual model (Alluvium, 2017)

Macroinvertebrates are identified as a key value as they are a food source for platypus, fish and frogs and they are very sensitive to changes in the environment which makes them a good overall indicator of waterway health. Additionally there are several macroinvertebrate taxa that are unique to the region and have recognition value to the local community, such as Dandenong Ranges amphipod. A conceptual model for macroinvertebrates as a key value was developed representative of the current scientific understanding at the time of strategy development (Alluvium, 2017) (Figure 21).

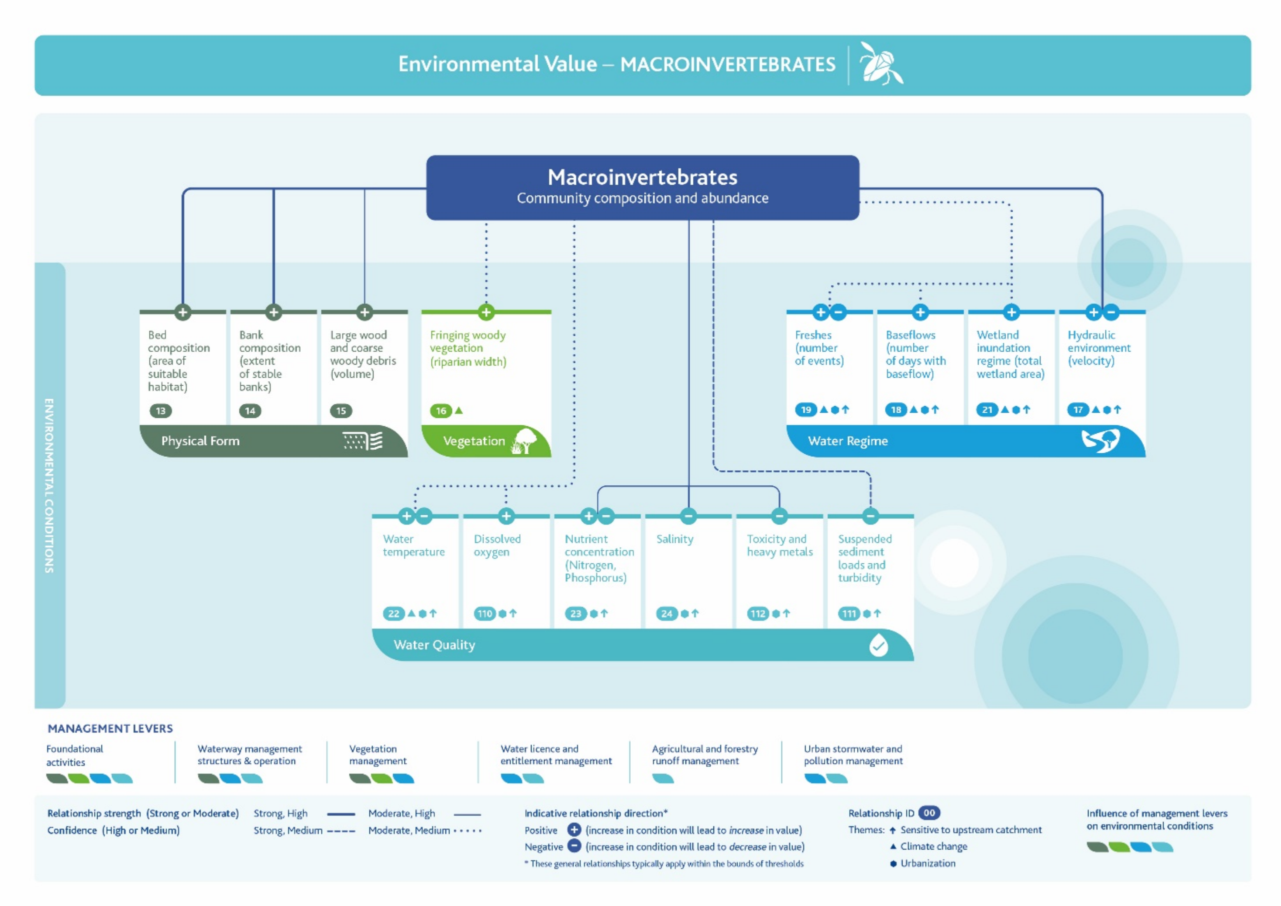

Figure 21. Macroinvertebrates conceptual model (Alluvium, 2017).

The conceptual models for fish, platypus and macroinvertebrates provided the basis for development of sophisticated predictive models known as Habitat Suitability Models (see

Box **2** in Section 1.5.) by the Melbourne Water Melbourne University Research Practise Partnership. This enabled a quantitative approach to assessing both the status and driving influences on these values. This has been a substantial improvement to the methods applied in the previous strategy as it enabled systematic modelling of threats and management scenarios. The outputs proved be a very powerful way of communicating during the development of the strategy. The development and use of these models is described more fully in Chee et al. (2020)

2.4.2 Available data, condition metrics and model development

Platypus, fish and macroinvertebrates were assessed using quantitative ecological models; Habitat Suitability Models (HSM). The development of these models was made possible because of the substantial monitoring data that has been collected across the Melbourne Water region by multiple agencies over the last two decades (eg. Melbourne Water, Bureau of Meteorology, other Victorian State Government surveys, environmental consultants and researchers etc.) (Table 18).

As part of the HSM model development phase, biological survey data were collated for the period from 1990 to 2009 (inclusive) across most taxa. This period was selected because it corresponded to the most recent versions of forest cover and DCI layer that were available at the time (2009 data). Data was only accepted from surveys that used standardised and comprehensive survey methods so that the biological data could be regarded as presence-absence data for the purposes of modelling. Sampling occurred extensively throughout the region, with no obvious bias in sampling coverage (though small and/or intermittent streams are, as to be expected, not as well-sampled as larger, perennial systems).

Macroinvertebrate data

There were a total of 1,724 survey samples collected at 562 unique reaches. Collection of macroinvertebrate data used standard rapid bioassessment protocol (EPAV publication 604 (1998) and 604.1(2003)) either from riffles or pool edges, and either in autumn (Feb–Jun) or spring (Sep–Dec). 84% of samples were sorted using a standard 30-min sort in the field, and 16% were subsampled in the laboratory, and sorted to 10% or 200 individuals, whichever was greater. Each survey sample from a site combined the data from a pair of samples: sample-pairs could be combinations of riffle and edge samples collected in spring or autumn.

Fish data

There were a total of 2293 survey samples collected at 1058 unique reaches. Data used in the model development came from a fish database that included the broader Victorian fish survey data (not just Melbourne Water data) and utilised all data up to 2009. The use of a consistent survey method was not considered essential for fish data because presence / absence was used. Most surveys utilised electrofishing or netting eg fyke netting method. There may have also been other techniques.

Platypus data

Survey data used for model development spanned a 14-year period from 1995 to 2009. There were a total of 2506 presence absence records survey samples collected at 609 unique sites. fyke nets were the technique used to survey platypus in Spring and Autumn.

Development and use of Habitat Suitability Models (HSM)

The development of HSM's has been a collaboration between researchers at Melbourne University (Waterways and Ecosystems Research Group) and Melbourne Water staff.

The models used a waterway network dataset which contains ~8,400 kms of streams throughout the Melbourne Water region are represented by ~8,200 hydrologically-delineated sub-catchments. While this network doesn't include all headwater streams it was the best available dataset at the time. Habitat suitability models (HSMs) were developed to describe habitat suitability for 52 macroinvertebrate families, 13 native fish species, and platypus, so as to visualise and quantify instream biodiversity value at the sub-catchment scale (median reach length ~0.5km). This provided information at a resolution that is directly useful for management.

HSMs analyse the relationships between the environmental characteristics at sites where a species is detected (and at sites where a species is not detected) to develop a quantitative model that predicts the likelihood of occurrence (technically detection) at a site as a function of habitat characteristics.

For each taxon of interest (i.e. macroinvertebrate families, fish species and platypus), 10-12 environmental characteristics ('environmental predictors' in Figure 22) were carefully selected to describe instream habitat suitability. Specifically, the chosen predictors were a balance of three considerations: i) theoretically-informed ecological relevance (sensu Austin 2002); ii) availability of spatial data across the region (because ultimately, we required predictions across the region); and the amenability of a predictor to management intervention (so that HSMs reflect biological responses to different environmental and/or management scenarios).

Table 18. Data used in the development of Habitat Suitability Models

Data	Description of predictor	Data source and time period	Reference
Platypus (cpu)	standardised survey methods converted to presence-absence data for modelling	Melbourne Water DELWP, EPAV, Platypus Conservancy, consultants data 1995-2009	Chee et al. (2020)
Fish	standardised survey methods converted to presence-absence data for modelling	Melbourne Water DELWP, EPAV, consultants data 1990-2009	Chee et al. (2020)
Macro-invertebrate	LUMaR calculated from standardised survey methods converted to presence-absence data for modelling	Melbourne Water DELWP, EPAV, consultants data 1990-2009	Chee et al. (2020)
Mean annual air temperature	Annual mean of mean daily air temperatures for the reach. As a proxy for water temperature	Derived from gridded air temperature data	Bureau of Meteorology
Mean annual run-off depth	an indicator of stream perenniality and variability. Mean annual run-off depth in the absence of human impacts (mm/year). This measure is a catchment-standardised measure of annual stream discharge	It is calculated by taking mean annual accumulated surface water surplus (derived from a simple water balance model using long-term rainfall and potential evapotranspiration data) and dividing by watershed area. Calculated as RUNANNMEAN/CATAREA	***Geofabric*** dataset (BoM 2011)
Antecedent Run-off (weighted)	48 month (long-term) antecedent runoff as a measure of previous rainfall-runoff. Default = 0, which denotes mean 48mth weighted antecedent runoff. -1 denotes drier than mean antecedent runoff conditions; +1 indicates wetter than mean antecedent runoff conditions	For each data point (i.e. platypus survey) the mean monthly runoff was calculated for the previous 48 months. SRI using a log normal distribution. Weighted moving average.	Australia water availability data (AWOP)
Attenuated imperviousness	A measure of the amount of impervious cover that is directly connected to a stream reach; reflects stormwater impact	Aerial imagery and Lidar. Based on initially on 2009 data and updated manually to reflect a current baseline (i.e. 2016)	Walsh and Kunapo impervious calculations 2009

Data	Description of predictor	Data source and time period	Reference
	associated with urban land drainage systems and all the attendant impacts on flow regimes and water quality. Ratio of attenuated impervious area in the watershed (using a half-decay distance of 9.4 m) to watershed area. Range = 0 – 1.		
Attenuated forest cover	A measure of the amount of forest cover alongside as well as upstream of the stream segment weighted using a decay function. (1500 m upstream (half decay) for fish and bugs and 35 m width, and 1000 m upstream (half decay) and 10 m width for platypus)	2009 Lidar data with aerial imagery to create the 2016 current baseline	Walsh and Web 2014
Large Woody Debris	Number of pieces of large woody debris per unit area of stream bank area of each sub-catchment.	ISC3 (uses aerial photography)	DELWP https://www.water.vic.gov.au/water-reporting/third-index-of-stream-condition-report
Streambank vegetation	Proportion of stream bank area that has vegetation cover	ISC3	DELWP https://www.water.vic.gov.au/water-reporting/third-index-of-stream-condition-report
In-stream barriers	Number of instream full and partial barriers to movement along the downstream flow path. Full barriers were typically very large barriers typically larger > 5 m with high confidence in them being a full barrier – everything else was considered partial – as they are likely to allow passage through some high flows	A review of barriers and fishways was undertaken in 2017 to create a new spatial layer – this was based on reports and checking of aerial imagery.	Melbourne Water
Catchment area	Sum of area of all upstream contributing sub-catchments, including large dams and all the sub-catchments that drain into the large dams	Subc layer which is associated with the stream network layer	Walsh and Web 2014 or 16?
Geology	Percentage of catchment with igneous geology.	Derived from CAT_IGNEOUS from ***Geofabric*** dataset (BoM 2011)	BoM 2011

Habitat Suitability Models (HSMs) analyse the relationships between the environmental characteristics at sites where a species is detected (and also at sites where a species is *not* detected) to develop a quantitative model that predicts how suitable any given stream reach is for each species. Higher habitat suitability implies higher probability of observation/catch.

By quantifying taxa-habitat relationships, HSMs help us understand important environmental drivers and interactions, and provide a rational and transparent means of using existing, patchily-occurring, discrete, point location data to make spatially-continuous predictions to unsampled locations.

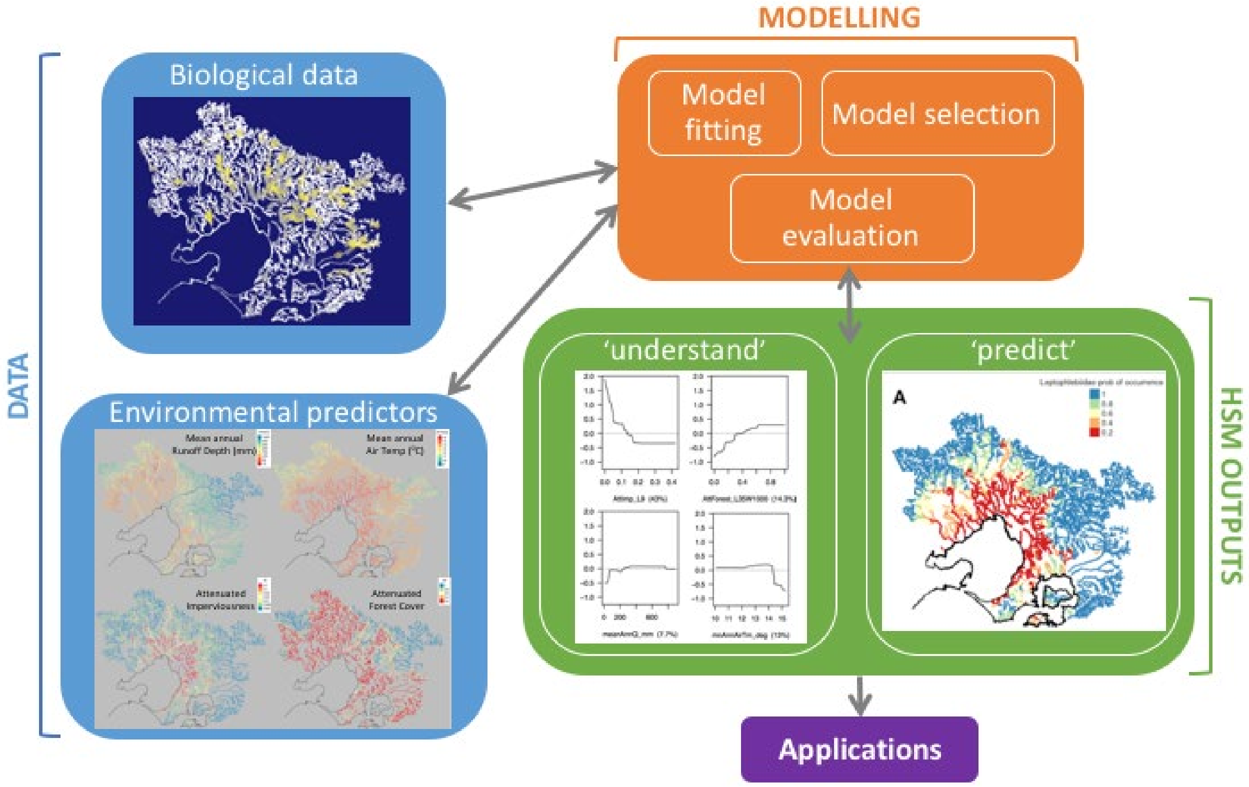

Figure 22. Overview of how Habitat Suitability Models were developed.

Metrics

Metrics for each of the instream values are slightly different to those used in the 2013 HWS for a couple of key reasons:

- improvement in data collection method
- change in how value is assessed (new indices)
- increased survey data points
- wider distribution of data

Macroinvertebrates

In the 2013 HWS, SIGNAL (Stream Invertebrate Grade Number – Average Level) scores were used for macroinvertebrates (Chessman, B (1995), Chessman, B (2003)). A new index known as LUMaR (Land Use Macroinvertebrate Response index) has been developed for the Melbourne region. LUMaR is arguably a more applicable measure of stream condition in the Melbourne region as it has greater sensitivity to changes in imperviousness (urbanisation) and land clearing which are major drivers of waterway health in the region. It combines an observed expected (OE) ratio with taxon-sensitivity weightings. Further explanation of the derivation of the index can be found in "LUMaR: a sensitive macroinvertebrate index of stream condition combining observed: expected ratios and sensitivity weightings" by Walsh (in prep).

Models for 59 macroinvertebrate taxa were developed (Walsh, in prep). Seven of the 59 macroinvertebrate families were deemed to be 'weedy' or invasive (see Chee et al. (2020) - Table 1). For the purposes of the HWS, we concentrated on the 52 non-weedy/invasive macroinvertebrate families. 23 of the 52 families were sensitive to urban stormwater impacts or deforestation.

The status of macroinvertebrates is determined based on the LUMaR score as shown in Table 19.

Table 19. Macroinvertebrate status metric.

Rating	Description	LUMaR categories
Very High	All or almost all macroinvertebrate taxa are predicted to be present, indicating very good stream health	0.7 – 1.0
High	Most macroinvertebrate taxa are predicted to be present, indicating good stream health	0.5 – 0.7
Moderate	Some macroinvertebrate taxa are predicted to be present indicating moderate stream health	0.3 – 0.5
Low	Low number of macroinvertebrate taxa are predicted to be present, indicating poor stream health	0.2 – 0.3
Very low	Very low number of macroinvertebrate taxa are predicted to be present, indicating very poor stream health	0.0 – 0.2

Fish

In the HWS 2013, fish status was determined using a combined score of observed over expected and nativeness. Due to the difficultly in developing the expected list of species at a fine spatial scale, it was decided that a simpler native fish richness indicator would be preferable. This index can also be readily generated from the outputs of the HSMs. The sum of species occupancy probabilities at a site is equal to the expected number of species present, and hence is a good estimator of species richness (Calabrese et al. 2014).

The following assumptions describe how the richness metric for fish was calculated and should be interpreted:

- Estimated native fish richness is based on individual HSM's developed for 13 native fish species (these are the species for which there is adequate data to model). Whilst 13 species is not a complete representation of the native fish species in the MW region, it was considered a reasonable representation of the cohorts of all native fish.

  Two threatened species, Yarra Pygmy Perch and Australia Grayling are considered important to the region and the Strategy but there are too few records to develop reliable HSM models. Surrogate species that most closely share habitat with the threatened species were used instead (Tarmo Raadik, Arthur Rylah Institute for Environmental Research, *pers. comm*.). Southern Pygmy Perch was used as a proxy for Yarra Pygmy Perch and Common galaxias was used as a proxy for Australian Grayling. Model outputs using proxy species were only examined in regions of current habitat for the threatened species or within a feasible projection of current habitat. For Yarra pygmy perch, that meant Deep Creek in the Maribyrnong catchment, and for Australian grayling, that meant just the mainstems of the Werribee, Maribyrnong, Yarra, Cardinia, Bunyip and Lang Lang rivers, downstream of major instream barriers.

  Additionally the two species of local lamprey were combined and modelled as a single species because in isolation there were not enough records to make a reliable model.

  Estuarine fish species such as small-mouthed hardyhead (*Atherinosoma microstoma*) were **not** modelled.

- At each sub-catchment, the individual native fish models were used to predict the habitat suitability for that species. Habitat suitability prediction values range from a minimum of 0 to a maximum of 1. All the habitat suitability prediction values were summed and divided by the total stream length in the sub-catchment to give the estimated native fish richness for the sub-catchment. The classes for estimated native fish richness are presented in Table 20.

- When examining estimated native fish richness, context is an important consideration when interpreting outputs. Where urban streams have a heavily-modified channel structure, flow regimes, degraded riparian zones and poor water quality, then estimated native fish richness is likely to be Low/Very Low. However, there may be alternative reasons for Low/Very Low estimated native fish richness at a reach. For instance, headwater and small tributary streams may only carry water intermittently and are expected to have Low/Very Low species richness (even if the riparian zone and immediate watershed are intact and in good condition). It is therefore important to note that Very Low and Low do not necessarily imply a poor state of affairs.

Table 20. Fish status metric (noting the description of low and very low does not readily apply to headwater streams which typically have naturally low species richness)

Rating	Description	Stacked richness categories
Very High	All or almost all native freshwater species recorded in the catchment likely to be present	> 4

High	Most native freshwater species recorded in the catchment likely to be present	3 – 4
Moderate	About half the native freshwater species recorded in the catchment likely to be present	2 – 3
Low	Few freshwater native species recorded in the catchment likely to be present	1-2
Very low	Very few or no native freshwater species recorded in the catchment likely to be present	< 1

The value of recreational fishing was considered through the social values defined in the strategy and as such were not modelled or assessed through the Habitat Suitability Models. It is recognised however that habitat improvement works proposed through the Strategy will also benefit recreational fish species.

Platypus

To date, captures per unit effort (CPUE) has been used as the primary index of relative abundance for platypuses to generate spatial and temporal population trends. It is a simple relative measure of abundance. Capture indices, such as CPUE, assume that the index is proportional to the actual population abundance and the relationship between the index and abundance is constant (Caughley 1977). Therefore, changes in CPUE over time or between survey sites represent proportional changes in abundance (Conroy & Nichols 1996).

To calculate CPUE, the number of individual platypuses captured in a sampling period is divided by the survey effort to standardise capture success and provide an index of relative abundance. Survey effort reflects the total number of nets deployed during a particular survey night. For example, if one site is set with two open traps this represents two trap nights, or if two traps are open at each of six sites, then the survey effort is 12 trap nights. Thus four platypuses captured during 24 trap nights would give you a CPUE of 0.167 (4 platypuses/24 trap nights = 0.167). This standardisation allows comparison of relative abundance across surveys sites, waterways, catchments and survey periods.

The difficulties in estimating population size for platypuses and limitations of CPUE has been discussed in previous reports (Griffiths et al 2019). Many factors can potentially influence CPUE such as seasonal behaviour and movement (e.g. males move further during breeding season, females restricted to burrows during early lactation), environmental conditions (e.g. low flows appear to restrict movement; Griffiths & Weeks 2015), restrictions in fyke net placement, temporal variation in sites, and potential for net avoidance (Griffiths et al. 2013).

Two HSMs were developed for platypus: all platypus of all life-stages (i.e. male and female, sub-adults/adults), and just female sub-adult/adults that have smaller home ranges and much higher food resource requirements during certain times of the year (e.g. during lactation). While both models were used for analysis purposes, the all platypus model was used for the strategy targets.

The Habitat Suitability Models use probability of occurrence which is very similar to CPUE. For instance, if there are 100 stream segments that each have a predicted probability of occurrence of 0.5 for platypus, then one would expect to find platypus at ~50 of those 100 stream segments. Similarly, if there are 100 stream segments that each have a predicted probability of occurrence of 0.2 for platypus, then one would expect to platypus at ~20 of those 100 stream segments (Table 21).

Table 21. Platypus status metric

Rating	Description	Probability of occurrence categories
Very High	Very high proportion of stream length likely to support platypus	0.4 – 1.0
High	High proportion of stream length likely to support platypus	0.3 – 0.4
Moderate	Moderate proportion of stream length likely to support platypus	0.2 – 0.3
Low	Low proportion of stream length likely to support platypus	0.1 – 0.2
Very low	Very low proportion of the stream length likely to support platypus	0.0 – 0.1

2.4.3 Setting scenarios for fish, platypus and macroinvertebrate

Current state

Habitat suitability models were run for each of the 54 macroinvertebrate species, 13 fish species, all platypus and female only platypus. Macroinvertebrate species were combined into a single output using LUMaR and a stacked probability score for fish. All platypus and female only platypus were retained as individual model outputs.

The models were constructed using data for values and predictor variables collected from 1995 to 2009, (Table 18). “Current state” of the values was modelled using 2016 predictor variable datasets (see Table 23 for a full list).

An example of the macroinvertebrate model "current state" output is provided in Figure 23. Similar outputs were developed for fish and platypus.

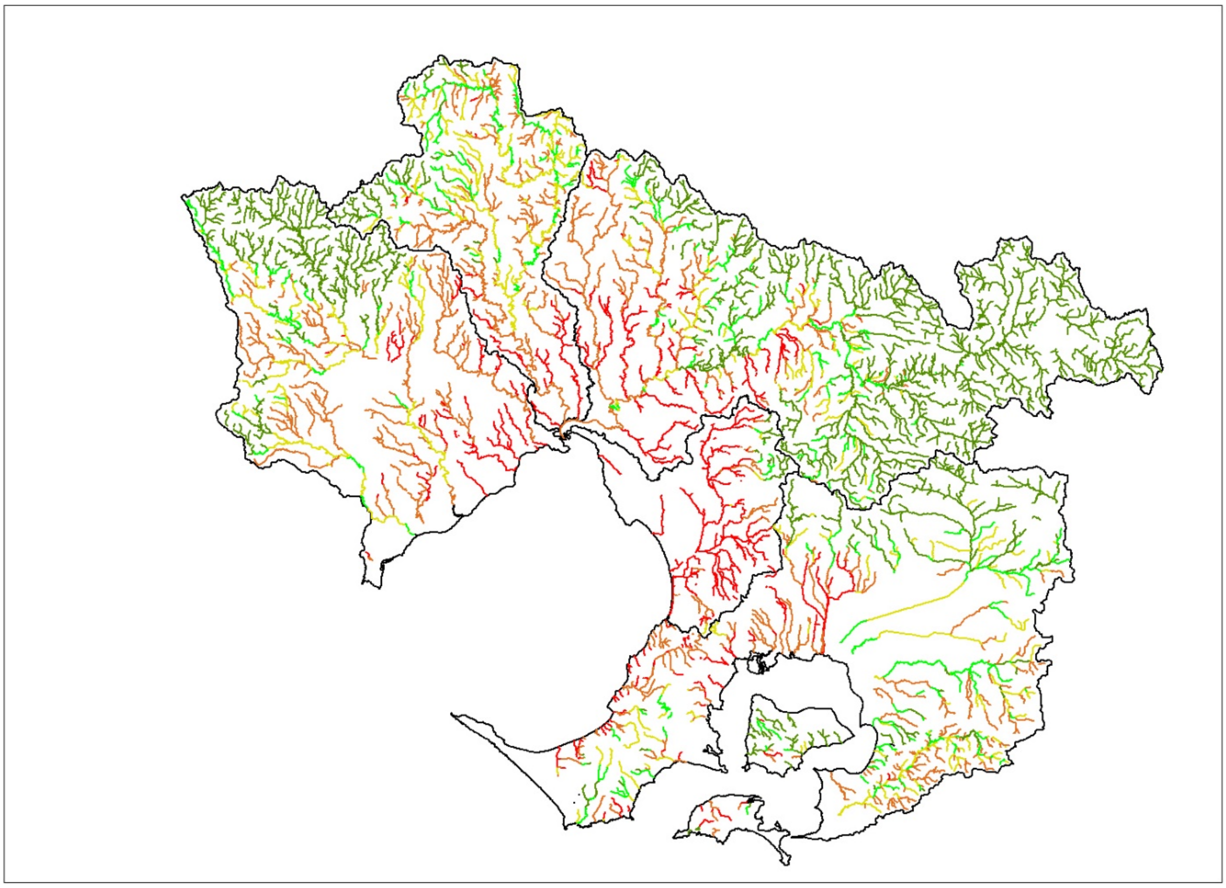

Figure 23: Habitat suitability model outputs for macroinvertebrates - current state. Output depicts LUMaR categories predicted across the region based on 2016 environmental conditions. Dark green = very high, green = high, yellow = moderate, brown = low, red = very low

While analysis and communication of results was carried out at the reach scale of the model, outputs were averaged to the strategy sub-catchment level (69 units) in order to define the current status and the targets. While there is some loss of data using this approach there was a need to be consistent with the overall approach for the other values and conditions. As the strategy sub-catchments are relatively small and homogenous the implications of this were deemed acceptable.

Platypus was initially modelled with a LWD predictor using the ISC3 large wood spatial layers, and while it was found to be a useful predictor for predicting current distribution, it was difficult to incorporate into future predictions from management interventions so it was removed.

Due to modelling limitations some outputs were overridden. This was the case for platypus where the model predicts suitable habitat however for various reasons they do not exist in those reaches. For example platypus do not inhabitant streams along the Mornington Peninsula simply because they are too small. Sub-catchment ratings were replaced with an N/A with the statements along the lines of "Small streams and artificial drains, such as those connected to the Dalmore Outfalls, are assumed to have never supported platypus populations. For this reason, there is no assessment or setting of targets". In some instances platypus have become locally extinct. See Table 22 for relevant sub-catchments and the reason why the decision was made.

Table 22. Sub-catchments where platypus are known to not exist and as such HSM Platypus outputs were overridden and no targets were set.

Catchment	Sub-catchment	Reason
Dandenong Creek	Blind Creek	Locally extinct due to threats
Dandenong Creek	Kananook Creek	Locally extinct due to threats
Werribee River	Cherry Creek	Ephemeral stream not likely to support platypus
Werribee River	Kororoit Creek Lower and Upper	Locally extinct due to threats
Werribee River	Laverton Creek	Ephemeral stream not likely to support platypus
Werribee River	Lolypop Creek	Ephemeral stream not likely to support platypus
Werribee River	Skeleton Creek	Ephemeral stream not likely to support platypus
Westernport	Dalmore Outfalls	Small streams and artificial drains, such as those connected to the Dalmore Outfalls, are assumed to have never supported platypus populations. For this reason, there is no assessment or setting of targets.
Westernport	French and Phillip Islands	French and Phillip Islands are assumed to have never supported platypus populations due to small size of the streams, and disconnection from other major river systems such as the Bunyip, Lang Lang and Bass rivers. For this reason, there is no assessment or setting of targets.
Westernport	Mornington Peninsula North-Eastern Creeks	The Mornington Peninsula is assumed to have never supported permanent platypus populations due to the small size of the streams.
Westernport	Mornington Peninsula South-Eastern Creeks	The Mornington Peninsula is assumed to have never supported permanent platypus populations due to the small size of the streams.
Westernport	Mornington Peninsula Western Creeks	The Mornington Peninsula is assumed to have never supported permanent platypus populations due to the small size of the streams.

Another manual override was made for the Yarra River upper rural sub-catchment. The raw score was 0.41, or "very high", however given that current trajectory is 0.25, and potential trajectory 0.36, which is close to original score, the score of high is given here to reflect that we are "holding the line", rather than a target which is showing a decline from the baseline.

Trajectory under business as usual scenario future

The modelling revealed that urbanisation and climate change are the two most significant threats likely to impact the values over the long term. Table 23 outlines the parameters used for the 'business as usual future' scenario. There was assumed to be no mitigation of Attenuated Imperviousness for future urbanisation. This is because current best practice guidelines for urban stormwater reduce nutrient and sediment loads but do not manage runoff volume which is one of the key drivers impacting stream health. Attenuated forest cover was not changed as it was difficult to predict where revegetation would occur in the future – and as such was considered within the management intervention scenarios. Climate change was modelled by changing air temperature and stream flows.

Table 23. Details of the current (CURR) scenario and the business-as-usual-future (BAUF) scenario.

Scenario Code	Mean annual air temperature (^{0}C)	Mean annual runoff depth (mm)	Attenuated Forest	Attenuated Imperviousness	Instream Barriers	
					Full	Partial
CURR	2016 values	2016 values	2016 values	2016 values	Barriers in place at 2016	Barriers in place at 2016
BAUF	2016 values + 1.5 ^{0}C	Equivalent to a 25% reduction in the long term mean value at the mouth of the Yarra River*	2016 values	Values reflecting attenuated imperviousness when all parcels within the MW region with 'urban' planning scheme zone codes have been developed to their full capacity	Barriers in place at 2016	Barriers in place at 2016

*To represent drier conditions reflecting a 25% reduction in the long term mean annual flows at the mouth of the Yarra River, Walsh & Webb (2013) identified a 4-year period (that happened to be the 48 months prior to December 2000) where mean annual discharge was 75% of the long-term average. The monthly discharge estimates for this particular 4-year period was used as an analogue for drier conditions. (In practice, dryMeanQ for each reach was set to mean annual discharge calculated from monthly discharge estimates in Geofabric (Bureau of Meteorology 2011) over that particular 4-year period.)

Results for the BAUF scenario were used in the HWS as the "Current trajectory" – i.e. the likely outcome if current policies and effort continue. A sub-catchment length weighted average for each of the key value status metrics was calculated from the reach scale data – and any manual changes as discussed above were made.

In addition to the business as usual scenario a number of other scenarios were run to help communicate threats and opportunities across the region and aided in setting long term targets for the strategy. A selection of these scenarios were presented at the co-design workshops. The scenarios were typically based on different revegetation scenarios, different levels of stormwater intervention and various combinations of fishway construction. Appendix 3 outlines all the various scenarios which were modelled using the HSMs. All scenarios used the climate change parameters unless noted. Several scenarios allowed for an increase in temperature but did not change the flow attribute. This scenario was used specifically to explore the impact on platypus as the drying scenario from climate change resulted in quite dire implications for platypus. It was considered that in priority locations interventions may be implementable which would prevent baseflows from reducing from current levels.

A number of native fish species are predicted to have greater amounts of suitable habitat under BAUF conditions that are warmer, drier and include urban expansion. An important caveat here is that while greater extents of waterways are predicted to be suitable habitat for these species, they may not take up the use of those waterways. This will depend on population processes such as births, deaths and migration and these population processes are not accounted for in the Habitat Suitability Models. It was the more common and wide spread species (those with a broader tolerance to environmental conditions) which increased their range under the BAUF scenario. This resulted in higher richness scores for some sub-catchments, which was at the detriment of the less tolerant native species (e.g. River Blackfish were predicted to decline under BAUF). As such these results should be used with and understanding of the species driving the score.

Long term Target setting for the instream values

The process of setting targets for the key values needed to consider both short term (10 yr outcomes) and long term (i.e. 20-50 years) horizons. The short term targets (known as performance objectives) are more closely aligned to environmental conditions while the long term targets included both key values and environmental conditions.

Setting targets for both these time periods was a somewhat iterative process. For example thought needed to be given as to what was achievable and cost effective in the short term and what was the long term goals set for the catchment. A combination of decision support tools, expert opinion and collaborative forum input was used in this process. An iterative process of modelling future scenarios and checking-in on what was considered achievable determined that a stretch in both the short term and long term was needed. This included consideration of budgets, partnerships and policy changes. At several points feedback was sought from key stakeholders including the forums participants. While the general approach is outlined below, the Stormwater Condition, Vegetation Extent and Instream Connectivity sections outline more detail around the assumptions for setting targets for these conditions which in turn drove the long term targets for the key values.

An overview of the approach which utilised the HSMs is provided below while the environmental conditions that were are explicitly part of the model are summarised in section 2.4.4

Box 8.

Key steps in developing targets for instream values:

1. Develop 10 year costs for revegetation, stormwater and fishways (Appendix 5 - Development of unit costs for zonation analysis).
2. Set up zonation (see
3. Box **8** and Appendix 6 - Overview of zonation application)
4. Use HSM outputs and zonation to determine the most cost effective action for any given reach (see map in Appendix 6 - Overview of zonation application)
5. Using the most cost effective action from the step above, run zonation to develop a zonation ranking map. The output spatially prioritises which reaches should be managed first according the most cost effective action for that reach (see Appendix 6 - Overview of zonation application
6. Analyse results and decide on ‘where’ and ’what’ actions (or combinations) will be prioritised for 10 year outcomes (refer to vegetation extent, stormwater and instream connectivity sections for detailed methods). The following broad considerations were made:
    a. All high ranking zonation actions were prioritised (unless sense checking ruled them out – see Appendix 6 - Overview of zonation application for process)
    b. If zonation ranking was moderate but aligned with a catchment forum action then it was prioritised.
    c. Forum actions which ranked low with zonation were not prioritised
7. Determine long term outcomes – to what extent will riparian buffers be established in the long term, how many fishways will be built and how extensive will stormwater management be (refer to vegetation extent, stormwater and instream connectivity sections for detailed methods)
8. The final benefit score for each subc (reach) was used scenarios Re-run HSM with long term outcome scenarios (for both the key values and the environmental conditions) and use outputs for the targets.

Box 8. Zonation: What is it and how does it work?

Zonation is a set of methods implemented in a software tool to support large-scale systematic spatial conservation prioritisation and planning (Moilanen et al. 2005, 2014). Three key concepts in systematic conservation planning are:
- *representativeness* - representing the full variety of biodiversity in the study area
- *irreplaceability* - prioritising unique or rare species occurrences without which we would fail to achieve *representativeness* and
- *complementarity* – ensuring that the selection of additional sites complements or adds new species rather than duplicating the species present in sites already selected

Zonation provides quantitative methods to operationalise these three principles.

Zonation has been used in conservation applications worldwide. A notable international example is the high spatial resolution (~0.86 km^2) conservation blueprint that was developed for Madagascar (areal extent 587,040 km^2) that involved 2,315 species across 6 major taxonomic groups (ants, butterflies, frogs, geckos lemurs and plants)(Kremen *et al*. 2008). In Australia, Zonation has been used for large-scale land use planning in the Lower Hunter region (Kujala *et al*. 2015), for strategic environmental assessment in West Australia's Perth-Peel region (Whitehead *et al*. 2016), for the Victorian Department of Environment, Land, Water and Planning's Strategic Biodiversity Values map (DELWP 2017a), and their Strategic Management Prospects (DELWP 2017 b, c).

Zonation works by iteratively removing the least valuable reaches (planning units) from the landscape while minimizing marginal loss of conservation value and accounting for connectivity needs and taxa/species weights. This process generates a nested sequence of connected landscape structures with increasingly important core areas of species habitats (or distributions) remaining last. The Zonation solution is mapped as a hierarchical, continuous ranking of spatial priorities across the study area that is easy to visualise and interpret.

Zonation offers many features and capabilities for addressing different questions and needs. For instance, there are different methods for (Moilanen et al. 2014):

- quantifying conservation value (known as 'cell removal rules' in Zonation terminology)

- inducing aggregation and connectivity (to minimize fragmentation and isolated patches in the solution)

- accounting for different types of costs

- accounting for landscape condition and biodiversity retention

These features and capabilities can be combined and configured to create customised Zonation analysis set-ups to suit user-needs.

2.4.4 Priority conditions, threats and management interventions

While the HSMs and zonation were able to assist in prioritising targets for the instream values and several of the environmental conditions (i.e. vegetation extent, instream connectivity and stormwater), water quality, physical form and water for the environment are not explicitly modelled. The interaction between the models and how targets were set for these conditions is outlined below.

Water for the Environment (see section 3.2)

The HSM do not currently include major flow diversions such as those from water supply dams. Long term targets and the 10 year performance objectives for flow regimes are based on existing flow studies which take into account a detailed analysis of flow requirements for instream values.

Water Quality (environmental) (see section 3.5)

The HSM do not currently directly use water quality data as a model predictor although to some extent attenuated forest cover and AI are indirectly related to water quality. As such for urban areas the HSM analysis was considered suitable for setting priorities for water quality protection, except for certain known hot spots where targeted investigations and solutions are required. In rural areas, priorities for managing intensive agriculture were guided by using the macroinvertebrate HSM data.

Physical form (see section 3.7)

The HSM do not currently use physical form as a predictor variable and this is an area of future improvement. Bank vegetation and LWD were included in the platypus model however there was not a large difference between management scenarios run with or without these predictors. This is partly due to the attenuated forest cover and AI variables being somewhat surrogate variables for physical habitat. I.e. if AI is low then physical habitat is likely to be intact. A prioritisation process to identify sub-catchments where excessive erosion is a key risk was undertaken using existing geomorphological studies and expert opinion.

Vegetation Quality (see section 3.4)

The HSM do not currently use vegetation quality as a predictor variable. In many cases the attenuated forest cover predictor is highly correlated with the quality of vegetation, however there are cases where reaches with relatively high attenuated forest cover may be highly degraded in terms of vegetation quality (e.g. high infestation of woody weeds). The impact of weeds on instream values is quite complex. Further work to include a predictor variable is underway. However for the purpose of the HWS there was an assumption made that instream values require a moderate level of vegetation quality. The HSM were used to identify reaches where maintaining existing moderate quality vegetation was a priority.

2.4.5 Key assumptions and improvement opportunities

There were a number of assumptions made in the process of setting targets for the instream values and associated conditions. The key high risk assumptions made in setting targets for the key values are outlined in Table 24.

Table 24. Key high risk assumptions made in setting the long term targets for instream values

Key assumption	Related Key Value	HSM Predictor variable
It was assumed that in key locations flows (particularly base flows) could be maintained through interventions which could offset the likely climate change drying conditions. As such the mean annual runoff depth set to 2016 values.	Platypus	Flow (mean annual runoff depth mm)
It was assumed that climate change will lead to a 25% reduction in flow at the mouth of the Yarra River as predicted by CSIRO (ref) and that this is an adequate representation of flows for other streams (see Table 23).	Fish and macroinvertebrates	Flow (mean annual runoff depth mm)
It was assumed that in response to an increase in stream temperature as a result of climate change, many common fish species expanded their range.	All instream values	Air temperature - 2016 values + 1.5 ^{0}C
It was assumed that in the long term a reduction in 25% of all attenuated imperviousness was feasible through renewal activity (see section 3.1.2 for further details).	All instream values	Attenuated imperviousness
It was assumed that a 20 m vegetated buffer either side of all priority reaches outside the UGB is achievable in the long term. It was assumed that a 10 m vegetated buffer is feasible to priority reaches within the UGB. (see section 3.3.2 for more details)	All instream values	Attenuated forest cover
It was assumed that all fish barriers would be removed except very large barriers such as water supply dams (see section 3.6.2 for more details).	Fish	Barriers

Through the strategy development process a number of improvement opportunities were identified (Table 25). These should be considered for future use of HSMs and zonation. Improvement opportunities will be developed through the HWS MERI framework and the associated Rivers Monitoring and Evaluation Plan (MEP).

Table 25. Improvement opportunities for the HSMs and zonation

Issue / Learning / Idea	Improvement initiative
Poor model prediction for highly modified waterways	Flag pipes, concrete, earthen channels and levees in models Develop an instream habitat predictor variable Assess whether pipes and channels be used as a predictor variable
Headwater streams not part of models	Prioritise headwater streams using separate process Include headwater streams in new generation of models
Internal feedback that estimated costs for revegetation seemed high	Factor in refined costs as they become available e.g. better knowledge of incentives Life cycle costs
The BaU future scenario did not factor in on-going revegetation efforts	Consider if some scenarios would be useful e.g. tribs versus main stems, urban versus rural
Feedback questioned whether 20 m wide buffer should be blanket everywhere	Investigate literature. Undertake modelling to ascertain whether lowland / floodplain streams would benefit from a larger buffer
It would have been useful to know which areas are more likely to develop in the next 10 years to assist in prioritising SW catchments	Continue to improve ability to predict development rates and utilise in next version of model analysis
The predictor variable - attenuated forest cover does not adequately reflect the natural low density of forest cover in western streams	Assess whether the kms to establish i.e. the gaps can be better articulated or recalculated based on and O/E assessment i.e. compare to EVC levels of canopy cover
The ability to adequately prioritise actions for flow stress	Farm dams are being assessed for possible predictor variable.
Not being able to prioritise rural land management from the models	Investigate whether WQ modelling being done by Anna Deletic could be used as a predictor variable in the model.
Assessing impacts of droughts	As part of the MERI plan think through appropriate monitoring during drought periods.

There was not enough time to redo another zonation run with the final HSM scenarios	Re-run zonation with final scenarios
Large dams and tiny gaps in veg in forested catchments lead to many small highly ranked reaches	Flag all large dams Flag tiny areas of no veg and decide whether to flag or change forest cover data if it's erroneous
A lot of SW1s didn't seem to be sensible priorities	Fix networking issues Reassess zonation outputs once channels and pipes have been removed Assess whether SW1 can be capped for certain catchment size before going into zonation
Platypus predictions for certain reaches where they are locally extinct / never found - made presentation of results difficult	Flag reaches where platypus not found or gone forever
How can platypus refuge habitat like farm dams be included in the models?	Use information from the Platypus Strategic Management Plan to assess gaps in current draft POs for platypus
There was mixed feedback on the climate change 'winners' which the model was predicting	Investigate more closely the predictions for individual species and decide how real the predictions are?

2.4.6 Further resources

Habitat suitability model outputs for platypus - https://data-melbournewater.opendata.arcgis.com/datasets/hws2018-habitat-suitability-modelling-results-for-platypus

Habitat suitability model outputs for macroinvertebrates - https://data-melbournewater.opendata.arcgis.com/datasets/hws2018-habitat-suitability-modelling-results-for-macroinvertebrates

Habitat suitability model outputs for fish - https://data-melbournewater.opendata.arcgis.com/datasets/hws2018-habitat-suitability-modelling-results-for-fish

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2.5 Amenity, Community Connection and Recreation

2.5.1 Context to expanding the HWS social value framework

The social value of waterways has long been recognized and considered in waterway management (Melbourne Water, 2007) . Management approaches to social values have evolved from risk assessment based on presence/absence of activities and/or features (e.g. camping, fishing) to consideration of how and why communities value their waterways.

The HWS 2013 considered the social benefits provided by waterways through the inclusion of "Amenity" as a key waterway value. Amenity was defined as "the pleasantness of a waterway to visitors and the ability of the waterway to provide a restorative escape from the urban landscape" and was chosen as a key value as it represents one of the most important reasons that people value and visit waterways, as understood through surveys undertaken by both Melbourne Water (Community Perceptions of Water Survey 2016 – TKP, 2016) and DELWP (My Victorian Waterway Survey date 2009).

Since the development of HWS 2013, the water industry has continued to build understanding of the social value of waterways and its role in helping the community to enjoy that value and this has ultimately influenced the HWS refresh. This increased understanding and evolution is illustrated by:

- Expanding water industry interest in liveability and community benefit, including a key report in this area, *The role of the urban water industry in contributing to liveability (WSAA, 2014)* which highlighted that water corporations could play a broader role in supporting the liveability of a city than traditional water supply, sewage treatment and waterway management.
- Melbourne Water's Strategic Direction Enhancing life and liveability, and supporting pillars: Healthy People, Healthy Places, Healthy Environment.
- State Government's Water for Victoria plan which commits to including recreational values in waterway planning (DELWP, 2016).

Additionally, there has been further consideration of social research that explores how and why people value waterways; the link between the natural environment and physical and mental health and well-being; and the different avenues through which people derive value from natural spaces. Equally important has been the collaborative co-design approach to strategy development with local government, the community, and other organisations which together have a broader sphere of influence in supporting the social values of waterways than Melbourne Water alone.

All of these factors have led to the expansion of the social values framework for the HWS 2018 to include Community Connection and Recreation alongside Amenity.

2.5.2 Defining social value

Research in Australia and internationally has shown that people value natural areas and waterways for a range of reasons.

Kendal and Farrar (2016) found that there is some consistency in the ways that people attribute value and conducted research which enabled them to categorise 6 different ways Melburnians value their waterways:

- Natural: valuing nature such as trees, biodiversity and habitat
- Experiential: valuing the opportunities natural areas provide for personal benefits such as relaxation and enjoying aesthetics (such as sights, sounds, smells)
- Social: valuing the opportunities areas provide for social interaction and meeting other people
- Cultural: valuing cultural heritage and practices and historic sites
- Ecosystem services: valuing the services that waterways provide such as filtering pollution
- Setting for recreation: valuing the opportunities to engage in activities such as canoeing, cycling, walking or swimming

This research aligns strongly with data from Melbourne Water's biennial Community Perceptions of Waterways survey The survey considers how people use waterways, why they visit them and their overall satisfaction with Melbourne's waterways.

The survey consistently shows that people's main reasons for visiting waterways include:

- natural and experiential activities such as general relaxation, nature appreciation, wellbeing, bird watching;
- social activities such as social meetings and family outings, picnics/bbqs;
- recreational activities such as exercising, jogging/walking, canoeing/fishing, swimming.

In updating the Social Value framework, consideration was give specifically to the value that people derive through visiting and experiencing waterways. This was for several reasons including:

- the value that people derive from their visit to a waterway can be influenced by management activities
- there is available data to understand why people visit waterways and their satisfaction with the waterway
- economic and cultural values of waterways are considered separately within the strategy
- management for environmental values and conditions will positively impact ecosystem service and intrinsic values.

The experiences that people have at waterways was used to define three key values for the Strategy:

1. Amenity - Waterways provide restorative places where people can go to relax, escape normal life, appreciate nature, and feel better through a variety of multi-sensory experiences. Amenity also includes the influence of the micro-climate on people's sensory experiences of waterways, for example by reducing the impact of the urban built environment by riparian vegetation providing shade and temperature moderation.

2. Community Connection - Liveable places are places that have a sense of community, with communities valuing waterways because they provide settings where people can join together for social interactions, learn from the environment, engage with art and culture and significant places i.e. to connect with people and nature. They also provide settings for Aboriginal people to connect with Country and their elders past and present (Stephens et al. 2007, Alluvium 2010).

3. Recreation – Waterways provide settings and opportunities for people to pursue active and/or passive activities within their leisure time, separate to activities that are necessary for their survival, such as work. Waterways can provide a good place for activities such as paddling, fishing, jogging and bike riding.

Expansion and development of the conceptual models for social values at waterways is an important part of increasing the robustness of the management approaches to maintaining and improving the social values of waterways.

A framework was developed to articulate the logic of how management levers can impact on the conditions that support each of the social key values (Figure 24). Conceptual models for each of the three social key values were developed to document the relationships and assumptions in more detail (Jacobs, 2017)(Figure 25, Figure 26 & Figure 27).

Development of the conceptual models was based on review of relevant literature and research and use of expert opinion to identify the relationship between elements of waterway condition and the three social values. An important output of the model development process is a database of relationships and the evidence that supports them.

Social Values	Recreation	Amenity	Community Connection
Experiences	- engage in active recreation - engage in passive recreation - use waterway corridors for transport	- escape from the usual (urban) environment - immerse in a natural environment -engage with aesthetically pleasing place - feeling safe	- connect with nature - interact with other members of the community - learn from the environment - engage with a culturally significant place - engage with art and culture
Condition attributes	Facilities (built environment) - Facilities that support community/cultural events - Pathways (access) along the waterway corridor - Access to the waterway corridor - Visitor facilities (toilets, BBQs, Playgrounds) - Dog walking areas (inlc. Off leash facilities) - Boat/canoe facilities - Exercise equipment - Sporting facilities -Interpretive signage and Community art		Landscape (natural environment) - presence of native animals - quality and extent of vegetation -water flow/levels -site maintained/cared for (safety) -type and extent of open space - sitelines/viewlines -stream form -topography
Supporting information (Community Perceptions data)	Relative levels of visitation and satisfaction; data on reasons for visiting and activities engaged in		
management objectives	- Enhanced active recreation opportunities - Enhanced passive recreation opportunities	- Enhanced variety and quality of positive experiences - Enhanced naturalness - Enhanced access and safety - Enhanced landscape aesthetics - Increased provision and enhancement of 'cool' spaces (urban cooling)	- Engaged and knowledgeable community - Engaged and supported community groups
Management levers	- increase open space for active/passive recreation opportunities -Provision of sporting facilities (e.g. fields, exercise equipment) -provision of facilities to support recreation (e.g. drinking fountains, toilets, cycling facilities)	-site appropriate vegetation management (may include vegetation for cooling/shade, habitat, screening from urban environment, naturalness) -faunal habitat improvement -environmental water management -maintaining natural channel form -site appropriate safety improvements (e.g. pathways, lighting) -aesthetic improvements (e.g viewlines, litter, vegetation) - access enhancement (e.g. remove barriers to access; improve pathways, signage, wayfinding)	-conduct engagement and education events -provide education and interpretive signage -Support community groups -support art and culture events and installations -- access enhancement (e.g. remove barriers to access; improve pathways, signage, wayfinding) -protect and enhance post-european cultural heritage
Threats	-poor access -lack of appropriate facilities -poor environmental condition	-inappropriate urban development (encroachment/ overshadowing) -lack of appropriate facilities -inappropriate maintenance (messy or unsafe vegetation or paths) -poor environmental condition/naturalness -poor access	-lack of appropriate facilities -poor environmental condition -lack of opportunities/experiences -poor access

Figure 24. Social values framework

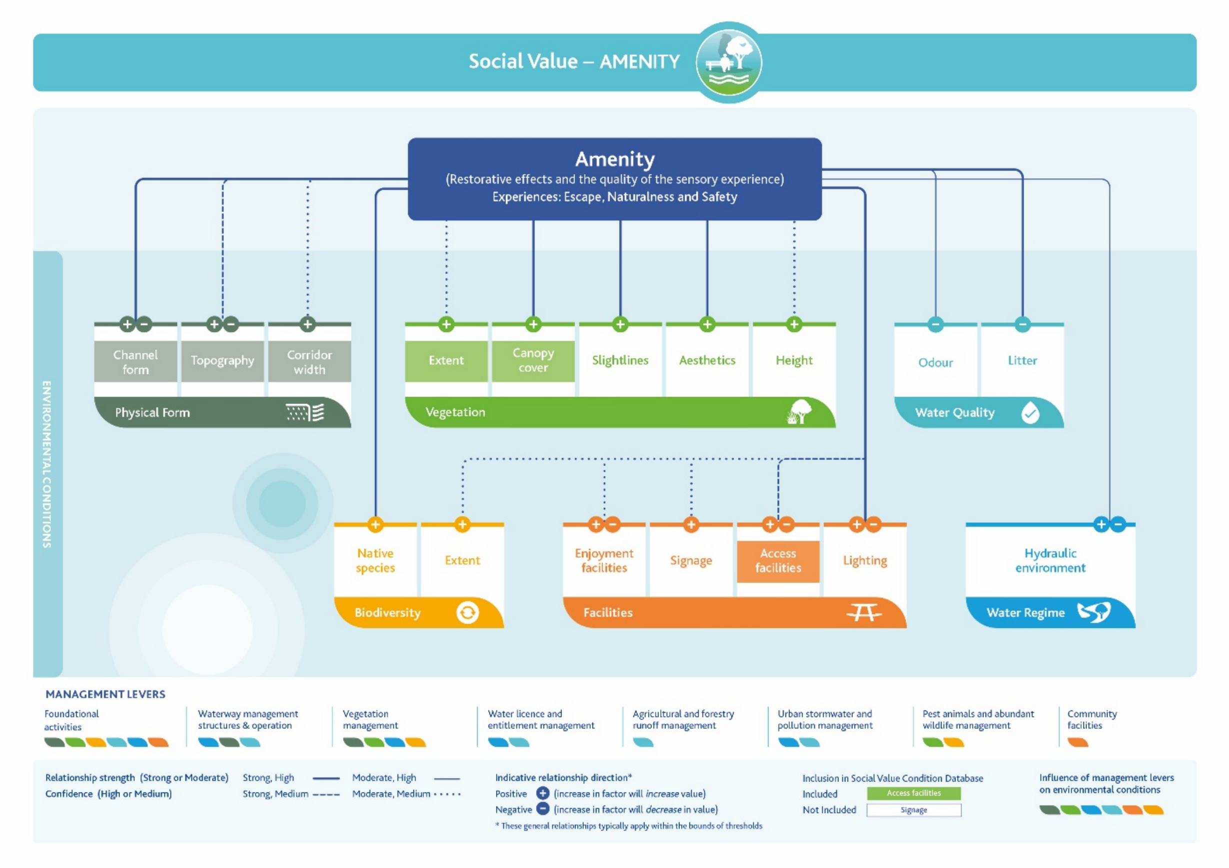

Figure 25. Amenity conceptual model (Jacobs, 2018)

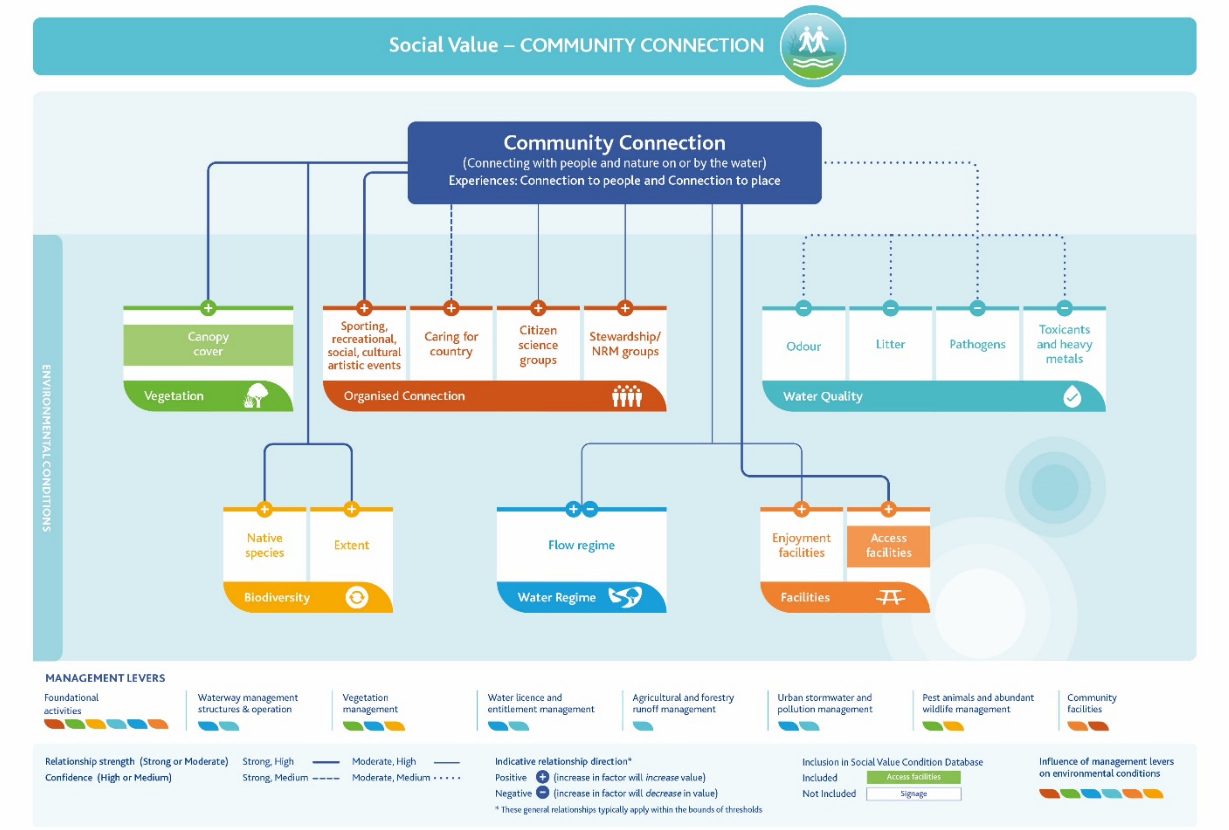

Figure 26. Community connection conceptual model (Jacobs, 2018)

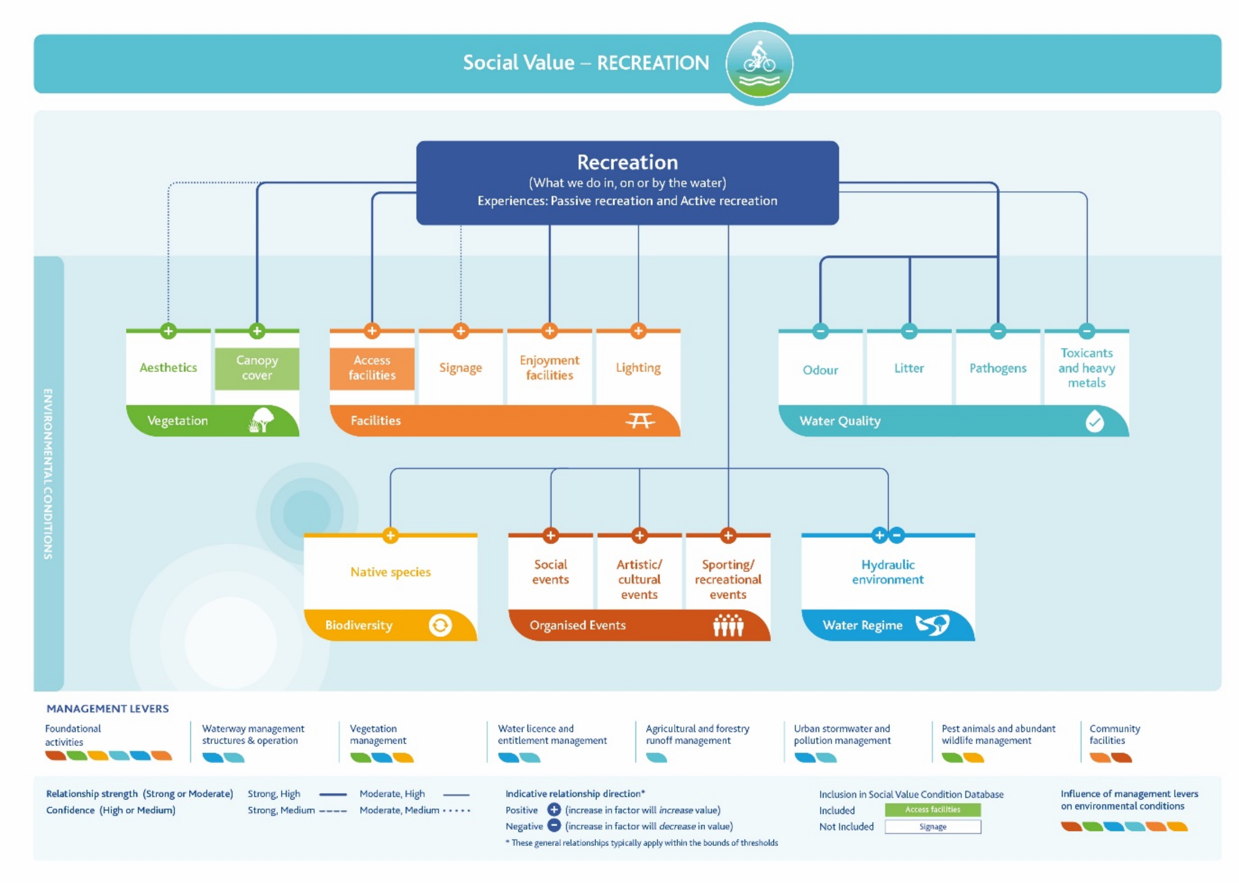

Figure 27. Recreation conceptual model (Jacobs, 2018)

2.5.3 Available data and condition metrics

Available data

Unlike environmental values, the condition of social values are human dependant by their nature. That is, the condition of recreation at waterways can be understood by considering if people are experiencing recreation at waterways and if they are satisfied with that experience. Data used to assess the three social values is the 2016 Community Perceptions of Waterways survey. The survey samples the population of greater Melbourne to understand how people use waterways, the reasons why and frequency with which they visit them and their overall satisfaction with Melbourne's waterways. It explores perceptions about the role of waterways, threats to waterways and attributes that influence satisfaction with them.

The survey typically has a sample size greater than 2000, with around 1,500 of those having visited waterways in the last 12 months. The survey ensures coverage across the region and across age and gender.

Data limitations

The survey is designed to have at least a sample size of 2,000 respondents to give 95% confidence that the sample results falls within +/- 2.2% of the population. However this confidence and margin of error is for the whole of region results. Once results are considered at smaller geographical scale the margin of error increases. The data has been analysed at the

HWS 2013 system scale which results in a margin of error of up to +/-7%, depending on the number of respondents in each system. Ideally, data would be analysed to 2018 sub-catchment scale, however the sample size is not large enough to support this analysis.

Additionally, whilst the survey provides an assessment of the respondent's satisfaction with waterways for the reason they visit them, the survey is not detailed enough to identify the cause/effect relationship that results in that perception. That is, the survey does not elicit the specific condition attributes that influences the respondent's experience. However, regression analysis has been used to identify condition attributes that are highly influential to respondents satisfaction.

For the 2018 survey a "pin drop" function was added to the survey to allow data collected to be attributed to a specific location.

Condition metric

The values are assessed by correlating survey respondents primary reason for visiting waterways with one of the three social values and then taking the average satisfaction score given in response to the survey question "How satisfied are you with Melbourne's waterways being suitable for how you use them?". This gives an assessment of satisfaction with waterways in relation to each social value.

Table 26 indicates shows the "reason for visiting waterway" that were correlated to each social value.

Table 26. Correlation between social values and reasons for visiting waterways

Corresponding social value	Correlated primary reasons for visiting waterway
Amenity	Feeding the ducks / other waterbirds General relaxation Nature appreciation Well-being
Community connection	Social meetings / Family outings Picnics / BBQs / lunch Cafes/Restaurants
Recreation	Bird watching Canoeing / kayaking / boating / rowing Commuting: walking / cycling Dog walking Exercising: cycling/walking/jogging/running Fishing Swimming/wading

The average satisfaction score is then categorised to a five point scale, to align with other value assessment (Table 27). Hence, satisfaction has been used as a proxy for condition for social key values.

Table 27. Condition metric for social key values

Key Value	Metric Description	Very low	Low	Moderate	High	Very high
Amenity	Based on data from Melbourne Water community perceptions of waterways research on 'satisfaction with waterways' in relation to amenity related activities	Very low level of satisfaction with amenity	Low level of satisfaction with amenity	Moderate level of satisfaction with amenity	High level of satisfaction with amenity	Very high level of satisfaction with amenity
Amenity	Average satisfaction scores (0 to 10) from survey respondents	0 - 4	4 - 6	6 - 7	7 - 8	8 - 10
Connection	Based on data from Melbourne Water community perceptions of waterways research on 'satisfaction with waterways' in relation to community connection activities	Very low level of satisfaction with community connection	Low level of satisfaction with for community connection	Moderate level of satisfaction with community connection	High level of satisfaction with community connection	Very high level of satisfaction with community connection
Connection	Average satisfaction scores (0 to 10) from survey respondents	0 - 4	4 - 6	6 - 7	7 - 8	8 - 10
Recreation	Based on data from Melbourne Water community perceptions of waterways research on 'satisfaction with waterways' in relation to community connection activities	Very low level of satisfaction with recreation	Low level of satisfaction with recreation	Moderate level of satisfaction with recreation	High level of satisfaction with recreation	Very high level of satisfaction with recreation
Recreation	Average satisfaction scores (0 to 10) from survey respondents	0 - 4	4 - 6	6 - 7	7 - 8	8 - 10

2.5.4 Setting scenarios for Amenity, Community Connection and Recreation

Current state

The current condition state for amenity, recreation and community connection was determined based on the metrics described in the previous section based on the HWS 2013 system scale. To identify the appropriate assessment rating for the HWS 2018, sub-catchments were assigned the score that corresponded to the HWS 2013 system that most closely aligned to the sub-catchment boundary (see Table 28).

Table 28. Average satisfaction for social values HWS 2013 system to HWS 2018 sub-catchments

HWS2013 system	HWS2018 sub-catchments	Amenity		Community connection		Recreation	
		Average satisfaction score	Value condition	Average satisfaction score	Value condition	Average satisfaction score	Value condition
Lower Bunyip, Lang Land and Bass (Rural)	Bunyip Lower, Lang Lang, Bass, King Parrot and Muck Creeks	7.64	High	7.58	High	6.55	High
Upper Bunyip and Tarago	Tarago, Bunyip River middle and upper	7.00	High	6.40	High	6.50	High
Cardinia	Dalmore Outfalls, Cardinia/Toomuc/Deep/Ararat creeks	7.24	High	7.00	High	7.09	High
Dandenong	Bayside, Dandenong Creek Lower, Dandenong Creek Middle, Dandenong Creek upper, Kananook, Eumemmerring, Blind, Corhanwarrabul/Monbulk/Ferny	7.64	High	7.46	High	7.34	High
Maribyrnong lower	Stony Creek, Steele Creek, Taylors Creek, Maribyrnong River	7.61	High	7.65	High	7.63	High
Maribyrnong Upper	Deep Creek Upper, Deep Creek Lower, Boyd Creek, Emu Creek, Jacksons Creek	6.92	High	7.09	High	7.00	High
Mornington Peninsula	Mornington Peninsula Western Creeks, Mornington Peninsula South Eastern Creeks, Mornington Peninsula North Eastern Creeks	7.62	High	7.15	High	7.45	High

HWS2013 system	HWS2018 sub-catchments	Amenity		Community connection		Recreation	
Cherry, Kororoit, Laverton and Skeleton (Werribee East)	Kororoit Creek Upper, Kororoit Creek Lower, Skeleton Creek, Laverton Creek, Cherry Creek	7.82	High	6.93	High	7.26	High
Werribee and Little River Lower	Werribee River Lower, Lollypop, Litter River Lower	7.78	High	7.63	High	7.41	High
Werribee and Little River Middle and Upper	Werribee Upper, Lerderderg, Werribee Middle, Little River Upper, Toolern, Parwan	5.67	Moderate	7.80	High	6.68	High
Yarra Lower	Gardiners, Koonung, Plenty River Lower, Plenty River upper, Plenty River source, Darebin Creek, Yarra River Lower, Merri Creek Lower, Merri Creek upper, Moonee Ponds Creek	7.58	High	7.11	High	7.31	High
Yarra Mid	Yarra River Upper (rural), Woori Yallock Creek, Olinda, Stringybark, Brushy, Mullum Mullum, Watts River rural, Yarra River Middle, Watsons, Diamond Creek Rural, Diamond Creek Source, Steels and Pauls Creek Rural, Steels and Pauls Creek Source	8.15	Very High	7.21	High	7.54	High
Yarra Upper	Little Yarra River and Hoddles Creek, Yarra River Upper (source), Watts River (source)	7.57	High	6.50	High	6.88	High

Forecast current trajectory under business as usual scenario

To forecast future condition for amenity, community connection and recreation, a series of assumptions are made in relation to the impact of: climate change, urbanisation; population growth and effectiveness of policy and programs on the key drivers (the attributes of waterway condition that have a strong link to satisfaction with satisfaction in relation to amenity, community connection and recreation) (Table 29, Table 30, Table 31).

Table 29. Assumptions about current trajectory for recreational values.

Recreation	BAU (continue current level of investment)			Improve (increased level of investment		
Primary condition drivers	**Recreational Water quality (driver of swimming and boating).**	**Shared paths along waterways (driver for cycling/walking/jogging)**	**Vegetation condition (indicator for the overall quality of the corridor)**	**Recreational Water quality (driver of swimming and boating).**	**Shared paths along waterways (driver for cycling/walking/jogging)**	**Vegetation condition (indicator for the overall quality of the corridor)**
Assumptions	- Recreational water quality is influenced by stormwater management practices and point source pollution current programs/policy not sufficient to meet SEPP in the majority of the waterways (some exceptions: Maribyrnong main stem in Brimbank Park); climate change: sees further declines in WQ Urban growth: reduces WQ due to changed land use (DCI); infill reduces WQ because BPEM doesn't apply. *Overall - rec water quality declines*	Shared paths have high profile in existing strategies current open space management arrangements lack clarity around roles/responsibilities land tenure restricts large regional projects paths are gradually being constructed, but not as quickly as community would like use increasing therefore suitability of paths declining (maintenance or overcrowded) Climate change: no impact on paths Urban growth and infill development offer opportunities to fill access gaps and extend access networks *Overall: the level of paths is gradually improving but not at a rate that meets community expectations*	Urban greening initiatives receive good level of planning and funding in the urban area (urban forest strategies): canopy increases climate change: negatively impacts vegetation Urban growth: new development neutral or negative for vegetation as new development must provide vegetated corridor but may be lesser value than existing *Overall: vegetation condition will gradually decline*	significant investment in retrofitting infrastructure (e.g. sewer maintenance; sewer containment upgrades; septic upgrade programs); and IWM; and rural land management investment in sanitary surveys investment in communicating to users (Yarrawatch etc.) significant investment in EPA regulation of point source pollution *Overall: Rec water quality improves*	shared paths have good level of planning and funding paths are being constructed at a rate that meets community needs *Overall: paths improve to keep pace with increased use*	vegetation improvement programs at level to meet moderate condition or above in 10 years
Summary assumption	***Recreation trajectory will gradually decline under BAU (10% decline over time)***			***Recreation trajectory will be improved over time (10% improvement over time)***		

Table 30. Assumptions about current trajectory for amenity values

Amenity	BAU (continue current level of investment)			Improve (increased level of investment		
Primary condition drivers	**Shared paths along waterways (enables access required to experience amenity)**	**Vegetation condition (indicator for the overall quality of the corridor)**	**Litter absence (indicator of degraded amenity)**	**Shared paths along waterways (driver of amenity as enables access to experience amenity)**	**Vegetation condition (indicator for the overall quality of the corridor)**	**Aesthetics (indicator of degraded amenity)**
Assumptions	As for recreation *Overall: the level of paths is gradually improving but not at a rate that meets community expectations*	As for recreation *Overall: vegetation condition will gradually decline*	Litter rates are associated with land use, population, local behavior and drains that flow to waterways. Existing litter management and behavior change programs are not effective in reducing overall volumes of litter. Increasing population and densification is expected to result in increasing litter. *Overall: litter volume is expected to increase.*	As for recreation *Overall: the level of paths will be improved to meet community expectations – requires maintenance, upgrading and extensions to network*	*As for recreation* *Overall: vegetation condition will be improved as new paths are built, open space improved and revegetation occurs*	Litter rates are associated with land use, population, local behavior and drains that flow to waterways. Increased focus on at source management and behavior change will be somewhat effective, but will likely be negated by with population increase; opportunity to improve significantly will be low. Litter volume is expected to remain constant. *Overall: litter volume is expected to maintained.*
Summary assumption	***Amenity trajectory will gradually decline under BAU (20% decline over time)***			***Amenity trajectory will improve (10 % improvement over time)***		

Table 31. Assumptions about current trajectory for community connection values

Community Connection	BAU (continue current level of investment)		Improve (increased level of investment)	
Primary condition drivers	**Shared paths along waterways (driver for cycling/walking/jogging)**	**Participation through grants, incentive programs for land improvement, and citizen science.**	**Shared paths along waterways (driver for cycling/walking/jogging)**	**Participation through grants, incentive programs for land improvement, and citizen science reflects the level of caring across the community for waterways health.**
Assumptions	As for recreation *Overall: the level of paths is gradually improving but not at a rate that meets community expectations*	Without significant further investment in programs and program promotion it is unlikely participation numbers will increase – and will most likely decline as older people leave these programs Visitor numbers and increased use of waterways for community based events will require additional space and facilities to keep pace with population increase *Overall: community connection will gradually decline*	As for recreation *Overall: paths improve to keep pace with increased use*	Increased investment in programs and program promotion will likely result in an increase to participation numbers. Investment in additional space and facilities to will support increased visitor numbers and increased use of waterways for community based events *Overall: community connection will be improved*
Summary assumption	***Community connection BAU trajectory will decline (10 %) over time***		***Community connection improve trajectory will improve (10 %) over time***	

Long term target setting

For the three social values the target is to improve or maintain the community's level of satisfaction with waterways for activities related to amenity, community connection and recreation.

In setting the long term targets some general assumptions have been made in relation to factors that influence community perceptions:

- Perception is influenced by various external forces (e.g. social media) as well as individuals' preferences and background.
- Whilst there are some community wide preferences evident (e.g. natural waterways are preferred to concrete channels) there is a continuum of preferences which makes identifying definitive relationships between value and perception difficult (e.g. one sector of the community is satisfied with a grassed parklike waterway, whilst another sector prefers a wild forested waterway). This means that a diversity of experiences is important for improving value.
- Conceptual models that set out the relationships between social values and waterway conditions are not yet mature enough to understand the quantitative nature of the relationship between condition and value (assessed through perceptions). That is we don't have strong evidence as to how much we need to change conditions in order to improve social values. However the models do indicate the condition attributes that are important, and some qualitative relationships between the attribute, condition and perception.
- Increasing opportunities for people to engage in a diverse range of experiences at waterways will increase positive perceptions and satisfaction with waterways.
- Improving environmental condition of waterways will generally increase positive perceptions and satisfaction with waterways.
- Setting of targets is based on the understanding that improving waterway condition in line with our conceptual models will lead to a long term improvement in values as measured through perception.

2.5.5 Priority conditions, threats and management interventions

Conditions

Whilst there are many elements of waterway condition that support social values, a subset of conditions have selected to set targets for and measure change in. The conditions were selected because they have a strong relationship with the values (as identified in conceptual models), can inform strategic direction for management, can be monitored over time (either through existing monitoring mechanisms or through new mechanisms to be developed) and can assist in differentiating between planning scenarios.

The main long term condition targets and associated 10 year performance objectives which drive the long term amenity, community connection and recreation value targets are:

- Access
- Water quality (recreational)
- Litter
- Participation
- vegetation

The approach to developing long term targets and associated 10 year performance objectives for these environmental conditions is detailed in sections xx and xx.

Threats

The following threats were identified from conceptual models as having the most impact on the status of the social key values:

Amenity:

- Inappropriate urban development (encroachment, overshadowing, views and vistas)
- Lack of appropriate facilities
- Inappropriate maintenance (unsightly or unsafe vegetation or paths)
- Poor environmental condition
- Poor or inappropriate access

Community connection:

- Lack of appropriate facilities
- Poor environmental condition
- Lack of opportunities/experiences
- Poor or inappropriate access

Recreation:

- Lack of appropriate facilities
- Poor environmental condition
- Poor or inappropriate access

Management interventions

The following management interventions were identified in the conceptual models as having the most effective impact to influence the outcome of the social key values:

- Vegetation management (aesthetics, naturalness, view lines, safety, cooling/shade)
- Habitat improvement/Eflows
- Planning controls to prevent inappropriate and encourage good development (urban design and adequate open space)
- Site appropriate facilities and safety improvements
- Aesthetic improvements
- Access enhancements (including visual access, interpretive signage/wayfinding)
- Engagement and education programs and events

2.5.6 Key assumptions and improvement opportunities

The following key assumptions were made at the time of developing the Strategy:

- actions and targets for social values will not negatively impact areas of high environmental value
- access to amenity will become more important in the future as population grows in region
- Perception is influenced by various external forces (e.g. social media) as well as individuals' preferences and background .
- Whilst there are some community wide preferences evident (e.g. natural waterways are preferred to concrete channels) there is a continuum of preferences which makes identifying definitive relationships between value and perception difficult (e.g. one sector of the community is satisfied with a grassed parklike waterway, whilst another sector prefers a wild forested waterway). This means that a diversity of experiences is important for improving value.
- Conceptual models that set out the relationships between social values and waterway conditions are not yet mature enough to understand the quantitative nature of the relationship between condition and value (assessed through perceptions). That is we don't have strong evidence as to how much we need to change conditions in order to improve social values. However the models do indicate the condition attributes that are important, and some qualitative characteristics that are associated with people valuing the relationships between the attribute, condition and perception.

- Increasing opportunities for people to engage in a diverse range of experiences at waterways will increase positive perceptions and satisfaction with waterways.
- Improving environmental condition of waterways will generally increase positive perceptions and satisfaction with waterways.
- Setting of targets is based on the understanding that improving waterway condition in line with our conceptual models will lead to a long term improvement in values as measured through perception.
- Waterways provide health and wellbeing benefits for individuals and communities.
- All waterways are valuable, however the value provided by waterways will vary depending on their ecological condition and community need – for some waterways environmental values may be low but social values high.
- Connection to waterway environments (i.e. feeling a sense of place or community associated with the waterway) and beside water use of waterways* is a precursor to stewardship behaviours. *(My Victorian Waterway Survey finding).
- Communities place high value on waterways providing natural environments and habitat for plants and animals, therefore most actions taken to maintain/improve environmental values will contribute to the maintenance/improvement of social values.
- Improvement of social values will not be at the expense of environmental values.
- Attributes of the waterway landscape and facilities that are appropriate to support social values will be different for different settings (e.g. mown grass, picnic tables and barbeques may be appropriate in an urban setting, but not in a natural forested area).
- Access to a diversity of experiences at waterways is important for overall community satisfaction with waterways
- All partners have a role in planning for, and implementing, management actions to improve the social values of waterways.
- Where roles and responsibilities for implementing management actions are not clearly defined a collaborative approach, which focuses on community benefit, will be adopted.

Some of the improvement opportunities to be progressed over time for the Strategy:

- conceptual models for Amenity, Community Connection and Recreation were developed within time and resource constraints. A more in depth literature review, as well as targeted monitoring and validation, will increase the robustness of the models.
- as highlighted above under “data limitations” the community Perceptions of Waterways survey is currently limited in assessing value at a scale useful for management actions due

to sample size and inability to elicit cause/effect relationships between respondent satisfaction and condition attributes.

  - The 2018 addition of pin drop functionality is one way the survey has been improved to increase its usefulness

- Much the same as for environmental values, a balance needs to be found between scale of sampling program and resources available for monitoring.

Improvement opportunities will be developed through the HWS MERI framework and the associated Rivers Monitoring and Evaluation Plan (MEP)

2.5.7 References

Jacobs, (2018). Conceptual Models for the Social Values of Waterways, report for Melbourne Water.

Melbourne Water, (2007). Port Phillip and Westernport Regional River Health Strategy, East Melbourne.

TKP, (2016). Waterway Perceptions Research Report. Prepared for Melbourne Water.

WSAA, (2014). The role of the urban water industry in contributing to liveability. Occasional Paper 30.

3 Condition metrics for rivers

A number of attributes contribute to the condition of rivers. The Strategy used the conceptual models and expert opinion to identify the condition attributes that have the strongest relationship with the key values. This is because it is these condition attributes that are most cost effective to manage to improve the outcomes for the key values. The condition attributes were further refined on the basis that there was a strong relationship with several key values. The list of conditions used in the Strategy for rivers included:

- Stormwater
- Environmental water
- Vegetation extent
- Vegetation quality
- Water quality (environmental)
- Water quality (recreational)
- Instream connectivity
- Physical form
- Access
- Participation
- Litter

A metric was developed for each condition to quantitatively describe the state (i.e. high, moderate, low etc.). The metrics were determined based on availability of data and were developed and applied in a variety of ways as described in the sections below.

3.1 Stormwater

The impacts of stormwater on stream health have been well documented over the last few decades and approaches to mitigating the impacts have been evolving (insert ref). The participants at the co-design workshops became well informed of the magnitude of the issue across the region (both current and future) and were part of setting targets in priority areas to protect key values.

Stormwater runoff from impervious surfaces via pipes to streams is the main reason for altered flow regimes and poor water quality. Once altered these two fundamental conditions impact the health of streams in many ways from physical habitat destruction to toxic levels of pollutants.

While flows and water quality are represented as separate environmental conditions, stormwater as measured by 'directly connected impervious' surfaces (or attenuated imperviousness) is a unique umbrella measure that integrates the two, is tied to modelling of treatment measures and can be readily tracked through remotely sensed data. It also represents a leading indicator, ahead of water quality or flow changes and as such can be used to drive interventions.

Attenuated imperviousness (AI) was chosen as the stormwater condition metric because it is shown to correlate with waterway health outcomes, notably macroinvertebrates (e.g. Walsh & Kunapo, 2009). Furthermore, it is a stronger indicator of waterway health than other potential stormwater metrics such as total imperviousness (TI) and a range of hydrological indicators (Burns et al. 2014). AI is defined as "a landscape measure of connected imperviousness that inversely weights impervious areas by their distance from the nearest stormwater drain or stream" (Burns et al. 2014).

The key reason AI is such a good indicator is because it represents the degree to which the hydrology of the catchment represents that of the pre-developed catchment. The closer the AI value is to zero, then the closer the hydrology of the catchment is to what would have occurred under natural or pre-European conditions.

3.1.1 Available data and condition metric

Available data

Impervious mapping has been evolving over the last 10 years or so and essentially uses LiDAR and 4-band aerial photography. Location of stormwater pipes is the other critical data set required to generate AI values. AI was first generated in 2009 (Walsh & Kunapo 2009) and has since been updated to create a 2016 baseline for use in the HSMs and the strategy.

LiDAR (2009) and 4-band aerial photography (2006) were used to define land cover at the sub-parcel scale. Land cover was classified into impervious areas and pervious areas via machine learning with manual corrections. Impervious areas were further classified into roof, road and other. Pervious areas were classified into tree cover and ground-surface. Where trees covered roads, these were classified as roads by using other input data (i.e. road centrelines and an assumed buffer distance). Manual processes were then used to further refine these land covers (e.g. where trees covered driveways or roofs).

A sub-catchment drainage network was developed using Melbourne Water and Council drainage networks. Sub-catchments were delineated everywhere there is a connection to a waterway (e.g. drainage pipe), or where a headwater forms. For this reason, fine detailed sub-catchments need to be identified to appropriately calculate AI. In this instance, AI was calculated for 16,346 sub-catchments across the Melbourne Water region at the time of developing the Strategy.

A comprehensive overview of the approach to calculate AI is provided in Kunapo et al. (in prep).

A pragmatic judgement call for AI estimates were required in addition to the comprehensive approach described in Kunapo et al. (Walsh & Kunapo 2009). These judgement calls were necessary given the scale of the analysis (i.e. the entire Melbourne Water region), the limited time available, and the unavailability of appropriate data (e.g. gaps in Council drainage networks). An example of this includes assigning AI values of zero to sub-catchments which have informal drainage of impervious areas (as evidenced by drainage network data and/or site visits and/or use of aerial photography and Google street view).

Condition metric

The term *attenuated imperviousness* is often interchangeably used with the terms *directly connected imperviousness* (DCI) and *effective imperviousness* (EI) which have very similar definitions.

AI or DCI are represented as a percentage – in essence it represents the percentage of impervious surfaces in the upstream catchment that are directly connected to the stream reach– ie there is no 'effective intervention' or pervious surfaces between the impervious surface and the stream. At present 'effective interventions' have not been factored into the 2016 AI baseline – as there are currently very limited cases where treatment measures have been employed to mitigate urban flows. This has been identified as an improvement initiative for the HWS as it will be crucial for evaluating change to AI based on implementation of the targets in the HWS.

The ranges for stormwater condition scores are based on the relationships between AI and waterway health (i.e. macroinvertebrates as indicators) (e.g. Walsh et al 2005, Burns et al. 2014). Scores less than 0.5% are designated very high, because the hydrology is close to 'natural' conditions and unlikely to adversely impact waterway health. However, once AI values begin increasing, the chances of adverse impacts rapidly increase. Streams are at a much higher risk once AI moves past 2%. For almost all waterways, macroinvertebrate health (as measured by SIGNAL or LUMaR ratings), is severely impacted for AI values greater than 5%. This is reflected by the ranges for stormwater condition scores shown in Table 32.

Table 32. Ranges for stormwater condition

<table>
<tr><th>Score</th><th>AI Range</th><th>Description</th></tr>
<tr><td>Very High</td><td><0.5%</td><td>Stormwater hydrology is similar to pre-European, and unlikely to adversely impact ecological waterway health.</td></tr>
<tr><td>High</td><td>>0.5%, <2%</td><td>Stormwater hydrology is a threat to waterway health, and may be adversely impacting waterway health</td></tr>
<tr><td>Moderate</td><td>>2%, <5%</td><td>Stormwater hydrology is a major threat to waterway health, and is almost certainly adversely impacting waterway health</td></tr>
<tr><td>Low</td><td>>5%,<10%</td><td rowspan="2">Stormwater hydrology has become modified to such as extent that waterway ecology health is severely impacted.</td></tr>
<tr><td>Very Low</td><td>>10%</td></tr>
</table>

A limitation of AI as an indicator is that it does not capture all benefits of stormwater management. For example, if best practice management is employed as per the *Best Practice Environmental Management Guidelines* (Victorian Stormwater Committee 1999), there may be some mitigation to water quality but very little improvements to flow regimes (e.g. Burns et al. 2012, Roy et al. 2008) Another example is where efforts are made to reduce point source pollutants, which is demonstrated to have benefit on waterway values (e.g. Pettigrove 2007). Because these efforts do not necessarily impact hydrology, there will not be a shift in AI, and therefore a shift in stormwater condition rating as we have defined it here.

This limitation is also reflected where stormwater control measures are being implemented in highly urbanised catchments. These catchments can have very high AI values of 30% or more. Substantial investment is required to reduce these AI values and shift the rating from "very low" to "low". This is despite the undoubted benefits that would be achieved to water quality as AI values decrease from 30% towards 10%.

Although AI does not capture all benefits of stormwater management, these benefits can be captured elsewhere. For example, the removal of nitrogen as a result of stormwater management is identified as a benefit to Port Phillip Bay. For this reason the *Port Phillip Bay Environmental Management Plan* has a target for nitrogen removal. In the Strategy, there are also separate conditions for water quality, which also have the potential to capture stormwater management benefits.

3.1.2 Setting scenarios for stormwater condition

Current state

The 2016 current condition for AI in the HWS was based on the methods described above. The 2006 data was updated with recent aerial imagery and was mostly a manual process.

While AI is generated at the reach scale and used in the HSM at this scale – an average for each of the 69 sub-catchments was generated for the purpose of communicating a baseline (current condition) and future trajectories and targets. The average is length weighted – ie the AI is multiplied by the reach length then divided by the total length of the sub-catchment.

Forecast current trajectory under business as usual scenario

Current trajectory AI was calculated by forecasting urban growth to the urban growth boundary. Planning scheme zone codes were assigned an expected impervious value for *ultimate development*, i.e., the maximum expected imperviousness of the parcel upon urbanisation. (e.g. in areas zoned as commercial, business or industrial, TI.Ultimate=0.9, whilst in areas zoned as public park & recreation, TI.Ultimate=0.1. Notes that this also assumed maximum infilling.).

To calculate Ultimate AI, we needed to account for 4 distinct situations:
1. No Infill, No Greenfield - subcs that will not experience any further urban development post-2016
2. Greenfield Only - subcs that will experience Only greenfield development post-2016
3. Infill Only - subcs that will experience Only infill development post-2016

4. Greenfield + Infill - subcs that will experience Both greenfield AND infill development post-2016

It is noted that it is not strictly a 50 year time frame as is supposed for the 'current trajectory' and 'target trajectory' scenarios, but rather an indeterminate time in the future when urban growth has expanded to the urban growth boundary. However, 50 years is a reasonable estimate, and given all the uncertainties of growth forecasts, a reasonable assumption for our purposes. For further details, see Chee et al. (2020) and Walsh 2016.

The most up-to-date available data on planning scheme zone codes came from VicMap Planning (https://www.data.vic.gov.au/data/dataset/vicmap-planning)

The planning scheme zone codes were split based on the 69 HWS sub-catchment boundaries. Urban areas and areas where future greenfield development was identified. This was a somewhat iterative and manual process carried out in QGIS.

Areas were designated as urban on the basis of planning scheme zone codes (e.g. Activity Centre Zone (ACZ1/ACZ2/ACZ3), Business Zone (B1Z/B2Z etc.), Commercial Zone (C1Z/C2Z etc.), Comprehensive Development Zone (CDZ1 etc.), General Residential Zone (GRZ1 etc), Industrial Zone (IN1Z etc.) and Mixed Use Zone (MUZ1 etc.). A full list of 113 zone codes is provided in Appendix 7. Note that a small number of parcels classified as Public Park & Rec Zone (PPRZ) were included as urban areas because they contain substantial impervious infrastructure and have piped drainage (e.g. State Netball & Hockey Centre).

In QGIS, areas where greenfield future urban development is expected from 2014 to Ultimate were identified by either manually selecting parcels or drawing polygons in areas zoned for urban development (e.g. Urban Growth Zone (UGZ1/UGZ2 etc.)), but which are *not* developed as at 2014, as far as can be determined from Google Satellite imagery. (Note: with respect to all 5 catchments, Google Satellite had more recent imagery than Bing Aerial).

In estimating AttImp_L9_Ultimate, each of the 5 MW catchments was processed separately since they sometimes include different stormwater management (SW) scenarios of interest e.g. MARI includes some IWM scenarios relating to proposed stormwater projects around Sunbury development.

In brief, the steps used to calculate AttImp_L9_Ultimate for each sub-catchment are as outlined in the following equations:

- subcTotImp_Area_m2_Ultimate = futDevArea_Ultimate * TI.Ultimate (for the corresponding ZONE_CODE)
- subcAttImp_L9Area_m2_Utimate = subcTotImp_Area_m2_Ultimate * 0.8
- AttImp_L9Area_m2 = sum(subcAttImp_L9Area_m2_Ultimate) across all upstream contributing subcs

- AttImp_L9_Ultimate = AttImp_L9Area_m2_Ultimate/CatchmentArea_m2_exclDams

Long term target setting

The long term target for stormwater was based on the following key assumptions/principals:

- Co-design participants wanted to see impacts of stormwater adequately managed so that key values were protected from urbanisation
- This translated to an assumption that there would be no increase in AI from new development
- There would be an overall decrease in AI over time as urban renewal occurs – ie there is an opportunity to include adequate stormwater treatment as buildings are knocked down and rebuilt or as roads are upgraded.

This reduction in AI is anticipated to come from:

- Meeting the performance objectives for stormwater management as described in this strategy;
- Capital projects undertaken by stormwater managers (e.g. councils, Melbourne Water). This could include streetscape measures (e.g. raingarden tree pits) and end-of-pipe systems (e.g. stormwater harvesting systems);
- New stormwater policies and guidelines. This could potentially include:
    - An enhanced *Best Practice Environmental Management Guidelines for Stormwater* (Victorian Stormwater Committee 1999) to include more stringent requirements for stormwater management, notably the inclusion of hydrological targets which would drive disconnection of stormwater drainage systems from receiving waterways.
    - Implementation of best practice stormwater management on all urban development. (Note: On October 26, 2018, the Victorian government amended the Victorian Planning Provisions so that stormwater management now applies to a broader range of developments, e.g. residential multi-dwelling developments, commercial subdivisions, industrial subdivisions. Until this point, best practice was typically only applied to residential subdivisions.)
    - Financial subsidies to landowners for on-lot stormwater management measures such as rainwater tanks and raingardens.

The degree to which AI would decrease over the long term was based on the following:

- Reducing AI by the amount of development (ie the catchment area) which is predicted to reduce AI to 0 through effective treatment.

- Infill and urban renewal is thought to be around 1% per year. So in 50 years' time 50% of the catchment will be renewed. While the renewal rate is likely to be even higher than 1% per year discussions (including with Melbourne Water and DELWP) were held around the feasibility of reducing AI to zero in all cases.
- It was decided that 25% reduction in DCI would be a more practical reduction over the long term. This would account for not all areas being able to be treated or for renewal rates to be lower than expected.
- As it is difficult to predict where renewal is going to happen each year an average across the region was applied.

Once the new AI values were calculated for every reach in the network a new length weighted average was derived and used as the long term target – or aka the ultimate trajectory. The new AI values were also used in the HSMs for predicting instream value ratings.

3.1.3 Ten year performance objectives

The performance objectives were set by firstly determining the areas across the region where protection from increased development was a priority followed by expressing the target for these areas in a practical manner (eg volumes of stormwater to be harvested and infiltrated).

The following principles were used to prioritise the areas for protection:

- As increased capacity and resources are required a relatively modest number of priority areas should be selected
- The priority areas should be driven primarily by the greatest 'bang for buck'
- Other areas can be prioritised based on existing commitment and momentum despite not being the most 'cost effective'
- These other areas needed to also have support from the co-design participants

The HSMs and zonation were used as the primary decision support tool to select the priority areas. The process was somewhat iterative and there are several key assumptions of note including:

- a combined action such as RV20_SW2 tends to deliver greater biodiversity benefit than a single action such as RV20 or SW2. But when cost is brought into consideration, single actions tend to be cheaper and therefore most cost-effective. However, MW reasoned that there could be particular situations where it might be reasonable to bend the 'most cost-effective' rule a little to achieve higher benefits. Specifically, if impervious cover of future development could be avoided as a result of regulation rather than a direct cost to an agency. On the basis of this reasoning, we devised the following customization:
- if for a given reach, the most cost-effective action is RV20 and the second most cost-effective action is RV20_SW2 *or* SW2, then we would select RV20_SW2 as the action to 'apply' for that reach.

There were other factors that taken were into account to select priority areas. This formed the sense checking exercise following the outputs from the HSMs and zonation and was undertaken by HWS team and Melbourne Research Partnership Practice. This was then cross checked with the community to see if priorities aligned. See Table 33 for a list of factors that were used in addition to HSMs to select priority areas.

Table 33. Factors that up weighted priority area selection

Factors	**Examples**
Many high ranking (>0.5) SW1s or SW2 within catchment	Deep Creek
Existing DCI levels low	Plenty d/s Whittlesea < 0.005
Small to moderate sized catchments ~ 2,000 imp ha for SW2 ~ 500 imp ha for SW1	Lower Yarra (SW2 = 0.9 in most d/s reach) lower Kororoit Creek (SW1 = 0.8 in most d/s reach)
Known good quality instream physical habitat	Stony Creek – high SW1 but very degraded
SW1 – surrounding rural land / space	Lancefield
Existing commitments	Northern Growth Corridor IWM Darebin Creek zonation ~ 0.4
Equity – having priorities in each of the 5 catchment	Wasn't necessary as good spread
Protection of Platypus, listed species	Monbulk Creek, Diamond Creek
Length of stream benefited	Coastal towns – small lengths
Supported by co-design	Most catchments supported by co-design actions for SW

Performance objectives were developed for each stormwater priority area. In total, there were 36 performance objectives, all of which had similar wordings, e.g. for *Corhanwarrabul, Monbulk and Ferny Creeks* sub-catchment:

"To improve stormwater condition, treat new and existing development (i.e. The Basin and Sassafras) to reduce directly connected imperviousness (DCI) of Dobsons Creek to less than 1% at the confluence with Dandenong Creek. To disconnect a hectare of impervious area requires harvesting approximately 6.0 ML/y and infiltrating 2.4 ML/y. To disconnect the entire catchment would require approximately 0.4 GL to be harvested, and 0.2 GL to be infiltrated."

For implementation of this strategy, the key numbers to consider in these targets are the volumes to be harvested and infiltrated for each impervious hectare. For the *Corhanwarrabul, Monbulk and Ferny Creeks* sub-catchment, this is the 6.0 ML/y/imp.ha. harvesting and 2.4 ML/y/imp.ha. infiltration values. To disconnect a development in this catchment, the required harvesting and infiltration volumes are simply a multiplication of the impervious area of the development by 6.0 ML/y and 2.4 ML/y respectively. For example, a development of 1 hectare, with 50% imperviousness would require 3.0 ML/y and 1.2 ML/y of harvesting and infiltration.

It should however be noted that these estimates provide a guide only. They do not replace the need for site-specific analysis. The numbers in the performance objectives were derived from Walsh et al. 2012. The HWS 2018 describes target ranges for harvesting and infiltration to achieve natural hydrology from impervious areas (see Figure 28). Note that mean annual rainfall as it varies across Melbourne was used to determine volumes to harvest. The numbers in the performance objectives are the mid-range (average) of the harvesting and infiltration volumes required.

The appropriate targets for a specific site will depend on factors that were not considered in the Walsh et al. 2012 paper. This will include the distinct features of each catchment such as soil type, geology, topography and pre-European vegetation. All of these factors influence the pre-developed hydrology, and hence the target hydrology. For most sites, additional hydrological targets will also be required (e.g. frequency of runoff, peak flows) to ensure post-developed hydrology adequately resembles pre-developed hydrology.

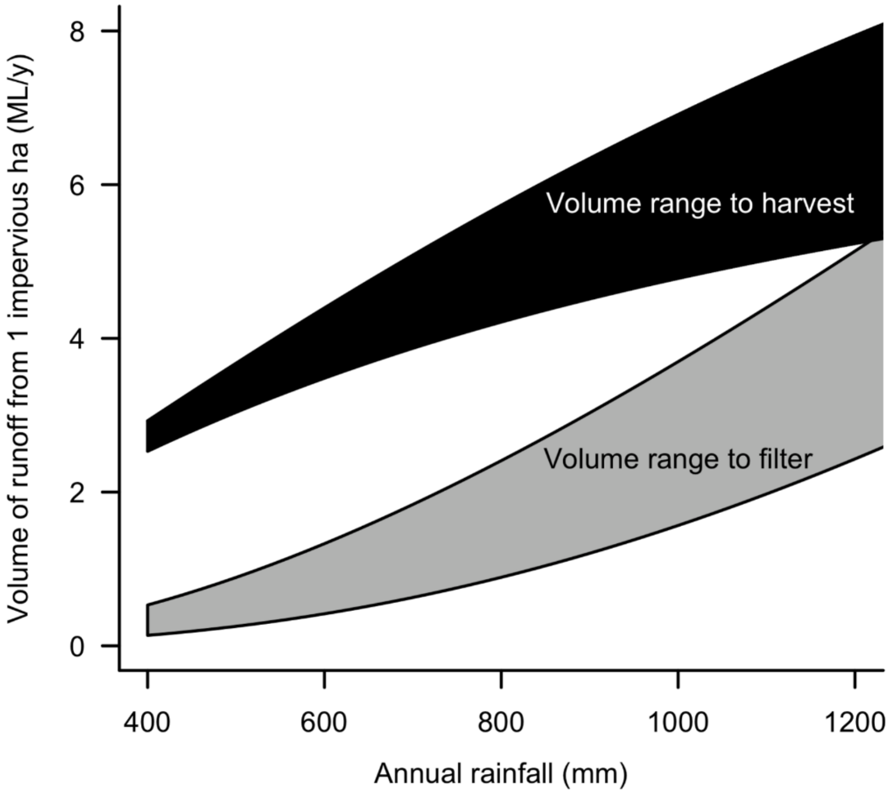

Figure 28. Impervious runoff volume partitioned into lost subsurface flows and lost evapotranspiration. (Reproduced figure from Walsh et al. 2012).

3.1.4 Key assumptions and improvement opportunities

The following key assumptions were made at the time of developing the Strategy:

- increased stormwater standards to better manage impacts of flow will be applied (with feasible solutions) to new urban development – at least within the priority stormwater catchments
- Refer to assumptions in Section 3.1.2
- Assumptions when calculating AI – everything impervious is connected if a pipe connects it, if no pipe then it is attenuated by the distance to a stream.

Some of the improvement opportunities to be progressed over time for the Strategy:

- Future improvements to the AI GIS layer are currently underway to have finer resolution sub-catchments, notably including better representation of headwaters).

Improvement opportunities will be developed through the HWS MERI framework and the associated Rivers Monitoring and Evaluation Plan (MEP).

3.1.5 Further Resources

Attenuated impervious data (HWS 2018): "Stormwater_AI(DCI)_Targets.xlsx"
http://inflo/inflo/llisapi.dll/properties/41842008

Melbourne water subcs: MWregion_subcs_260117 http://inflo/inflo/cs.exe/properties/43757710

Land use land cover data (Grace GIS, 2015). Melbourne Waterways Research Practice Partnership Project 1.1 \\mwc.melbournewater.com.au\dfs\groupdata\Waterways\MEL\1. SHARED FOLDERS (Waterways Group) Inflo Migration\Cross Team Information\Data Management\Datasets\MWRPP\Project 1.1 LULC

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3.2 Water for the Environment

Water for the environment is water managed to improve or maintain the health of rivers and wetlands – including the plants and animals that depend on them. Cultural values and liveability values are of high importance supporting shared benefits.

The management of flow regimes is considered either regulated or unregulated. In regulated rivers (those with dams), some of the environmental water reserve is made up of the entitlement held by the Victorian Environmental Water Holder (VEWH). This includes the Yarra, Tarago and Werribee. Not all regulated rivers have an environmental entitlement. Unregulated rivers (those without dams), are managed through Stream Flow Management Plans or local management plans.

It is critical, especially in the face of climate change and urbanisation that recovery options for the regulated systems continue to be investigated and in the unregulated systems, water for the environment continues to be maintained or improved.

3.2.1 Available data and condition metric

Available data

There is much available data that helps define the current status of the water for the environment. This includes river flow, river level, rainfall, groundwater levels and ecological condition data.

Condition metric

The current state of water for the environment for streams assets was assessed by hydrological condition, based on three measurements: flow stress ranking (FSR), compliance with environmental flow recommendations (FLOWs) and directly connected imperviousness (DCI) where urban streams did not have FSR or flow compliance scores. Hydrological condition was categorised into 5 categories (very poor, poor, moderate, good and excellent).

Flow stress ranking

Annual Flow Stress Ranking was scored on a scale of 0-10. FSR scores were calculated in 2010 using modelled natural and current flow data for each SDL catchment. Seasonal sub-indices were calculated for zero flows, low flows, seasonality of flow and variability. The annual score is an average of the seasonal sub-indices. The FDR scores were aggregated to the MU catchment level by averaging the scores across the MU.

FLOW compliance

FLOW compliance is the percentage compliance of the current flow regime with FLOWS study recommendations on a scale of 1-100 (100 being 100% compliance). Compliance was calculated for each year of available flow record up to 2017 for gauges in reaches that have FLOWS recommendations. Compliance was calculated for each flow component (e.g. low flows, freshes, high flows etc) and an annual average was determined that was then averaged over all years.

Directly Connected Imperviousness

For many of the MUs (particularly urban waterways) there was no FSR score or FLOWS recommendations/compliance scores. For these MUs, the hydrological condition rating was based on an assessment of current and future Directly Connected Imperviousness (DCI) and professional judgement.

3.2.2 Setting scenarios for environmental water

Current state

The current state of each MU was determined using a combination of the measures outlined above. Where a MU had both a FSR and FLOWS compliance score, the FLOWS compliance score was used. Compliance scores were applied to all Sub-catchments located within/above the flow gauge at which compliance was calculated up to the next closest compliance point. See Table 34 for metric scores.

Table 34. Water for the environment - current state metric scores – note flow compliance was used preferentially, then FSR, then DCI when these weren't available.

Condition category	Description	Flow compliance	FSR score	%DCI	Current state
very poor	Flow recommendations are rarely achieved and overall hydrological condition is considered very poor	1-20%	0-2	>20%	1
poor	Flow recommendations are occasionally achieved, mostly in wet and average climate years but not in dry climate years and overall hydrological condition is considered poor	21-30%	2-4	10-15%	2
moderate	Flow recommendations are often achieved in wet and average climate years and occasionally achieved in dry climate years. Overall hydrological condition is considered moderate	41-60%	4-6	5-10%	3
good	Flow recommendations are often achieved across all climate years and overall hydrological condition is considered good	61-80%	6-8	1-5%	4
excellent	Flow recommendations are frequently achieved across all climate years and overall hydrological condition is considered excellent	81-100%	8-10	0-1%	5

Hydrological condition mapping current

The hydrological condition of each sub-catchment is shown in Figure 29.

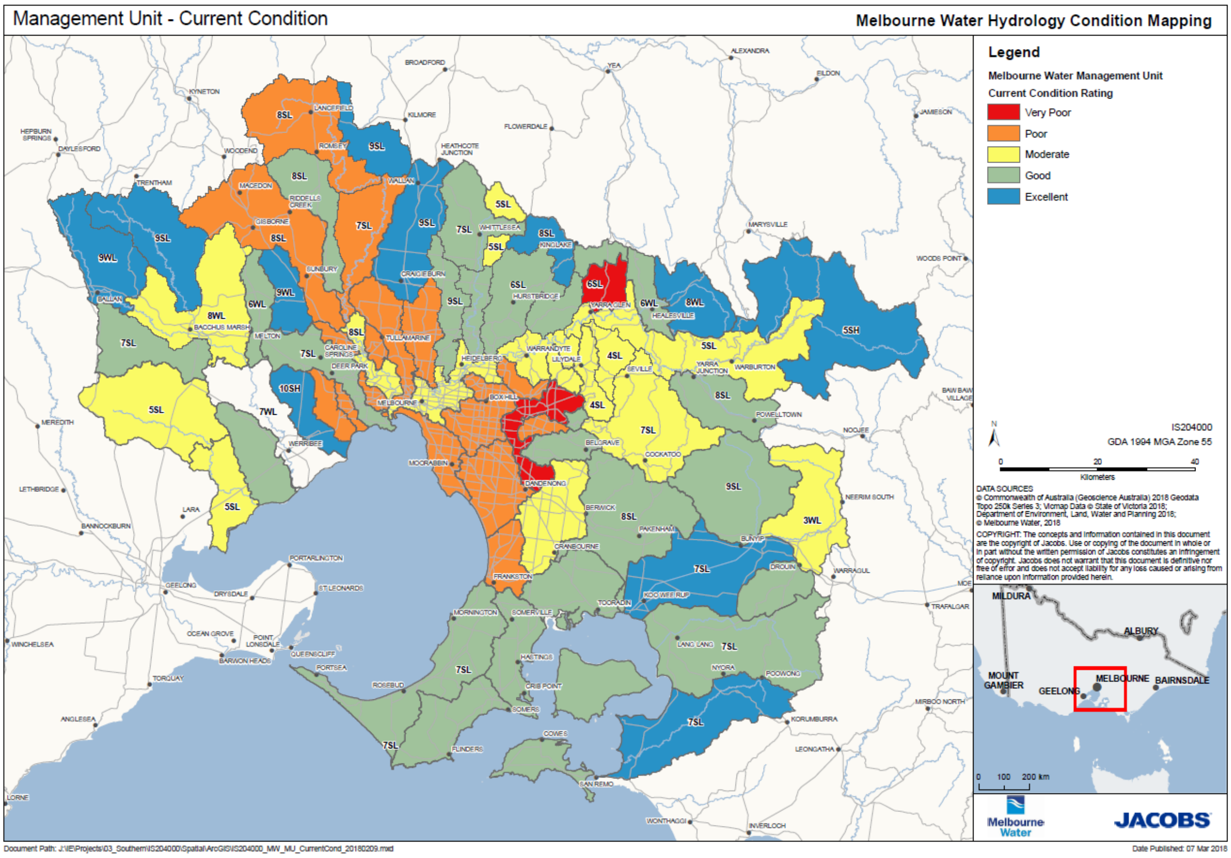

Figure 29. The current state of water for the environment (hydrological condition) of each sub-catchment.

Forecast current trajectory business as usual scenario

The predominant threat facing water for the environment is climate change. Future stream flows are now predicted to be lower than previously modelled, and it is clear that additional water will be needed to meet environmental objectives for the region's waterways. It is also acknowledged that there will be additional and ongoing demand for rural and urban water supply from the catchments, including water for domestic, stock and agricultural uses.

The predicted flow compliance under current trajectory (including climate change impacts) was calculated by reducing the gauge flows by 44.3% in line with DELWP 2065 dry climate predictions (representing a worst case climate change outcome) (DELWP, 2016) and re-calculating compliance as described in Section 3.5.1 above. FLOWS compliance scores were adopted in preference to FSR scores as flow regimes are being managed against FLOWS recommendations, therefore these scores are likely to have a larger impact on the current trajectory. Current trajectory scores were then assigned as for current state (see Table 34 above).

The calculation does not account for changes in stream flow as a result of stormwater management under current trajectory as this would have required significant catchment scale modelling based on changes in DCI which was not able to be completed within the time constraints of strategy development. For urban waterways with no flow recommendations and for those rural waterways that will be subject to significant urban development, the future hydrological condition is based on predictions for future DCI, which significantly increases in some catchments (such as Upper Merri Creek), hence these MUs can expect to experience a significant degradation in hydrological condition under current trajectory stormwater management. The predicted current trajectory for each MU is displayed in Figure 30 below.

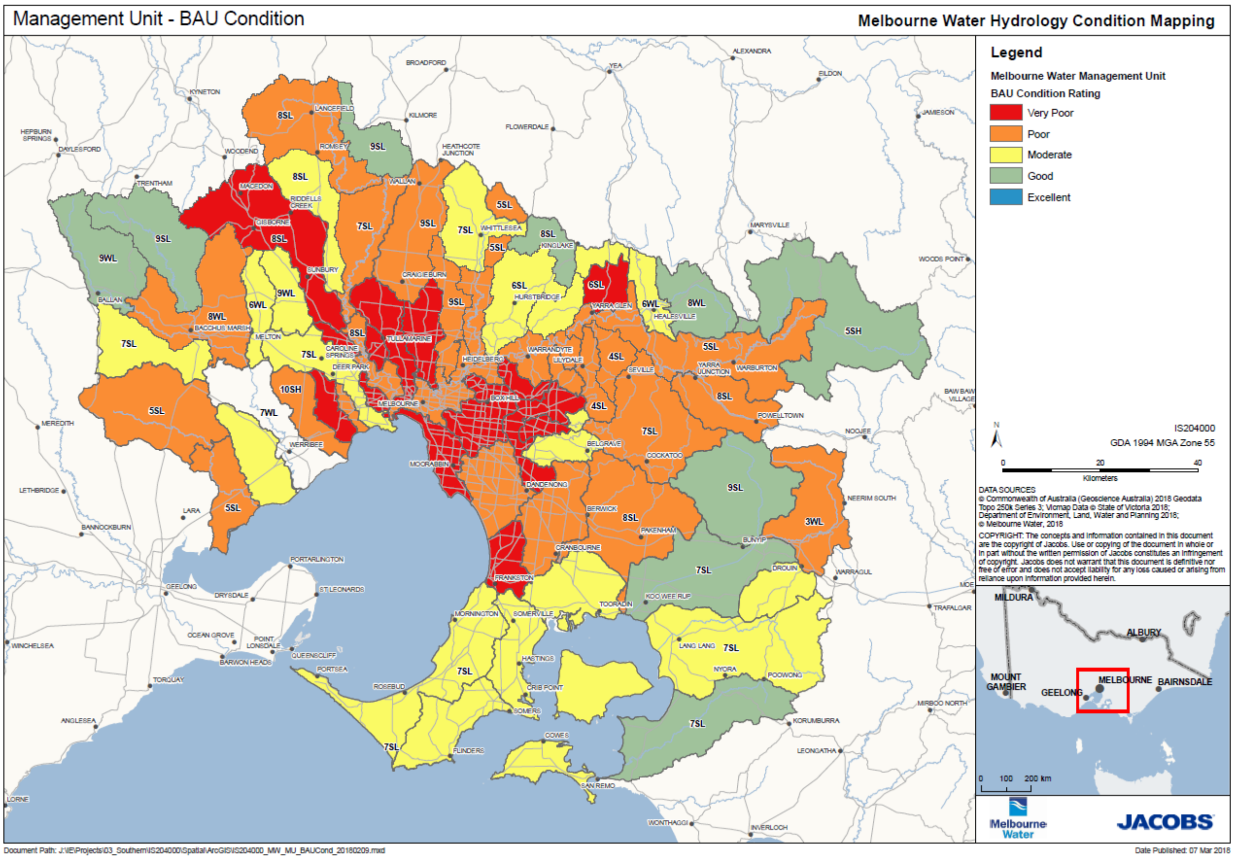

Figure 30.The current trajectory of water for the environment (hydrological condition) of each sub-catchment (Jacobs, 2018b).

Long term target setting

Ideally, determining target trajectory at the sub-catchment scale would involve the development of catchment-specific Source models that could be adjusted for different rainfall and runoff rates to represent different scales of urbanisation and climate change as well as different stormwater management assumptions. This approach was not possible within the timeline of Strategy development. Instead, once predicted flow compliance had been determined (for current trajectory), predicted environmental water shortfalls were calculated. This was only possible at sites where flow compliance has been calculated.

Over the long term, the region-wide shortfall due to climate change is estimated at between 36–70 billion litres (36 GL–70 GL) per year. This Strategy targets an increase of the environmental water reserve by 23 billion litres (23 GL) per year by 2028, aiming to secure environmental water reserves earlier in the life of the strategy for maximum environmental impact and lowest cost. While this target is less than the lower end of the shortfall estimate, it was seen to be a realistic target by key stakeholders. Any water recovery for the environment is to be considered through the Victorian Sustainable Water Strategies (SWSs), markets and use of alternative water. Table 35 describes current environmental water reserves and calculated future requirements. This information is attached to the lowest sub-catchment in the catchments and applies to the whole of the catchment. It does not include passing flow requirements. Further investigation is required to understand the climate change impacts on passing flows e.g. Bass River and Candowie Reservoir.

Table 35. Detailed environmental water requirements (all values in ML/year).

Catchment Entitlements	Yarra	Werribee	Tarago and Bunyip	Maribyrnong
Central Region Sustainable Water Strategy commitment ("Needs and additions to environmental water reserves by 2015")	20,000 ML/Yr	6,000 ML/Yr	3000 ML/Yr	3000 ML/Yr
Existing Entitlement as at 2018 as a result of recovery through the Central Region Sustainable Water Strategy negotiation	Minimum environmental flows of water in the Waterway (as per Schedule 1 of the EE), plus, the first 17,000 ML of net inflow into the Yarra headworks system per annum and up to 55 ML per annum in the Yarra River downstream of the confluence with Olinda Creek. A storage capacity of 17,000 ML in the Melbourne headworks system reservoirs not being used by Primary Entitlement Holders (or any storage if not spilling that isn't being used by Primary entitlement holders).	10% share of inflow into Lake Merrimu, after passing flows have been provided and no dedicated storage	10.3 % inflows up to 3000 ML storage and 12 ML/d passing flows at Drouin West.	No entitlement secured.
Current shortfall from CRSWS recommendations	None	5,500 ML/yr Since being granted, the 10% of inflow provision in the Werribee Environment Entitlement has yielded an average of 555.4ML per year	None	3000 ML/Yr
Longer term Shortfalls based on current Climate change studies –Shortfalls required in the longer term based on new information. This does not include storage provision and is	15-25 GL/yr This range has taken into account the range of figures that have been calculated from the recent studies undertaken on the Yarra using a combination of	10-20 GL/yr This range has taken into account the range of figures calculated for all reaches in the system using	1-5 GL/yr This range has taken into account, the range of figures calculated from the combination of climate scenarios	10-20 GL/yr This figure has taken into account the range of figures calculated for all reaches in the

Catchment Entitlements	Yarra	Werribee	Tarago and Bunyip	Maribyrnong
addition to the CURRENT Entitlement (i.e. there is no entitlement in the Maribyrnong so the new range represents the new shortfall whereas the Yarra has 17GL existing so the 15-25 is in addition to the 17GL)	climate scenarios (such as current baseline climate, 2040 median climate, 2065 median climate).	the 'step climate change record'.	analysed (current baseline climate, 2040 median climate, 2065 median climate).	system using the 'step climate change record'.
Current Shortfall based on Climate change studies in the next 10 years (2028). Based on new information from climate change studies on the long-term requirements (these figures have been determined using an assumption that it is hoped that more water is provided in the earlier years in an attempt to achieve the long term target).	10,000 ML/Yr This figure is the average shortfall calculated of all the shortfall figures that have been calculated through the various climate change studies in the Yarra to date.	7,000 ML/Yr This figure is half of the full amount of shortfall calculated for the longer term at the lowest compliance point in the river using the 'step climate change record'.	1,000 ML/Yr This figure is half of the full amount of shortfall calculated using the median 2065 climate change scenario.	5,000 ML/Yr This figure is half of the full amount of shortfall calculated for the longer term at the lowest compliance point in the river using the 'step climate change record'.
Source of data	(Melbourne Water, 2017; GHD, 2016; Jacobs, 2018a & c; Horne, et al. 2017) Assessing the impact of climate change on environmental water management outcomes in the Yarra River, Victoria	(Melbourne Water, 2017; Alluvium, 2016)	(GHD, 2016)	(Melbourne Water, 2017; Alluvium, 2016)

3.2.3 *Ten year performance objectives*

Performance objectives have been developed to enhance the delivery of water for the environment and expand the environmental water reserve holdings. This includes managing current Environmental Entitlements, securing shortfalls due to climate change, securing environmental water where EE's are currently not set, and setting and implementing management plans. Performance objectives are set at both a region-wide level and at the catchment scale. For regulated systems, performance objectives aim for full recovery of environmental water shortfalls. In unregulated systems, water recovery objectives were more moderate. Table 36 summarised the types of performance objectives set out for the environmental water program, along with intent, background and source of data.

Table 36. Environmental Water performance objectives – underlying rationale.

#	Performance objective template	Intent	Source of data/ measurement
1	PO at Lowest Sub-catchment: Environmental water reserve is increased by X GL by 2028 to meet ecological watering objectives and cover projected shortfalls. Environmental Water Recovery Targets captured at lowest downstream sub-catchment which reflects targets for whole catchment. Any future water recovery for the environment will be considered through the Sustainable Water Strategies. PO in upstream sub-catchments: Environmental Water Recovery Targets captured at lowest downstream sub-catchment (NAME OF SUB-CATCHMENT) which reflects targets for whole catchment. See next table for more detail.	• To identify shortfall volumes, secure and recover for major regulated catchments – Yarra, Werribee, Tarago & Bunyip and Maribyrnong. • Figures to be included based on systems strategy or most updated value. • Key to understand that PO is to be met by whole of stakeholder group. • Shortfall figures to influence Central Region Sustainable Water Strategy – 50 year timeframe. • Lowest sub-catchments o Yarra River Lower o Bunyip Lower o Werribee River Lower o Maribyrnong River	Melbourne Water Systems strategy data, including whole catchment values at lower compliance sub-catchment. Yarra Environmental flow review Werribee, Tarago & Bunyip – systems strategy.
2	Reduce the key threat of <u>summer/winter low</u> flow stress by reducing risk associated impacts such as farm dams, climate change, diversions or urbanisation.	• To reduce flow stress in unregulated catchments – understand the drivers current and future and to plan	Jacobs (2018b) Hydrological compliance spreadsheet and hydrological Condition produced for HWS.

#	Performance objective template	Intent	Source of data/ measurement
	Note: summer or winter low is sub-catchment dependent – see Jacob's hydrological compliance for seasonality (Jacobs, 2018b).	and put programs in place to mitigate such impacts. • This work includes Statutory Management Plans (SFMPs and LMPS), mitigating catchment impacts program, impact of farm dams. • Flow stress refers to either too much water or not enough.	Measured by compliance tool based on environmental flow recommendations.
3	Where an Environmental Water Plan (EWAP) has been drafted i.e. the catchment has been investigated, triggers and actions identified: "Maintain critical flow components in refuge reaches along SUB-CATCHMENT to protect SPECIES. " Where further investigations are required: "Identify opportunities to maintain and improve the flow regime in refuge reaches to support *platypus populations* and other instream values."	• To understand and manage drought refuge reaches and groundwater dependent ecosystems. • There are several areas of the catchment which are critically dependent upon the maintenance of low flows (usually supported by groundwater). These ecosystems provide refuge for many plants and animals in dry conditions and can be sometimes the only water in a creek (e.g. Monbulk Creek for platypus). Managing these areas depends upon understanding the role groundwater plays and identifying management actions to support these high value ecosystems (such as resource management, bankside vegetation for shading etc.) • Environmental Water Action Plans have been developed for high priority systems that include proactive management actions and reactive management actions – these can be implemented by multiple stakeholders.	NOTE - this will be achieved by rolling out the draft Environmental Water Action Plan during the first few years of the Strategy. To be measured by actions delivered in EWAPs.

#	Performance objective template	Intent	Source of data/ measurement
		Some sub-catchments need investigating. • E-water delivery greatly enhances platypus trajectory under a climate change scenario – therefore this species is used as a flagship species when advocating for e-water.	
4	Establish water regime to ensure protection of Seasonally Herbaceous wetland character, Dwarf Galaxias and Latham Snipe habitat. OR Water regime implemented to meet ecological watering objectives, improve ecosystem services, cultural and social value. OR Investigate opportunities to improve wetland water regime to meet ecological watering objectives, improve ecosystem services, cultural and social value.	• Investigate and implement water regime at wetlands. • The PO's vary in words depending upon status and knowledge of wetlands. • Some overlap with performance objective ref #3 as they have a drought refuge/GDE status.	Billabong Program Groundwater Dependent E/drought refuge program

All regional and catchment-specific performance objectives related to environmental water are listed below.

Regional

- **RPO-10.** An adaptive pathways approach is adopted to understand and manage the risks of climate change on waterways.
- **RPO-11.** Understanding of groundwater dependent ecosystems is improved and opportunities to maintain or improve these continue to be investigated.
- **RPO-12.** Water for the Environment continues to be managed and delivered to the region's rivers and wetlands and recovery options continue to be investigated.

Westernport and Mornington Peninsula:

- Investigate options to increase the environmental water reserve by 1 GL/year by 2028 to meet ecological watering objectives and cover projected shortfalls. This will benefit the lower Bunyip River. Any water recovery for the environment will be considered through Victorian Sustainable Water Strategies, markets and use of alternative water.

- Identify opportunities to maintain or improve the flow regime in refuge reaches to support instream values, including platypus.
- Identify opportunities to reduce the key threat of flow stress on waterways by addressing threats and other activities that impact waterways such as domestic, stock and agricultural uses, climate change, diversions or urbanisation

Werribee catchment region:

- Investigate options to increase the environmental water reserve by 7 GL/year by 2028 to meet ecological watering objectives and cover projected shortfalls. Any water recovery for the environment will be considered through the Victorian SWSs, markets and use of alternative water.
- Identify opportunities to maintain or improve the flow regime in refuge reaches to support instream values, including platypus.

Maribyrnong catchment region (including Moonee Ponds Creek):

- Investigate options to increase the environmental water reserve by 5 GL/year by 2028 to meet ecological watering objectives and cover projected shortfalls. This will benefit Jacksons Creek and the lower Maribyrnong River. Any water recovery for the environment will be considered through the Victorian SWSs, markets and use of alternative water.
- Identify opportunities to reduce the key threat of flow stress on waterways by addressing threats and other activities that impact waterways such as domestic, stock and agricultural uses, climate change, diversions or urbanisation

Dandenong catchment region

- Identify opportunities to maintain or improve the flow regime in refuge reaches to support instream values, including platypus along Monbulk Creek.
- Reduce the key threat of flow stress on waterways by addressing factors such as domestic, stock and agricultural uses, climate change, diversions or urbanisation.

Yarra catchment region

- Investigate options to increase the environmental water reserve by 10 GL/year by 2028 to meet ecological watering objectives and cover projected shortfalls from climate change. This will benefit the middle Yarra River. Any water recovery for the environment will be considered through the Victorian SWSs, markets and use of alternative water.
- Reduce the key threat of flow stress on waterways by addressing factors such as domestic, stock and agricultural uses, climate change, diversions or urbanisation.

Linked performance objectives

- Revegetation priority reaches (sub-catchments) have been checked to overlap with drought refuge/GDEs as this is a key action that helps build up resilience along the waterways.
- Wetlands and estuaries have performance objectives set around water regime.

3.2.4 Key assumptions and improvement opportunities

Assumptions inherent in the development of the current state and current and target trajectories include that:

- Local Management Plans and Streamflow Management Plans will lead to environmental watering objectives being met.
- in highly urbanised areas (with high DCI) the environmental flow condition is very low.
- high DCI drives poor environmental flow condition in urbanised waterways.
- the Total shortfall volume of water can be recovered.
- the flow regime identified in FLOWs studies is adequate to protect the environmental values.
- Assume that complementary actions to protect waterways will be implemented on private land (e.g. take up of incentives programs for fencing)
- Assume continued support for environmental water within the community over the next 10 years (research commissioned by Melbourne Water is testing this).
- A larger portion of the long-term environmental entitlements required will be secured in the first ten years of the strategy (informed target volumes).
- that flow improvements can be made to offset drying from climate change (particularly relevant for platypus).

Some of the improvement opportunities to be progressed over time for the Strategy:

- Improve flow compliance while recognising the challenges this poses to due to climate variability. ..
- Water for the environment delivered as defined in Seasonal Watering Proposals with Victorian Environmental Water Holder.
- Vegetation outcomes at high value billabongs delivered through the water for the environment program.
- Monitoring and research program implemented to demonstrate value.

Improvement opportunities will be developed through the HWS MERI framework and the associated Rivers Monitoring and Evaluation Plan (MEP).

3.2.5 References

Alluvium, (2016). *Report on the EFlow Predictor analysis for Werribee and Maribyrnong*. Report prepared for Melbourne Water

DELWP (2016). Guidelines for assessing the impact on climate change on Water supplies in Victoria, Melbourne.

GHD, (2016) *Melbourne Headworks Environmental Flow Modelling Report*. Report prepared for Melbourne Water, Docklands.

Horne, A., Nathan, R., and Wang., J. (2017) *Assessing the impact of climate change on environmental water management outcomes in the Yarra River, Victoria*.

Melbourne Water, (2017) *Melbourne Water Systems Strategy*, Docklands, Melbourne.

Jacobs, (2018a). *Environmental Flow Study Review for the Yarra River*. Report prepared for Melbourne Water.

Jacobs, (2018b). *Environmental Flow Compliance and Hydrological Condition*. Unpublished data prepared for Melbourne Water, Docklands.

Jacobs, (2018c.) *Yarra River Scenario and Flow Management Tool*. Tool and Report prepared for Melbourne Water

3.3 Vegetation Extent

Riparian vegetation is a critical condition that has strong correlations with all of the waterway environmental and social values of the HWS 2018.

Vegetation is important in the riparian zone for all the key environmental values because it:

- Stabilises stream banks, which prevents erosion and preserves channel form;
- Buffers and filters nutrients and pollutants that run off from the catchment;
- Provides continuity of habitat for animals (e.g. birds, reptiles, bats and frogs);
- Shades streams, which regulates water and air temperature, attracts insects (an important food source for fish and frogs
- Provides organic matter into streams which acts as habitat and a food source

Riparian vegetation is also important for social values for reasons such as provision of shade (urban cooling) and enhanced landscapes (aesthetics). The establishment and maintenance of riparian vegetation was considered important and as such targets and performance objectives were developed around this condition.

As described in Vegetation Value section, extent and quality are two fundamental ways to describe the condition of vegetation. As such there were two environmental condition metrics used in the HWS for rivers.

- Vegetation Extent – the amount riparian vegetation based on canopy cover above 2m
- Vegetation Quality – the quality of the vegetation using a 1-5 rating scale broadly describes the condition of vegetation based on species composition, structural intactness and weediness

3.3.1 Available data and condition metric

Available data

Data used to quantify vegetation extent (aka canopy cover) was based on data developed initially for the HSMs. The models refer to this predictor variable as attenuated forest cover (refer to Table 18). Canopy cover (i.e. canopy above 2 m) was estimated from 4-band aerial photography (2009) and LiDAR data (2016). An algorithm was applied to these data to develop an initial estimate of canopy cover above 2m for a 200m buffer width along waterways. Thorough quality assurance was then undertaken, and the dataset was updated manually.

Canopy cover estimates do not discern between native of weedy vegetation. While a dataset of woody weeds was available at the time of the strategy, these reaches were not excluded from the canopy cover estimates. In some cases therefore some high canopy estimates may be mostly due to a high cover of weeds – which is not considered an ideal outcome. It is assumed that these woody weeds will be removed and replaced with native vegetation within priority reaches.

Condition metrics

The 200m canopy cover dataset was used as the basis for developing the vegetation extent metric. The data was cropped at a 20m or 10m buffer from either side of the streambed. The rationale for these approaches is provided below:

<u>20m buffer</u> along rural reaches (ie outside the UGB) - The 20m buffer was based on outputs from the HSMs which demonstrated diminishing returns in instream value benefits for wider riparian corridors.

<u>10m buffer</u> along urban reaches was used as it is considered unrealistic to establish greater than 10 metres of vegetation in many areas of the riparian zone due to limited land availability.

<u>Streambed</u> - The streambed (the low water line or the toe of the bank) was used instead of the stream centreline (or the top of bank) because adopting the centreline often includes large areas of open water (e.g. lower Maribyrnong and lower Yarra); and because adopting the top of bank often excludes vegetation which shades the stream.

From this the current (2018) area of canopy cover in ha was estimated for each of the 69 sub-catchments. A 5 point scoring method was developed to categorise the extent into very low to very high condition ratings (Table 37). A simple equal division of bands was adopted. This became the baseline canopy cover for the HWS extent metric.

Table 37. Vegetation extent score ratings

Score	Range	Description
Very High	80-100%	Greater than 80% of the riparian zone is covered by vegetation.
High	60-80%	60-80% of the riparian zone is covered by vegetation.

Score	Range	Description
Moderate	40-60%	40-60% of the riparian zone is covered by vegetation.
Low	20-40%	20-40% of the riparian zone is covered by vegetation.
Very Low	<20%	Less than 20% of the riparian zone is covered by vegetation.

3.3.2 Setting Vegetation extent scenarios

Current state

The methodology outlined above was used to determine the current condition for vegetation extent.

Forecast current trajectory under business as usual scenario

The business as usual trajectory for vegetation extent was assumed to be no change in vegetation extent from current. The main reasons for this included:

- It is expected that under business as usual revegetation would have continued across the region, however there was limited time available to estimate how much and where it would occur. It was assumed that it would not be well targeted and hence may not lead to significant environmental benefits.
- It is expected that threats like climate change, urbanisation and agricultural practices would lead to incremental reduction in the extent of vegetation.
- And hence on balance it was predicted that there would be negligible change to vegetation extent overall.
- The business as usual future (BAU) scenarios in the HSMs also made the assumption that there would no change to vegetation extent. The reasons for this are largely due to the above – but also as they were mostly concerned with showing the impacts from urbanisation and climate change.

The business as usual trajectory for vegetation quality however did predict an overall decline – and the assumptions for this can be found in section 3.4.

Long term target setting

Long term targets for vegetation extent were developed iteratively and changed considerably from the preliminary to the final targets. The main decision support tool used was the HSM and zonation which is described in section 2.4.3. Zonation uses the outputs from the HSMs which were developed for the instream values. The process included the following:

Preliminary targets:

- Sense checking zonation outputs with key Melbourne Water teams and identifying priority reaches – consideration of priorities from co-design workshops were also considered.
- The extent of effort was initially based on unit costs used for zonation scaled to business as usual investment programs for vegetation management – resulting in around an estimated 1000 km of revegetation over 50 years (note that this assumption was challenged).
- The 10 year performance objectives were based on achieving 20% of the 50 year target.
- Seeking feedback on priorities via the preliminary target feedback process.

Finalising targets:

- There was overwhelming feedback that the targets were not ambitious enough.
- Melbourne Water staff involved in delivering vegetation programs were more comfortable using rates of establishment from the previous strategy in preference to the unit costs. The main reason was that the unit costs were derived from capital projects and it was believed that significant savings would be made through greater use of incentives and a co-delivery model of the strategy. There were significant discrepancies between the establishment rates achieved in the last strategy and the unit costs developed for this strategy and relating the 2 was difficult.
- So using a rate of 800 km of vegetation established over 5 years (previous strategy target) the long term target would effectively result in continuous riparian vegetation along all waterways. This was seen as a good long term goal to aim for.
- This aspirational goal was endorsed by Melbourne Water Team Leaders responsible for delivering vegetation programs.
- Based on this the 10 year performance objectives were increased substantially. The process to refine them is outlined in the section below.

Target trajectory scores (50 year targets) were assumed to include achievement of the 10 year performance objectives, retention of existing vegetation, together with continued revegetation to achieve continuous vegetation along most waterways in the long term.

Once reaches were prioritised the area of canopy cover for each sub-catchment was generated based on a 20 m buffer outside the UGB and a 10 m buffer within the UGB.

3.3.3 Ten year performance objectives

A number of other factors were re-considered when finalising the 10 year priorities - ensuring priorities for all the environmental and social values were considered. The steps below outline the process used to finalise the 10 year performance objectives:

1. Using zonation outputs to identify high priority reaches for revegetation see Chee et al. (2020).
2. Consulting widely with stakeholders to sense-check and make commensurate modifications to the priority reaches as identified by Zonation. This included reviewing the priorities which were generated through the co-design workshops.
3. Including priority drought refuge reaches as areas where vegetation establishment is an important action to protect species during periods of drought.
4. Including additional 10 year priority reaches for birds and frogs based on spatial analysis outlined in the bird and frog sections. As there was good overlap between the priorities for instream values resulting from the above steps and the frog and bird analysis that there were relatively few additional reaches that were added to the 10 year priorities.
5. Including revegetation in sub-catchments which contained threatened fauna species. This was undertaken by finding sub-catchments which did not contain revegetation priorities from the above process and adding them. There was actually only one sub-catchment which was not prioritised for revegetation which had a threatened species in it. As such 1 km of vegetation establishment was added as a 10 year performance objectives for this sub-catchment.
6. Including for social amenity outcomes so that the target of 50% canopy cover along streams within the UGB was met. If these reaches were not already prioritised based on above steps then the additional amount of vegetation to be established was estimated and added to the 10 year performance objective for that sub-catchment.

Once the priority reaches had been identified the area of vegetation to be established was calculated using the 20 m buffer from the streambed for rural streams and 10 m buffer in urban streams. The targets were represented as both an area of vegetation and a length. The conversion between length and area determined by multiplying by 20 metres in urban areas and 40 metres in rural areas. However, due to sinuosity of streams, this conversion is not exact.

In addition to prioritising increases to riparian vegetation – prioritising retention of existing riparian areas was also undertaken. This analysis was undertaken utilising the macroinvertebrate HSM and is summarised in the vegetation quality section 3.4.3.

The 10 year performance objectives were expressed as an area (ha) and a length (km). <u>The length represents both sides of the waterway</u> i.e. if the performance objective requires 1km of revegetation then this means both sides of the waterway at the required width i.e. 20 m in rural and 10 m in urban areas.

3.3.4 Key assumptions and improvement opportunities

The approach adopted was fit-for-purpose, however there are some assumptions and limitations to note. These include:

- There are some differences between actual vegetation extent and that estimated by the algorithm. Thorough manual quality assurance and commensurate updates have been undertaken, but there are bound to be differences between actual vegetation extent and measured vegetation extent.
- Shrubs (below 2 m) and grasslands have not been identified in the calculation of this metric and the HSMs currently do not take into account grassland type vegetation communities. It is assumed in the models that increasing forest cover will lead to improved instream values. As such the models used to develop priorities need to be viewed with caution in grassland communities. The performance objectives deal with this issue by stating that appropriate EVCs be used to establish vegetation.
- Deciduous woody weeds are counted as vegetation cover in the metric – which does is not a good reflection of the condition of the riparian zone. This means that when using this calculation approach, the removal and replacement of deciduous woody weeds with native vegetation, would not count towards the target. The removal of woody weeds was factored into the costs used in the zonation analysis which was then used to prioritise different types of intervention (eg stormwater versus revegetation). If the vegetation priority reaches contain woody weeds then their removal should be a priority for that reach. This relates to the vegetation quality metric which is discussed in the section chapter.
- Streams change location over time. This means the riparian buffer area also changes. This has implications (most likely minor implications when considered at a regional scale) for ongoing measurement of vegetation extent.
- It was assumed the Level 3 is the minimum quality standard where vegetation begins to play a role as habitat for instream fauna and provide additional ecosystem service (e.g. shading, contribute to large woody debris, leaf litter etc.). This is based on the assumption that establishment of trees and shrubs should be adequate to provide the main organic inputs to the stream for essential ecosystem functioning.
- Headwater streams were not included within the HSMs or the zonation analysis – and in many cases are not included in the vegetation vision data. However due to the importance of headwater streams they were prioritised and included within the performance objectives relating to agricultural runoff and is documented in the Water Quality section 3.5.3.

Upon implementation of the strategy, it should be noted that:

- Riparian vegetation should be focused on continuity and connectivity rather than buffer width alone. To maximise waterway value outcomes, it is preferable to have a continuous narrow strip along the waterway rather than clumpy wide vegetated areas with large gaps.
- Consideration should also be given to whether there is value going beyond the buffer ranges defined for this metric. There is potential for substantial waterway value outcomes for riparian vegetation beyond the extents adopted in this strategy. Revegetation works should therefore not be limited to these buffer areas. Instead,

consideration should be given on a case by case basis to the feasibility and cost of going beyond these buffer widths, together with likely benefits for waterway values in doing so. For example, revegetating to wider buffers around a previously disengaged billabong if landholder is willing and supporting the billabong to be re-engaged.

Improvement opportunities will be developed through the HWS MERI framework and the associated Rivers Monitoring and Evaluation Plan (MEP).

3.3.5 Further resources

Vegetation priority areas

GIS layer: http://inflo/inflo/llisapi.dll/properties/50430046

Data guide: http://inflo/inflo/llisapi.dll/properties/50643391

Metadata: http://inflo/inflo/llisapi.dll/properties/50641548

Vegetation extent for each of the 16,344 sub-catchments (GIS layer):

GIS layer: http://inflo/inflo/llisapi.dll/properties/43753562

Data guide: http://inflo/inflo/llisapi.dll/properties/43754275

Metadata: http://inflo/inflo/llisapi.dll/properties/43756639

Supporting GIS data:

Riparian buffer: http://inflo/inflo/llisapi.dll/properties/43754377

Vegetation extent within buffer: http://inflo/inflo/llisapi.dll/properties/43755888

Stream bed: http://inflo/inflo/llisapi.dll/properties/43756326

Stream network: http://inflo/inflo/llisapi.dll/properties/43755795

3.3.6 References

Chee, YE, Coleman, R, RossRakesh, S, Bond, N and Walsh, C (2020) Habitat Suitability Models, Scenarios and Quantitative Action Prioritisation (using Zonation) for the Healthy Waterways Strategy 2018: A Resource Document. Melbourne Waterway Research-Practice Partnership Technical Report 20.3, March 2020.

3.4 Vegetation Quality

As outlined above in the Vegetation Extent introduction section and as described in the Vegetation Value section, understanding and managing the quality of vegetation is fundamental to river health in many ways.

3.4.1 Available data and condition metric

Available data

The most comprehensive dataset on vegetation quality is the Vegetation Visions (see

Box 6 in section 2.1.2). While the data is based on expert elicitation it was considered fit for purpose for developing long term targets and performance objectives for the HWS. A number of critical data gaps were identified in areas thought to be of high quality. Recent field based surveys were used to justify applying high quality vegetation ratings to these reaches. There was not however time to adequately review all the data and update all gaps ahead of the strategy.

Condition metric

The 1-5 rating scale used for the 2030 Vegetation Visions was adopted for the HWS (see

Box **6**).

3.4.2 Setting scenarios for vegetation quality

Current state

The current status of vegetation was based on the 2030 Vegetation Visions which were formulated in 2009. There was not enough time to review and update the data and as such the 2009 dataset was used. Given the broad categories and the slow changing nature of vegetation quality, this was not considered a major issue.

Forecast current trajectory under business as usual scenario

The approach to predicting vegetation quality under a business as usual future was based on expert elicitation with Melbourne Water vegetation specialists and is outlined below:

- Business as usual scenario for vegetation quality was essentially a ‘do nothing’ scenario which was considered to approximate opportunistic investment within an unprioritised process. This was largely due to limited time and data to drive a more quantitative approach.
- The two main aspects considered under this scenario were no management intervention and climate change impacts
- Climate change considerations were based on Spatial Vision (2014) modelled vegetation sensitivity to climate change (temperature and rainfall) for seven Catchment Management Authority areas. Assessment of the results of the sensitivity mapping identified the majority of riparian vegetation will be impacted by increasing temperatures under both medium and high climate change.

- It was recognised that extreme events (e.g. bush fires) may also have significant impacts to vegetation however given it is difficult to predict where they are likely to occur and under what timeframe – there was no attempt to change condition scores for these types of disturbances. The intent would be to be able to monitor condition change over time to better understand how vegetation recovers from such events.
- A qualitative assessment of threat levels from pest plants and animals was carried out using local knowledge at the sub-catchment scale. This identified areas of high quality vegetation as having the highest risk.
- Urbanisation was considered a significant threat to vegetation quality
- Given the above - a decision was made that on the whole vegetation quality is likely to decline overtime without significant and targeted investment to manage threats.
- The forecasted future under 'business as usual' made the following assumptions:
    - In areas where future urbanisation and DCI was set to increase there would be a reduction in vegetation quality by one quality score.
    - In areas of high vegetation condition (level 4 and 5) there would be expected to be some loss of resilience of the system as a result of impacts from climate changes (drying climate and extreme events) and known threats such as deer grazing on high quality sites and increased weed threat. For these reaches, it was expected that quality would be reduced by one. This would result in scores of 5 becoming 4 and scores of 4 becoming 3.
- All rules were applied at the management unit scale.

Long term target setting

There were several key principles used for setting the long term condition targets including:

- Protection of high quality areas (ie level 4s and 5s) was considered the highest priority – ie protect the best principle.
- The vegetation 2030 Vegetation Vision scores developed during the previous strategy still held as long term outcomes to aim for and as such became the 50 year target – except where priorities based on zonation results recommended a higher quality.

3.4.3 Ten year performance objectives

The 10 year performance objectives for vegetation quality were focused on protecting level 4 and 5 vegetation quality reaches. It was acknowledged that there are some gaps in knowledge and as such the performance objectives should be updated when new information is available. The performance objectives were represented as kms as there was not enough time to determine the width of vegetation within the various high quality reaches that required maintenance. In many cases the vegetation width may be wider than 20m which if used could have perverse outcomes.

The performance objectives also include a statement about protecting threatened EVCs which occur within the priority reaches.

The key drivers for increasing vegetated riparian buffers were around habitat requirements for the other environmental values such as fish, platypus, macroinvertebrates, frogs and birds. A key assumption was made that a vegetation quality rating of 3 is required to provide adequate riparian and instream habitat for these other values. This assumption is based on a level 3 quality having at least reasonable quality over and mid story vegetation which is going to provide many of habitat requirements of aquatic fauna such as shade, organic matter, large woody debris etc. If the Vegetation Quality rating was not already at a level 3 or had a vision for a level 3 then the Long Term target rating was updated.

3.4.4 Key assumptions and improvement opportunities

Most of the main assumptions used in setting the targets and performance objectives are outlined in the methods sections above. A key improvement initiative is to determine the width to which vegetation should be managed so that area targets can be developed. This would provide a more consistent approach with the vegetation extent targets.

Significant knowledge gaps were identified in headwater streams where data and knowledge of vegetation quality was limited. These areas were identified through querying the data, comparing it to the headwater streams layer and sense checking and prioritising with on-ground staff. Where these existed an additional performance objective was included eg *"Improve understanding of the extent, composition and condition of high and very high quality vegetation, and effectively monitor and manage both values and threats."*

Improvement opportunities will be developed through the HWS MERI framework and the associated Rivers Monitoring and Evaluation Plan (MEP).

3.4.5 Further Resources

Vegetaion Visions: VegetationQuality_1-5Comparison_techniques.pdf:
http://inflo/inflo/cs.exe/properties/15404881

3.4.6 References

Spatial Vision (2014). NRM planning for climate change: Final project report 1 – Impact and vulnerability assessment process and spatial outputs. Report prepared for Victorian Catchment Management Authorities (on behalf of seven Victorian CMAs)

3.5 Water Quality – Environmental

Water quality is a key environmental condition that supports environmental and social values and it was evident throughout the co-design process that the community has a good understanding of this as many of the issues and concerns raised by community were related to water quality.

In-stream values can be impacted by both what is in the water as well as what accumulates in the sediment; for example, some fish species lay their eggs on sediments, and many macroinvertebrates live on or graze on sediments. For the purpose of this strategy, water quality refers to what has been detected in both sediments and water.

3.5.1 Available data and condition metric

Available data

Melbourne Water's waterway water quality monitoring program measures ambient water quality either monthly or bimonthly at 132 locations across the catchment. Most sub-catchment had at least one monitoring location however, monitoring data was not available for a few sub-catchments. A method was developed that estimates the average water quality threat for a whole sub-catchment area based on the available data.

Melbourne Water also has a sediment quality monitoring program that has been coordinated by The Centre for Pollution Investigation and Mitigation (CAPIM). CAPIM amalgamated all available sediment quality and pollutant investigation data for each sub-catchment and this information (Pettigrove, 2018) was one of the data sets used to set water quality performance objectives in the strategy.

Condition metric

The State Environment Protection Policy (SEPP) sets water quality objectives for waterways across Victoria. The SEPP was under review during the time the Healthy Waterway Strategy was developed and the new guidelines (SEPP (Waters)) had not yet been passed by Parliament. Consequently, the existing policy objectives, SEPP (Waters of Victoria), were used in the Strategy rather than the new draft ones.

The Environmental Protection Agency, Victoria has developed a Water Quality Index (WQI) that amalgamates a range of water quality parameters onto a single index and reports against compliance with SEPP (Waters of Victoria) objectives. A web-based report card has been developed, led by the Environment Protection Agency Victoria (EPA) using Melbourne Water data. (https://yarraandbay.vic.gov.au/report-card)

The WQI was one of the metrics used in setting current condition for the HWS. (https://yarraandbay.vic.gov.au/report-card/scoring-method)

The Healthy Waterways Water Quality Visions was one of a range of 20 year Visions developed as tools of HWS 2013) (see

Box **6**). The main aim of the Visions was to communicate the threats to water quality for different land use types across the catchment and to set the vision of what the community expected to see achieved over time. This relationship between catchment land use and water quality threat was used for the HWS target setting. Catchment land use was divided into 7 broad categories; forest, parks and reserves, rural, rural township, rural drain (the Koo Wee Rup area), existing urban and new urban (areas that are yet to be urbanised).

Some sub-catchments have a range of catchment land uses that extend from forested to urban so a deriving a single measure of water quality for larger areas where land uses changes significantly is potentially problematic. However, broadly speaking, the WQI tends to decline as catchment land use intensifies (Figure 31) so the proportion of each catchment land use category in each sub-catchment can be used as an estimate of the likely water quality threat present at sub-catchment scale. Changes in catchment land use over time e.g. increases in urbanisation, or improvements in rural land management can be used to predict the future under business as usual and long term targets.

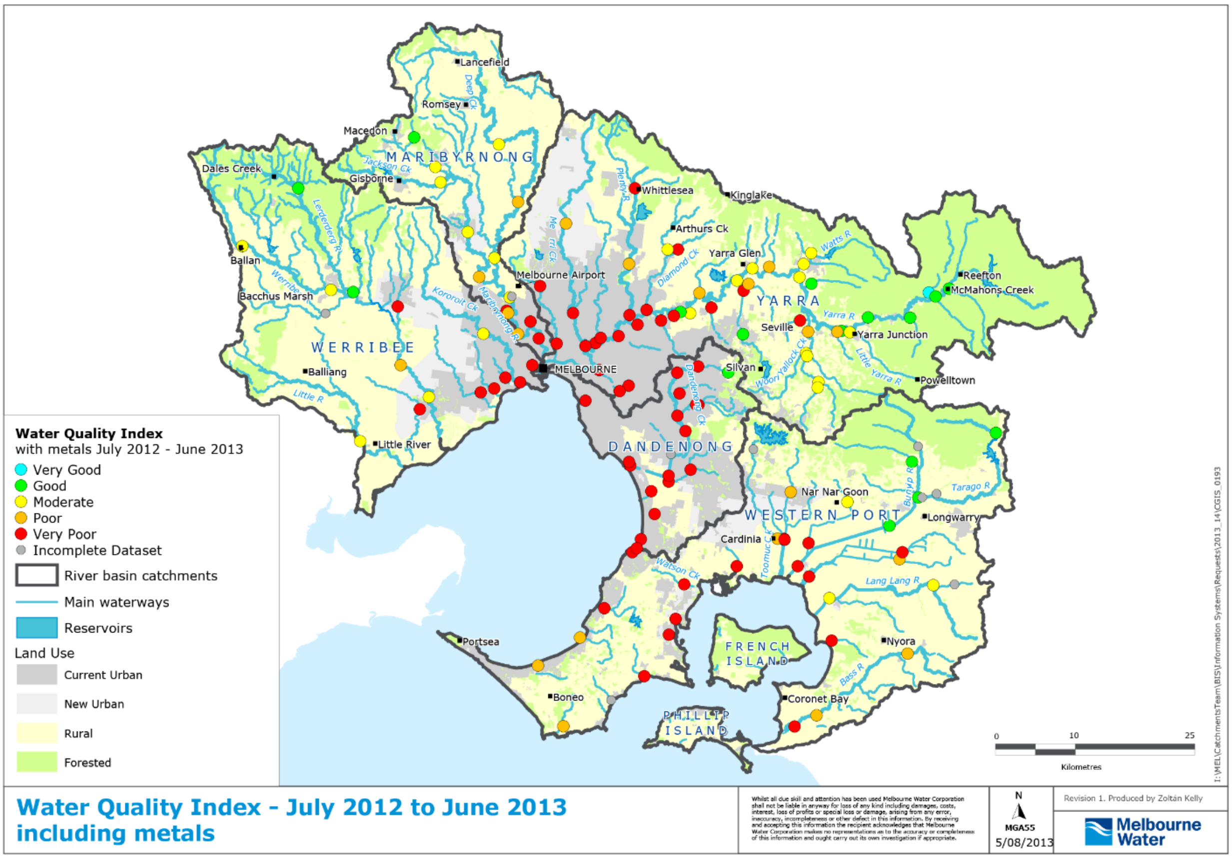

Figure 31. Water Quality Index across the Port Phillip and Westernport catchment for the 2012-13 year

3.5.2 Setting scenarios for water quality

Current state

For each sub-catchment, the area of land in each of the 7 land use categories (determined based on minor modifications to VLUIS 2014) was calculated and assigned a corresponding water quality rating (Table 38).

Table 38. Land use categories and designated water quality rating used to set current water quality condition at sub-catchment scale for HWS.

Land use category	Land use description	WQI rating
Forest	Area is near natural, generally upper catchment areas, water quality is near natural	Very High
Parks and Reserves	Areas of parkland that are sometimes in outer urban or rural areas. These areas can act to improve water quality	High
Rural Townships	Some signs of impact from stormwater are evident against a largely rural background	Moderate
Rural	Land is cleared and used for a range of agricultural purposes. Sediments, nutrients and some pesticides detected in water and sediments	Moderate
Rural Drains	Koo Wee Rup - land is drained and intensively used for agriculture. Significant water quality impacts evident.	75% Low
		25% V Low
New Urban (yet to be urbanised)	Areas yet to be urbanised, currently rural land where DCI is very low but some nutrient and sediment run-off evident.	Moderate
Existing Urban	Already urbanised with minimal stormwater controls. DCI is very high. Industrial areas are highly impervious and connected.	Very Low

This resulted in a proportional description of the water quality threat averaged for each sub-catchment. The sub-catchment average was based mostly on the predominant land use category for the sub-catchment. On rare occasions when catchment land uses were fairly evenly distributed, data validation, (see Table 39), was used to decide on an overall sub-catchment threat rating category.

Table 39. Maribyrnong catchment example: use of land use data to estimate proportion of water quality threat per sub-catchment. This same methodology was used for sub-catchments across all of the 5 major catchments.

% total for sub Catchment	Forest	Parks and Reserves	Rural	Rural Towns	New Urban	Existing Urban	Rural Drains	Average for sub catchment
	V.Good	*Good*	*Moderate*	*Moderate*	*Moderate*	*V. Poor*	*Poor(75%) /V.Poor (25%)*	
Boyd Creek	0	0	100	0	0	0	0	Moderate
Deep Creek Lower	0	0	100	0	0	0	0	Moderate
Deep Creek Upper	5	0	92	3	0	0	0	Moderate
Emu Creek	0	0	87	2	10	1	0	Moderate
Steele Creek	0	0	24	0	2	75	0	Very Low
Stony Creek	0	0	0	0	0	100	0	Very Low
Taylors Creek	0	0	22	0	0	78	0	Very Low
Jacksons Creek	13	0	69	7	7	5	0	Moderate
Maribyrnong River	0	0	31	0	0	69	0	Very Low
Moonee Ponds Creek	0	6	25	0	10	59	0	Very Low

Data (in the form of WQI) from the ambient waterway water quality monitoring program was used to validate these estimates of current threat. Not all sub-catchments had data available and some sub-catchments had multiple locations where water quality data had been collected.

The WQI for each monitoring site for the previous 5 years was calculated and averaged across the sub-catchment and compared with the estimate based on land use categories. For the vast majority of sub-catchments, the available data correlated with the estimate based on land use. There were a few instances e.g. in the Koo Wee Rup rural drain area and Watsons Creek where the data indicated a greater threat than was predicated based on land use categories. In these instances the average of the available data was used instead of the land-use based threat estimate. For sub-catchments where there was no available data to validate against, the land-use estimate of threat was used solely.

Forecast current trajectory under business as usual scenario

To estimate the future threat to water quality based on a business as usual trajectory some assumptions were made about how land use was likely to change and how climate change might impact water quality. Summarised these assumptions were:

- No change to stormwater policy, therefore areas of sub-catchments that are predicted to urbanise over the next 50 years will result in water quality declining to be similar to existing urban areas.
- Climate change reducing flows in rivers and creeks overall but increasing the frequency of summer storm events resulting in greater periodic erosion and run-off This results in some water quality parameters declining such as reduced dissolved oxygen (because flows are slower, water is more stagnant) water temperature increasing, turbidity potentially increasing due to storm events and algal growth etc.

In general, in a BAU future, each land use category dropped by one rating (Table 40);

- Forests lose water overall and warm and drop from Very High to High,
- Parks and Reserves stay the same,
- Rural areas and Rural Townships drop from Moderate to Low,
- New Urban areas are now urbanised and because of no changes to stormwater policy have dropped to Very Low.

Table 40. Land use categories and designated water quality rating used to set BAU water quality condition at sub catchment scale

Land use category	Land use description	WQI rating
Forest	Area is near natural, but reduced flow and increased water temperature, lower dissolved oxygen due to climate change	High
Parks and Reserves	Areas of parkland that are sometimes in outer urban or rural areas. These areas stay the same	High
Rural Townships	Increasing signs of impact are evident due to climate change and reduced streamflow	Low

Rural	Increasing signs of impact are evident due to climate change and pressures for water resources. Nutrient and sediment impacts evident	Low
Rural Drains	Koo Wee Rup - land is drained and intensively used for agriculture. Significant water quality impacts evident and intensifying	Low (50%) V Low (50%)
New Urban (yet to be urbanised)	No improvement to stormwater policy means these areas degrade as they are developed.	Very Low
Existing Urban	Areas already urbanised with minimal stormwater controls. No change in policy means no improvement seen over time.	Very Low

Calculations using business as usual categories and assumptions were made at the sub-catchment scale as described under current condition. Averages were derived per sub-catchment.

Long term target setting

To set long term targets a different set of assumptions were made about the potential for change into the future (Table 41). It was assumed over the long term that;

- Climate change impacts on streamflow would largely be mitigated through works to secure environmental water
- Areas about to be urbanised would have higher stormwater standards applied to maintain very low DCI and achieve no decline in water quality from current. In these areas water quality threat remains moderate
- 25% of existing urban areas have been renewed providing opportunity to implement better stormwater management policy. So 25% of urban land would improve to low and 75% would remain very low. Given of urban renewal is estimated to be 2% pa this is more than feasible potentially.
- 25% of rural land would have improved management to reduce sediment and nutrient run-off and improve to high with 75% remaining moderate
- Forested areas, despite climate change, would remain very high
- Areas of rural drain around Koo Wee Rup would see improvement so that 25% would improve to moderate and 75% remain at low.

Calculations using long term target categories were made at the sub-catchment scale as described for current and BAU.

Table 41. Land use categories and designated water quality rating used to set long term target water quality condition at sub catchment scale for HWS.

Land use category	Land use description	WQI rating
Forest	Area is near natural, generally upper catchment areas, water quality near natural. Despite climate change these areas remain v.high	Very High
Parks and Reserves	Areas of parkland that are sometimes in outer urban or rural areas. These areas can improve water quality	High
Rural Townships	Some improvement as better stormwater policy is implemented and stormwater is disconnected	High
Rural	Land use practise improvement to 25% of all rural land	75% Moderate
		25% Good
Rural Drains	Koo Wee Rup – rural land management improves on 25% of land.	75% Low
		25% Moderate
New Urban (yet to be urbanised)	New stormwater policy has kept DCI below 2% and water quality has been maintained at pre development	Moderate
Existing Urban	New stormwater policy has improved 25% of urban land as urban renewal occurs	Very Low

A summary of the water quality threat for land use categories under current, BAU and long term target is presented in Table 42.

Table 42. Summary land use categories and attributed water quality threat for current condition, future under business and usual and long term target

	Current Condition	**Business as usual** (existing stormwater policy + climate change)	**Long term targets** (improved (stormwater policy, improved rural land management, and improvements in current urban over time as improved stormwater policy takes effect)
Forest	Very High	High	Very High
Parks and Reserves	High	High	High
Rural Townships	Moderate	Low	High

Rural	Moderate	Low	Moderate (75%) High (25%)
Rural Drains	Poor (75%) V Low (25%)	Poor (50%) V Low (50%)	Moderate (25%) Low (75%)
New Urban	Moderate	Very Low	Moderate
Existing Urban	Very Low	Very Low	Very Low (75%) Low (25%)

3.5.3 Ten year performance objectives

Works to protect and improve water quality will benefit most of the key environmental and social values that are central to the HWS 2018 (Alluvium 2017).

Many catchment-based activities can impact water quality in rivers and creeks including;

- Land clearing
- Rural land management including dairy effluent management, cattle access to waterways, fertiliser and sediment run off, pesticide use etc.
- Septic tank impacts
- unsealed road run-off
- Industrial stormwater run-off and illegal discharges
- Stormwater from roads and residential areas
- Urban development
- Sewage treatment plant effluent
- Wet weather sewage overflows

Management interventions to improve water quality will often improve multiple parameters. For example, works to reduce polluted run-off from rural land are likely to reduce turbidity, nutrient and pesticide impacts in the stream; works to reduce sewage treatment plant discharges will reduce nutrients primarily as well as other chemicals that escape the treatment process such as some pharmaceuticals.

Environmental water quality performance objectives were set for a range of reasons including;

- Protection and improvement of environmental values in waterways
- Protection and improvement of environmental values in bays (to mitigate sources of impact coming from the catchment)
- In response to input from co-design highlighting concerns about
    - Targeting known sources of chronic high pollution such as industrial areas of the urban catchment

- chemical of emerging concern such as microplastics

Water quality related performance objectives are closely linked to performance objectives for other key conditions such as stormwater, revegetation and environmental water (Alluvium 2018). Disconnection of stormwater, maintenance of stormwater treatment wetlands, revegetation of riparian areas and establishment of near natural flow regimes will all contribute to improving water quality and overall waterway health. Given that performance objectives set for these other environmental conditions will contribute to water quality outcomes, the focus of the water quality specific performance objectives for the strategy time frame was on areas of the landscape that needed additional focus and that wouldn't be treated by other performance objectives, such as rural land, sediment from construction, septic tanks and effluent from sewage treatment plants etc.

Rural Land performance objectives

Ten year performance objectives were set with the intent to focus on areas of the catchment where existing macroinvertebrate scores were highest and where the available data (from the ambient WQ monitoring program and the sediment quality data sets) indicated a water quality threat was present. Targeting these areas is likely to protect and restore the best remaining areas of the catchment in a cost effective way, treating threats when they are at a scale that is manageable.

Macroinvertebrate scores from the Habitat Suitability Models (see Section 2.4, Figure 23) were used to identify current high value areas for macroinvertebrates because these, along with water quality are the focus of the SEPP (WoV). This approach for prioritising the protection of high value areas is consistent with the approach outlined in draft SEPP (Waters) Clause 18. Macroinvertebrates are a good overall measure of river health and actions taken to protect and improve these are likely to also protect and improve other key values such as fish and platypus.

While the SEPP (WoV) uses SIGNAL score as the metric for macroinvertebrates, the outputs of the Habitat Suitability Model use LUMaR as the metric (see Section 2.4). Any difference between the two metrics was not considered to be problematic in achieving the overall intent of the SEPP and the HWS. Areas of good predicted macroinvertebrate scores tended to be located higher in the catchment, in and close to forested areas and in some rural areas with low levels of urbanisation.

The available water quality data for monitoring locations closest to high value macroinvertebrate areas was examined to determine what water quality parameters were exceeding SEPP. In most cases exceedances were for nutrients and turbidity.

In addition to water quality data the sediment quality data set provided by CAPIM (now A3P) (Pettigrove, 2018) was used to delve further to determine if any other more transitory water quality impacts may be accumulating in sediments. Data collected by CAPIM over the period of 30 years from the early 90's was summarised by Pettigrove (2018) "Pollution Issues in the Melbourne Water Region and options for their management". Maps of each sub catchment were produced that combined the available data for each site into a rating. Sometimes no sediment quality data was available for a sub-catchment. Sediment quality data detects more persistent issues not measured in the ambient water quality monitoring program such as pesticide residues. In the context of the sub catchment so it was inconclusive but some locations identified evidence of pesticides.

Performance objectives were worded to focus on reducing nutrients, sediments and pesticides run-off from rural land. Depending on the area, other potential sources of threat were included such as the edge of the Dandenong Ranges, or the main stem of the Yarra River through the Yarra Valley where rural land management as well as unsealed road management and septic tanks and sewage treatment plant discharges were mentioned as mechanisms to manage threat.

The valuable role of protecting headwater streams was included in performance objectives for rural land as these play a critical role in the maintenance of stream health and are worthy of focussed attention;

Rural land water quality performance objectives were considered alongside vegetation and stormwater performance objectives. On several occasions it made sense to target improved rural land management when significant targets had already been set for both revegetation and stormwater.

Melbourne Water offers a range of incentives to stakeholders and partners for interventions that protect and improve waterways. One of the incentives available is for rural land holders in priority areas to reduce nutrient and sediment run-off and to revegetate headwater streams and waterways running through properties. This was considered the most likely mechanism for on-going delivery of rural land improvements so our target setting reflects a pragmatic approach and flexible approach to deliver the outcomes.

The program leads for the rural land program (RLP) were consulted closely during the development of the targets and advised that flexibility to deliver across more sub-catchments was desired without necessarily increasing the overall program resources, including staffing. The RLP program had collected 3 years of data on areas of land that had been treated through the rural land incentives. This data was extrapolated to create 10 year targets set at catchment scale. So the program has not expanded on its deliverables but has more flexibility to deliver across a larger number of sub-catchments than in previous strategies.

Table 43. Catchment scale targets derived for rural land improvement for the benefit of waterways and bays

Scale	Performance Objective
Werribee Catchment	Reduce nutrient and sediment runoff from rural land through improved management of 320 hectares of land including works to protect and increase vegetation along headwater streams

Maribyrnong Catchment	Reduce nutrient and sediment runoff from rural land through improved management of 530 hectares of land including works to protect and increase vegetation along headwater streams.
Yarra Catchment	Reduce nutrient and sediment runoff from rural land through improved management of 1800 hectares of land including works to protect and increase vegetation along headwater streams.
Dandenong Catchment	Reduce nutrient and sediment runoff through improved management of 10 hectares of rural land including works to protect and increase vegetation along headwater streams
Westernport	Reduce nutrient and sediment runoff from rural land through improved management of 16,000 hectares of land including works to protect and increase vegetation along headwater streams – contributes to reducing sediment loads to Western Port.

Performance Objectives for sewage treatment plants

Sewage treatment plants discharge treated waste water to waterways in some sub-catchments. The Environmental Management Plan for Port Phillip Bay and the SEPP (Waters) have targets to cap loads of nutrients being discharged to waterways from sewage treatment plants as an action contributing to maintaining nutrient loads to Bays. This will also have benefit in maintaining environmental values and in some cases, protecting drinking water quality. Performance objectives were set for sub-catchments where an existing sewage treatment plant is located.

Performance objectives for wetlands

Regional performance objectives highlight the need to maintain assets that had been built under previous strategies and not allow their function to degrade. This highlights that maintenance is an integral function that underpins the ability to make progress over time.

Melbourne Water, developers and councils have invested significantly in stormwater treatment wetlands that treat low stream flows to allow sediment to settle and nutrients to be removed. This performance objective also aligns with SEPP (Waters) and the Port Phillip Bay Environmental Management Plan.

Performance Objectives for sediment from construction

Other performance objectives were set for areas that are about to urbanise to highlight the need for the large impacts of construction to be controlled. Sediment that is mobilised during the construction phase is a known significant issue so these performance objectives were set for all sub-catchments that have planned significant urbanisation projected. These Performance objectives protect waterways as well as Westernport and the protection of seagrass as well as help meet targets for maintaining water quality in Port Phillip Bay and contribute to load targets set for these Bays in SEPP (Waters)

Performance Objectives for industrial pollution and areas of high pollutions

Significant water quality issues occur in areas with large areas of industrial land use or other contribution to pollution. Regional performance objectives targeting the need to address these were set to allow a risk based approach to their remediation.

Table 44. Summary of Water Quality Performance Objectives

#	Performance objective template	Intent	Source of data/ measurement
1	PO for Sub-catchment with high macro values in HSM's: Eg. Improve water quality for environmental values and Port Phillip Bay by reducing turbidity and nutrient run-off from rural land. This may include establishment of vegetated buffers in headwater streams. OR Eg. Improve water quality for environmental values and Port Phillip Bay by reducing turbidity impacts from rural land, urban growth and unsealed roads as well as nutrient inputs from rural land and septic tanks in Monbulk creek between Birdsland and Lysterfield Rd.	• To target water quality impacts from rural land for the protection of waterways • Target impacts from other land uses in some areas e.g. septics, urban growth • To link catchment works to the significant areas of industrial land use. Port Phillip Bay Environmental Management Plan and SEPP Waters targets for nutrient and sediment to bays • Highlight the role and importance of headwater streams on rural land in the maintenance of stream health • It is expected the PO's will be delivered by MW through rural land incentives, councils managing roads and septics	Melbourne Water Ha rural land treated # septic tank investigations, % impacting septic treated Others to be developed

#	Performance objective template	Intent	Source of data/ measurement
2	PO for sub-catchments about to be urbanised Eg. Protect water quality for environmental values, the Bass River estuary and seagrass in Western Port by managing sediment loads from construction activities to ensure no pollutant or sediment laden run-off enters drains and waterways.	• To specifically target sediment mobilisation during the construction phase • This performance objective is aimed at protection of seagrasses in Westernport	Research programs aimed to estimate construction phase impact Others to be developed
3	PO in sub-catchments with a sewage treatment plant discharge Eg. Protect water quality for Port Phillip Bay and waterways by maintaining the current quality of discharges from sewage treatment plants (and reducing where possible) ensuring they are released in a manner that ensures environmental values are supported in the waterway. Often this is paired in the same PO with reducing nutrients and sediment from rural land	• This PO was to align with the Port Phillip Bay Environmental Management Plan action to maintain sewage treatment discharges at 2017 levels • Specifies that discharges can be considered beneficial if they are of sufficient quality and discharged in a way so as to support the environmental values	Melbourne metro water corps and Western Water Annual loads of nutrient
4	PO in sub-catchments on the edge of Westernport where there was evidence of water quality threat in the available data Eg. Improve water quality for environmental values and seagrass in Western Port by reducing turbidity and nutrient run-off from rural land in Deep Creek, Stoney Creek and Toomuc Creek. This may include establishment of vegetated buffers in headwater streams.	• This PO was specific to address threats to Westernport from rural land • Data indicated high levels of pesticides, nutrients and sediments in Westernport that are likely to be originating on farm land	ha land managed metrics to be developed for construction based on research

#	Performance objective template	Intent	Source of data/ measurement
	Eg. Protect water quality for environmental values, coastal vegetation and seagrass in Western Port by managing runoff from agricultural and urban areas, including sediment loads from construction activities, to ensure no pollutant or sediment laden run-off enters drains and waterways. Increase support for improved water stewardship.		
5	RPO on emerging contaminants. The potential impacts of emerging contaminants of concern such as microplastics, pesticides and pharmaceuticals, and toxic chemicals are better understood and mechanisms to respond collaboratively developed.	This RPO was added to highlight the need to keep abreast of new chemicals being used and new information on associated risks This was a focus of comments during co-design	Research such as A3P
6	RPO for pollution sources Risk-based programs are in place to mitigate sources of urban pollution (licenced and unlicensed discharges) to protect bays and waterways.	This RPO was added to support the formulation of a risk-based pollution mitigation program Many co-design comments highlighted the need for additional attention in this area	Collaboration between EPA, MW and council

3.5.4 Key assumptions and improvement opportunities

A range of key assumptions were made during the setting of current BAU and long term targets that have already been outlined above.

Other assumptions were made at the time of creating the performance objectives, some of which were tested with strategy collaborator. These include:

- Continuity of the Rural Land Program at Melbourne Water
- That nutrient load data is available for sewage treatment plants which can therefore enable targets of maintain current to be reported on

- Un-sealed road management can be influenced such that drainage can be disconnected
- Historical data on rural land program delivery could be extrapolated to a ten year target
- That a risk based approach for targeting areas of high pollution and prioritising investigations, remediation and enforcement can be agreed to between a variety of agencies

A key area for improvement is to refine the process for determining water quality at the sub-catchment level. A review of the long term water quality monitoring program is envisaged to re-distribute and add sites to the network so that we have a better representation of waterway water quality in each of HWS sub-catchments. Additionally we are investigating analyses of existing data that may be able to support an improved estimate of water quality condition at sub-catchment scale.

A Source catchment model to allow us to test actions and options, integrate water quality works across the catchment and report on waterway and bay outcomes is being built as are catchment planning tools to help prioritise works in the Western Port catchment to reduce sediments.

Another improvement opportunity is to update the current condition metric using the 2018 SEPP Water standards.

Improvement opportunities will be developed through the HWS MERI framework and the associated Rivers Monitoring and Evaluation Plan (MEP).

3.5.5 Further Resources

Melbourne Water Water Quality Visions - http://inflo/inflo/cs.exe/properties/18287301

Land use data sets used in the WQ Visions - Q:\GISData_GDA94\Drainage\River_Health\Healthy_Waterways

Habitat suitability models for Macroinvertebrates – current condition https://data-melbournewater.opendata.arcgis.com/datasets/hws2018-habitat-suitability-modelling-results-for-macroinvertebrates?selectedAttribute=CURRENT_2

3.5.6 References

Alluvium (2017). Healthy Waterways Strategy Waterway Science Conceptual Models, Melbourne Water.

Pettigrove, V. (2018) Pollution Issues in the Melbourne Water Region and Option for Management. CAPIM technical Report no. 88. http://inflo/inflo/cs.exe/properties/42481735

Melbourne Water (2013) Water Quality 2030 Vision – User Note. http://inflo/inflo/cs.exe/properties/22237536

Victorian Government (1999), State Environment Protection Policy Schedule F7 (Waters of the Yarra catchment). S 89

Victorian Government (2003), State Environment Protection Policy (Waters of Victoria). S 107

Victorian Government (2018), State Environment Protection Policy Schedule (Waters) S 493 (in draft at the time) http://www.gazette.vic.gov.au/gazette/Gazettes2018/GG2018S499.pdf

3.6 Instream Connectivity

In the context of the HWS2018 preparation instream connectivity is a measure of the ability of fish to travel through a stream network. Anthropogenic features of stream networks such as dams, reservoirs, culverts, road-crossings, weirs and rock chutes, together with natural features such as waterfalls, can impede the ability of fish to travel through a stream network. Platypus conceptual models also reference the importance of length of suitable connected habitat however it was considered that platypus are able to climb over and access upstream of some in-stream structures that fish cannot. Some structures such as underground pipes can prohibit access for both fish and platypus and further considerations for improving the information we use to assess this environmental condition is outlined in 3.6.4

Native Australian fish typically require unimpeded passage through stream networks to thrive and survive. Most fish native to south-eastern Australia migrate as part of their lifecycles, some over thousands of kilometres.

Anthropogenic fish barriers lead to:

- Fragmentation of populations and consequential reduction in genetic diversity;
- Interference with migratory patterns which impact life cycles and breeding cycles; and
- Restricted access to food resources and preferred habitat.

To improve fish passage, the anthropogenic features can be removed, or infrastructure added to allow fish passage (e.g. fish ladders).

3.6.1 Available data and condition metrics

Available data

Melbourne Water spatial data for fish barriers was updated and fish barriers categorised in the following ways:

- The fish barriers GIS spatial layer was cross referenced with aerial imagery and local knowledge to ensure each fish barrier was located in the correct place, referencing it to the right subc for use in Habitat Suitability Models,

- Each fish barrier was classified as either Full or Partial Barrier. Full meant there is no doubt that the barrier is total. These included large reservoirs such as Upper Yarra, Melton etc. as well as large drop structures such as Heads Rd on the Lang Lang River and Werribee Diversion weir etc. Partial meant that it was conceivable that some fish could access upstream reaches during high flows. Where the status was unknown the barrier was assumed to be partial.
- Each barrier was categorised in a standard way. The categories are
    - Artificial rock
    - Concrete channel
    - Crossing
    - Dam
    - Drop structure
    - Estuary mouth
    - Farm dam
    - Gauging station
    - Gauging weir
    - Natural rock
    - Other
    - Pipe
    - Retarding basin
    - Stormwater wetland
    - Weir
- Where possible, information about the fish barrier height was extracted from available reports and added as metadata into the fish barrier GIS layer
- Obvious duplicates were removed eg. diversion weirs that were already identified as fish barriers
- Obvious additions, identified via aerial imagery and local knowledge were added.

For each fish ladder that has been built, the year of construction/rectification was collated (extracted from Maximo and from local knowledge) and used along with fish monitoring data to help determine the success of the structure and to inform the development of Habitat Suitability Model predictions.

Condition metrics

For this HWS 2018, instream connectivity has been measured at a sub- catchment scale, and is an average of:

- Connectivity to stream outlet: Proportion of stream network within each sub-catchment that has fish passage to the stream outlet (i.e. Port Phillip Bay or Western Port) (%).
- Connectivity within sub-catchment: Longest stream length with fish passage within the sub-catchment, divided by total length of stream within the sub-catchment (%).

So the calculation was:

Average instream connectivity = connectivity to stream outlet (%)+connectivity within sub-catchment/2. Averages were then converted into Scores as presented in Table 45.

In other words, this is a combined score of connectivity within each of the 69 sub-catchments, together with connectivity to the bay. This can be thought of as a combined metric for migratory and non-migratory fish.

Consideration was given to using the above measures independently, and also to adopting:

- Connectivity to sub-catchment outlet: Proportion of stream network within each sub-catchment that has fish passage to the sub-catchment outlet (%).

The approach of adopting the average of the first two measures was considered the best approach for the following reasons:

- It measures connectivity of migratory and non-migratory fish. In comparison, Option 1 measures only migratory fish, and Option 2 measures non-migratory fish. By combining these two measures, we get a combined score for migratory and non-migratory fish.
- Option 3 is flawed because it does not adequately measure the improvement in fish passage achieved when removing barriers close the sub-catchment outlet. In other words, there is close to no change in score when a barrier is removed close the sub-catchment outlet, despite the potential for substantial improvement in connectivity.

3.6.2 Setting scenarios for instream connectivity

Current state

Score ratings for current condition are described in the Table 45.

Table 45. Ranges for instream connectivity (a measure of the average of connectivity for migratory and non-migratory fish)

Score	Range	Description
Very High	80-100%	A very high proportion of the stream network has fish passage. There is high to very high fish passage within the sub-catchment (non-migratory fish) and to the stream outlet (i.e. Port Phillip Bay or Western Port for migratory fish).
High	60-80%	A high proportion of the stream network has fish passage. Typically, this will mean migratory and non-migratory connectivity will have ratings of moderate, high and very high, with the minimum rating for either being low.
Moderate	40-60%	The stream network has moderate fish passage. This could be a combination of moderate fish passage for non-migratory and migratory fish, or a combination of higher and lower ratings for each.
Low	20-40%	The stream network has low fish passage. This means either migratory or non-migratory fish passage has a low or very low rating, or they both have low ratings. Neither migratory or non-migratory connectivity achieves a very high rating.
Very Low	<20%	The stream network has very low fish passage. This means both migratory or non-migratory fish passage ratings no higher than low.

Forecast current trajectory under business as usual scenario

This business-as-usual trajectory was calculated by assuming:

- Existing fish ladders are satisfactorily maintained so they operate as per the design intent;
- No further fish ladders installed;
- No further fish barriers are added, or existing fish barriers removed.
- So condition under BAU is the same as current condition. This scenario assumes that climate change and urbanisation were not going to necessarily increase the in-stream barriers.

Long term target setting

Long term targets were developed by running a scenario that removes all feasible barriers except the crazy big ones – like major dams. Additional exclusions included some barriers that are in the very upper parts of the stream network where the benefit of removing these was determined to be relatively low.

3.6.3 Ten year performance objectives

The performance objectives for instream connectivity were primarily aimed at benefiting fish by removing barriers to open up as much additional habitat in the most cost effective manner.

Priorities for the 10 year life of the strategy were established by first making the assumption that some super large barriers (such as reservoirs) are likely to remain even over the 50 year time frame. These fish barriers were not considered further.

Fish barrier removal (including provision of fish passage) was then prioritised by:

- Identifying which barrier removals provided greatest improvements in habitat suitability. This was estimated by using outputs from the habitat suitability fish models (Chee et al. 2020).
- Considering likely costs of barrier removal.

The key scenario of the habitat suitability model was "FW2", which identified habitat suitability outcomes for removal of FULL fish barriers (i.e. all those except the large dams and smaller instream dams on private land). The benefit of removal was explored using this scenario in comparison to the business as usual trajectory. Priority was typically given to removing groups of barriers (i.e. multiple barriers along a waterway, as opposed to individual barriers), as this provided greatest improvements to fish connectivity and habitat suitability scores.

Benefit scores from the HSM's were then combined with an estimate of cost of barrier removal to form a cost-benefit analysis.

An estimated cost per meter of fish barrier height removed was determined based on previous Melbourne Water fishway capital projects (design, operation and maintenance of fish barriers). Given that individual fish barrier removal cost estimates were not available, this was determined the best way to provide a comparative cost/benefit analysis for the purpose of establishing Strategy priorities.

In this analysis of priorities fishways that are known to be in need of maintenance were added because they are likely acting as barriers at the moment. These were included in the priorities for the 10 year program because HSM's assume these are working.

The prioritised fish barriers to be removed over the 10 year life of the Strategy are shown in Table 46.

No changes were made as a result of co-design input because no specific feedback on fish barriers was received. Performance objectives for fishways were set only for those sub-catchments which contained fish barriers to be removed.

Table 46. Fish barriers to be removed (or have fish passage incorporated) as per performance objectives

Catchment	Sub-Catchment	Barriers to be removed or to have fish passage incorporated
Dandenong	Dandenong Creek Lower	Pillars Crossing and National Water Sport Centre
Maribyrnong	Maribyrnong River	Arundel Road Weir McNabs Weir
Werribee	Little River Lower	Five fish barriers between the mouth and Geelong-Bacchus Marsh Rd.
Werribee	Toolern Creek	Barrier near Exford Road, Melton South High St, Melton
Werribee	Werribee River Lower	Ten barriers between the mouth and Melton Reservoir Cobbledicks Ford Reserve
Westernport	Lang Lang River	Heads Rd Western Port Rd
Yarra	Darebin Creek	Increase instream connectivity to provide fish passage along Darebin Creek from the confluence with the Yarra River to the upper reaches (remove 2 fish barriers).
Yarra	Watts River (Source)	Donnellys Weir Graceburn Weir
Yarra	Yarra River Lower	Rectify Dights Falls fishway
Yarra	Yarra River Upper (Source)	Armstrong Weir McMahons Weir

3.6.4 Key Assumptions and Improvement Opportunities

The following is a list of potential improvements to consider in future updates of the metric:

- Weightings between the two component measures (i.e. migratory and non-migratory). These are currently weighted 1:1. No consideration has been given to whether other weightings are more appropriate.
- Further consideration given the classification (meaningfulness) of scores into very high, high, moderate, low and very low.
- The stream network (MW Natural Waterway Centreline) used for this metric could be tidied to make it more relevant to instream connectivity. Potential improvements include removing

the parts of this GIS stream network which are, in fact, underground channels rather than open waterways.

- Better classification physical form for all reaches as described in section 3.7. This would also be beneficial to identify other barriers not currently identified in the barrier layer. It would also resolve issues with some underground pipes not being clearly identified in the current waterways GIS layers and their potential as fish barrier to be addressed e.g. concrete channels, underground pipes etc.
- Consider calculating the metric using the main stem of waterways, i.e. not including tributaries, as for most species, the main stem is the primary habitat.
- Incorporate consideration of connectivity for other values (such as platypus).
- Thoroughly reviewing and updating the fish barriers layer. In the calculation of this metric, a number of assumptions were made about fish barriers that were not included in this layer (i.e. categorisation of partial and full barriers was conservative. Full barrier was really only assigned to really big known barriers. Otherwise the barrier was assumed to be partial because large flow events might allow some connectivity. This assumption needs to be tested).
- Consider an alternative approach of length-weighted connectivity:
  - For each stream reach, measure the length between barriers upstream and downstream (reach connectivity).
  - For each sub-catchment, sum the multiples of reach connectivity and reach length, calculate the average of these values, and divide it by the total stream length.
- Consider combining a length-weighted approach with information on the quality of instream habitat so that a measure of quality of habitat that each barrier removal opens up can become part of a cost benefit analysis.
- In all fish barrier future projects, include the requirement for an initial downstream barrier investigation to mitigate the potential for an unidentified downstream barrier impacting on the cost effective increase in habitat created by the project. This will help to identify new barriers. This information could update the spatial layers for fish barrier and be used in the Strategy mid term review of priority works.
- Consider the need for the fish barrier layer to be validated on ground during twice over the life of the strategy.

3.6.5 Further resources

Fish barrier spatial dataset , which includes identification of fish barriers to be removed to meet performance objectives of HWS 2018.

Habitat suitability model outputs, which includes outputs for all species of fish, together with the FW2 scenario for fish barrier removal.

Calculation on stream lengths to determine scenarios for current, BAU and Target
http://inflo/inflo/cs.exe/properties/41468003

Calculation on fish barrier removal to set 10 year performance objectives
http://inflo/inflo/cs.exe/properties/41773038

P:\MEL\Integrated Solutions Planning\Water Services Planning\Projects\084 Regional Waterways Strategy 2016\Analysis\Waterway science\Spatial Data\Fish Barriers

3.6.6 References

Chee, YE, Coleman, R, RossRakesh, S, Bond, N and Walsh, C (2020) Habitat Suitability Models, Scenarios and Quantitative Action Prioritisation (using Zonation) for the Healthy Waterways Strategy 2018: A Resource Document. Melbourne Waterway Research-Practice Partnership Technical Report 20.3, March 2020.

3.7 Physical Form

The physical form of waterways is an important environmental condition as it provides the structure from which other environmental conditions act upon and within. Physical form refers to the size, shape and form of the bed and banks of rivers. The condition of the physical form is influenced by many factors including geology, soils, vegetation, flows, sediment and topography. The interaction of these factors result in geomorphic processes such as erosion, sediment transport and deposition.

The physical form of waterways can also be a value in its own right, such as unique or rare types, and features which can be declared sites of geomorphological and geological significance. Our approach therefore seeks to manage physical form condition as both a value and a threat in different contexts, using risk-based decision-making.

The conceptual models for the key values outlined the range of physical form condition indicators and metrics relevant to the various key values (Table 47).

Table 47. Relationship between physical form and key values

Environmental Condition Indicator	Typical Metric	Key value relationship
Bed composition	Extent of suitable habitat	Platypus, fish, macroinvertebrates
Bank composition	Extent of preferred habitat	Platypus, fish, macroinvertebrates, vegetation
Large wood and coarse woody debris	Volume	Platypus, fish, macroinvertebrates

Environmental Condition Indicator	Typical Metric	Key value relationship
Wetland habitat form	Depths, gradient	Frogs, birds, vegetation
Riparian rock habitat	% cover of rock within 10 m of water	Frogs

3.7.1 Available data and condition metrics

Defining physical form condition for waterways can be complex, as 'condition' may be considered in reference to several different elements of channel form. These may include 'naturalness', 'erosion potential', consideration of past, current and future states of the waterway, and often conflicting views on what the desirable form of the waterway should be.

The Index of Stream Condition provides an assessment of physical form using three key aspects of physical form including artificial barriers, LWD and bank condition. As LWD and instream barriers are both part of the HSMs it was not considered particularly useful to use this data for this aspect because it was covered by other data sets used in HSM that were more indicative of the region. A separate condition measure for instream barriers has been developed based on the priorities which came from these HSMs. Given the sparsity of data on LWD and a strategic decision that increasing LWD in the long term will mostly occur in proportion with increased vegetation extent (ie the trees will eventually fall into the stream) a target for LWD on its own was not considered necessary. In addition the bank condition scores are a static point in time and do not necessarily give much of an indication of the rate or threat of erosion.

The potential for excessive / unnatural erosion was considered the most appropriate approach to developing priorities around physical form for the Strategy. Physical form condition can be improved over time in most cases through revegetation efforts where as in other areas incision processes may need to be addressed through building bed control structures. An 'erosion potential' index was selected as the most meaningful and tangible parameter at the sub-catchment scale. An additional assessment of 'naturalness' has also been completed, which can be considered in combination with 'erosion potential' to further inform the on-ground prioritisation of management works.

The data used to assess erosion potential included:

- Geology and sedimentology GIS layers
- RiverStyles GIS layers and associated reports
- Aerial photography
- Technical geomorphology reports of various waterways previously undertaken for Melbourne Water

The data was supplemented with expert opinion through a workshops which included consultants and Melbourne Water staff who have had a long history of involvement with, and understanding of, the geomorphic condition of Melbourne Water's waterways.

Box 9. Stream form visions

The stream form visions developed as part of Melbourne Water's waterway visions project in 2013 are still relevant today. They provide a long term vision and consistency in the approach to managing the stream form of waterways in the Melbourne Water region. The stream form visions outline the physical form and expected ongoing physical processes occurring within the waterway. The visions include a description of channel character (valley abutment, sinuosity, hydrology), behaviour (stability and timescales of adjustment) and geomorphic features (e.g. pools, riffles, benches). The visions for stream form were developed based on a combination of two data sets: River Styles™ physical form assessments and the existing and future land use in the Port Phillip and Westernport region. A total of 50 stream form visions have been developed to represent the range of stream form and land use combinations, and they apply to all major waterways across the Melbourne Water region, as well as the minor waterways in areas identified for future urban growth. While this data did not contribute directly to setting targets in the HWS Strategy they should be considered an important strategic planning tool.

3.7.2 Setting scenarios for physical form

Current state

The erosion potential index was applied to identify the current condition by collating and reviewing the majority of past reports, investigations and data sources on physical form condition across the Melbourne Water region and through workshops to develop the rating. A qualitative rating scale was developed and applied to each sub-catchment using available data sources and expertise (Table 48).

Table 48. Physical form condition description

Physical Form condition score	Description
Very High	**Very low erosion potential**. This includes: geomorphically 'intact' channels with bedrock control or no known triggers for instability. Primarily source headwater streams. Adjustment within a dynamic equilibrium is appropriate (e.g. fire, flood).
High	**Low erosion potential**. This includes: waterways with no known active erosion, however may have some minor impacts from land use, local disturbance etc. Also includes waterways that have been substantially modified such that erosion potential is now limited by infrastructure (e.g. drains, concrete channels etc.).

Moderate	**Moderate erosion potential**. This includes: waterways with no known active deepening, however susceptible to widening and bank erosion due to local land use and disturbance.
Low	**High erosion potential**. This includes: waterways with known active deepening and widening, and will continue to be susceptible to erosion processes.
Very Low	**Very high erosion potential**. Waterways with known active deepening and widening, in highly erodible soils, with likely ongoing disturbance from adjacent land use, and will continue to be susceptible to erosion processes.

A confidence rating of low to high was developed based on :

Low confidence: sub-catchment not well known to the expert panel members but know of a couple of examples where erosion was occurring (note all 'low' confidence scores were shifted to 'moderate' by the end of the workshopping process with Melbourne Water).

Moderate confidence: The sub-catchment was reasonably well known to the expert panel members.

High confidence: The sub-catchment was well known to many of the expert panel members

A map of the current state erosion potential of each sub catchment was developed (Figure 32)

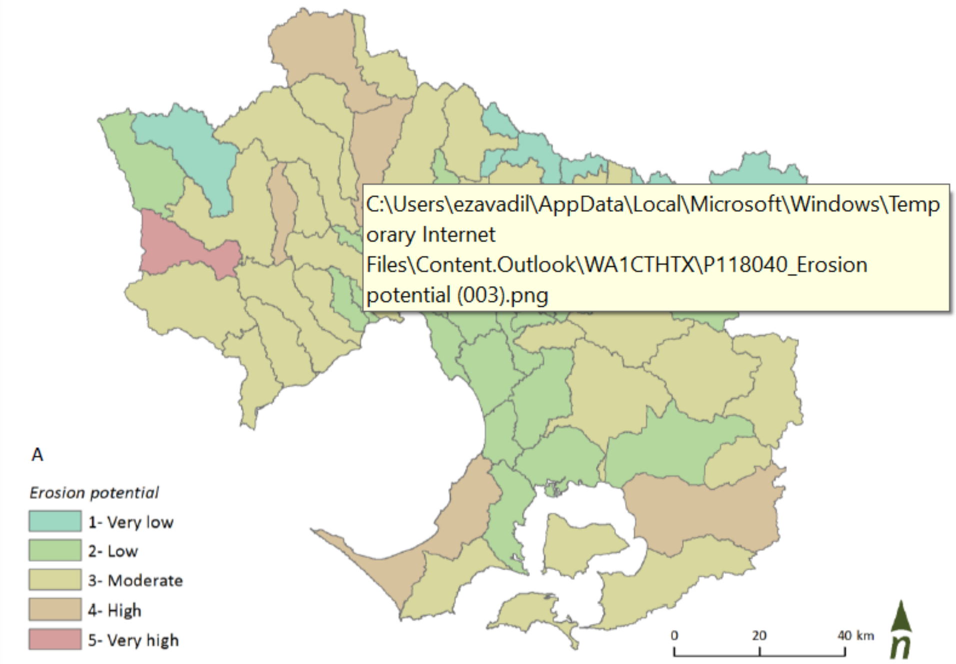

Figure 32. Current state erosion potential at sub-catchment scale

Forecast current trajectory under business as usual scenario

Assessing a business as usual future was based on predicted climate impacts and planned urban growth over the next 50 years (Figure 33). The following key assumptions were thought to lead to an increase in erosion potential:

- Drier conditions (and impacts on vegetation)
- Flashier flows (due to extreme events and urbanisation)
- Impacts of urban growth

For sub-catchments where these threats were predicted in the future, the erosion potential rating was increased by one with a few exceptions where the impact was considered higher – these were Dalmore Outfalls, Darebin Creek, Merri Creek (Rural and Forested) and Mornington Peninsula North-Eastern Creeks.

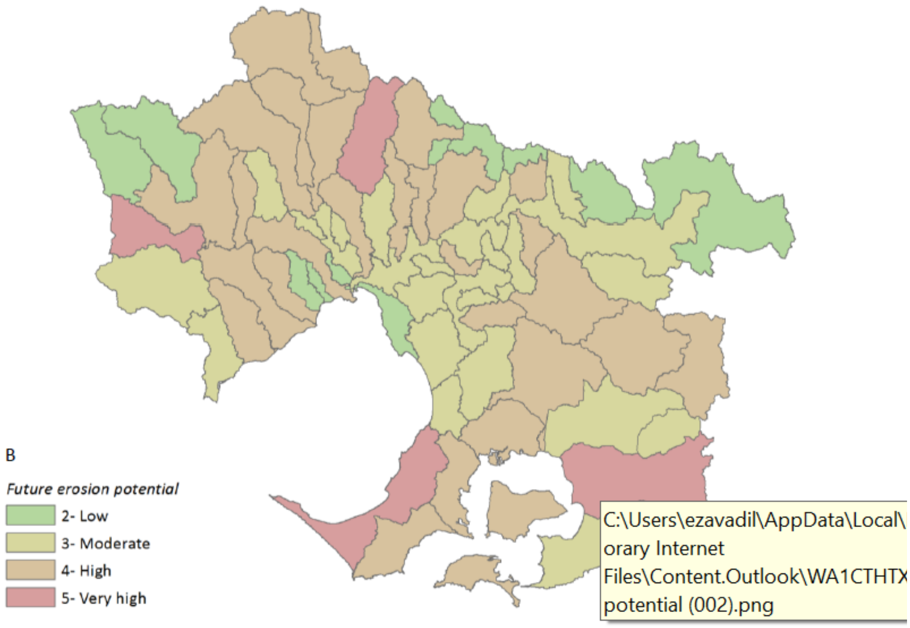

Figure 33. Erosion potential at sub catchment scale under Business as Usual future

Long term target setting

A 50 year target score for physical form condition (erosion potential) was set with reference to current and future erosion potential scores, naturalness score (see 3.7.3), and the broader range of Performance Objectives for key values of each sub-catchment (Figure 34). It needs to be recognised though that erosion is one potential threat but there could be others (deposition, development encroachment, stormwater flows) that influence physical form condition. Overall, the 50 year objectives that have been set (if achieved) will halt that decline, and shift the trajectory back towards some net improvement in physical form (compared to current conditions).

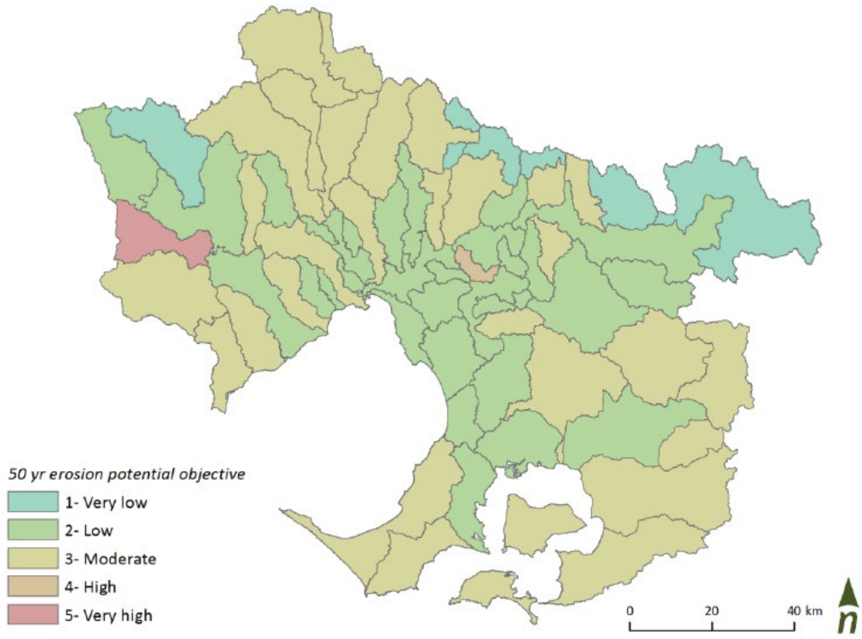

Figure 34. Long term target for erosion potential at subcatchment scale

3.7.3 Ten year performance objectives

Sub-catchments needing investigation and intervention around physical form issues in the first 10 years of the strategy were prioritised if the physical form condition for the business as usual scenario was a low or very low (indicating high erosion potential) – irrespective of the current condition. Naturalness was also considered at this stage

A naturalness score was also defined for each management unit, to assist Melbourne Water with future works prioritisation (Figure 35). Naturalness refers to the physical form of the waterway with reference to pre-European / urbanisation conditions. Naturalness scores are based on the dominant condition of waterways within a given management unit (majority of main channel and tributaries).

1 – intact: waterway is largely maintaining original form

2 – minor change: some minor changes in form

3 – moderate change: moderate changes associated with localised bed and bank disturbance

4 – major change: substantial change in form due to urbanisation (infrastructure) and/or major erosion processes

5 – fully modified: waterway does not retain any features of its pre-modified form (e.g. concrete channel).

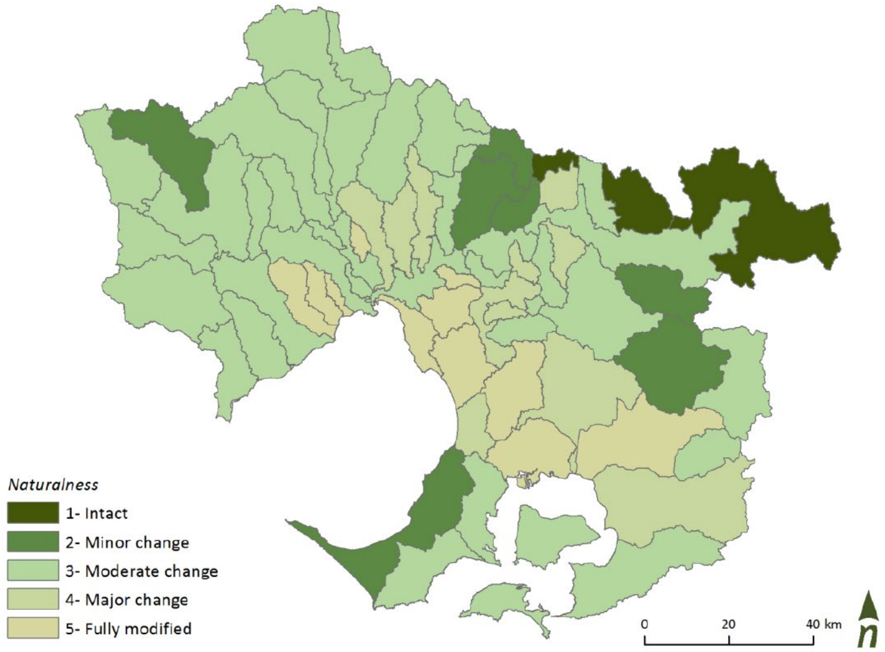

Figure 35. Naturalness scores at sub catchment scale

Naturalness scores were used as additional information to help prioritise where physical form investigations and works should focus attention in the immediate future.

High naturalness combined with high erosion potential – these subcatchments became top priority for actions in the next 10 years

High naturalness combined with low erosion potential - these sub catchments were low priority for action.

A review of the 'major actions' to address in order to mitigate erosion issues in each management unit were considered. These included (where relevant): maintenance of existing structural assets that have been critical to halting erosion, erosion management plans for known problem areas, and investigating erosion issues where needed.

Other performance objectives for key values in each management unit were reviewed, and it was identified where erosion would be a particular threat to achieving the other objectives. This typically included objectives reliant on vegetation condition and extent, and fish passage objectives.

The Performance Objectives for priority sub catchments were worded along the lines of: "Investigate and mitigate threats to physical form and other high values (including impacts of urbanisation)".

Some performance objective targeted specific areas for investigation and intervention

Eg Mornington Peninsula Western Creeks - Investigate and mitigate threats to physical form and other high values (particularly valley fill reaches).

Cardinia, Toomuc, Deep and Ararat Creeks - Investigate and mitigate threats to physical form (particularly at the change in slope at the top of the old swamp) and other high values.

Diamond Creek (Rural) - Investigate and mitigate threats to physical form and other high values (particularly along tributaries and from urbanisation).

The types of actions which would be related to this performance objective include: investigations and interventions such as bed and bank control structures.

3.7.4 Key assumptions and improvement opportunities

- A qualitative and somewhat subjective and course measure of erosion potential was used as a surrogate measure of physical form. This measure was selected under tight time lines with limited information apart from identifying already know high erosions sub-catchment. Since the strategy development more work has been done to further characterise and identify appropriate metrics that can be applied to a higher resolution dataset. (Veitz, 2019)
- Other measure of physical form such as the positive benefits of sediment deposition on habitat structure need to be explored further and potential experimental works to be included as trial in the mid-term review.
- No need for a long term LWD target because we assume it will increase in the long term as a result of increased riparian vegetation and trees naturally falling into the stream and not being removed. Improvement opportunity could be to include other forms of physical habitat and what they might be and where they might be most effective.
- Re-introduction of LWD is considered a costly action to do on a widespread basis and as such no PO was developed for this action. It should not however rule out opportunistic re-introductions in priority areas
- Investigation of geomorphic condition and erosion potential within sub catchments where there is only low-moderate confidence about current on-ground conditions is required to provided further information. In particular this includes intact systems including sources streams and other, including rarer, channel form types (e.g. chain of ponds). These systems typically support important ecological communities and maintaining their intact status may be critical to achieving Performance Objectives for key values.
- Applying a risk assessment approach in the implementation of the HWS for physical form would be beneficial. In particular, the ongoing review and maintenance of existing infrastructure that is halting erosion in many waterways is critical to achieving the Performance Objectives for many sub catchments.
- Develop a conceptual model for physical form which provides links to other key values and allows for a more comprehensive metric to be developed.

Further improvement opportunities will be developed through the HWS MERI framework and the associated Rivers Monitoring and Evaluation Plan (MEP).

3.7.5 Further Resources

ISC data https://www.water.vic.gov.au/water-reporting/third-index-of-stream-condition-report

Melbourne Water stream form visions – User note
http://inflo/inflo/cs.exe/properties/22240606

Melbourne Water Stream Form Visions http://inflo/inflo/cs.exe/properties/10294679

MW Geomorph Mgmt Units scores_v1b.xlsx
http://inflo/inflo/cs.exe/link/42316949

3.7.6 References

Veitz, G.(2019) Framework for Physical form asset management within the Melbourne Water catchment. Report by Streamology for Melbourne Water.

Alluvium (2018) Physical form condition assessment – Management Unit scale: Melbourne Water Healthy Waterways Strategy. A report prepared for Melbourne Water.
http://inflo/inflo/cs.exe/link/51291199

3.8 Access

Access to the waterway and riparian corridor enables people to derive value from a range of experiences. "Access" can capture many variables that allow people to experience the waterway including access: to/or along the waterway corridor; to/or along the waterway itself for swimming/ paddling; quality of access such as legible environments (e.g. wayfinding signage); visual access; connection to points of interest (Jacobs, 2018).

Access is an enabling condition of all three social values; amenity, recreation and community connection, as outlined in the conceptual models (see Section 2.5.2). Access has a strong relationship and confidence rating towards social values. For Community Connection and Recreation this relationship is considered positive, however when considering Amenity social values, it is acknowledged that access paths can provide both:

- Positive relationships: one can use a path to access and interact with a waterway, increasing the number of visitors can also increase the sense of safety
- Negative relationships: individual enjoyment of a waterway can be detracted as a result of crowding.

3.8.1 Available data and condition metrics

The access metric is defined as the proportion of streams having walking or cycling paths (as defined by the Principle Path Network, VicRoads) within 200m on at least one side of the waterway. This metric is limited in that it does not capture informal paths, access for on-water activities, cross-over points along streams and connectivity with other paths. However, these aspects of access, together with protection of environmental values, should be considered in the planning, and implementation of projects designed to improve access.

Score categories for access are described in the Table 49.

Table 49. Access scores representing proportion of stream corridors that have accessible waterways (paths)

Score	Range	Description
Very High	80-100%	A very high proportion of the stream corridor that has access paths.
High	60-80%	A high proportion of the stream corridor that has access paths.
Moderate	40-60%	A moderate proportion of the stream corridor that has access paths.
Low	20-40%	A low proportion of the stream corridor that has access paths.
Very Low	<20%	A very low proportion of the stream corridor that has access paths.

3.8.2 Setting scenarios for access

Current state

The current condition was calculated using the access metric by:

1. Using GIS tools to measure the length of stream having walking or cycling paths (as defined by the Principle Path Network, VicRoads) within 200m on at least one side of the waterway..
2. Calculating the percentage of the stream length that has access as a ratio of the total stream length.

   Scores for access range from less than 1% through to 79%. The higher scores occur in highly urbanised sub-catchments that have good existing path networks (for example, Koonung Creek - 79%, Gardiners Creek - 73%). The sub-catchments with very low scores for access are those in rural areas with no townships.

The targets don’t consider the feasibility and practicality of constructing a path at a certain location in the future (e.g. is the land too steep for a path).

Forecast current trajectory under business as usual scenario

The delivery of access infrastructure (i.e. pathways) is primarily undertaken by other agencies, such as local government. However, Melbourne Water may also facilitate, enable or contribute to construction, or construct and then gift assets to another owner, in accordance with meeting its Corporate Strategic KPI to measure the extent to which “the community enjoys nature and recreational facilities on our land and waterways”.

Business as usual assumes the continued delivery of access infrastructure mostly by external parties, which may not be coordinated strategically with the delivery of other waterways values.

Long term target setting

The target for each sub-catchment is based on the current score, an understanding of proposed levels of investment (for example through council plans and strategies), and regional opportunities (for example proposals for shared trails extending from urban areas to rural towns, plus a “stretch” factor).

Overall there is 8185 km of streams within the streams dataset, of which 808 km are accessible via walking or cycling paths. Long-term waterway condition target for access is to increase access to streams in urban areas to 80%. This target takes into consideration constraints associated with land availability, alignment with existing open space and path strategies, and a comparative assessment across the region. In less populated areas where demand is lower and it is less practical to build new paths, a lower target is proposed. Hence sub-catchments in rural or forested landscapes have much lower targets for access. Where sub-catchments have a mix of urban and rural areas, the target is proportionally less because of the reduced demand in the less populated rural areas.

3.8.3 Ten year performance objectives

The Performance Objectives for each catchment have been developed to respond to catchment needs identified by collaboration partners during the co-design process. The access related performance objectives will support improved value of all three social values, as improved appropriate access will allow the community to enjoy amenity, community connection and recreation at our waterways.

The target for each sub-catchment is based on the current score, an understanding of proposed levels of investment gained through the co-design process (for example investment proposed through council plans and strategies; PSP’s), and regional opportunities (for example proposals for shared trails extending from urban areas to rural towns, plus a “stretch” factor).

Performance Objectives for access focus on increasing access to and along waterways by improving connections with existing path networks; extending paths into new urban areas and where appropriate, improving access for on-water activities. The PO’s respond to the individual conditions within each management unit for example, focusing on improving crossings of major roads in Dandenong Creek, extending the Maribyrnong River Trail, investigating options for improved on water activities in the lower Werribee, or implementing strategic recreational facilities identified in collaborative strategic plans along the Yarra.

3.8.4 Key assumptions and improvement opportunities

The data available to measure the conditions influencing social values are not as well defined or mature as for environmental values. Testing and subsequent improvement of the social value conceptual models, refinement of condition metrics and collection of associated datasets is required to inform the development of performance objectives and strategy improvements. This will form one of the improvement elements to be actioned through the HWS MERI process.

The following is a list of assumptions to test and consider in future updates of the metric:

- Proximity to waterways influences their use and recreational, health and other benefits that people can gain.
- Accessibility is a multidimensional construct - not just a matter of distance from a waterway, but affected by variables such as socio-economic status, educational background and population density.
- Users of space are aware of connectivity and that extensive connected open space encourages greater usage.
- Access does constitute other forms i.e. paddling etc. and this will be considered in future improvements to the metric.
- In the future, the onground activities that can be undertaken to improve access should also not necessarily be restricted to improving path connections i.e. building more paths it could include removing barriers or installing canoe ramps.

3.8.5 Further Resources

Principle Bicycle Network shared-pathway data is owned by VicRoads and can be access from the Data Vic open data platform.

Principle Bicycle Network data is routinely downloaded and stored at:
Q:\GISData_GDA94\Landuse\

3.8.6 References

Jacobs, (2018). Conceptual Models for the Social Values of Waterways, report for Melbourne Water.

3.9 Water Quality - Recreational

Activities in and on the water, such as swimming, wading and paddling, provide an important recreational value as well as connection to the waterway. Appropriate water quality is critical to minimise human health risks associated with such activities. Exposure to pathogens via primary and/or secondary contact can lead to sickness and the risk of illness depends on the level of exposure.

Untreated sewage releases during wet weather, leaks in the sewage system and cross connections between the sewerage system and stormwater drains can impact both ecological and social values, particularly in urban areas. In-stream recreational water quality can be impacted by microbes that can increase the risk of illness. These microbes can arise from a variety of sources including cross connections between sewers and stormwater, leaking sewers, poorly operating or old-design septic tanks, food waste discharges and animal faeces.

Even though litter has little direct impact on environmental water quality it is widely perceived within the community as a water quality issue and is included in social conceptual models. For the purpose of the strategy development litter has been included as part of the water quality environmental condition rather than treated separately.

The State Environment Protection Policy (Waters of Victoria, 2003) and the National Health and Medical Research Councils Guidelines for Managing risks in recreational waters (2008) provide guidelines to characterise water that is suitable for primary contact and secondary contact recreation.

3.9.1 Available data and condition metrics

Melbourne Water collects *E. coli* data for waterways in two different programs. Firstly as part of the long term ambient water quality monitoring program which samples either monthly or every two months at 132 locations across the region. This data set does not comply with the frequency of data collection required by SEPP (WoV) to assess recreational water quality but it is useful for determining chronic issues that may be ongoing at a site. Secondly, at a range of key recreation locations across the region, data is collected weekly during the summer period in order to better understand recreational risks. This data is collected for the 12 weeks of summer starting in December and ending in March to target high recreation use and to optimise the more intense sampling program required to assess compliance with SEPP guidelines.

The State Environment Protection Policy principle policy (Waters of Victoria) and Schedule F7, (Water of the Yarra catchment) were the relevant guidelines at the time the strategy was being developed (**Table 44**). The new draft SEPP (Waters) guidelines were out for comment but had not officially been accepted as new policy so were not used. The intention is that the new SEPP (Waters) guideline values will be adopted and reported against during the life of the Strategy.

Different statistics are prescribed in the two policy documents. SEPP (WoV) uses a median calculated on 5 samples taken over 30 days and Schedule F7 uses a geometric mean.

Table 43. *E. coli* guidelines used for determining recreational water quality current condition

Policy	Primary contact	Secondary contact	statistic
WoV	≤150 org/100ml	≤1000 org/100ml	Median of 5 samples at regular intervals in 30 days
Schedule F7	<200 org/100ml	<1000 org/100ml	Geometric mean

Both data sets were used to set current recreational water quality condition but the datasets were kept separate. Only the last 5 years of data was used as older data was not considered to be likely to represent "current" condition. For data collected as part of the ambient program or as part of the summer program, the rolling median or geomean of 5 consecutive samples was calculated across the 5 years of data against both primary contact and secondary contact criteria.

3.9.2 Setting scenarios for recreational water quality

Current state

Current condition state was graded Very High if primary contact was protected 90% or more of the time and High if secondary contact was protected 80% or more of the time. If neither primary or secondary contact were protected to the above criteria then condition was graded as Low. A grading of Very Low was given when compliance to secondary contact criteria was never or rarely met. This grading indicates there was a significant problem in a sub-catchment. In cases where the grading was uncertain, then the raw data was examined. If there were repeated high *E. coli* levels then a conservative approach was taken and a lower grade assigned.

The gradings described were developed pragmatically based on likelihood of consumption of a critical dose whilst boating vs swimming and the need to flag sites with ongoing chronic issues. Greater clarity is provided in the newly revised SEPP (Waters) on methodologies for grading of recreational water bodies and these will be brought into future reporting and tracking of recreational water quality over time through the MERI process.

Gradings for each site were brought together from the two programs. For sites in both programs, theoretically the lower of the two gradings would be given precedence. However it was found that there were no cases where there was a discrepancy between the grading established using the monthly data and the grading assigned using the weekly data.

To determine condition for a sub-catchment with multiple sites, an average grading was made based on the gradings calculated at each site. For sites where there was an equal number of sites with the same category eg 2 sites with Low and 2 with High then a conservative approach was taken and the overall condition for the sub-catchment matched to the lower of the two. No current condition was set for sub-catchments where no data existed or data was limited eg. Emu Creek sub-catchment.

Forecast current trajectory under business as usual scenario

The following assumptions were made in establishing a Business as Usual future for recreational water quality condition;

- Climate change and population growth means warmer condition and more people wanting to recreate in water.
- Urban densification and growth with no change in stormwater policy
- Some decline in rural land, particularly for tributaries
- Some degradation in sewage infrastructure over time and more impact on waterway pathogen risk.
- Main stems of major waterways are more likely to remain stable compared with urban and rural tributaries.
- These assumptions translated into:
    - urban sub-catchments becoming low or remaining low. There were a few exceptions to this were the current data was reliably meeting secondary contact and BAU was retained at current
    - Sub-catchments that will urbanise will decline by one category. High goes to Low. Very high drops to High.
    - Sub-catchments with main stems of a major waterways - current condition is maintained as BAU.

Long term target setting

Originally the target setting aimed at retaining current condition with a few improve targets for sub-catchments where it was expected recreation to remain high or become high in the future. However, based on codesign feedback and the overarching aim of the SEPP the targets were refined in the final strategy to support the aspiration of all sub-catchments achieving at least secondary contact standards (High) over the 50 year time frame and for areas currently achieving primary contact (Very high) to be maintained.

3.9.3 Ten year performance objective

Water quality links to all of the Social Values; Recreation. Amenity and Community Connection (see Social Conceptual Models, Jacobs 2018) and is made up of multiple variables such as odour, litter, pathogens and toxicant and heavy metals. The data we have used to set targets will be predictive of pathogen risk. Toxicants and heavy metals are covered by environmental water quality performance objectives (See section 3.5) and litter is assessed in Section 3.10. No data is available to assess waterway odour. Pathogen risk, which this data is most indicative of, is a key condition for Recreation and Community Connection.

Performance objectives for the 10 year life of the strategy are set at maintaining the existing known high recreation locations in current condition as a minimum and improving where possible. As such performance objectives were only set in subcatchments with existing high recreation locations eg National Water Sports Centre, Yarra River main stem, Kananook Creek etc.

3.9.4 Key assumptions and improvement opportunities

Improvements will be made to the methodology for assessing condition at sub-catchment scale utilising the new SEPP (Waters) guidelines for recreational water quality. Where additional information (such as from Quantitative Microbial Risk Assessment) is available, site specific guideline values will be developed and adopted as the criteria for reporting.

Improvement opportunities will be developed through the HWS MERI framework and the associated Rivers Monitoring and Evaluation Plan (MEP).

3.9.5 References

Jacobs, (2018). Conceptual Models for the Social Values of Waterways.

Victorian Government (1999), State Environment Protection Policy Schedule F7 (Waters of the Yarra catchment). S 89

Victorian Government (2003), State Environment Protection Policy (Waters of Victoria). S 107

Victorian Government (2018), State Environment Protection Policy Schedule (Waters) S 493 (in draft at the time) http://www.gazette.vic.gov.au/gazette/Gazettes2018/GG2018S499.pdf

3.10 Litter

Litter (and rubbish dumping) is consistently rated by the community as one of the biggest threats to waterways. The presence of litter impacts the community's ability to enjoy waterways for all three social values. People see litter as a strong indicator of stream health – they perceive clean waterways are healthy waterways and aesthetically pleasing. The presence of litter creates a perception that a place is not cared for by people.

Litter is a enabling condition of all three social values; amenity, recreation and community connection, as outlined in the conceptual models (see section 2.5.2). Litter has strong (active recreation, amenity-naturalness) to medium (connection to people and place, passive recreation and amenity-safety/health/wellbeing) relationships and confidence rating towards social values. All Litter relationships are negative.

3.10.1 Available data and condition metrics

There is no readily accessible dataset that indicates the amount of litter in waterways across the Greater Melbourne region. Landuse provides a reasonable proxy for likelihood of litter being present but does not account for local differences associated with existing litter reduction programs and community attitudes.

The Clean Communities Assessment Tool (CCAT) methodology was designed in 2003 by Community Change P/L. The CCAT provides a systematic assessment of littering behaviour, litter and key features of public places. In 2003, 2005, 2007, 2009, 2010, 2011 and 2013, Sustainability Victoria used the CCAT to establish statewide benchmarks and assess the state's progress against targets. Metropolitan municipalities included in the assessments were Casey, Dandenong, Geelong, Hume, Manningham, Melbourne, Port Phillip and Yarra.

CCAT includes a site category for waterfronts. These sites are representative of reserves next to a body of water, e.g., river, lake or pond, often with seats or grassy areas used by the community for recreation and picnicking, e.g. Albert Park lake or Yarra river bank Melbourne. Generally, no significant retail activity takes place in these areas. There is also a site category for waterfront precincts, which includes areas where there is significant retail activity, e.g. Southbank and Docklands area in Melbourne.

Summary scores for surveys undertaken in 2013 across eight municipalities were consistent, ranging between 67 and 85 on a 100-point scale. On a 5-point scale this equates to scores of either high or very high (Table 50).

Table 50. Metrics based on The Clean Communities Assessment Tool (CCAT) methodology

Score	Description
Very High	Very high proportion of waterways have an absence of litter and very unusual for people to do the wrong thing with used items
High	High proportion of waterways have an absence of litter and majority of people do the right thing with used items
Moderate	Moderate proportion of waterways are impacted by litter, but normally people do the right thing with used items
Low	Some of the waterways are impacted by litter, and low expectation for people to do the right thing with used items
Very Low	Most waterways are highly littered, and no expectation for people to do the right thing with used items

3.10.2 Setting scenarios for litter

Current state

Generalisations taken from the CCAT results were that scores for litter were worse in areas where there was a higher concentration of urban drains and more people to litter. However, despite anecdotal evidence that specific locations on some waterways are very badly littered, the overall scores for litter at a sub-catchment scale have been assessed as moderate to very high. Moderate scores are in highly urbanised sub-catchments, and improve to very high in those sub-catchments that have not been developed.

Forecast current trajectory under business as usual scenario

It is assumed that the current trajectory for litter scores will be for some degradation to occur as urban populations increase and there is no significant change in littering behaviours and design of urban drainage systems. Where scores are currently assessed as high and there is likely to be significant urban growth, the current trajectory is for them to degrade to moderate.

Long term target setting

For setting of the 50-year target, it has been assumed where scores are currently assessed as high that there is potential to either maintain or improve the score to high or very high through increased investment in litter prevention initiatives.

3.10.3 Ten year performance objective

The litter performance objectives are regional actions that states:

- RPO-26 Methods are in place to assess volume and source of litter to inform and promote litter reduction programs.
- RPO-27 Incidence of littering and illegal dumping is reduced through raised community awareness and knowledge, infrastructure and enforcement.

3.10.4 Key assumptions and improvement opportunities

The following key assumptions applied to developing Litter condition and targets to the Strategy:

- The assessment of the current status for litter and the setting of targets for litter in the Strategy has been limited by a lack of survey data specific to waterways across the region. The current status and targets should be considered as interim until further data has been compiled.
- As part of the Strategy implementation there will be a need to improve the measurement and assessment of litter in waterways across the region, and to develop a better understanding of the factors that increase litter in waterways.
    - The National Litter Index uses site survey data to provide a national comparative assessment of litter types in specific locations (e.g. parks, beaches, commercial areas etc), and is a broad indicator of changes over time for littering relative to other states. But the data lacks the spatial resolution to indicate variation across Melbourne or how bad the problem is for waterways.
    - Sustainability Victoria collates information from Councils on their annual spending and achievements for managing litter. This includes information on gross pollutant traps (GPTs), street sweeping, illegal dumping, public bins and clean-ups. However, this data is limited for informing waterways management.
    - The Victorian Waste Education Strategy (2016) has no targets for litter, but does provide strategic direction for reducing litter and illegal dumping. The strategy recognises that litter prevention requires an integrated program of education, infrastructure and enforcement.

- The Clean Communities Assessment Tool (CCAT) methodology provides a systematic assessment of littering behaviour, litter and key features of public places. From 2003 to 2013, Sustainability Victoria used CCAT to establish statewide benchmarks and assess the state's progress against litter reduction targets. However, the program finished in 2014, and an alternative method for assessment has not been developed.

There is enthusiasm to incorporate citizen science for litter surveys. Port Phillip Bay EcoCentre has developed methods for street surveys (and beaches), and the Yarra River Keeper undertakes trawl surveys to assess volumes and types of litter in the Yarra and Maribyrnong .

There is potential to develop these further to get a region-wide assessment, and ideally tailor a method for informing waterways management.

Through the Aquatic Pollution Prevention Partnership (A3P) project "Operational guidelines for litter monitoring and assessment" and further investigation into the regional performance objectives, it is likely that future metrics can be developed that can better address the issue of litter in waterways.

Improvement opportunities will be developed through the HWS MERI framework and the associated Rivers Monitoring and Evaluation Plan (MEP).

3.10.5 References

Community Change 2003. The Clean Communities Assessment Tool, https://www.communitychange.com.au/insights-and-tools/changing-littering-behaviour/clean-communities-assessment-tool-ccat.html

Sustainability Victoria, 2016. Victorian Waste Education Strategy, Melbourne Australia.

3.11 Participation

The Participation condition refers to community participation in stewardship activities – that is, activities that are related to caring for a waterway. These activities may include volunteer tree planting, weed control, or other management activities, or citizen science activities such as frog census.

The conceptual model primarily recognises Participation as an enabling condition of the social value Community Connection (see section 2.5.2). The model identifies a group of attributes related to participation, collectively termed Organised Connection;

- Sporting
- recreational
- social
- Cultural

- artistic events
- citizen science groups,
- Stewardship
- NRM groups and
- caring for country.

Organised connection has both strong and medium relationships and confidence rating towards social values. All relationships are considered positive.

Of these attributes, those related to stewardship, NRM Groups and citizen science, collectively termed stewardship activities, have been used in development of the participation metric.

Conceptual models, including the HWS conceptual models and those developed through the My Victorian Waterway survey, highlight that connection to waterways can be created and/or enhanced by participating in stewardship activities. Stewardship activities also improve connection to each other, by providing an opportunity to meet people and enhance social networks.

Participation is therefore an important condition to support Community Connection, as highlighted in the conceptual model. However it also supports many other values by improving waterway condition and contributing to the knowledge base.

3.11.1 Available data and metrics

This metric is limited by the assumptions made about the number of participants involved in groups and repeat participants vs new ones. It is also limited in that it includes only participation in Melbourne Water's programs (Stream Frontage Management Program (SFMP), Rivers and Land Program, and Community Grants. Citizen science programs include participation in the Frog Census, Platypus environmental DNA sampling, Waterwatch, and Birdlife surveys), and not in other stewardship activities supported by local government or other organisations.

3.11.2 Setting scenarios for participation

Current state

Current condition was is based on the percentage of population involved in grants and citizen science (related to waterways) over previous 3 years as a proportion of population within sub-catchment (Table 51).

Table 51. Percentage of population involved in grants and citizen science (related to waterways) over previous 3 years as a proportion of population within sub-catchment.

Score	Description	Range
Very High	Very High percentage of population participating in grants and citizen science programs	> 2%
High	High percentage of population participating in grants and citizen science programs	1-2%
Moderate	Moderate percentage of population participating in grants and citizen science programs	0.5-1%
Low	Low percentage of population participating in grants and citizen science programs	0.1-0.5%
Very Low	Very Low percentage of population participating in grants and citizen science programs	<0.1%

Forecast current trajectory under business as usual scenario

The business as usual trajectory assumes that population will double in 50 years and participant rates will remain constant – thus halving of participation rate.

Long term target setting

The long term target is to increase participation rates to very high (2% of population) in all sub-catchments.

3.11.3 Ten year performance objectives

Performance objectives aim to increase participation rates through support for community groups, including connecting and supporting new groups in with growth areas, and building capacity of land owners in upper catchments through rural programs. The regional performance objectives related to participation include:

- RPO-37 Participation rates in education, capacity building, incentive programs and citizen science activities have increased and enable greater levels of environmental stewardship for our waterways.
- RPO-38 Key messages, stories and resources for waterways and waterway health are collaboratively developed and broadly distributed, increasing community knowledge and engagement around waterways.

- RPO-39 Systems and pathways to share knowledge and information between communities and stakeholders have been developed and expanded to empower communities to participate and influence waterway management (for example, digital portals, social media, Communities of Practice, signage programs).
- RPO-40 The profile of waterways is lifted, local connections to waterways are increased, and leaders in waterway management are celebrated and fostered.

The sub-catchment performance objectives refer to a target of increasing participation rates supporting community groups, connecting with growth area communities and building capacity of land owners in upper catchment through rural programs. This includes increasing support for community/environment groups as population increases.

3.11.4 Key assumptions and improvement opportunities

The following key assumptions were made at the time of developing the Strategy:

- population will double between now and 2070

Some of the improvement opportunities to be progressed over time for the Strategy:

- the data available to measure the conditions influencing social values are not as well defined or mature as for environmental values. Testing and subsequent improvement of the social value conceptual models, refinement of condition metrics and collection of associated datasets is required to inform the development of performance objectives and strategy improvements. This will form one of the improvement elements to be actioned through the HWS MERI process.
- the participation metric could be further developed over time to include a broader range of programs (ie local government programs that are waterway related) or be measured through perceptions survey questions about participation in volunteering.

3.11.5 Further Resources

- Participation-Stats.xlsm: http://inflo/inflo/cs.exe/link/42336547
- Social&Env Values&Cond current v5.xlsx: http://inflo/inflo/cs.exe/link/42427878

3.11.6 References

N/a


Estuaries

4 Estuarine values

4.1 Introduction

Estuaries are zones where a river meets the sea, including the lower section of a river that experiences tidal flows where fresh water and saline (salty) water mix together. For the *HWS 2018*, estuaries are more pragmatically defined to be coastal river outlets where the marine influence (most typically a salt wedge) of a river can be detected for at least 1 km upstream or have a lagoon greater than 300 m in length.

Previously, Melbourne Water has planned for and managed 29 estuaries through the Healthy Estuary Strategy (Melbourne Water 2011). In accordance with state government policy, planning for all waterways including estuaries, will now be performed through the regional waterway strategies. Accordingly, estuaries have been incorporated into the *HWS 2018* and supporting MERI.

There are 133 waterways in the region that flow into the sea, 36 that flow into Port Phillip Bay and 97 into Westernport. Of these, 29 waterways can be considered to have an estuarine component: 17 in Port Phillip and 12 in Westernport (Table 52). There are also 13 waterways in the region that may include an estuarine component but require further investigation to conclusively determine this – a knowledge gap to be filled in the future. There are also waterways in the region that have been piped for some or all of their length. Those that have been piped where an estuary would have previously occurred are not included in the Strategy.

Table 52. Estuaries in the Melbourne Water region included in the Strategy

Port Phillip	Western Port
Little River	Tooradin Rd Drain
Werribee River	Merricks Creek
Skeleton Creek	Warringine Creek
Laverton Creek	Kings Creek
Kororoit Creek	Olivers Creek
Stony Creek	Watson Creek
Yarra River	Cardinia Drain
Maribyrnong River	Deep Creek
Mordialloc Creek	Bunyip River
Patterson River	Yallock Creek
Kananook Creek	Lang Lang River
Balcombe Creek	Bass River
Chinamans Creek	
Moonee Ponds creek	
Stony Creek	
Sheepwash Creek	
Elwood Canal	

Of the nine key values identified as representative measures of waterway values for the HWS, six of these were reported on in the HWS for estuaries (three environmental:, birds fish and vegetation and three social: amenity, community connection and recreation).

Although, Platypus and frogs use estuaries opportunistically, advice provided at the estuary expert workshop (February 2018) informed the decision to exclude these as key values of estuaries. While there are occasional sightings of platypus in the region's major estuaries (such as the Yarra and Werribee Rivers)[3], according to the Australian Platypus Conservancy, estuarine habitat is not ideal for Platypus due to difficulties in locating sufficient food in these environments. Specific investigations into the value of the region's estuaries for frogs have not occurred.

Estuarine experts supported the inclusion of Macroinvertebrates as a key value of estuaries, however a lack of available data and a suitable metric made it impractical to incorporate macroinvertebrates as a key value in this iteration of the Strategy. A metric to measure the macroinvertebrate value of estuaries (and wetlands) may be developed during the implementation period of the Strategy subject to appropriate scientific basis for their inclusion.

A summary of the key environmental values in estuaries and their corresponding environmental conditions in provided in Figure 36.

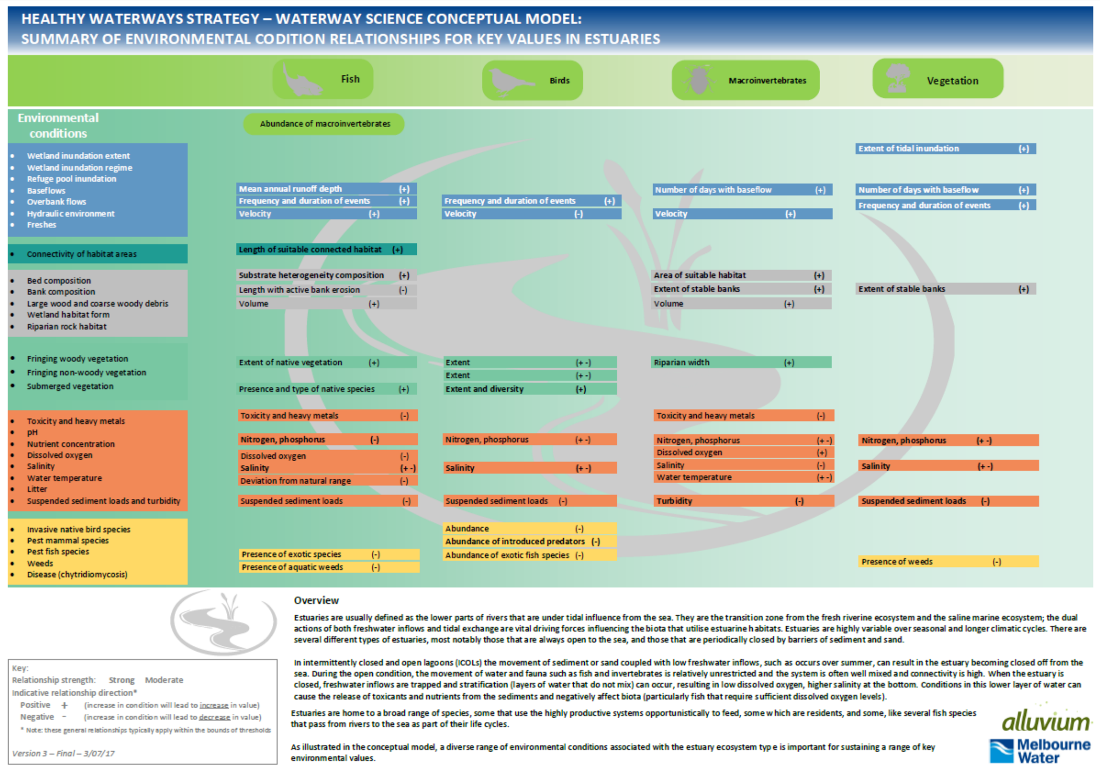

Figure 36. Summary of environmental values and the condition relationships for estuaries (Alluvium 2017)

[3] Citizen science data recorded on PlatypusSPOT: http://platypusspot.org/

The approach used to determine the current state of estuarine key values was based on the AVIRA method (refer to Section 1.5). A brief summary of the main steps involved in the process is outlined below.

Collating data on values and threats:

- Undertaking a data inventory to map existing Melbourne Water and state data sources against the AVIRA metrics and measures. Due to the time constraints of this project, the population of the data inventory focused largely on available spatial datasets that could be used consistently to assign value measures and metrics across the Melbourne Water region.
- Undertaking a workshop with an Estuary Working Group (13th February 2018) to populate some of the metrics and measures for the selected estuaries based on local and expert knowledge and to identify data gaps.
- Undertaking gap-filling activities including field assessments of selected estuaries to capture information relating to values and threats at the sites.

Developing value and threat scores:

- Developing AVIRA value and threat scores for each measure for each estuary (based on the existing and newly captured data). This included assessing threats to estuary values using the AVIRA risk assessment framework (an estuary-specific version was developed).
- AVIRA value, threat and risk data were collated for 29 estuaries across the region for the HWS. It is acknowledged that there are data gaps, however, an important part of any planning process is acknowledging those gaps and providing actions to fill these in the future. AVIRA includes protocols for missing data.

Identifying estuary trajectories under various scenarios

- Hosting a workshop with experts in aquatic ecology, environmental flows, wetland and estuary ecology and management to assess which threats are most likely to impact estuary and wetland key values and conditions and how this is likely to vary across the region and with estuary typology. In particular, which threats would be particularly exacerbated by climate change and urbanisation.
- Using outputs from this workshop and expert opinion to combine AVIRA metrics to develop rules-based metrics to determine current state and current trajectory for each estuary asset. Metrics were refined to ensure that they were appropriate to the region and asset types and based on the available data
- The specific process and data used to determine current state and current and target trajectory for each key value and condition is outlined in subsequent sections of this report. Threats scores that had been rated as increasing under climate change and urbanisation were moderated up to a high.

- Reviewing preliminary scores against local knowledge of the assets. These reviews could alter the rating in either direction if additional knowledge showed the site to have a different current state or trajectory than indicated by the AVIRA score. Comments were received from subject matter or local experts and used to refine the value status and trajectory ratings.

Developing performance objectives

- The AVIRA risk assessment informed the development of performance objectives for estuaries. The risk assessment recommends a treatment (reduce risk, protect, fill data gap, no action) based on the relationship (association) between the values and threats. Where a risk was rated high or very high and the recommended treatment was 'reduce threat level, performance objectives were developed to address these threats.
- In addition to the 'current' level of risk identified by AVIRA, the trajectories information was used to consider 'future' level of risk under the 'current trajectory' scenario. Where the risks were likely to become high or very high a performance objective was identified to address the threat.
- Actions arising from co-design workshops were also considered and where they related to protecting existing high value vegetation were included in the formulation of the targets.
- Feasibility was also assessed through testing with stakeholders, use of aerial photographs and reviewing existing plans and strategies. Performance objectives for the Ramsar wetlands were drawn from the Ramsar management plans, and where an additional threat was identified, particularly the likely threats under the 'current trajectory' scenario, performance objectives were added where likely to be feasible.

Details of how AVIRA was applied for each key value is described in the sections below.

The science that underpins the estuarine values in the Strategy is not as well developed compared to the river values. As such, a number of knowledge gaps exist that required assumptions to be made in order to estimate condition and future targets for estuarine values in the Strategy. Melbourne Water will be undertaking a number of studies during the implementation of the Strategy to test these assumptions and fill knowledge gaps.

4.2 Key threats for estuarine values

Key drivers of estuarine ecology are the mixing of salt and freshwaters and the intermittent flooding of adjacent, connected wetlands. Predicted changes due to climate change and urbanisation will affect this balance by changing runoff patterns, reducing freshwater stream flows and sea level rise inundating additional areas. While estuarine systems are somewhat resilient due to their inherent ability to adapt to the constant flux of conditions, more permanent changes to the ecology may occur if the conditions move to outside the previously experienced range of conditions.

4.2.1 Climate Change

The Victorian Government's coastal policy recommends to 'plan for sea level rise of not less than 0.8 metres by 2100 (see Figure 37), and allow for the combined effects of tides, storm surges, coastal processes and local conditions, such as topography and geology when assessing risks and impacts associated with climate change.

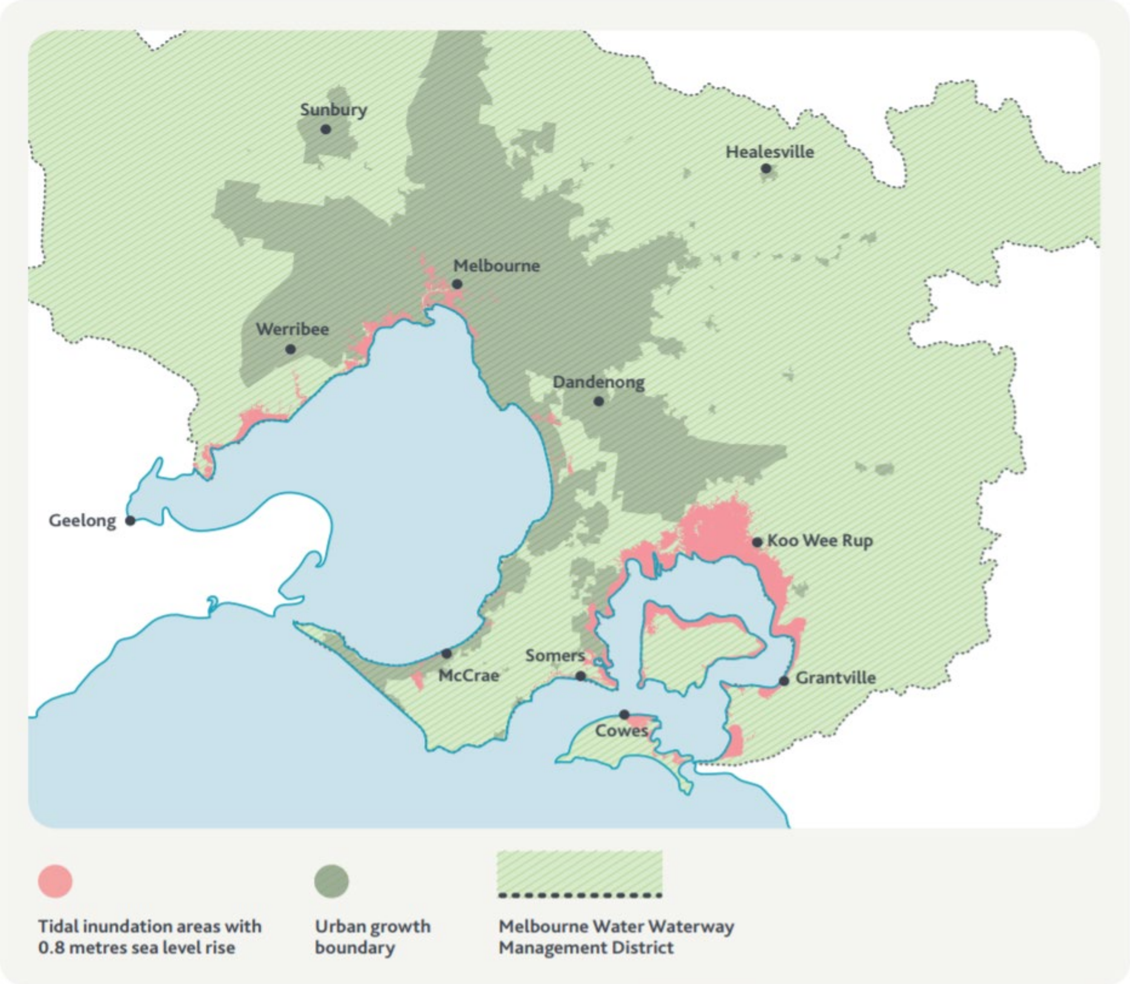

Figure 37. Predicted tidal inundation areas in the Port Phillip and Westernport region by year 2100 [4]

The coastline is subject to coastal inundation, coastal erosion/recession, sea level rise and flooding which will be exacerbated because of a number of factors, including changes in:

- mean sea level
- storm climates (storm surges, storm tides and atmospheric changes)
- tidal ranges
- wave climates
- rainfall.

The NRM planning for climate change project (Spatial Vision, 2014) identified factors contributing to asset vulnerability to climate change. Climate stressors most likely to impact

[4] Planning for Sea Level Rise Guidelines – Port Phillip and Westernport Region (Melbourne Water, 2017)

estuaries included March to November rainfall and Sea level rise and storm surge. Sensitivity to climate change for estuaries was linked to whether the estuary was:

- Intermittently open or permanently closed
- Bay or open coastline
- Within a regulated or unregulated catchment.

Adaptation capacity of the estuary was linked to the percentage of native vegetation in the catchment, quality of native vegetation within the catchment and the population density within the catchment. Coastal areas sensitive to climate change under the Representative Concentration Pathway 4.5 scenario are shown in Figure 38

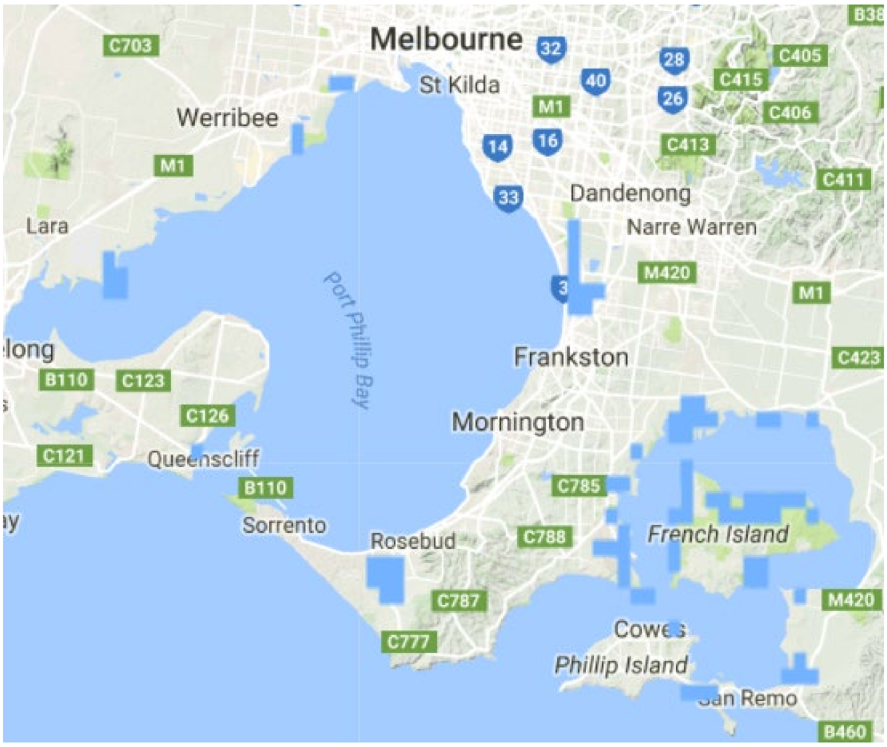

Figure 38. Coastal areas sensitive to climate change under the Representative Concentration Pathway 4.5 scenario (Spatial Vision 2014)

The estuary expert workshop identified the estuarine conditions most impacted by climate change and urbanisation. These included altered flow regimes due to increased flashiness and altered seasonality (associated with urbanisation and climate change) and increased directly connected imperviousness across the catchment (urbanisation); altered marine exchange associated with sea level rise (climate change); and degraded estuarine vegetation due to increased saline inundation (climate change).

4.2.2 Urbanisation

Greenfield development in the Port Phillip and Westernport region and intensification of existing urban areas (infill development) will be significant over the next 50 years. This will result in an increase in impervious surfaces, increasing runoff and pollution through the stormwater system. It may also result in more stormwater drains discharging into our estuaries.

Many estuaries in the region are already highly impacted by the impacts of urbanisation, inappropriate estuary mouth opening, runoff of catchment nutrients, weeds and pests and salinization (Melbourne Water, 2011). Estuaries where extensive development has already occurred in the catchment (such as those in the Maribyrnong, Werribee, Dandenong and Yarra catchments) are most severely impacted. However, those estuaries that are within the urban growth boundary but yet to be fully developed (such as those of Westernport) will be facing increased threats from these issues in coming decades as Melbourne's population continues to grow rapidly.

Many of the environmental issues for estuaries and their catchments are primarily the result of cumulative impacts from a variety of land and waterway uses and activities. These contribute to changed estuary processes including reduced water quality and quantity.

Threats from further urban development include:

- encroachments on open space
- flooding and altered flows
- clearing of vegetation
- effluent and stormwater discharge
- demand for access and
- pest plants and animals.

For waterways within canal developments there can be major adverse impacts including loss of habitat, pollution from urban runoff and boating activities and disturbance of coastal acid sulphate soils.

4.3 Birds

4.3.1 Defining Values

Estuaries provide important bird habitat for nesting, foraging and roosting. Over 70 species of birds recorded in the region's estuaries have a conservation status listing. Thirty-four of these species are particularly associated with estuaries.

Higher numbers of listed species were associated with all estuaries entering the western and northern parts of Port Phillip Bay and two estuaries on the eastern shore (Kananook and Balcombe Creeks). Higher numbers were also reported from four Westernport Bay estuaries: Merricks Creek, Tooradin Road Drain, Yallock River and Bass River. Further monitoring is required to determine whether any estuary provides critical habitat for particular species. Sixteen of the region's estuaries are listed as Important Bird Areas, and several are included within the boundaries of the region's Ramsar sites, particularly in the Westernport Ramsar wetland. Some estuaries have an important function as drought refuges and can support large numbers of bird species, particularly when areas of open water inland are scarce.

4.3.2 Current state

The assessment of the bird value was based on the AVIRA method (see

Box 4 in Section 1.5) and the metric is described below. It should be noted that this approach has several shortcomings as described in Box 10 and plans are underway to re-evaluate the bird value status for estuaries.

The assessment of the current state of the estuarine bird key value incorporated elements of the AVIRA formally recognised significance, rare or threatened species and landscape features value categories as outlined in Table 53.

A summary of the current condition for the estuary bird value at a catchment scale is provided in the Strategy in Part D – Catchment Summaries. Further information is provided at the sub-catchment level for each estuary in the five co-design catchment programs.

Table 53. Data used to determine the current state of the estuarine bird key value.

AVIRA value category	AVIRA metric	Measure(s) used to determine current state	Data source / notes	HWS Scoring
Formally recognised significance	Ramsar sites	International significance - listed as a key feature of a Ramsar site	Ramsar Wetland Areas in Victoria dataset (www.data.vic.gov.au)	Very High – If 5 metrics meet criteria High – If 4 metrics meet criteria Moderate – If 2 or 3 metrics meet criteria
	East Asian-Australasian Flyway Sites	International Significance – listed as a key feature of an East Asian-Australasian Flyway Site	East Asian-Australasian Flyway Sites in Victoria (www.data.vic.gov.au)	

AVIRA value category	AVIRA metric	Measure(s) used to determine current state	Data source / notes	HWS Scoring
	Nationally Important Wetlands	Listed in the Directory of Important Wetlands in Australia (DIWA)	Victorian Wetlands listed in – A Directory of Important Wetlands in Australia - DIWA (www.data.vic.gov.au)	Low - If 1 metrics meet criteria Very low - If no metrics meet criteria and/or vegetation condition is very poor Criteria: Ramsar Site = Yes/Listed East Asian-Australasian Flyway Site = Yes/Listed Nationally Important Wetlands (DIWA) = Yes/Listed Supports Significant fauna birds =5 Important Bird Area =5
Rare or threatened species	Significant birds	• Listed on the International Union for Conservation of Nature Red List • Listed under the Environment Protection and Biodiversity Conservation (EPBC) Act 1999 • Listed on the Advisory List of Rare or Threatened Vertebrate Fauna in Victoria (VROT)	• Victorian Biodiversity Atlas (VBA) records post-1980 – records within 100m of a waterway. • Classified as water dependent significant fauna as listed in AVIRA manual (DELWP 2015). • Melbourne Water threatened bird datasets • MW SoBS database	
Landscape features	Important bird habitats	Listed as an Important Bird Area (IBA) in AVIRA.	Meets at least one of four global criteria used by BirdLife International for IBAs, as listed in AVIRA manual (DELWP 2015).	
		Listed as an Important habitat for migratory shorebirds in AVIRA	As classified by Birds Australia and listed in AVIRA manual (DELWP 2015).	

Basing the assessment of current state mainly on formally recognised significance lacked sensitivity however, given that some sites with high scores on these metrics (which may have been awarded/assessed decades previously) are currently in poor condition, with a reduced capacity to support the bird values. To account for this issue, the provisional score was moderated based on current estuarine vegetation condition, with the degraded estuarine vegetation threat score inverted. I.e. if the threat score was 1, then the corresponding condition score was 5.

Scores were moderated in the following way:

- If vegetation condition was 5, then the provisional bird key value current state status was moved up one rank (e.g. from a high to a very high).
- If vegetation condition was 4, then no change was made to the provisional status.
- If vegetation condition was 3, then the provisional status was moved down one rank (e.g. from a low to a very low)
- If vegetation condition was 1, then the provisional bird status was moved down two ranks (e.g. from a very high to a moderate).

The underlying rationale for incorporating vegetation condition into the bird key value condition is the reliance of birds on the estuarine vegetation for habitat (nesting, feeding and cover), with poor quality vegetation providing low habitat value and therefore affecting the success of key lifecycle stages of the birds.

Box 10– Estuary bird value limitations

The AVIRA approach used to assess the bird value had a number of limitations due to the criteria and data used:

- only 2 of the 5 criteria can be modified

- *rare and threatened species' presence* did not use the Birdlife Australia database (an omission due to time constraints) so may have missed important bird values

- estuarine vegetation condition which was assessed through a rapid site assessment was used to moderate the bird value

- The ARI report on estuarine birds for the Index Estuary Condition was not used by omission at the time of the development of the HWS 2018 (Hanson and Menkhorst 2014).

These limitations are acknowledged and will be an area for improvement in the future.

4.3.3 Setting scenarios

Forecast current trajectory under business as usual scenarios

A long-term Business as Usual trajectory (current trajectory) was based on rules and assumptions around the likely impacts of significant future threats, particularly climate change and urbanisation. Accordingly, predictions on the current trajectory for bird key value status ratings were moderated (from current rating) as outlined in Table 54.

Table 54. BAU trajectory assumptions for estuary bird value

Value	Current trajectory assumptions
Birds	The current trajectory of bird values in estuaries was assessed by incorporating the predicted estuarine vegetation condition over the next 50 years. As estuarine vegetation condition is projected to be low or very low for all estuaries in the Melbourne Water region under current trajectory, all current bird scores were preliminarily moderated down 2 ranks (unless already at 'very low'; see Section 4.4.3 for further discussion).

Long term target setting

To set long term targets a different set of assumptions were made about the potential for change into the future. It was assumed over the long term that;

- Estuarine bird values would be maintained in current condition for those estuaries in a rural landscape(i.e. Westernport and Werribee catchments) due to the assumption that these could migrate further in the landscape as sea levels rise and retain important bird habitat. This assumes that farmland can be forgone for this purpose and/or a barrier can be removed.
- Bird values would decline (i.e. be the same a BAU trajectory) for those estuaries in current or future urban or industrial areas reflecting the inability of estuaries to migrate into a constricted landscape as sea levels rise.

Each estuary was assessed via desktop using aerial photography to determine the long term target. Some urban estuaries were allocated higher targets than current BAU scenario if migration into landscape was deemed possible due to close proximity of public or recreational land.

4.3.4 Priority conditions, threats and management interventions

Priority conditions

Several conditions interact to influence bird values in estuaries (refer to . The main condition targets and associated 10 year performance objectives which drive the long term bird value targets for estuaries are:

- Estuarine vegetation
- Water quality

Priority threats

The key threats to birds in estuaries is similar to those outlined in Section 2.2.4 for Riparian birds. The threats applied to the AVIRA framework include:

- Degraded estuarine vegetation

- Invasive flora
- Invasive fauna
- Reduction in high flow magnitude
- Degraded water quality
- Disturbance of acid sulfate soils

Priority management interventions

The main interventions that can be employed to protect or improve bird values in estuaries include:

- Revegetation of corridors to link habitat patches.
- Planning controls to preserve set-backs and areas of native vegetation.
- Revegetation to increase depth of riparian zone.
- Pest plant and animal control
- Stock exclusion fencing
- Controlling human (and dog) access or disturbance.
- Promoting natural regeneration of vegetation (as opposed to revegetation)
- Manage estuary opening/closures

4.3.5 Relevant performance objectives

The 10-year performance objectives for estuarine bird values were focused around reducing threats from invasive fauna as well as works to protect vegetation values.

- Protect/Enhance estuarine vegetation condition and reduce the threat of invasive plant species to significant estuarine vegetation communities.
- Reduce threat of invasive plant species to significant estuarine vegetation communities.
- Enhance estuarine emergent vegetation condition that provides instream habitat
- Plan to enable lateral and longitudinal migration of estuarine vegetation communities on the floodplain to allow adaption to climate change risks.
- Identify opportunities and undertake planning to re-engage estuarine floodplains in the long-term.
- Reduce the threat of invasive animals such as foxes, cats and dogs to key estuarine habitats.

4.3.6 Key assumptions and knowledge gaps

Data for estuaries in the region is patchy, and data gaps include but are not limited to:

- Patchy data on bird values due to the use of Victorian Biodiversity Atlas.
- Stock access to estuaries (e.g. identification of fencing)
- Level of involvement of community groups.
- Presence and level of impact of invasive species (plants and animals)

Additionally, the datasets used in AVIRA assessment process are developed and contain data for a specific point in time (e.g. Wetland Inventory, Victorian Biodiversity Atlas) and thus have currency issues (Jacobs, 2018a).

4.3.7 References

Alluvium (2017). Healthy Waterways Strategy Waterway Science Conceptual Models. Report by Alluvium Consulting Australia for Melbourne Water, Docklands

Hansen, B. and Menkhorst, P. 2014. Investigating the utility of monitoring bird communities to inform the Victorian Index of Estuarine Condition. Unpublished report to the Department of Environment and Primary Industries, Melbourne, Victoria.

Melbourne Water, 2011, Healthy *Estuaries Strategy*, Melbourne Water, East Melbourne.

4.4 Fish

4.4.1 Defining Values

Fish utilise estuaries in a number of ways, depending on their lifecycle and feeding needs. Fish species are grouped as per functional groups as outlined below.

Non-estuarine dependent – Marine: Species in the marine group are regularly recorded from estuaries but are more commonly found in the marine environment. They only move into the estuary on flood tides or when freshwater discharge has decreased and salinity levels in the estuary are close to seawater.

Non-estuarine dependent – Freshwater: The freshwater group species are generally only in the estuary during periods of high freshwater flow or may also be found in wetlands adjacent to the estuary.

Estuarine dependent - Seasonal Facultative and Obligate: Estuarine dependent, seasonal group species use the estuary at different times in their life history. Species in the seasonal facultative group often utilise the estuary as juveniles but also utilise sheltered marine embayments. Use of the estuary for migration, between the sea and freshwater, is an essential part of the lifecycle for species in the seasonal obligate group.

Estuarine Dependent – Permanent: Species in the permanent group are able to complete their lifecycle in the estuary.

Forty species of fish have been recorded in the region's estuaries and six have a conservation status listing. Species include the Australian Mudfish (*Neochanna cleaveri)*, a range of gobies (*Gobiidae spp.*), eels (*Anguilla* spp.), Australian Grayling (*Prototroctes maraena*) and Black Bream (*Acanthopagrus butcheri*) (Melbourne Water 2011).

4.4.2 Current state

The assessment of the estuarine fish value was based on the AVIRA method (see Box 4 in Section 1.5) however, there were significant gaps in available data.

Fish surveys have been carried out in a number of estuaries including Patterson River, Stony Creek, Merricks Creek, Kings Creek and some of the Mornington Peninsula creeks as well as some studies focusing on specific species such as the Grayling and Black Bream. Fish sampling has also been undertaken by DELWP as part of Index of Estuary Condition (IEC) assessments in 2010 to 2012. And data from the Victorian Biodiversity Atlas was used to try and fill data gaps but many estuaries had no data. Alternate data sources were required from those recommended in the AVIRA framework due to lack of data.

The assessment of the current state of the estuarine fish key value incorporated the AVIRA rare or threatened species and landscape features value categories as well as the Estuary Entrance Management Support System(EMSS)[5] (estuary asset score for fish) which is outside of the AVIRA scoring framework (see Table 55). The highest of the three metrics was assigned as the current status. A summary of the current condition for the estuary fish value at a catchment scale is provided in the Strategy in Part D – Catchment Summaries. Further information is provided at the sub-catchment level for each estuary in the five co-design catchment programs.

Table 55. Data used to determine the current state of the estuarine fish key value.

AVIRA value category	AVIRA metric	Measure(s) used to determine current state	Data source / notes	Scoring
Rare or threatened species	Significant fish	• Listed on the International Union for Conservation of Nature Red List • Listed under the Environment Protection and Biodiversity Conservation (EPBC) Act 1999	• Victorian Biodiversity Atlas (VBA) records post-1980. • Recent fish surveys (2015/16) • Available reports • Victorian Biodiversity Atlas (VBA) records post-1980 – records	Very high – records include listed species High – records include estuarine dependent (seasonal facultative and

[5] EEMSS is a decision support tool that guides estuary managers when making the decision whether or not to artificially open an estuary. It was developed by the Western Coastal Board in 2006, and subsequently refined by CMAs.

AVIRA value category	AVIRA metric	Measure(s) used to determine current state	Data source / notes	Scoring
		• Listed on the Advisory List of Rare or Threatened Vertebrate Fauna in Victoria (VROT)	within 100m of a waterway. • MW SoBS database *Note: Many of the estuaries had no data.*	seasonal obligate species) Moderate – Records of only non-estuarine dependent fish (marine or freshwater) Low – not used as not applicable Very low – No records of fish
Landscape refuges	Drought refuge	Modelled drought refuge for significant fish species OR nominated drought refuge for significant fauna and/or significant EVCs	Melbourne Water drought refuge and groundwater dependent ecosystem datasets	
EEMSS *(note: outside of AVIRA assessment)*	Asset score	Scores were assigned based on the dependence of the fish species present on estuarine habitat. Classifications include estuarine dependent (Seasonal facultative and Seasonal obligate) species and non-estuarine dependent fish (marine or freshwater) species	As for rare and threatened species	

4.4.3 *Setting scenarios*

Forecast current trajectory under business as usual scenario

A long-term Business as Usual trajectory (current trajectory) was based on rules and assumptions around the likely impacts of significant future threats, particularly climate change and urbanisation. Predictions on the future trajectory for fish key value status ratings was based on the assumptions outlined in Table 56.

Table 56. BAU trajectory assumptions for estuary fish value.

Value	Current trajectory assumptions
Fish	It is assumed that the fish communities will largely be unaffected under future climate change and urbanisation scenarios. Estuarine fish are resilient and able to move between estuaries and live in estuaries with overall poor conditions. However, the coarseness of the fish key value metric means that the presence of a species contributes to the key value status and the key value metric does not consider key lifecycle processes for species that may not be supported by poor estuarine conditions and predicted impacts.

Long term target setting

To set long term targets a different set of assumptions were made about the potential for change into the future. It was assumed over the long term that;

- Estuarine fish values would be maintained in current condition for those estuaries in a rural landscape(i.e. Westernport and Werribee catchments) due to the assumption that these estuaries could migrate further in the landscape as sea levels rise and retain important fish habitat. This assumes that farmland can be forgone for this purpose and/or a barrier can be removed.
- Fish values would be maintained for those estuaries in current or future urban or industrial areas due to estuarine fish being resilient and able to move between estuaries.

4.4.4 Priority conditions, threats and management interventions

Priority conditions

Several conditions interact to influence fish values in estuaries. The main condition targets and associated 10 year performance objectives which can be influenced to drive the long term fish value targets for estuaries are:

- Flow regime
- Longitudinal extent
- Water quality
- Estuarine wetland connectivity

Priority threats

The key threats to fish in estuaries is similar to those outlined in Section 0 for fish in rivers. The threats that frequently were applied to AVIRA framework include:

- Degraded estuarine vegetation
- Altered streamflow seasonality
- Reduced floodplain and wetland connectivity
- Degraded water quality
- Invasive fauna
- Livestock access

Priority management interventions

The main interventions that can be employed to protect or improve fish values include:

- Revegetation
- Pest plant and animal control
- Stock exclusion fencing
- Mitigating impacts of urbanisation (eg through WSUD)
- Improving flow regimes
- Erosion control

4.4.5 Relevant performance objectives

The 10-year performance objectives for estuarine fish values were focused around protecting refuge habitats through maintaining key hydrological components and improving longitudinal connectivity for fish migration.

- Protect refuge habitats through maintaining critical stream flow components.
- Improve longitudinal connectivity in estuaries.
- Reduce flow stress to the Little River and Werribee estuaries.

4.4.6 Key assumptions and knowledge gaps

Data for estuaries in the region is patchy and data gaps include but are not limited to:

- Patchy data on flora and fauna values.
- Estuary native fish (observed versus expected)
- Stock access estuaries (e.g. identification of fencing)
- Level of involvement of community groups.
- Presence and level of impact of invasive species (plants and animals)

Additionally, the datasets used in AVIRA assessment process are developed and contain data for a specific point in time (e.g. Wetland Inventory, Victorian Biodiversity Atlas) and thus have currency issues (Jacobs, 2018).

AVIRA was developed for regional freshwater rivers and as such, has some limitations when extrapolated to estuaries in the Melbourne area. For future iterations of the Healthy Waterways Strategy, the Index of Estuary Condition methodology should be adopted.

4.4.7 References

Jacobs (2018) Wetlands and Estuaries in the Melbourne Water Catchment, developed for Melbourne Water, Docklands, Victoria.

Melbourne Water (2011). Healthy Estuaries Strategy, Melbourne Water, East Melbourne.

4.5 Vegetation

4.5.1 Defining Values

Estuarine vegetation is essential to estuary ecosystem function, to support habitat for aquatic animals and has fundamental worth for its aesthetic appeal. Vegetation adjacent to estuaries (such as mangroves, seagrasses and saltmarshes) help to maintain water quality, assist with nutrient cycling, and provide a buffer to catchment-derived sediments, nutrients and other pollutants entering the marine environment.

There are 14 Ecological Vegetation Classes (EVCs) that are considered to be estuarine i.e. those that are subject to inundation with brackish water. These include riparian and in-stream communities and species. These EVCs include coastal saltmarsh, sedgelands, seagrass meadows, reedbeds and grasslands.

There are over 60 species of flora recorded from the catchments of estuaries in the region that have a conservation status assigned to them (Arundel and Barton, 2007). Key listed species that are particularly associated with estuarine EVCs include Creeping Rush (*Juncus revolutus*), Tiny Arrowgrass (*Triglochin minutissima*), Yellow sea-lavender (*Limonium australe*) and Grey Mangrove (*Avicennia marina subsp australasica*). The Yarra River, Kororoit Creek and Stony Creek have the highest number of listed 'estuarine' species in the Port Phillip Bay estuaries. Olivers Creek and Kings Creek have the highest number of listed 'estuarine' species in the Westernport estuaries. Most of these listed species are found in association with seagrass meadows and mangroves.

4.5.2 Current state

The assessment of the estuarine vegetation value was based on the AVIRA method (see Box 4 in Section 1.5) and incorporated elements of the AVIRA rare or threatened species/communities and naturalness value categories (see Table 57).

Alternate data sources were required from those recommended in the AVIRA framework due to lack of data.

A summary of the current condition for the estuary vegetation value at a catchment scale is provided in the Strategy in Part D – Catchment Summaries. Further information is provided at the sub-catchment level for each estuary in the five co-design catchment programs.

Table 57.Data used to determine the current status of the estuarine vegetation key value.

AVIRA value category	AVIRA metric	Measure(s) used to determine current state	Data source / notes	HWS scoring
Rare or threatened species / communities	Significant flora	• Listed on the International Union for Conservation of Nature Red List • Listed under the Environment Protection and Biodiversity Conservation (EPBC) Act 1999 • Listed on the Advisory List of Rare or Threatened Plants in Victoria (VROT)	• Victorian Biodiversity Atlas (VBA) records post-1980 – records within 100m of a waterway. • Classified as water dependent significant flora as listed in AVIRA manual (DELWP 2015). • Melbourne Water SoBS Database *The significant flora score was determined by combining scores from the metrics underneath these measures. The hierarchy of values followed was in order of priority: IUCN, EPBC and Vic advisory lists, i.e. if there was a conflict in the scoring, then the IUCN score would take precedence then EPBC, then VROT.*	• Very high: If all three metrics meet criteria (score 5) • High: If condition = 5 and one other metric meets criteria • Moderate: If Condition = 3 and one other metric meets criteria or condition is 5 • Low: If condition = 3 (moderate) and meets one significance metric Very low: If condition = 1 (Very poor or poor)
	Significant Estuary EVC	• Ecological Vegetation Class Bioregional Conservation Status	• Measure 1: Native Vegetation - Modelled 2005 Ecological Vegetation Classes: Bioregional Conservation Status of EVCs (www.data.vic.gov.au) • Measure 2: Classified as water dependent EVC as listed in AVIRA manual (DELWP 2015).	
Naturalness	Estuary vegetation condition	Rapid manual assessment of vegetation condition to classify from near natural to highly disturbed, based on presence of fringing macrophytes	• site assessment • aerial imagery Used similar method as threat metric Degraded estuarine vegetation': Highly disturbed: no remaining fringing macrophytes = 5 Modified: fringing macrophytes present, some EVCs absent or modified from benchmark = 3 Near natural: no change in extent or condition of EVCs = 1 Estuary has not been assessed for degraded vegetation condition = 0	

4.5.3 Setting scenarios

Forecast current trajectory under business as usual scenarios

A long-term Business as Usual trajectory (current trajectory) was based on rules and assumptions around the likely impacts of significant future threats, particularly climate change and urbanisation. Accordingly, predictions on the current trajectory for vegetation value status were moderated (from current rating) as outlined in Table 58.

Table 58. Current trajectory of estuary key values

Value	Current trajectory assumptions
Vegetation	To reflect projections regarding sea level rise and the inability of estuarine vegetation to migrate in a confined area, estuarine vegetation current state scores were moderated down two ranks (if not already low) for current trajectory if they were located in an urban or industrial area. Given that most estuaries to the west of Melbourne are located in urban or industrial areas (with the exception of the Werribee and Little River estuaries, surrounded by farmland and the Western Treatment Plant respectively), estuarine vegetation condition in the west is projected to experience significant decline as it is not feasible to relocate this infrastructure and were scored accordingly for current trajectory. Estuarine vegetation in the Dandenong catchment is also expected to experience decline as the impacts of recent and ongoing urban development are realised. To the east of Melbourne, in the Westernport catchment, many estuaries flow through an agricultural setting and the feasibility of planning for saltmarsh communities to migrate landward is considered higher. Accordingly, these estuaries are not projected to decline to the same extent as those in the west.

Long term target setting

To set long term targets a set of assumptions were made about the potential for change into the future. It was assumed over the long term that;

- Estuarine vegetation values could be maintained or improved from current condition for those estuaries in a rural landscape(i.e. Westernport & Werribee catchments) if the estuaries migrate further in the landscape as sea levels rise and important salt marsh habitat is retained. This assumes that farmland can be forgone for this purpose and/or a barrier can be removed.
- Estuarine vegetation values would be maintained in current condition for those estuaries in current or future urban or industrial areas. This because these estuaries are in very low or low condition and are unlikely to improve due to constraints in estuary migration due to land use.

4.5.4 Priority conditions, threats and management interventions

Priority conditions

Several conditions interact to influence vegetation values in estuaries. The main condition targets and associated 10 year performance objectives which can be influenced to drive the long term vegetation value targets for estuaries are:

- Estuarine vegetation (as a condition)
- Flow regime
- Tidal exchange
- Water quality
- Estuarine wetland connectivity

Priority threats

The key threats to vegetation in estuaries is similar to those outlined in Section 2.1.4 for vegetation in rivers. The threats that frequently were applied to AVIRA framework include:

- Invasive flora
- Degraded estuarine vegetation
- Reduced floodplain and wetland connectivity
- Livestock access
- Bank instability
- Changed estuary opening conditions

Priority management interventions

The main interventions that can be employed to protect or improve vegetation values include:

- Revegetation
- Pest plant and animal control
- Stock exclusion fencing
- Mitigating impacts of urbanisation (eg through WSUD)
- Improving flow regimes

- Erosion control
- Manage estuary opening/closures

4.5.5 Relevant performance objectives

The 10-year performance objectives for estuarine vegetation values were focused around the areas of existing high-quality vegetation, enhancing lesser quality areas, protecting and enhancing the habitat values of vegetation and enabling the movement of the estuarine vegetation as sea levels rise.

- Protect/Enhance estuarine vegetation condition and reduce the threat of invasive plant species to significant estuarine vegetation communities.
- Reduce threat of invasive plant species to significant estuarine vegetation communities.
- Enhance estuarine emergent vegetation condition that provides instream habitat
- Plan to enable lateral and longitudinal migration of estuarine vegetation communities on the floodplain to allow adaption to climate change risks.
- Identify opportunities and undertake planning to re-engage estuarine floodplains in the long-term.

4.5.6 Key assumptions and knowledge gaps

Data for estuaries in the region is patchy and data gaps include but are not limited to:

- Patchy data on flora and fauna values.
- Stock access estuaries (e.g. identification of fencing)
- Level of involvement of community groups.
- Presence and level of impact of invasive species (plants and animals)

Additionally, the datasets used in AVIRA assessment process are developed and contain data for a specific point in time (e.g. Wetland Inventory, Victorian Biodiversity Atlas) and thus have currency issues (Jacobs, 2018).

AVIRA was developed for regional freshwater rivers and as such, has some limitations when extrapolated to estuaries in the Melbourne area. For future iterations of the Healthy Waterways Strategy, the Index of Estuary Condition methodology should be adopted.

4.5.7 References

DELWP (2015). Aquatic Value Identification and Risk Assessment (AVIRA) Manual, State of Victoria: Department of Environment, Land, Water and Planning.

Jacobs (2018) Wetlands and Estuaries in the Melbourne Water Catchment, developed for Melbourne Water, Docklands, Victoria.

4.6 Amenity, Community Connection and Recreation

4.6.1 Defining Values

Estuaries in the region have high social values associated with their variety of landscapes as well as the aesthetic enjoyment and recreational opportunities they provide. For example, estuaries enable people to access the coast for fishing, swimming, boating, picnicking, walking and viewing wildlife associated with these waterways.

There are many structures that have been built in estuaries to enable these activities to occur. For example, Mordialloc Creek, Kororoit Creek and Kananook Creek all have jetties and moorings for recreational boating. Skeleton, Laverton and Balcombe Creeks each have open space adjacent to the waterway with pathways for walking. Maribyrnong River has fishing platforms, boat moorings and jetties that are highly used. Werribee River has a jetty and boat ramp that are popular for recreational fishers and Patterson River has one of the most highly used boat launching complexes in Melbourne. Rowing occurs on both the Maribyrnong and Yarra Rivers estuaries.

There has been an increased policy focus at the state and regional level and social conceptual models (Jacobs, 2018b) developed for waterways in the region were used to identify the environmental conditions (e.g. access to facilities, aesthetics) that support the social key values.

The social value category is broken down into three key values as referred to in Section 2.5.2:

- Amenity
- Community connection
- Recreation

The approach to identifying the current status of each value within an estuary context is described below.

4.6.2 Current state

The assessment of the estuarine social values was based on the AVIRA method (see

Box 4 in Section 1.5) and incorporated metrics from the AVIRA activity, place and degraded habitats value categories as well as a measure of the presence of community groups. These are described below.

Amenity: Based on assessment of the presence of facilities and activities that support passive enjoyment of the site. The highest of the metrics was assigned as the current status (Table 59).

Table 59. Data used to determine the current state of the estuarine amenity key value.

AVIRA value category	AVIRA metric	Measures used to determine current state	Data source / notes	AVIRA Scoring	HWS scoring
Activity	Walking, Hiking, Cycling (Tracks - beside water activity)	Presence of tracks adjacent to asset	• Parks and reserves (www.data.vic.gov.au) • Base maps and imagery • Literature review – Camping guides, Park Notes, Walking guides • Internal/ Melbourne Water workshop outputs – local knowledge • Site assessment – estuaries	• AVIRA score 5 - Sealed or formed tracks follow estuary and are mapped or signposted	• Very High – if 4 or more of metric are scored • High – if 4 metrics are scored • Moderate if 3 metrics are scored • Low – if 2 metrics are scored • Very low if 0 – 1 metrics are scored
	Picnics Barbecues (beside water activity)	Presence of designated picnic/BBQ areas	• Parks and reserves (www.data.vic.gov.au) • Literature review – Park Notes/ Local Government • Internal/ Melbourne Water workshop outputs – local knowledge • Site assessment - estuaries	• AVIRA score 5 - Designated picnic/BBQ areas present • AVIRA score 0 – no designated picnic/BBQ areas present	
	Sightseeing (beside water activity)	Identified site of interest with high visitor numbers	• Parks and reserves (www.data.vic.gov.au) • LGA websites • Internal/ Melbourne Water workshop outputs – local knowledge	• AVIRA score 5 - Identified estuary of interest with high visitor numbers	
Place	Landscape	Presence of a Significant Landscape Overlay (Victorian Planning Scheme)	Planning scheme overlay - Vicmap Planning - Significant landscape overlay (www.data.vic.gov.au)	• AVIRA score 5 – covered by a SLO • AVIRA score 0 – not covered by a SLO	
Degraded habitats	Degraded estuarine vegetation	Presence of fringing macrophytes	• Site assessment • available reports • review of aerial imagery.	• AVIRA score 5 – Highly disturbed: no remaining fringing macrophytes • AVIRA score 3 – Modified: fringing macrophytes present, some EVCs absent or modified	

AVIRA value category	AVIRA metric	Measures used to determine current state	Data source / notes	AVIRA Scoring	HWS scoring
				from benchmark • AVIRA score 1 – Near natural: no change in extent or condition of EVCs • AVIRA score no data - Estuary has not been assessed for degraded vegetation condition	

Recreation: Based on assessment of the presence of facilities and activities that support active recreation. The highest of the three metrics was assigned as the current status (Table 60).

Table 60. Data used to determine the current state of the estuarine recreation key value.

AVIRA value category	AVIRA metric	Measure used to determine current state	Data source / notes	AVIRA Score	HWS scoring
Activity	Recreational fishing	Identified as preferred fishing locations OR listed as a priority/key/ popular fishery in a RFMP OR Rated as a best fishing water in *A Guide to the inland Angling Waters of Victoria* OR known to be	• Recreational Fishing Spots (https://data.gov.au/dataset/recreational-fishing-spots) • Guide to Angling Waters of Victoria (on-line guide) http://www.dpi.vic.gov.au/angling • Literature review - Park Notes/other • Internal/ Melbourne Water workshop outputs – local knowledge • Site assessment – estuaries	• AVIRA score 5 - More than six recreational fishing licence holders identified this reach as their most preferred fishing location OR Listed as a priority/key/popular fishery in a RFMP OR Rated as a best fishing water in A Guide	Very High – if 4 or more of metric are scored Moderate if 3 metrics are scored Low – if 2 metrics are scored Very low if 0 – 1 metrics are scored

AVIRA value category	AVIRA metric	Measure used to determine current state	Data source / notes	AVIRA Score	HWS scoring
		used for recreational fishing.			
	Non-motor boating		• Literature review – Park Notes/ other • listed as a site for canoeing/kayaking, white-water rafting or rowing in AVIRA manual (DELWP 2015). • Internal/ Melbourne Water workshop outputs – local knowledge • Site assessment - estuaries	• AVIRA Score 5 - Estuary used for annual (or more frequent) non-motor boating event • AVIRA Score 4 - Estuary popular for non-motor boating	
	Motor boating	Used for motor boating (including events and general usage)	• Victorian Waterway Boating Zone Data (www.data.vic.gov.au) • Listed as a popular water-skiing location or where power boat racing events occur in the in AVIRA manual (DELWP 2015). • Internal/ Melbourne Water workshop outputs – local knowledge • Site assessment - estuaries	• AVIRA score 5 -estuary used for annual (or more frequent) motor boating event • AVIRA Score 4 - Estuary popular for motor boating with accessible formal boating facility (boat ramp, trailer park)	
	Camping	Campground adjacent to site	• Parks and reserves (www.data.vic.gov.au) • Literature review – Camping guides, Park Notes • Internal/ Melbourne Water workshop outputs – local knowledge • Site assessment - estuaries	• AVIRA score 5 - Serviced campground adjacent to estuary OR Multiple campsites with basic facilities adjacent to estuary. • AVIRA score 4 - Campground with basic facilities adjacent to wetland OR Multiple bush camping areas adjacent to wetland	
	Swimming	Known to be a swimming location	• Literature review – Camping guides, Park Notes • Internal/ Melbourne Water workshop outputs • Site assessment - estuaries	• AVIRA score 5 - Popular swimming location • AVIRA Score 4 - Some swimming	
	Game hunting	Game hunting permitted	• Parks and reserves (www.data.vic.gov.au) - State Forest and other unoccupied Crown Land, State Game Reserve, Sanctuary, some	• AVIRA score 5 – Game hunting permitted • AVIRA score 0 – no game hunting permitted	

AVIRA value category	AVIRA metric	Measure used to determine current state	Data source / notes	AVIRA Score	HWS scoring
			parks, Leased Crown Land, Licensed Crown Land, Private Land.		
	Walking, Hiking, Cycling (Tracks - beside water activity)	Presence of tracks adjacent to asset	• Parks and reserves (www.data.vic.gov.au) • Base maps and imagery • Literature review – Camping guides, Park Notes, Walking guides • Internal/ Melbourne Water workshop outputs – local knowledge • Site assessment – estuaries	• AVIRA score 5 - Sealed or formed tracks follow estuary and are mapped or signposted	

Community connection: Based on assessment of the presence of active community groups connected to the waterway (Table 61).

Table 61. Data used to determine community connection current state.

AVIRA value category	AVIRA metric	Measure(s) used to determine current state	Data source / notes	HWS Scoring
People	Community groups	Presence of active community groups	• Site specific information • Melbourne Water SoBS database • Melbourne Water community groups list • Literature review – 'friends of' and Landcare websites	Very high - If community groups are present.

4.6.3 Setting scenarios

Forecast current trajectory under business as usual scenario

A long-term Business as Usual trajectory (current trajectory) was based on rules and assumptions around the likely impacts of significant future threats, particularly climate change and urbanisation. Accordingly, predictions on the current trajectory for key value status and waterway condition ratings were moderated (from current rating) as outlined in Table 62.

Table 62. BAU trajectory assumptions for social values in estuaries

Value / waterway condition	Name	Current trajectory assumptions
Key value	Amenity	It was assumed that the social value status would be unchanged under the current trajectory. It is likely that current investment would support the adaptation of facilities in line with changing conditions. E.g. raising of paths etc.
	Recreation	If the recreational value was located in an urban area or within the urban growth boundary, then the value was projected to increase. If located in farmland outside the UGB, no change was expected.
	Community connection	If there was an active community group connected to the waterway, then the current trajectory of Community Connection value was considered to stay high.

Long term target setting

To set long term targets a set of assumptions were made about the potential for change into the future. It was assumed over the long term that;

- Amenity, Recreation and Community connection values would be maintained from current condition if already high to very high based on assumptions outlined for BAU trajectory
- Amenity and Recreation values would be improved if current condition was low to moderate due to the assumption that future investment would enable adaption of facilities or improved recreation in line with changing conditions. Community connection value was not part of this assumption as the value is typically high due to the presence of an active community group.

4.6.4 Priority conditions, threats and management interventions

The priority conditions, threats and management interventions for estuaries are the same as for rivers. Please refer to section 2.5.5 for details.

4.6.5 Relevant performance objectives

The 10-year performance objectives for estuarine social values were focused around enhancing existing recreational facilities and investigating opportunities to improve access and condition to support social values (e.g. water quality).

- Investigate opportunities to improve access for on-water activities and improve connections with existing path networks
- Enhance site appropriate opportunities for recreation (boating, fishing, walking/cycling, swimming).
- Enhance site appropriate facilities that support passive enjoyment and recreation.
- Maintain existing high value facilities that support passive enjoyment and recreation.
- Maintain existing high value opportunities for recreation (walking/cycling, boating, fishing etc.).
- Maintain recreational water quality within the Maribyrnong/Yarra estuary so that it suitable for secondary contact (boating and fishing)

4.6.6 Key assumptions and knowledge gaps

Data for estuaries in the region is patchy and data gaps include but are not limited to:

- Level of involvement of community groups.
- Type and level of recreation along estuaries

A number of assumptions were included during the evaluation of social values in estuaries:

- Communities place high value on estuaries providing natural environments and habitat for plants and animals, therefore most actions taken to maintain/improve environmental values will contribute to the maintenance/improvement of social values
- Improvement of social values will not be at the expense of environmental values
- Attributes of the estuary landscape and facilities that are appropriate to support social values will be different for different settings (e.g. mown grass, picnic tables and barbeques may be appropriate in an urban setting, but not in a natural mangrove area)

AVIRA was developed for regional freshwater rivers and as such, has some limitations when extrapolated to estuaries in the Melbourne area. For future iterations of the Healthy Waterways Strategy, the Index of Estuary Condition methodology should be adopted for filling data gaps for the social metrics.

4.6.7 References

DELWP (2015). Aquatic Value Identification and Risk Assessment (AVIRA) Manual, State of Victoria: Department of Environment, Land, Water and Planning.

Jacobs (2018b) Conceptual Models for the Social Values of Waterways, developed for Melbourne Water, Docklands, Victoria.

5 Condition metrics for estuaries

5.1 Introduction

Estuary condition refers to the overall state of the estuary and key processes that underpin well-functioning estuary ecosystems. Estuary conditions support the estuary values (environmental, social, cultural and economic). Improvements in estuary conditions in turn improve the estuary values and the benefits that can be derived from that estuary. AVIRA threat data was used as the basis for reporting of estuary conditions. The conditions supporting environmental key values for estuaries were identified through the conceptual models (refer to Figure 36) and are assessed on the following:

- **Flow regime**: Changes from 'natural conditions' to the flow regime. This includes increases in low flow magnitude, reductions in high flow magnitude, increase in the proportion of zero flow, changes to monthly streamflow variability and altered streamflow seasonality.
- **Tidal exchange**: The ability of sea water and fresh water to mix in the estuarine environment, in both intermittently or permanently open estuaries.
- **Longitudinal extent**: Considers the proportion of estuary affected by constructed barriers that interfere with the movement of water (in a typical year).
- **Water quality**: Water quality indicators such as nutrients, water clarity (turbidity), dissolved oxygen, pH and metals.
- **Estuarine vegetation**: The extent to which estuarine vegetation extent and condition is modified.
- **Estuarine wetland connectivity**: The proportion of the estuary that is connected to its fringing wetlands.

The metrics and measures underpinning these assessments are described in further detail in the following sections.

5.2 Flow regime

5.2.1 Current state

The assessment of the current rating of the estuarine flow regime incorporated elements of the AVIRA (DELWP, 2015) altered water regimes threat category (see Table 63). A combined altered flow regime score was assigned as per the highest score of the 5 metrics. As there were limited estuaries incorporated within the Index of Stream Condition, alternate data sources were used to populate this metric including the Estuary Prioritisation Tool.The Estuary Prioritisation Tool was developed to assist Melbourne Water to prioritise estuaries in the region for flow investigations and work. It is based on data regarding estuary hydrological impairment, ecological and social values and vulnerabilities (such as tidal exchange, entrance closure, elevated sediment and organic matter, pollution and barriers to movement upstream). For information on the tool's development and use please see Lloyd et al., (2013).

Table 63. Data used to determine the current rating of the estuarine flow regime waterway condition.

AVIRA threat category	AVIRA metric	Measure(s) used to determine current rating	Data source / notes	HWS Scoring
Altered water regimes	Altered flow regime – increase in low flow magnitude	Estuary Prioritisation Low Flow Impairment assessment	• Melbourne Water Estuary Prioritisation Tool • *Note that ISC data was only available for a few estuaries so the Estuary prioritisation tool was used instead.* • ISC - Low Flow Index Score, High Flow, Streamflow Variability, Altered Streamflow Seasonality could be used.	• Very high: High Flow Index Score 8.5 – 10.0 Low Flow Index Score 8.1 – 10.0 Zero Flow Index Score 8.1 – 10.0 Variability Index Score 8.1 - 10.0 Seasonality Index Score 8.5 - 10.0 • High: High Flow Index Score 6.5 - 8.49 Low Flow Index Score 6.1 - 8.0 Zero Flow Index Score 6.1 - 8.0 Variability Index Score 6.1 - 8.0 Seasonality Index Score 6.5 - 8.49 • Moderate: High Flow Index Score 4.5 - 6.49 Low Flow Index Score 4.1 - 6.0 Zero Flow Index Score 4.1 - 6.0 Variability Index Score 4.1 - 6.0 Seasonality Index Score 4.5- 6.49 • Low: High Flow Index Score 2.5 - 4.49 Low Flow Index Score 2.1 - 4.0 Zero Flow Index Score 2.1 - 4.0 Variability Index Score 2.1 - 4.0 Seasonality Index Score 2.5 - 4.49 • Very low: High Flow Index Score 0.0 - 2.49 Low Flow Index Score 0.0 - 2.0 Zero Flow Index Score 0.0 - 2.0 Variability Index Score 0.0 - 2.0 Seasonality Index Score 0.0 - 2.49
	Altered flow regime – increase in high flow magnitude	Estuary Prioritisation High Flow Impairment assessment	Melbourne Water Estuary Prioritisation Tool	
	Increase in Proportion of Zero Flow	ISC Zero flow index score	ISC only available for a small number of estuaries, remaining estuaries scored '0' = no data.	
	change in monthly streamflow variability	ISC Variability Index Score		
	Altered streamflow seasonality	ISC Seasonality Index Score		

5.2.2 Setting scenarios

Forecast current trajectory under business as usual scenario

A long-term Business as Usual trajectory (current trajectory) was based on rules and assumptions around the likely impacts of significant future threats, particularly climate change and urbanisation. Accordingly, predictions on the current trajectory for key value status and waterway condition ratings were moderated (from current rating) as outlined in Table 64.

Table 64. BAU trajectory assumptions for flow regime

Estuary condition	Current trajectory assumptions
Flow regime	Under current trajectory, all flows scores were reduced to very low, due to the impacts of climate change (reduced inflows) particularly in rural areas, urbanisation (increased stormwater impacts) in urban, industrial or developing areas.

Long term target setting

To set long term targets a set of assumptions were made about the potential for change into the future. It was assumed over the long term that;

- Flow regime condition would improve by one category due to focused efforts to invest in climate change mitigation
- The Yarra estuary flow regime will improve significantly due to the assumption that the Environmental water reserve is increased in line with the environmental water performance objectives.

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5.2.3 10 year Performance Objective

The 10 year performance objectives for flow regime were largely focused on maintaining or improving flow regimes in unregulated systems:

- Maintain critical flow components in refuge reaches to protect instream environmental values
- Reduce the threat of flow stress on Little River (e.g. climate change, diversions and water for domestic and stock uses) by developing and implementing agreed environmental watering objectives.
- Investigate opportunities to increase the environmental water reserve is increased by 7 GL by 2028 to meet ecological watering objectives and cover projected shortfalls.
- Identify opportunities to maintain and improve the flow regime in the Werribee River downstream of the Werribee diversion weir to support platypus populations.

5.2.4 Key assumptions and improvement opportunities

AVIRA was developed for regional freshwater rivers and as such, has some limitations when extrapolated to estuaries in the Melbourne area. For future iterations of the Healthy Waterways Strategy, the Index of Estuary Condition methodology should be adopted.

5.2.5 References

DELWP (2015). Aquatic Value Identification and Risk Assessment (AVIRA) Manual, State of Victoria: Department of Environment, Land, Water and Planning.

Lloyd, L.N., Cooling, M., Gippel, C. & Watkins, D. 2013. Melbourne Water Estuary Prioritisation Tool. Lloyd Environmental Developed for Melbourne Water.

5.3 Tidal exchange

5.3.1 Current state

Estuaries within the region include those that are permanently open to the sea, such as the Werribee, Maribyrnong and Yarra, and those which are naturally intermittently open and closed to the sea, such as the Balcombe and Merricks creeks estuaries. The assessment of the current rating of the estuarine tidal exchange waterway condition incorporated elements of the AVIRA altered water regimes threat category (DELWP, 2015). This includes one metric for intermittently open estuaries and one for permanently open estuaries due to their different hydrological characteristics (see Table 65). Alternate data sources were required from those recommended in the AVIRA framework due to lack of data.

Table 65.Data used to determine the current rating of the estuarine tidal exchange waterway condition.

AVIRA threat category	AVIRA metric	Measure(s) used to determine current rating	Data source / notes	HWS Scores
Altered water regimes	Altered marine exchange (intermittently open estuaries)	Proportion of estuary openings that are artificial	Local knowledge Melbourne Water Estuary Prioritisation Tool - scoring from “entrance closure” used to determine how often open/ closed (Lloyd et al., 2013).	• Very high: Threat score 0 - No artificial estuary mouth openings* occur with non-environmental objectives Threat score 0 Dredging of the estuary mouth does not occur AND No training walls have been constructed at the estuary mouth • High: <25% of all estuary mouth openings* are artificial with non- environmental objectives • Moderate: 25% -50% of all estuary mouth openings* are artificial with non-environmental objectives • Low:

AVIRA threat category	AVIRA metric	Measure(s) used to determine current rating	Data source / notes	HWS Scores
				>50% of all estuary mouth openings* are artificial with non-environmental objectives Dredging of the estuary mouth occurs OR Training walls have been constructed at the estuary mouth
	Altered marine exchange (permanently open estuaries)	Presence of training walls and or occurrence of dredging at the estuary mouth and	Local knowledge	AVIRA Threat score 1 - 1-25% of estuary is affected by an artificial barrier that interferes (intermittently or selectively) with the movement of water (in a typical year)

5.3.2 Setting scenarios

Forecast current trajectory under business as usual scenario

A long-term Business as Usual trajectory (current trajectory) was based on rules and assumptions around the likely impacts of significant future threats, particularly climate change and urbanisation. Accordingly, predictions on the current trajectory for key value status and waterway condition ratings were moderated (from current rating) as outlined in Table 66.

Table 66. BAU trajectory assumptions for tidal exchange

Estuary condition	Current trajectory assumptions
Altered marine exchange	Under current trajectory altered marine exchange scores for permanently open estuaries was not expected to change significantly under current trajectory, therefore their current trajectory scores stayed the same. The hydrology of the intermittently open estuaries is projected to be changed to permanently open due to sea level rise, therefore their current trajectory rating was very low.

Long term target setting

To set long term targets a set of assumptions were made about the potential for change into the future. It was assumed over the long term that marine exchange will not change significantly from current conditions so the target is to maintain the condition.

5.3.3 10 year Performance Objective

The 10 year performance objectives for tidal exchange were largely focused on improving connectivity for fish passage and to improve social values:

- Improve longitudinal connectivity and tidal exchange in estuary.
- Artificial estuary mouth openings are only undertaken when a risk assessment concludes that opening conditions are low risk for the environment.

5.3.4 Key Assumptions and Improvement Opportunities

AVIRA was developed for regional freshwater rivers and as such, has some limitations when extrapolated to estuaries in the Melbourne area. For future iterations of the Healthy Waterways Strategy, the Index of Estuary Condition methodology should be adopted.

5.3.5 References

DELWP (2015). Aquatic Value Identification and Risk Assessment (AVIRA) Manual, State of Victoria: Department of Environment, Land, Water and Planning.

5.4 Longitudinal extent

5.4.1 Current state

The assessment of the current rating of the estuarine longitudinal extent waterway condition was based on the AVIRA altered physical forms threat category (DELWP, 2015), which uses the presence of instream barriers as a proxy (see Table 67). Alternate data sources were required from those recommended in the AVIRA framework due to lack of data. Field and remote sensed data were key inputs as described below.

Table 67. Data used to determine the current rating of the estuarine longitudinal extent waterway condition.

AVIRA threat category	AVIRA metric	Measure(s) used to determine current rating	Data source / notes	HWS Scoring
Altered physical forms	Reduced estuary extent	Proportion of the estuary affected by an artificial barrier that partially or completely blocks the movement of water (in a typical year)	• IEC Physical Form Sub Index using 2ISC. • Melbourne Water Estuary Prioritisation Tool – scoring from Barriers to Fauna Movement Upstream” to determine the presence of an artificial barrier (Lloyd et al., 2013).	Score 5 - No artificial barrier occurs within estuary Score 4 – 1-25% of estuary is affected by an artificial barrier that interferes (intermittently or selectively) with the movement of water (in a typical year) Score 3 – >25-50% of estuary is affected by an artificial barrier that interferes (intermittently or selectively) with the

AVIRA threat category	AVIRA metric	Measure(s) used to determine current rating	Data source / notes	HWS Scoring
			• Site assessment • Aerial imagery	movement of water (in a typical year) Score 2 – – 1-50% of estuary is affected by an artificial barrier that completely blocks the movement of water (in a typical year) OR >50% of estuary is affected by an artificial barrier that interferes (intermittently or selectively) with the movement of water (in a typical year) Score 1 - >50% of estuary is affected by an artificial barrier that completely blocks the movement of water (in a typical year)

5.4.2 Setting scenarios

Forecast current trajectory under business as usual scenario

A long-term Business as Usual trajectory (current trajectory) was based on rules and assumptions around the likely impacts of significant future threats, particularly climate change and urbanisation. Accordingly, predictions on the current trajectory for key value status and waterway condition ratings were moderated (from current rating) as outlined in Table 68.

Table 68. BAU trajectory assumptions for longitudinal extent

Estuary condition	Current trajectory assumptions
Longitudinal extent	Under current trajectory, the longitudinal extent of all estuaries was expected to improve. Existing barriers such as weirs and roads may be overtopped more frequently due to sea level rise, flashier stormwater flows and storm surges in some areas. Additionally, many current barriers are slated for removal under current works programs. Construction of barriers in estuaries is expected to decline due to improved works practices approvals, (e.g. works on waterways permits). Accordingly, condition was improved by one rank (e.g. from low to moderate) at all sites.

Long term target setting

To set long term targets a set of assumptions were made about the potential for change into the future. It was assumed over the long term that;

- Estuarine longitudinal extent would improve for those estuaries in a rural landscape(i.e. Westernport and Werribee catchments) due to the assumption that these could migrate further in the landscape as sea levels rise. This assumes that farmland can be forgone for this purpose and/or a barrier can be removed.
- Estuarine connectivity would decline for those estuaries in current or future urban or industrial areas reflecting the inability of estuaries to migrate into a constricted landscape as sea levels rise.

Each estuary was assessed via desktop using aerial photography to determine the long term target. Some urban estuaries were allocated higher targets than current BAU scenario if migration into landscape was deemed possible due to close proximity of public or recreational land.

5.4.3 10 year Performance Objective

The 10 year performance objectives for longitudinal extent were largely focused on improving connectivity for fish passage:

- Improve longitudinal connectivity and tidal exchange in estuary (Skeleton Creek Estuary)
- Improve longitudinal connectivity and tidal exchange by removing barrier at Racecourse Road (Kororoit Creek Estuary).

5.4.4 Key assumptions and improvement opportunities

The AVIRA framework for estuaries is based fundamentally on protocols developed for inland freshwater rivers. The extension to estuaries creates a number of difficulties (Jacobs, 2017):

- Reaches of inland rivers are by definition relatively homogeneous, but estuaries are not longitudinally heterogeneous, with marine influences dominating at the bottom end and freshwater influences dominating at the upper end. This variation affects both in-stream values (e.g. via salinity gradients) and the types of vegetation associated with the estuarine fringe (e.g. belts of mangroves at the seaward margin; coastal saltmarsh behind them; brackish-water assemblages further upstream). The application of the AVIRA framework for Melbourne Water estuaries therefore does not differentiate adequately between the different parts of an estuary. A good example is provided by Merricks Creek which is near-natural at the mouth, but severely altered by runoff (with resultant algal blooms) only a few kms upstream.
- A related difficulty in applying the AVIRA framework is the assessment and scoring of condition and longitudinal modification with estuaries that have been differentially modified with varying distance from the outlet. An example is how the upper- and mid-parts of the estuarine streams that drain the northern sections of Western Port have been severely affected by channelisation, deepening and vegetation clearing, but the

lower-most sections retain some, perhaps much closer to Western Port, of their original geomorphology and thus habitat value.

- Many of the obvious modifications to estuaries are not addressed in the AVIRA framework. An example is the severe, and in some cases extensive, modification of the estuary shoreline by rock armouring, which facilitates recreation but decreases habitat value. This type of shoreline protection is not captured by the 'seawalls' threat metric in the existing AVIRA framework, however is a major change to estuarine form and function.

An improvement opportunity is to revise the estuarine AVIRA framework so that it better suits the conditions experienced in estuaries in the Melbourne Water area (Jacobs, 2017).

5.4.5 References

DELWP (2015). Aquatic Value Identification and Risk Assessment (AVIRA) Manual, State of Victoria: Department of Environment, Land, Water and Planning.

Jacobs (2017). Wetlands and Estuaries in the Melbourne Water catchment: Values and Threats Assessment. Developed for Melbourne Water, Melbourne.

Lloyd, L.N., Cooling, M., Gippel, C. & Watkins, D. (2013). Melbourne Water Estuary Prioritisation Tool. Lloyd Environmental Developed for Melbourne Water.

5.5 Estuarine Vegetation

5.5.1 Current state

The assessment of the current rating of the estuarine vegetation waterway condition incorporated elements of the AVIRA degraded habitats and reduced connectivity threat categories (see Table 69). Alternate data sources were required from those recommended in the AVIRA framework due to lack of data. Remote sensed data was a key input as described below in addition to rapid site assessments (Jacobs 2017).

Table 69. Data used to determine the current rating of the estuarine vegetation waterway condition.

AVIRA threat category	AVIRA metric	Measure(s) used to determine current rating	Data source / notes	HWS Scoring
Degraded habitats	Degraded estuarine vegetation	Presence of fringing macrophytes	Site assessment and aerial imagery	• Very high – Near natural: no change in extent or condition of EVCs and very high connectivity • High – vegetation is relatively intact, most structural component present and high connectivity • Moderate – vegetation consists of fragmented relevant EVCs

AVIRA threat category	AVIRA metric	Measure(s) used to determine current rating	Data source / notes	HWS Scoring
				• Low – Vegetation is highly modified and fragmented • Very Low – Vegetation is highly modified, predominately comprising invasive species

5.5.2 Setting scenarios

Forecast current trajectory under business as usual scenario

A long-term Business as Usual trajectory (current trajectory) was based on rules and assumptions around the likely impacts of significant future threats, particularly climate change and urbanisation. Accordingly, predictions on the current trajectory for key value status and waterway condition ratings were moderated (from current rating) as outlined in Table 70.

Table 70. BAU trajectory assumptions for estuarine vegetation

Estuary condition	Current trajectory assumptions
Estuarine vegetation	Under current trajectory, all scores decline to low or very low, due to the incorporation of vegetation condition scores in the metric and their poor trajectory, as well as the impacts of climate change and urbanisation.

Long term target setting

To set long term targets a set of assumptions were made about the potential for change into the future. It was assumed over the long term that;

- Estuarine vegetation would improve for those estuaries in a rural landscape(i.e. Westernport and Werribee catchments) due to the assumption that these could migrate further in the landscape as sea levels rise. This assumes that farmland can be forgone for this purpose and/or a barrier can be removed.

- Estuarine connectivity would decline for those estuaries in current or future urban or industrial areas reflecting the inability of estuaries to migrate into a constricted landscape as sea levels rise.

Each estuary was assessed via desktop using aerial photography to determine the long term target. Some urban estuaries were allocated higher targets than current BAU scenario if migration into landscape was deemed possible due to close proximity of public or recreational land.

5.5.3 10 year Performance Objective

The 10 year performance objectives for estuarine vegetation were largely focused on protecting / maintaining or improving vegetation quality:

- Protect remnant estuarine vegetation communities, particularly coastal saltmarsh, through targeting key invasive plant species.
- Maintain remnant estuarine vegetation communities at moderate through targeting key invasive plant species.
- Enhance estuarine emergent vegetation to provide instream habitat for fish.
- Identify opportunities to enhance habitat connectivity, access and vegetation links to other green spaces (e.g. Maribyrnong River estuary).
- Improve estuarine vegetation condition to high by reducing threats from salt tolerant weed species in saltmarsh communities

5.5.4 Key assumptions and improvement opportunities

AVIRA was developed for regional freshwater rivers and as such, has some limitations when extrapolated to estuaries in the Melbourne area. For future iterations of the Healthy Waterways Strategy, the Index of Estuary Condition methodology should be adopted to improve data for metrics related to estuarine vegetation..

An improvement opportunity is to revise the estuarine AVIRA framework so that it better suits the conditions experienced in estuaries in the Melbourne Water area (Jacobs, 2017). Three specific ideas include:

- Implicit consideration of the longitudinal and lateral variability of estuaries, with clearer guidelines as to the spatial area to be assessed.
- Similar clarification on the temporal variability in estuaries; e.g. how should long-term changes in climate (with impacts on freshwater discharge etc) be included within the scoring protocols?
- Scoring metrics and protocols that better reflect the anthropogenic changes that occur in estuaries but have been poorly served in the extrapolation from the assessment protocols developed for inland freshwater rivers. Examples of areas that require revision include armoured shorelines for stabilisation and shoreline protection; the presence of estuarine-specific vegetation threats (e.g. invasive species other than willows); and altered landuses including urban and industrial modification. An example for the latter issue is provided by Kororoit Creek, which despite being surrounded by heavy industry and seemingly scoring poorly under the AVIRA framework supported a large number of shoreline bird species when assessed in late November 2017.

5.5.5 References

Jacobs (2017). Wetlands and Estuaries in the Melbourne Water catchment: Values and Threats Assessment. Developed for Melbourne Water, Melbourne.

5.6 Estuarine wetland connectivity

5.6.1 Current state

The assessment of the current rating of the estuarine vegetation waterway condition was based on the AVIRA reduced connectivity threat category (DELWP, 2015) - the level of restriction for estuarine biota that require connection with adjacent wetlands and floodplains (see Table 71). Alternate data sources were required from those recommended in the AVIRA framework due to lack of data. Remote sensed data was a key input as described below.

Table 71. Data used to determine the current rating of the estuarine wetland connectivity waterway condition.

AVIRA threat category	AVIRA metric	Measure(s) used to determine current rating	Data source / notes	HWS Scoring
Reduced connectivity	Reduced Estuary Connectivity	Proportion of the estuary perimeter that has artificial barriers	• Local knowledge • Vegetation and physical habitat intactness – Melbourne Water Estuary Prioritisation Tool (Lloyd et al., 2013) • Site assessment • Aerial imagery	• Very high – • Estuary has no artificial structures • AND • Wetlands fully connected to the estuary • OR • No estuarine wetlands exist naturally • Moderate – • 1-15% of the estuary perimeter has artificial structures • OR • Wetlands are connected to the estuary but less than natural • Low – • >15% of the estuary perimeter has artificial structures • OR • Wetlands are no longer connected to the estuary
	Barriers to estuarine biota	Proportion of estuary length that is affected by an artificial barrier that partially or completely blocks the movement of biota (in a typical year)	• IEC Physical Form Sub Index • Database relating to barriers in estuaries (Jan, Barton, Deakin University) • Barriers to fauna movement upstream – Melbourne Water Estuary Prioritisation Tool • Site assessment • Aerial imagery	

5.6.2 Setting scenarios

Forecast current trajectory under business as usual scenario

A long-term Business as Usual trajectory (current trajectory) was based on rules and assumptions around the likely impacts of significant future threats, particularly climate change and urbanisation. Accordingly, predictions on the current trajectory for key value status and waterway condition ratings were moderated (from current rating) as outlined in Table 72.

Table 72. BAU trajectory assumptions for estuarine wetland connectivity

Estuary condition	**Current trajectory assumptions**
Estuarine wetland connectivity	Under current trajectory, estuaries in some Westernport catchment systems (Cardinia and Lower Bunyip, Lang Lang and Bass) improved from low or very low to moderate, reflecting the potential for estuaries to migrate in a rural landscape as sea levels rise. Little River (Werribee catchment) was projected to be maintained as very good due to the opportunity to expand within Melbourne Water's Western Treatment Plant land. All other estuaries declined to very low, reflecting the inability of estuaries in current or future urban or industrial areas to migrate into a constricted landscape as sea levels rise.

Long term target setting

To set long term targets a set of assumptions were made about the potential for change into the future. It was assumed over the long term that;

- Estuarine connectivity would improve for those estuaries in a rural landscape(i.e. Westernport and Werribee catchments) due to the assumption that these could migrate further in the landscape as sea levels rise. This assumes that farmland can be forgone for this purpose and/or a barrier can be removed.
- Estuarine connectivity would decline for those estuaries in current or future urban or industrial areas reflecting the inability of estuaries to migrate into a constricted landscape as sea levels rise.

Each estuary was assessed via desktop using aerial photography to determine the long term target. Some urban estuaries were allocated higher targets than current BAU scenario if migration into landscape was deemed possible due to close proximity of public or recreational land.

5.6.3 10 year Performance Objective

The 10 year performance objectives for estuarine wetland connectivity were largely focused on protecting and improving vegetation quality and re-engaging floodplains:

- Enable lateral and longitudinal migration of estuarine vegetation communities on the floodplain to allow adaptation to climate change risks.

- Identify opportunities to re-engage estuarine floodplains and wetlands
- Investigate opportunities to mitigate climate change impacts to significant salt marsh vegetation community by facilitating lateral or longitudinal migration on the floodplain including in Altona Meadows Natural Features Reserve and aligning with planned mitigation measures for Cheetham Wetlands.

5.6.4 Key assumptions and improvement opportunities

AVIRA was developed for regional freshwater rivers and as such, has some limitations when extrapolated to estuaries in the Melbourne area. For future iterations of the Healthy Waterways Strategy, the Index of Estuary Condition methodology should be adopted when filling in data gaps on estuarine wetland connectivity.

5.6.5 References

DELWP (2015). Aquatic Value Identification and Risk Assessment (AVIRA) Manual, State of Victoria: Department of Environment, Land, Water and Planning.

Lloyd, L.N., Cooling, M., Gippel, C. & Watkins, D. (2013). Melbourne Water Estuary Prioritisation Tool. Lloyd Environmental Developed for Melbourne Water.

5.7 Water Quality

5.7.1 Current state

The assessment of the current rating of the estuarine water quality waterway condition incorporated elements of the AVIRA poor water quality threat category (DELWP, 2015) (see Table 73). Alternate data sources were required from those recommended in the AVIRA framework due to lack of data. Field based and remote sensed data were key inputs as described below.

Table 73. Data used to determine the current rating of the estuarine water quality waterway condition.

AVIRA threat category	AVIRA metric	Measure(s) used to determine current rating	Data source / notes	HWS Scoring
Poor water quality*	Degraded water quality	Ability to meet EPA guideline values for: DO, DO, turbidity, pH, Chlorophyll	IEC Water Quality Sub Index using 2ISC. *Largely 'no data' available*	Very high: Meets all EPA Victoria water quality guideline values for estuaries IF NO MONITORING SITE THEN No algal blooms are known to have occurred in the estuary in the last 10 years AND
		Frequency of algal blooms	Algal blooms observed in field or conditions observed likely to lead to algal blooms (i.e. high runoff area).	
		Excessive Instream	Excessive instream macrophyte growth observed in field.	

AVIRA threat category	AVIRA metric	Measure(s) used to determine current rating	Data source / notes	HWS Scoring
		Macrophyte Growth		No fish deaths resulting from anthropogenic degradation of water quality are known to have occurred in the last 10 years AND <5% of the estuary length has excessive instream macrophyte growth Moderate: Fails to meet one EPA Victoria water quality guideline values for estuaries IF NO MONITORING SITE THEN Algal blooms occur every 3 to 10 years (on average) OR Fish deaths resulting from anthropogenic degradation of water quality occur every 3 to 10 years (on average) OR 5-25% of the estuary length has excessive instream macrophyte growth Low: Fails to meet two or more EPA Victoria water quality guideline values for estuaries IF NO MONITORING SITE THEN Algal blooms occur every 1 to 2 years (on average) OR Fish deaths resulting from anthropogenic degradation of water quality occur every 1to 2 years (on average) OR
	Disturbance of Acid Sulphate Soils	Potential of adjacent land to contain Coastal Acid Sulphate Soils	Coastal Acid Sulphate Soils (www.data.vic.gov.au) Australian Soil Resource Information System – Atlas of Australian Acid Sulfate Soils mapping - Probability code A	

AVIRA threat category	AVIRA metric	Measure(s) used to determine current rating	Data source / notes	HWS Scoring
				>25% of the estuary length has excessive instream macrophyte growth

**The poor water quality score was determined by a combination of the three degraded water quality metrics, as outlined in Jacobs 2018a.*

5.7.2 Setting scenarios

Forecast current trajectory under business as usual scenario

A long-term Business as Usual trajectory (current trajectory) was based on rules and assumptions around the likely impacts of significant future threats, particularly climate change and urbanisation. Accordingly, predictions on the current trajectory for key value status and waterway condition ratings were moderated (from current rating) as outlined in Table 74.

Table 74. BAU trajectory assumptions for water quality

Estuary condition	Current trajectory assumptions
Water quality	Under current trajectory, water quality in all condition in all estuaries was expected to decline significantly. Causes include: • Lower catchment flows leading to longer residence time for water in the estuary (less flushing) and more algal blooms • Increased stormwater impacts from a more urbanised catchment (increased DCI and nutrient levels) • Increased salinity associated with the combination of sea level rise and reduced catchment flows. Accordingly, all water quality scores declined to very low under current trajectory.

Long term target setting

To set long term targets a set of assumptions were made about the potential for change into the future. It was assumed over the long term that water quality condition will slightly improve from the BAU trajectory as a consequence of managing stormwater impacts through implementation of 25% reduction in attenuated imperviousness uniformly across the region from current value.

5.7.3 10 year Performance Objective

The 10 year performance objectives for estuarine water quality largely focused on improving water quality from agricultural land practices:

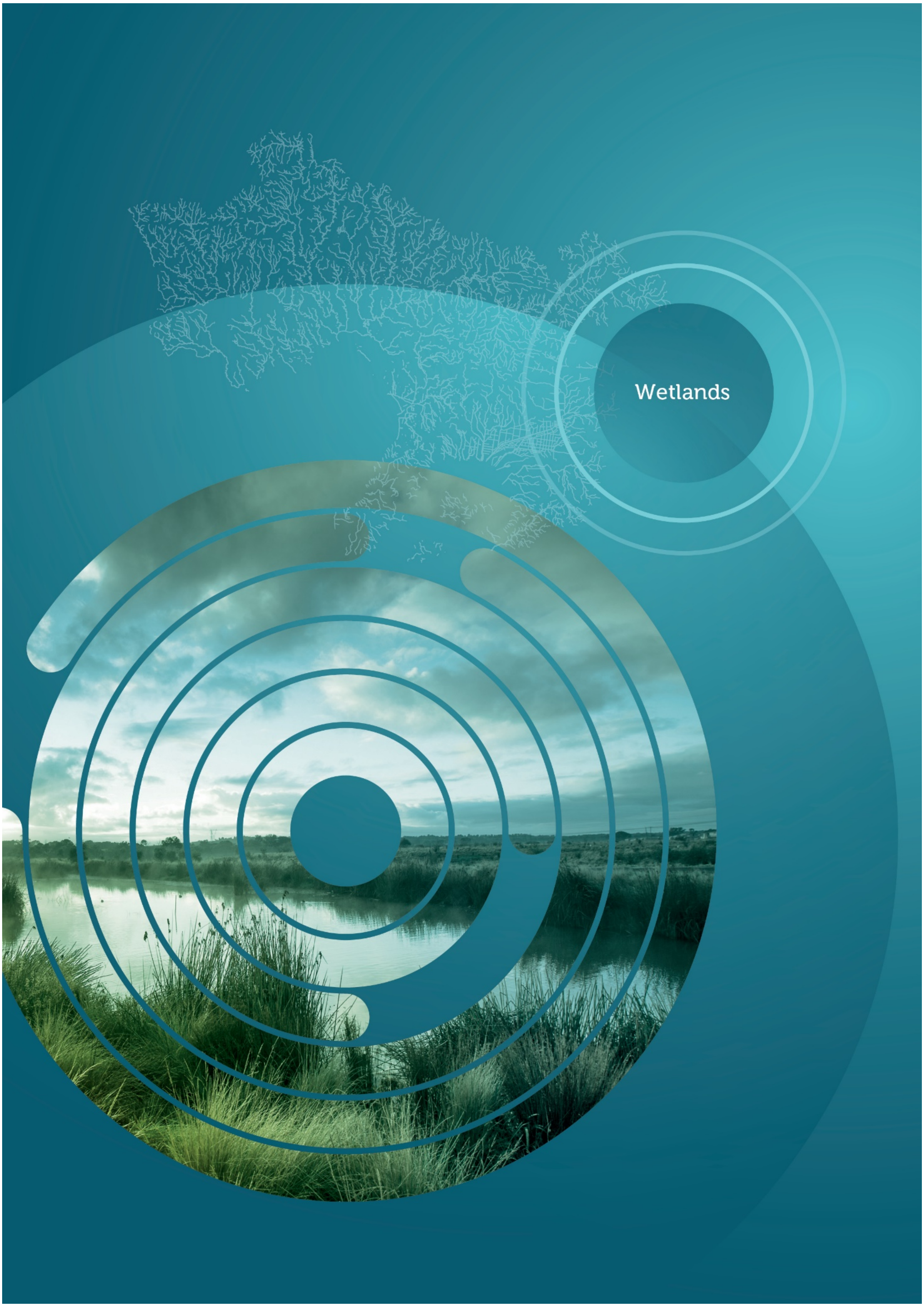
- Implement rural land program in catchment to minimise sediment and nutrient loads to the estuary.
- Monitor and reduce the threat of catchment sediment impacts on the estuary.

5.7.4 Key assumptions and improvement opportunities

AVIRA was developed for regional freshwater rivers and as such, has some limitations when extrapolated to estuaries in the Melbourne area. For future iterations of the Healthy Waterways Strategy, the Index of Estuary Condition methodology should be adopted alongside the metric used for riverine water quality.

5.7.5 References

DELWP (2015). Aquatic Value Identification and Risk Assessment (AVIRA) Manual, State of Victoria: Department of Environment, Land, Water and Planning.


Wetlands

6 Wetland values

6.1 Introduction

Wetlands are areas that hold static or very slow moving water. They can be natural, modified or artificial and be subject to permanent or temporary inundation by fresh or saline water. Wetlands are also known by many different names and can also be referred to as swamps, billabongs, marshes, ponds, lagoons to name a few

The previous Melbourne Water Healthy Waterways Strategy (2013) focussed on rivers and creeks. A significant improvement in the new HWS 2018 has been the incorporation and development of targets for prioritised wetlands. There are over 14,000 natural wetlands and 370 constructed wetlands in the Port Phillip and Westernport Region covered by the HWS 2018.

Whilst many wetlands have significant environmental, social or economic values, a sub-set of wetlands was selected based on a list of known significant wetlands that Melbourne Water currently manages. This was done to prioritise efforts for managing highly significant social and environmental values. The wetlands selected for analysis were based on the following criteria related to recognised listing and/or high environmental, social or cultural values:

- International significance
    - Ramsar, Important Bird Areas listed wetlands
- National Significance
    - Wetlands included in the Directory of important Wetlands in Australia, Seasonal Herbaceous Freshwater Wetlands, Growling Grass Frog reserve wetlands, Dwarf Galaxias habitat ponds
- Regional Significance
    - Sites of Biodiversity Significance (SoBS), DNRE 2000 biosites, Western wetlands, Yarra billabongs
- Local significance
    - Constructed wetlands with high environmental values (i.e. listed species)
    - Wetlands with high cultural and/or social values

The wetlands selected for analysis are shown in Figure 39 and their significance is outlined in Table 75. Note that some constructed wetlands were added during the co-design process with the community due to feedback that these wetlands had significant values they wished to maintain or improve.

During the analysis undertaken for the Strategy, the list of 133 wetlands assessed was consolidated to 81 wetlands/wetland complexes. In some cases, wetlands were combined where they had a similar function (e.g. stormwater treatment wetlands that are listed as Sites of Biodiversity Significance) or where they formed the one site for management purposes (e.g. wetlands within Western Treatment Plant or Eastern Treatment Plant). There are also some anomalies left out of the wetland list such as the WTP operational ponds (which are RAMSAR listed), due to operational constraints on these wetlands.

It is important to note that at the time of writing the HWS 2018, there was limited data and targets for wetlands across the region. The HWS 2018 does not preclude consideration of other wetlands through the implementation period. It is anticipated that through the Monitoring Evaluation and Reporting Improvement (MERI) plan, additional wetlands can come under the umbrella of the wetland performance objectives.

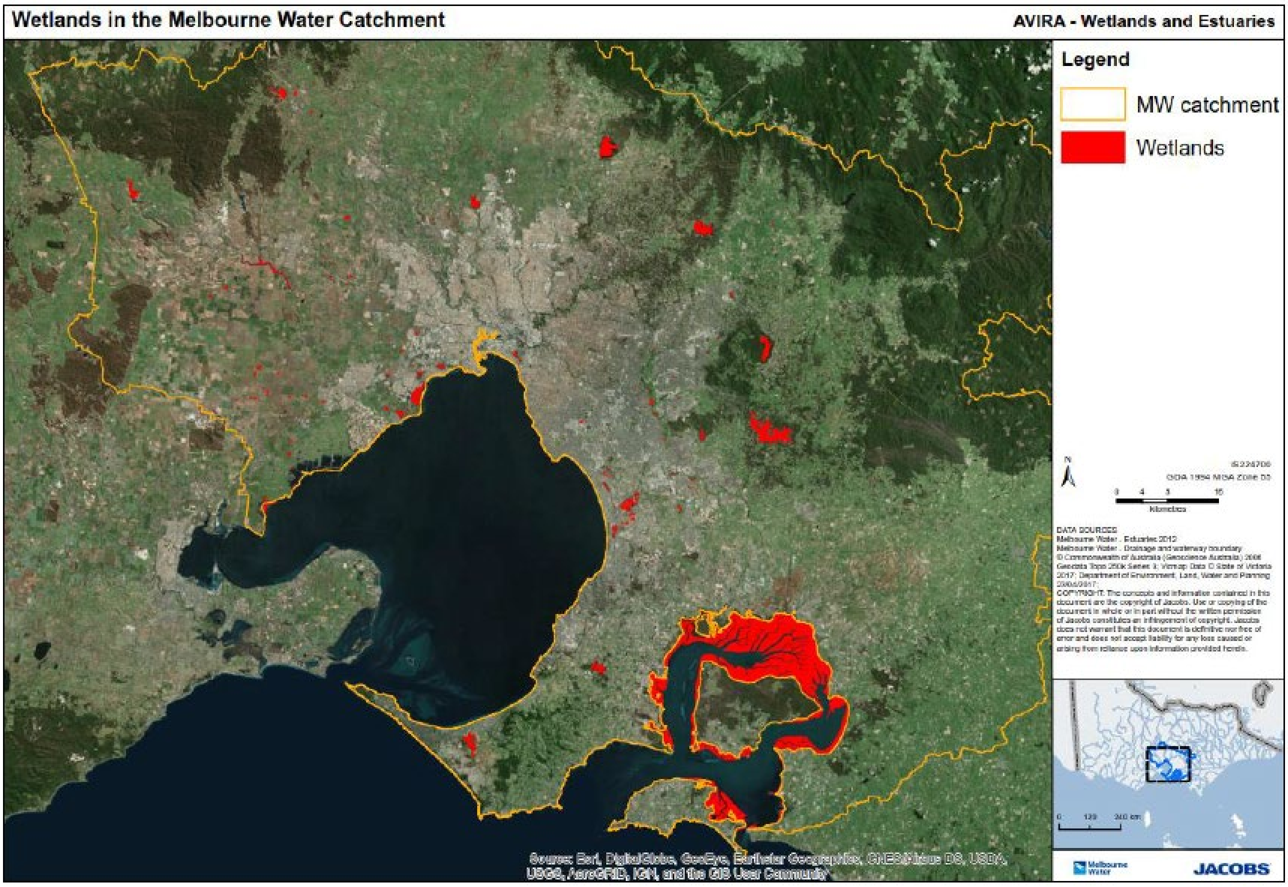


Figure 39. Wetlands included within the analysis for the HWS 2018

Table 75. Wetlands included in HWS 2018 and their significance

Catchment	Wetland Type		
Maribyrnong	**Potential SoBS** Gisborne Marsh Jacana wetlands	**High social value** Pipemakers Park Queens Park wetlands Greenvale Reservoir	
Werribee	**Ramsar** Point Cook Wetlands - RAAF Lake Point Cook Wetlands - Spectacle Lake The Spit Nature Conservation Reserve WTP - Paul & Belfrages Wetland WTP - Ryans Swamp Western Treatment Plant - Ponds **DIWA** Cheetham Wetlands **SoBS** Cherry Lake Truganina Swamp, Laverton Creek	**SHW** Balls Wetland Complex Baths Swamp Black Forest Rd Wetland Cobbledicks Ford cluster Greens Rd E Wetland No. 2 Kirksbridge Rd W Wetland Kororoit Creek No. 3 Live Bomb Wetland Paynes Rd Swamp Rabbitters Lake & swamp Richmonds Grass Swamp Rockbank No. 1 Rockbank Railway Swamp Target Range Swamp Troups Rd Swamp West Quandong Swamp Wyndham Vale Swamp	**Western Wetlands** Altona Treatment Plant Black Swamp Cunningham's Swamp Deans Marsh, Rockbank Paisely Challis Wetland, Jawbone Reserve Laverton RAAF Swamp **Others** Jenz swamp Holden Rd Wetland, Diggers Rest Bingham's Swamp
Yarra	**SHW** Hearnes Swamp Kalkallo Creek Wetland **High value/ priority billabongs** Banyule Flats Billabong Bolin Bolin Billabong Burke Road Billabong Domain Chandon Billabongs Spadonis Billabong Willsmere Billabong Yarra Bridge Stream Side Reserve	**SoBS** Yering Backswamp **GGF reserves** Growling Grass Frog reserve wetlands **Western Wetlands** Donnybrook Road Lake Westgate Park wetlands	**High social value** Annulus Billabong, Yarra Flats Hays Paddock Billabong Lillydale Lake Ringwood Lake **Other** Growling Grass Frog reserve wetlands Stormwater wetlands Cockatoo swamp

Catchment	Wetland Type		
Dandenong	**Ramsar** Edithvale Wetlands Seaford Wetlands **Important Bird Area** Banyan Waterhole Boggy Creek Stormwater Treatment Wetland Braeside Park Eastern Treatment Plant wetlands **SHW** Barnbam Swamp Tirhatuan Wetlands, **Dwarf Galaxias** Dwarf Galaxias habitat ponds - Dandenong Creek	**SoBS** Dwarf Galaxia Conservation Wetland, Narre Warren Hallam Valley Floodplain wetlands Tamarisk Waterway Reserve wetlands Wannarkladdin Wetlands Winton Wetlands	**Constructed** Ten Dandenong Catchment stormwater treatment wetlands
Westernport	**Ramsar** Westernport (including coastal wetlands)	**DNRE 2000 Biosites** Tootgarook Swamp SoBS Cardinia Creek Retarding Basin	**High social value** Coolart Wetlands The Briars **Other** Lang Lang floodplain wetlands Yallock Creek floodplain wetlands

Four environmental key values were identified as representative measures of wetlands; vegetation, birds, fish and frogs. The remaining two environmental key values of platypus and macroinvertebrates were not included due to:

- the assumption that platypus only use wetlands opportunistically (for example, billabongs along the Yarra that intermittently connect to the river) and so were not reported as a key value for wetlands.
- insufficient data or no available metric to identify macroinvertebrate status in wetlands. A macroinvertebrate metric may be developed for wetlands during implementation of the strategy.

The lack of suitable metric for wetland fish was identified as a knowledge gap for wetlands. The fish value status was reported for wetlands only where a significant fish species, such as Dwarf Galaxias, is known to occur.

A summary of the key environmental values in estuaries and their corresponding environmental conditions in provided in Figure 40.

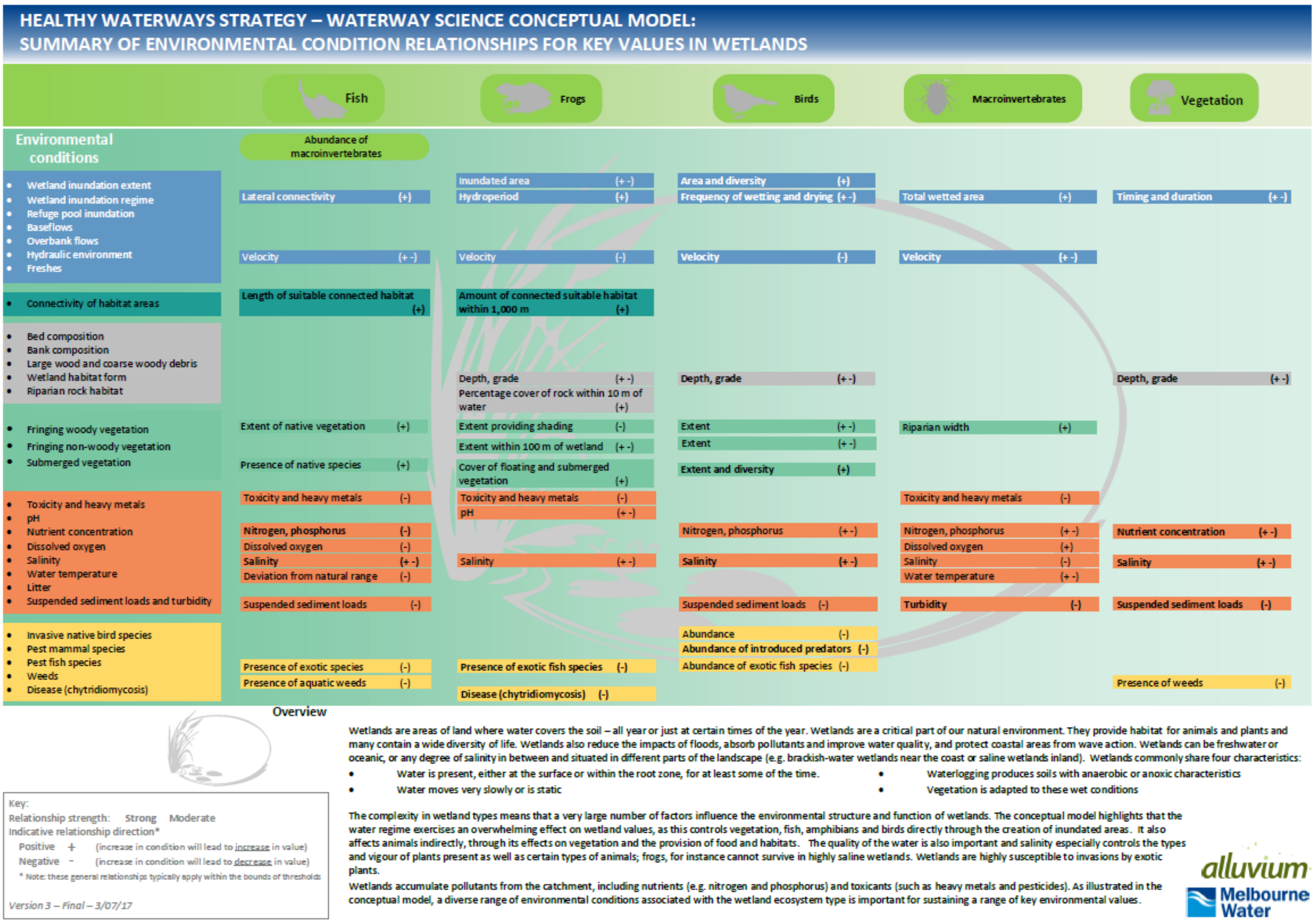


Figure 40. Summary of environmental values and the condition relationships for estuaries (Alluvium 2017).

Whilst many wetlands in the region provide significant social values, a significant lack of data lead to the exclusion of reporting on these values in the HWS. Benchmarking social values of wetlands will be undertaken during strategy implementation.

The cultural values of wetlands, that is the physical and spiritual connection of people to land and waters is important to Aboriginal Traditional Owners. Their connection to wetlands in this region has been damaged by the processes of colonisation and urbanisation and as such, knowledge of the cultural values is limited. There are some exceptions to this, such as Bolin Bolin Billabong which has been identified by Wurundjeri people as being highly cultural significant. Where this knowledge is available, it has been included in the selection of the 81 wetlands and referred to in performance objectives for a particular wetland.

The economic values of wetlands are currently not well understood or comprehensively analysed. Data and knowledge to better understand these values needs to be developed so that catchment specific targets and performance objectives can be developed for wetland economic values in the future.

Ramsar Convention

A number of wetlands of international importance occur within the Melbourne Water catchment, including the Edithvale-Seaford Wetlands, Port Phillip Bay (Western Shoreline) and Bellarine Peninsula and Western Port Ramsar sites. These sites are Ramsar-listed and are managed under site specific management plans. Performance objectives for Ramsar wetlands under the refreshed HWS have been adopted from the relevant management actions under these plans. Additionally, performance objectives have been developed to specifically address adaptation to the impacts of climate change. For example:

- Implement the Edithvale-Seaford/Western Port Ramsar/Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site Management Plans and plan for climate change adaptation and resilience.

The approach used to determine the current state of estuarine key values was based on the AVIRA method (refer to Section 1.5). A brief summary of the main steps involved in the process is outlined below.

Collating data on values and threats:

- Undertaking a data inventory to map existing Melbourne Water and state data sources against the AVIRA metrics and measures. Due to the time constraints of this project, the population of the data inventory focused largely on available spatial datasets that could be used consistently to assign value measures and metrics across the Melbourne Water region.
- Undertaking a wetland workshop in early 2018 to populate some of the metrics and measures for the selected estuaries based on local and expert knowledge and to identify data gaps.
- Undertaking gap-filling activities including an additional report and data review for wetlands.

Developing value and threat scores:

- Developing AVIRA value and threat scores for each measure for each wetland/wetland complex (based on the existing and newly captured data). This included assessing threats to wetland values using the AVIRA risk assessment framework (the existing statewide AVIRA spreadsheet for wetlands was modified to be more appropriate to the HWS).

  AVIRA value, threat and risk data were collated for 132 wetlands/wetland complexes across the region for the HWS. It is acknowledged that there are data gaps, however, an important part of any planning process is acknowledging those gaps and providing actions to fill these in the future. AVIRA includes protocols for missing data.

Identifying wetland trajectories under various scenarios

- Hosting a workshop with experts in aquatic ecology, environmental flows, wetland and estuary ecology and management to assess which threats are most likely to impact wetland key values and conditions and how this is likely to vary across the region and wetland typology (see Box 11). In particular, which threats would be particularly exacerbated by climate change and urbanisation.
- Using outputs from this workshop and expert opinion to combine AVIRA metrics to develop rules-based metrics to determine current state and current trajectory for each estuary and wetland asset. Metrics were refined to ensure that they were appropriate to the region and asset types and based on the available data.

  Threats scores that had been rated as increasing under climate change and urbanisation were moderated up to a high.
- Reviewing preliminary scores against local knowledge of the assets. These reviews could alter the rating in either direction if additional knowledge showed the site to have a different current state or trajectory than indicated by the AVIRA score. Comments received from subject matter or local experts and used to refine the value status and trajectory ratings.

Developing performance objectives

- The AVIRA risk assessment informed the development of performance objectives for wetlands. The risk assessment recommends a treatment (reduce risk, protect, fill data gap, no action) based on the relationship (association) between the values and threats. Where a risk was rated high or very high and the recommended treatment was 'reduce threat level, performance objectives were developed to address these threats.
- In addition to the 'current' level of risk identified by AVIRA, the trajectories information was used to consider 'future' level of risk under the 'current trajectory' scenario. Where the risks were likely to become high or very high a performance objective was identified to address the threat (see Box 12).
- Actions arising from co-design workshops were also considered and where they related to protecting existing high value vegetation were included in the formulation of the targets.
- Feasibility was also assessed through testing with stakeholders, use of aerial photographs and reviewing existing plans and strategies. Performance objectives for the Ramsar wetlands were drawn from the Ramsar management plans, and where an additional threat was identified, particularly the likely threats under the 'current trajectory' scenario, performance objectives were added where likely to be feasible.

Box 11. Wetland Typology

A typology for wetlands in the Melbourne Water region was developed based on findings from expert workshops regarding the key characteristics of wetlands in the region. This was used to guide 'rules-based' decisions determining the trajectory of key values and waterway conditions. The three main typologies are based on both wetland geology/geomorphology and position in the landscape. The typologies are Basalt plains (Maribyrnong and Werribee rivers), Alluvial Plains (Yarra, Westernport and Dandenong) and coastal wetlands (see Figure 41). A further three subsets sit under these typologies, based on land use. These are: existing urban, urban growth area, forest and/or remaining rural.

It must be noted that a range of wetland typologies have been developed and are used for the classification and management of wetlands both at the state and federal level, and this typology does not override these. This typology was developed solely for HWS planning and is not intended to be utilised for other purposes.

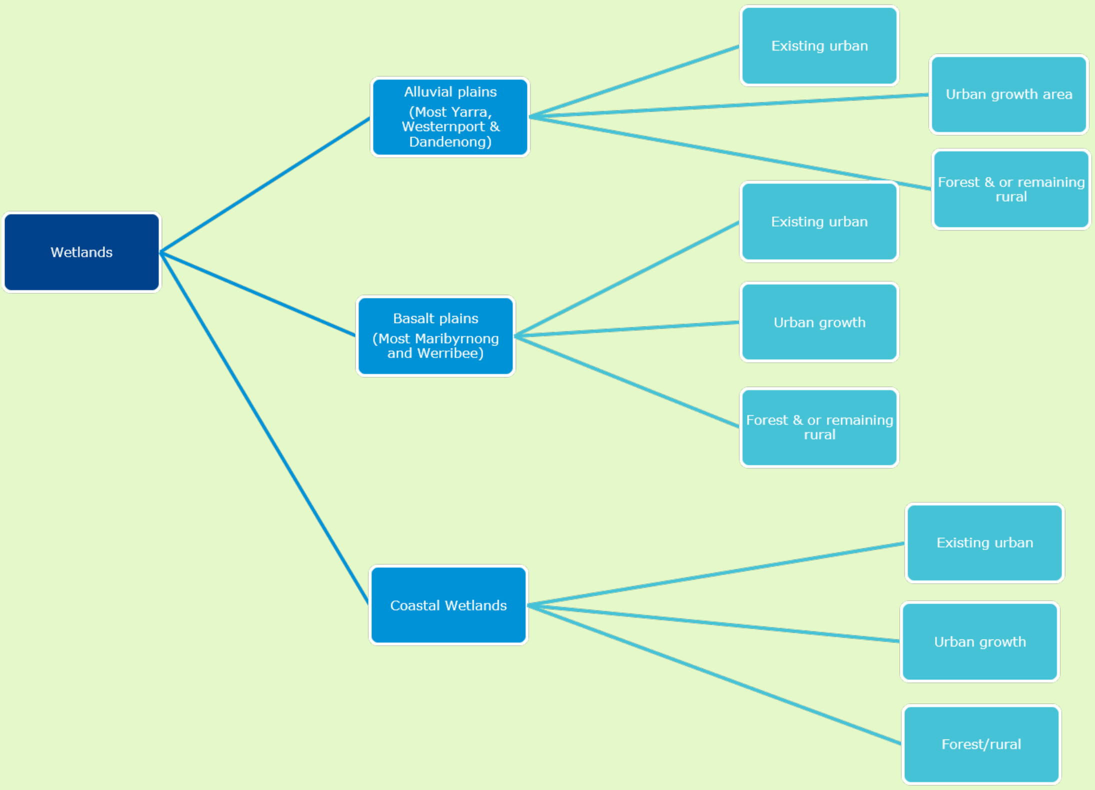


Figure 41. Typology adopted for trajectory planning for wetlands in the HWS.

Box 12. Wetland Trajectory

In the absence of quantitative models such as Habitat Suitability Models for wetlands, predictions on the current trajectory for wetlands, were aided by the use of the wetland typologies introduced in Box 11.

For each group, the projected current trajectory of condition was predicted based on high level threats to that group, based around catchment characteristics such as bioregion and development trajectory. Victorian bioregion classifications are shown in

Figure 42.

Wetlands located in the alluvial plains are considered to have a better trajectory than those located in the coastal and basalt plains regions as in many cases there are management options available to protect these (such as environmental flow releases and pumping of water to priority billabongs, particularly in the Yarra) and reductions in rainfall are projected to be less in the Yarra, Dandenong and Westernport catchments than in the western catchments (Maribyrnong and Werribee).

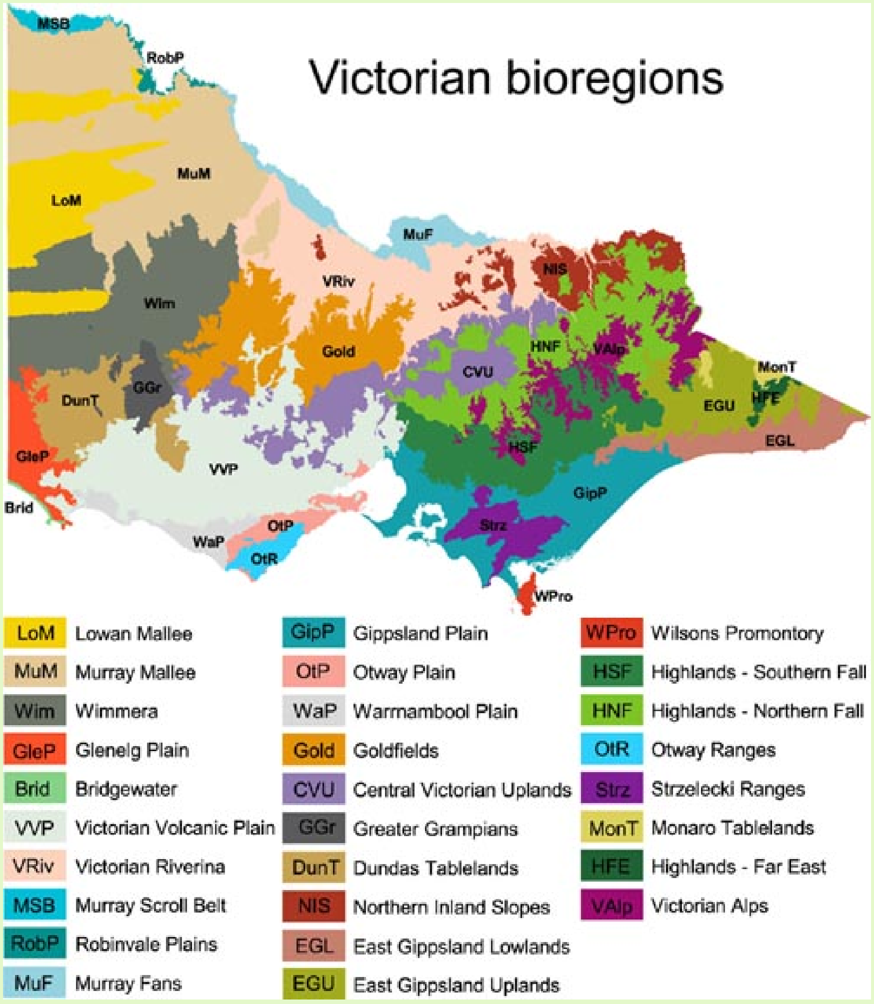


Figure 42. Victorian bioregions (DELWP, 2019).

Forward planning for adaption and migration of coastal wetland and estuarine vegetation is essential in light of predicted climate change impacts. Trajectory assumptions for wetlands are strongly influenced by their typology (Figure 43).

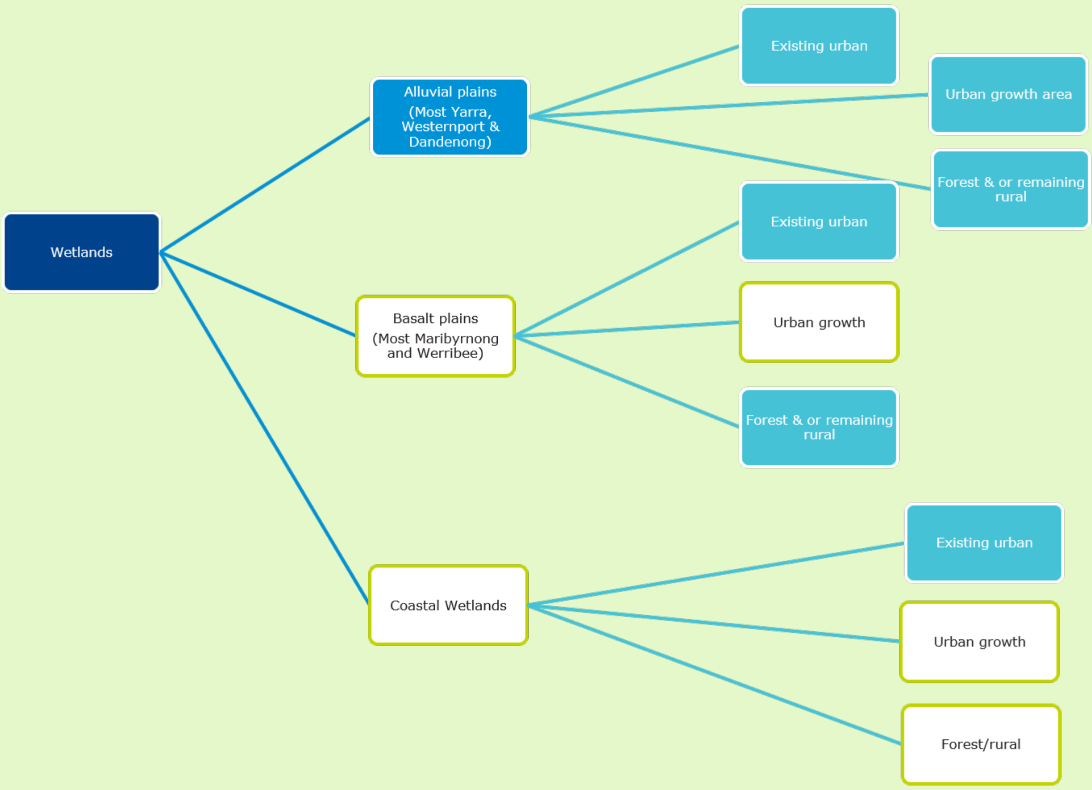


Figure 43. Typology adopted for trajectory planning for wetlands in the HWS showing wetland types (green outline) most at risk from urbanisation and climate change.

6.2 Key threats to wetlands

6.2.1 Climate Change

The range of impacts that climate change may have on wetlands is wide and varied (see Table 76), but the overarching driver is via changes in wetland hydrology, particularly the frequency and duration of inundation events (SKM, 2013). The impacts of climate change on wetland ecology is predicted to vary widely, depending on wetland type, proximity to the coast, catchment characteristics and climatic region.

Table 76. Predicted changes in wetlands (permanent and temporary) and their biotic communities in response to forecasts of changes in climate change drivers (Nielsen & Brock 2009, cited in DELWP 2013)

Driver	Changes–permanent wetlands		Changes–temporary wetlands	
	Wetland changes	Biotic changes	Wetland changes	Biotic changes
Decreased rainfall	↓ Connectivity ↓ Wetland flushing ↑ Salinity ↑ Drying means ↓ wetlands in landscape	↓ Biota before salinity exceeds 1 g L^{-1} ↑ Distance for dispersal & recolonisation ↓ Habitat structure	↓ Inundation periods ↑ Dry periods ↓ Flushing of salts leads to ↑ salinity	↓ Time for biota to reproduce ↑ Seedbank depletion with ↑ drying time ↓ Habitat structure
Increased temperature	↑ Evaporation leads to ↓ water levels	↓ Time for biota to reproduce ↓ Habitat structure	↓ Inundation periods ↑ Concentration of salt	↓ Time for biota to reproduce ↑ Seedbank depletion with ↑ drying time ↓ Habitat structure ↓ Biota before salinity exceeds 1 g L^{-1}
Extreme events (short intense rainfall events)	↓ Connectivity ↓ Inundation times ↑ Drying means ↓ Wetlands in landscape	↓ Biota as permanent wetlands ↓ ↑ Time and distance for dispersal & recolonisation ↓ Habitat structure	↑ Dry periods	↑ Seedbank depletion with ↑ drying time ↓ Habitat structure
Salinity	↑ Salinity from ↓ flushing, evaporation & intrusion of saline groundwater	↓ Biota before salinity exceeds 1 g L^{-1} ↓ Biotic diversity ↓ Habitat structure	↑ Salinity from reduced flushing and evaporation	↓ Biota before salinity exceeds 1 g L^{-1} ↓ Biotic diversity ↓ Habitat structure
Management intervention	Managed for permanent water supply as permanent water reserve	↓ Loss of variability ↓ Habitat diversity ↓ Biotic diversity	↑ Periods of dry ↓ Reliability as seasonal water ↑ In cropping	↓ Time for biota to reproduce ↑ Seedbank depletion with ↑ drying time ↓ Habitat diversity ↓ Seedbank depletion through mechanical disturbance

Seedbank refers to dormant eggs of zooplankton and seeds of plants; (↓) decrease or reduction or loss of and (↑) increase or gain

Using information from the SKM (2013) wetland assessment and other relevant information, the climate change and values expert workshop identified that the wetlands most at risk from urbanisation and climate change were:

- Coastal wetlands within both rural and urban areas, due to sea level rise and storm surge projections and associated changes to water quality (increased salinity), inundation frequency and vegetation community change.
- Wetlands of the basalt plains within new urban growth areas due to both the physical loss of wetlands under development and changed hydrological regimes.

Coastal wetlands

The region's low-lying coastal wetlands and shallow wetlands rely on direct rainfall and are affected by saltwater intrusion from the sea. Climate change will impact on these ecosystems as a result of increased drought frequency and intensity, decreases in freshwater inputs, rising sea levels and increases in coastal storm surges. These conditions may also change the character of coastal wetlands through a reduction in size, conversion to dryland or a shift from one wetland type to another (e.g. brackish to saline). The retention of coastal wetlands will require planning approaches which allow for the landward movement of wetland communities in order to avert significant loss and degradation to coastal wetlands and associated biodiversity.

DELWP assessed wetland vulnerability to climate change. Wetlands most vulnerable to climate change include coastal wetlands located within and just above the intertidal zone and areas of low topography and wetlands adjacent to embayments and estuaries and where landward migration is restricted due to topography or linear barriers.

In low relief areas, sea level rise is likely to result in the permanent inundation of wetlands that are currently tidal. These wetlands comprise mostly estuarine reed bed wetlands and swamp scrub, although mangroves exist in the eastern part of region around the Bellarine Peninsula and western shore of Port Phillip Bay. Wetlands that are currently intermittently inundated during spring tides and storm surges will become more frequently inundated. These wetlands are mostly coastal saltmarsh systems. A change in the frequency of sea water inundation will have dramatic effects on wetland vegetation types. Mangroves will advance into saltmarsh communities in the eastern part of the region and where topography and land use allows, saltmarsh may be able to migrate inland. Given that much of the Port Phillip and Westernport coastlines are highly developed, either with urban or industrial development, in many cases there is little room for the saltmarsh community to migrate and it will likely be lost. In addition, these wetlands are also at risk from change due to urban growth, so a combined impact is possible.

Inland wetlands

For all inland wetlands, the primary impact of climate change, regardless of source water will be a reduction in the frequency and duration of inundation events and an increase in the duration of dry periods. The specific impacts on individual wetlands will depend on local characteristics and water sources. However, permanent wetlands will experience a more variable water regime with a shift towards a more seasonal wet and dry inundation pattern, may experience temporal changes in inundation events and may experience an increase in the number and /or duration of dry phases. Seasonal wetlands will experience a more intermittent wet phase and a longer duration dry phase. This may result in a shift in vegetation community structure away from species that are dependent on flooding (aquatic and semi-aquatic) to more terrestrial species that can tolerate occasional inundation. Intermittent wetlands may experience a longer dry phase, although they are already adapted to a mostly dry regime, so from a biological perspective are likely to remain relatively unchanged. In summary, there will be an increase in the number and area of intermittent wetlands and a decrease in the permanent and seasonal wetlands.

Regional differences

Climate change is predicted to affect different regions of Victoria in various ways. Two climate regions identified in the study are relevant to the Melbourne Water region. These are the South West – including the Werribee and Maribyrnong catchments and the South East including the Yarra, Dandenong and Westernport catchments. Under climate change the west of the region is likely to become drier than the east. Coastal wetlands have the potential to be impacted by sea level rise and coastal storm surges.

South West – including Werribee and Maribyrnong catchments (basalt plains)

Rainfall is predicted to decline by between 4 and 8 per cent by 2030 and between 8 and 16 per cent by 2055 in the Werribee and Maribyrnong catchments. Under a dry climate change scenario inundation frequency of rainfall fed wetlands will halve by 2055 (SKM, 2013).

The majority of wetlands in the South West are associated with regional groundwater systems and are hence unlikely to be significantly affected by climate change induced reductions in rainfall, at least in the short to medium term (next 50 years). These volcanic plain wetlands also have a saline nature and increased freshwater or stormwater may have an associated impact. Shallow wetlands that rely on groundwater from local flow systems as their primary water source are therefore likely to be at risk from climate change due to associated changes in groundwater quantity and quality. These wetlands may continue to receive surface run off from local rainfall, but the duration of inundation is likely to decrease if they become disconnected from the groundwater system. They may also dry out more quickly, even if inundated by rainfall, due to high recharge flux rates once groundwater levels fall (SKM, 2013).

In low relief areas, sea level rise is likely to result in the permanent inundation of wetlands that are currently tidal. These wetlands comprise mostly estuarine reed bed wetlands and swamp scrub, although mangroves exist in the eastern part of region around the Bellarine Peninsula and western shore of Port Phillip Bay. Wetlands that are currently intermittently inundated during spring tides and storm surges will become more frequently inundated. These wetlands are mostly coastal saltmarsh systems. A change in the frequency of sea water inundation will have dramatic effects on wetland vegetation types. Mangroves will advance into saltmarsh communities in the eastern part of the region and where topography allows, saltmarsh may be able to migrate inland. In addition, these wetlands are also at risk from change due to urban growth, so a combined impact is possible.

South East – including Yarra, Dandenong and Westernport catchments (alluvial plains)

Rainfall in the Yarra basin is predicted to decrease by between 8 and 14 per cent by the 2055 (SKM, 2013). In the south east region river fed wetlands along the major river systems are likely to experience a small to moderate reduction in the frequency of inundation for wetlands that would have historically experienced seasonal inundation around once every one to three years. In addition, regulated rivers have an impact on reducing overbank flow frequency.

For rain fed wetlands, an increase in the interval between inundation events from around once every 1 year to once every 2 years could occur under the worst case scenario by 2055. Implications for groundwater fed and coastal wetlands are as described for the South West. The groundwater fed wetlands tend to be of a fresher nature compared to the south west as they tend to be alluvial based.

Increased saltwater intrusion is also projected to expand the spread of salt tolerant weeds into saltmarsh communities, though effective management of this issue through weed control is feasible.

6.2.2 Urbanisation

Urbanisation impacts wetlands not just through loss of wetlands due to land use change, but also through changes to wetland and habitat form, vegetation and buffer removal, modified flows, loss of connectivity between wetlands and floodplains and increased pressure from recreational access.

Melbourne Water, as the Waterway Manager for the region undertakes works on waterways across the region through large and small capital projects and through operational actions such as maintenance. Wetlands haven't been subject to the same rates of investment as the rivers and creeks of the region, and there are most likely many types of wetlands across the region e.g. off-stream wetlands on private land that have not been able to access funding. The environmental water program (through the GDE program and billabong program) is starting to readdress this, in additional to other projects such as the Dandenong creek habitat creation. Additionally, wetlands associated with first order streams within the urban growth corridor are especially at threat through current policy and practice around urban development and drainage.

It is clear that current levels of investment in the regions wetlands will fall short of being able to maintain condition in light of climate change and urbanisation, except at some specific sites of focus. The practicalities of undertaking works on wetlands is also a function of land management i.e. ease of working is increased on Crown Land or Melbourne Water land compared to private land.

Urban planning provides an opportunity to minimise the effects of future population growth. Melbourne Water, as the regional drainage and floodplain authority, has a key role in assessing development proposals, providing advice and participating in the development of new planning guidelines and reviews and additions to planning schemes.

The collaborative approach to HWS 2018 development, along with the inclusion of range of on-stream and off-stream wetlands across a range of land tenure will drive investment in all wetlands types across the catchments.

A number of wetlands have also been protected through the Melbourne Strategic Assessment and Western Grasslands Reserve through the Planning process in recognition of their significance to species such as Growling Grass Frog or their significant wetland type such as Seasonal Herbaceous Wetlands.

6.2.3 References

Nielsen, D. L. and Brock M. A. (2009) Modified water regime and salinity as a consequence of climate change: prospects for wetlands of Southern Australia. Climatic Change 95, 523–533.

SKM (2013). Indicative Assessment of Climate Change Vulnerability for Wetlands in Victoria. Report prepared for Department of Sustainability and Environment (now DELWP).

6.3 Vegetation

6.3.1 Defining vegetation value

Many wetlands in the Melbourne Water region support rare and threatened vegetation species and communities. This includes Commonwealth Environment Protection and Biodiversity Conservation Act - listed Seasonal Herbaceous Wetlands as well as a range of vegetation communities and species of state significance.

6.3.2 Current state

Vegetation data exists in several forms which are listed in Section 2.1.2. Additional information included undertaking a data inventory to map existing Melbourne Water and state data sources against the AVIRA metrics and measures. Due to the time constraints of the HWS development process, the population of the data inventory focused largely on available spatial datasets that could be used consistently to assign value measures and metrics across the Melbourne Water region. Due to gaps in data sets, an additional report and data review process of vegetation condition data was undertaken for wetlands.

Mapping of Significant Wetland EVC used spatial intersect method using Native Vegetation EVC classes (100m buffer applied in line with AVIRA). Only EVCs with a Bioregional Conservation Status were retained for analysis. EVCs were then restricted to the water dependent EVCs listed in DELWP and Jacobs coastal project spreadsheets. Where a wetland supported more than one significant EVC the one with the highest status was applied (Jacobs, 2018).

The assessment of the current state of the wetland vegetation key value incorporated elements of the AVIRA naturalness and rare or threatened species value categories (see Table 77). Note that the assessment of the current state of the vegetation wetland value was solely based on the wetland vegetation condition AVIRA metric (see Table 69). Alternate data sources were required from those recommended in the AVIRA framework due to lack of data. Remote sensed data was a key input as described below.

Table 77. Data used to determine the current state of the wetland vegetation key value.

AVIRA value category	AVIRA metric	Measure(s) used to determine current state	Data source / notes	HWS scoring
Naturalness	Wetland vegetation condition	Condition of wetland Ecological Vegetation Class	• IWC biota sub-index • Melbourne Water SoBS database • Other literature • Aerial photography • DEPI 2013: Seasonal Herbaceous Wetlands assessment - rule set development	Note that scores were combined as follows: • Very high – If all 3 AVIRA metrics meet criteria: score of 5 • High – If vegetation condition = 5 and one other metric meets criteria • Moderate – If vegetation condition = 3 and one other metric meets criteria or condition is 5 • Low – If vegetation condition = 3 AVIRA score 1 - EVCs present completely displaced and meets one significance metric • Very low - If vegetation condition = 1
Rare or threatened species / communities	Significant flora	• Listed on the International Union for Conservation of Nature Red List • Listed under the Environment Protection and Biodiversity Conservation (EPBC) Act 1999 • Listed on the Advisory List of Rare or Threatened Plants in Victoria (VROT)	• Victorian Biodiversity Atlas (VBA) records post-1980 – records within 100m of a waterway. • Classified as water dependent significant flora as listed in AVIRA manual (DELWP 2015).	
	Significant Wetland EVC	• Ecological Vegetation Class Bioregional Conservation Status	• Native Vegetation - Modelled 2005 Ecological Vegetation Classes: Bioregional Conservation Status of EVCs (www.data.vic.gov.au)	

AVIRA value category	AVIRA metric	Measure(s) used to determine current state	Data source / notes	HWS scoring
			• Classified as water dependent EVC as listed in AVIRA manual (DELWP 2015). • DELWP - water dependent EVC list and refined wetland EVC list - Paul Boon/Jacobs (https://www.water.vic.gov.au/__data/assets/pdf_file/0025/68434/Climate-Change-and-Coastal-Wetlands_DSF_Volume-1.pdf)	

6.3.3 *Setting scenarios*

Forecast current trajectory under business as usual scenario

A long-term Business as Usual trajectory (current trajectory) was based on rules and assumptions around the likely impacts of significant future threats, particularly climate change and urbanisation. Accordingly, predictions on the current trajectory for key value status and were moderated (from current rating) as outlined in Table 78.

Table 78. Current trajectory of wetland vegetation key value

Value	Current trajectory assumptions
Vegetation	The current trajectory of vegetation values in wetlands on the basalt plains (western catchments) and in coastal wetlands was predicted to decline to very low as a result of changed hydrology, including groundwater contributions, reduced rainfall and runoff and saline intrusion in coastal wetlands. The current trajectory of vegetation values in most wetlands on the alluvial plains (eastern catchments) was also predicted to decline by one to two ranks with the exception of some billabongs in the Yarra catchment that are able to receive environmental water from the Yarra. These were predicted to stay at, or improve to, high vegetation values.

Long term target setting

To set long term targets a set of assumptions were made about the potential for change into the future. It was assumed over the long term that;

- The target trajectory of vegetation values in wetlands on the basalt plains could improve (from current BAU trajectory) once programs to improve wetland buffers, vegetation condition and habitat form are implemented. This also assumes that forward planning for adaptation and migration of coastal wetland vegetation is undertaken.
- The target trajectory of vegetation values in wetlands on the alluvial plains could improve (from current BAU trajectory) once actions to reduce threats of changed water regime and invasive plants and animals are implemented. The Western Port coastal wetlands are assumed to improve significantly from BAU current trajectory due to the opportunity to allow landward migration of key vegetation communities in the long term.

6.3.4 Priority conditions, threats and management interventions

Priority conditions

Several conditions interact to influence vegetation values in wetlands. The main condition targets and associated 10 year performance objectives which can be influenced to drive the long term vegetation value targets for wetlands are:

- Wetland vegetation (as a condition)
- Water regime
- Wetland habitat form
- Wetland buffer

Priority threats

The key threats to vegetation in wetlands is similar to those outlined in Section 2.1.4 for vegetation in rivers. The threats that frequently were applied to AVIRA framework include:

- Invasive flora
- Degraded estuarine vegetation
- Reduced floodplain and wetland connectivity
- Livestock access
- Habitat form
- Impact to buffers
- Poor water quality

- Modified flows

Priority management interventions

The main interventions that can be employed to reduce the threat to vegetation values include:

- Revegetation
- Pest plant control
- Stock exclusion fencing
- Mitigating impacts of urbanisation (eg through WSUD)
- Improving flow regimes

6.3.5 Relevant performance objectives

The 10-year performance objectives for wetland vegetation value were focused around protecting buffering vegetation and reducing the threat posed by invasive flora, particularly salt-tolerant species in coastal wetlands. Performance objectives also address knowledge gaps, particularly for management options to protect coastal wetlands from the impacts of sea level rise and storm surge.

- Improve/Increase the buffer of native vegetation around key wetlands and reduce the threat of invasive plant species
- Reduce the threat of invasive plant species, including the impact of salt tolerant species in significant coastal wetlands.
- Identify and assess management options for addressing risk to coastal wetland habitat from sea level rise and increasing coastal storm surge.
- Prepare adaption pathways for climate change impacts, including opportunities to maintain water regime through prevention of activities that increase the altered wetland area and altered wetland form threats (e.g. construction of levees).
- RPO-28. Seasonal Herbaceous Wetland vegetation communities are identified and a management program is in place to protect them on public and private land
- RPO-29. Programs, standards, tools and guidelines are in place to protect wetland vegetation communities from urban and rural threats, including adequate planning controls.

- RPO-30. Climate change resilient revegetation management practices are understood and implemented by selecting plant species, provenances and vegetation communities that are suited to projected future climatic conditions

6.3.6 Key assumptions and improvement opportunities

Data for wetlands in the region is limited, particularly for those sites located on private land. Consequently, a number of assumptions were made due to these data limitations. Data gaps regarding wetlands encountered during development of the strategy include but are not limited to:

- Very few Index of Wetland Condition assessments – assumption that alternative data sources used to collate information
- Incomplete mapping of flagship species for the region and their catchment – assumption that while more species may be present, the AVIRA assessment was based on available data
- Patchy data on flora and fauna values – assumption that remote sensing helped to provide additional information
- Wetland native fish (observed versus expected) – assumption that known populations are present. Where no data was available this was recorded.
- Stock access to wetlands (e.g. identification of fencing) - assumption that remote sensing undertaken helped to provide additional information
- Level of involvement of community groups – assumption that group is active
- Presence and level of impact of invasive species (plants and animals) – assumption that available information is current and correct.
- Degree of soil disturbance at wetlands – assumption that soil disturbance visible from aerial photography can be assessed into the different catogories
- Use of wetlands for rural water source for production, rural water storage, water carrier and water discharge – assumption that information in GIS layers is correct

Additionally, the datasets used in AVIRA assessment process are developed and contain data for a specific point in time (e.g. Wetland Inventory, Victorian Biodiversity Atlas) and thus have currency issues (Jacobs, 2018a).

Improvement opportunities for wetland data and monitoring will be developed through the HWS MERI Strategy and the associated Wetlands Monitoring and Evaluation Plan (MEP). A more comprehensive regional wetland ‘prioritisation’ assessment is planned late 2019 to include additional wetlands of ecological or social value.

6.3.7 References

Jacobs (2018), Wetlands and Estuaries in the Melbourne Water catchment: Value and Threat Assessment. A Report prepared for Melbourne Water Corporation by Jacobs Australia Pty Ltd, Melbourne, Australia

Nielsen, D. L. and Brock M. A. (2009) Modified water regime and salinity as a consequence of climate change: prospects for wetlands of Southern Australia. Climatic Change 95, 523–533.

SKM (2013). Indicative Assessment of Climate Change Vulnerability for Wetlands in Victoria. Report prepared for Department of Sustainability and Environment (now DELWP).

6.4 Birds

6.4.1 Defining Bird value

Thousands of migratory birds travel annually to Port Phillip Bay and Western Port wetlands from as far away as Alaska, Siberia, China and Japan. More than 280 bird species have been recorded just at Melbourne Water's Western Treatment Plant (Melbourne Water 2017). Wetlands in the region also support many rare and threatened endemic bird species such as the Brolga (*Grus rubicunda*), Australasian Bittern, Freckled Duck and the Orange-bellied Parrot (*Neophema chrysogaster*).

6.4.2 Current state

The assessment of the current state of the wetland bird key value incorporated elements of the AVIRA formally recognised significance, naturalness, rare or threatened species and landscape features value categories (Table 79). This was a similar approach to that used for estuarine bird values.

Table 79. Data used to determine the current state of the wetland bird key value.

AVIRA value category	AVIRA metric	Measure(s) used to determine current state	Data source / notes
Formally recognised significance	Ramsar sites	International significance - listed as a key feature of a Ramsar site	Ramsar Wetland Areas in Victoria dataset (www.data.vic.gov.au)
	East Asian-Australasian Flyway Sites	International Significance – listed as a key feature of an East Asian-Australasian Flyway Site	East Asian-Australasian Flyway Sites in Victoria (www.data.vic.gov.au)

AVIRA value category	AVIRA metric	Measure(s) used to determine current state	Data source / notes
	Nationally Important Wetlands	Listed in the Directory of Important Wetlands in Australia (DIWA)	Victorian Wetlands listed in – A Directory of Important Wetlands in Australia - DIWA (www.data.vic.gov.au)
Naturalness	Wetland vegetation condition	Condition of wetland Ecological Vegetation Class	• IWC biota sub-index • Melbourne Water SoBS database • Other literature • Aerial photography • DEPI 2013: Seasonal Herbaceous Wetlands assessment - rule set development
Rare or threatened species / communities	Significant fauna*	• Listed on the International Union for Conservation of Nature Red List • Listed under the Environment Protection and Biodiversity Conservation (EPBC) Act 1999 • Listed on the Advisory List of Rare or Threatened Plants in Victoria (VROT)	• Victorian Biodiversity Atlas (VBA) records post-1980 – records within 100m of a waterway. • Classified as water dependent significant fauna as listed in AVIRA manual (DELWP 2015).
	Significant Wetland EVC	• Ecological Vegetation Class Bioregional Conservation Status	• Native Vegetation - Modelled 2005 Ecological Vegetation Classes: Bioregional Conservation Status of EVCs (www.data.vic.gov.au) • Classified as water dependent EVC as listed in AVIRA manual (DELWP 2015). • DELWP - water dependent EVC list and refined wetland EVC list - Paul Boon/Jacobs (https://www.water.vic.gov.au/__data/assets/pdf_file/0025/68434/Climate-Change-and-Coastal-Wetlands_DSF_Volume-1.pdf)
Landscape features	Important bird habitats	Listed as an Important Bird Area (IBA) in AVIRA.	Meets at least one of four global criteria used by BirdLife International for IBAs, as listed in AVIRA manual (DELWP 2015).
		Listed as an Important habitat for migratory shorebirds in AVIRA	As classified by Birds Australia and listed in AVIRA manual (DELWP 2015).

6.4.3 *Setting scenarios*

Forecast current trajectory condition under business as usual scenario

A long-term Business as Usual trajectory (current trajectory) was based on rules and assumptions around the likely impacts of significant future threats, particularly climate change and urbanisation. Accordingly, predictions on the current trajectory for bird value status and were moderated (from current rating) as outlined in Table 80.

Table 80. Current trajectory for wetland bird value

Value	Current trajectory assumptions
Birds	The current trajectory of bird values in wetlands was assessed by incorporating the predicted wetland vegetation condition over the next 50 years[6]. As wetland vegetation condition is projected to decline to very low in all wetlands in the basalt plains under current trajectory, all current bird scores in the west were moderated down 2 ranks (unless already at 'very low'). On the alluvial plains, at wetlands where vegetation and bird habitat is predicted to be stable or improve due to environmental water delivery or intensive management (such as the Yarra Billabongs and Cockatoo Swamp), bird values are predicted to improve by one to two ranks. Bird values at other wetlands in the east are predicted to stay at low or very low.

Long term target setting

To set long term targets a set of assumptions were made about the potential for change into the future. It was assumed over the long term that;

- The target trajectory of bird values in wetlands on the basalt plains could improve (from current BAU trajectory) once programs to improve wetland buffers, vegetation condition and habitat form are implemented.
- The target trajectory of bird values in wetlands on the alluvial plains would remain the same or improve (from current BAU trajectory) once actions to reduce threats of changed water regime and invasive plants and animals are implemented. The Western Port coastal wetlands bird values are assumed to improve significantly from BAU

[6] For further discussion of projected decline in wetland vegetation values, see section Climate Change

current trajectory due to the opportunity to allow landward migration of key vegetation communities in the long term thereby providing habitat.

6.4.4 Priority conditions, threats and management interventions

Priority conditions

Several conditions interact to influence bird values in wetlands (refer to Figure 40). The main condition targets and associated 10 year performance objectives which drive the long term bird value targets for wetlands are:

- Wetland vegetation
- Water quality
- Wetland habitat form

Priority threats

The key threats to birds in wetlands is similar to those outlined in Section 2.2.4 for Riparian birds. The threats applied to the AVIRA framework include:

- Degraded wetland vegetation
- Invasive flora
- Invasive fauna
- Reduction in flow regime
- Degraded water quality

Priority management interventions

The main interventions that can be employed to protect or improve bird values in estuaries include:

- Revegetation of corridors to link habitat patches.
- Planning controls to preserve set-backs and areas of native vegetation.
- Revegetation to increase depth of wetland buffer zone.
- Pest plant and animal control
- Stock exclusion fencing

- Controlling human (and dog) access or disturbance.
- Promoting natural regeneration of vegetation (as opposed to revegetation)

6.4.5 Relevant performance objectives

The 10-year performance objectives for wetland vegetation value were focused around protecting buffering vegetation and reducing the threat posed by invasive flora, particularly salt-tolerant species in coastal wetlands. Performance objectives also address knowledge gaps, particularly for management options to protect coastal wetlands from the impacts of sea level rise and storm surge.

- Improve/Increase the buffer of native vegetation around key wetlands and reduce the threat of invasive plant species
- Reduce the threat of invasive plant species, including the impact of salt tolerant species in significant coastal wetlands.
- Identify and assess management options for addressing risk to coastal wetland habitat from sea level rise and increasing coastal storm surge.
- Prepare adaption pathways for climate change impacts, including opportunities to maintain water regime through prevention of activities that increase the altered wetland area and altered wetland form threats (e.g. construction of levees).
- RPO-28. Seasonal Herbaceous Wetland vegetation communities are identified and a management program is in place to protect them on public and private land
- RPO-29. Programs, standards, tools and guidelines are in place to protect wetland vegetation communities from urban and rural threats, including adequate planning controls.
- RPO-30. Climate change resilient revegetation management practices are understood and implemented by selecting plant species, provenances and vegetation communities that are suited to projected future climatic conditions.

6.4.6 Key assumptions and improvement opportunities

The data used to inform the metrics for the wetland bird values was limited in some areas due to limited or absent bird data (or not all available datasets used) or assumptions made on vegetation condition in wetlands based on remote sensing. The underlying rationale for incorporating vegetation condition into the bird key value condition is the reliance of birds on wetland vegetation for habitat (nesting, feeding and cover), with poor quality vegetation providing low habitat value and therefore affecting the success of key lifecycle stages of the birds. Given that vegetation condition has been applied as a strong driver for bird values in the Strategy, there is a plan to improve the data collation of this variable in the near future.

Improvement opportunities will be developed through the HWS MERI Strategy and the associated Wetlands Monitoring and Evaluation Plan (MEP).

6.4.7 References

DELWP (2015). Aquatic Value Identification and Risk Assessment (AVIRA) Manual, State of Victoria: Department of Environment, Land, Water and Planning.

DEPI (2013). The impact of Melbourne's growth on 'seasonal herbaceous wetlands (freshwater) of the temperate lowland plains'. Department of Environment and Primary Industries, East Melbourne, Victoria.

6.5 Frogs

6.5.1 Defining Frog value

The still and/or slow flowing waters and moist conditions of wetlands provide breeding habitat for frogs, insect food resources as well as aquatic vegetation that providing shelter for adult frogs and structures for biofilms and organic matter to grow, providing a food source for tadpoles. A range of frog species are found in the Melbourne Water region, including the Commonwealth Environment Protection and Biodiversity Conservation Act - listed Growling Grass Frog (*Litoria raniformis*). Refer to Section 7.3.1 for further context about the frog value.

6.5.2 Current state

The assessment of the current state of the wetland frogs key value incorporated elements of the AVIRA rare or threatened species value category, as well as a measure of current frog condition (taken from the streams key value assessment for frogs) (see Table 81). If there were records of significant amphibians, then the wetland scored high or very high. If there was no data, then the sub-catchment streams score for frogs was used.

Table 81. Data used to determine wetland frog current state.

AVIRA value category	AVIRA metric	Measure(s) used to determine current state	Data source / notes	HWS Scoring
Rare or threatened species	Significant frogs	• Listed on the International Union for Conservation of Nature Red List • Listed under the Environment	• Victorian Biodiversity Atlas (VBA) records post-1980. • Available reports	• Very high – supports significant frog species

AVIRA value category	AVIRA metric	Measure(s) used to determine current state	Data source / notes	HWS Scoring
		Protection and Biodiversity Conservation (EPBC) Act 1999 • Listed on the Advisory List of Rare or Threatened Vertebrate Fauna in Victoria (VROT)	• Melbourne Water threatened frog dataset *Note: Many of the wetlands had no data.*	• High—as per sub-catchment score • Moderate—as per sub-catchment score • Low —as per sub-catchment score Very low—as per sub-catchment score. As for estuarine vegetation key value (see Table 57).
Current frog condition - the sub-catchment score for frogs (*used if no data regarding significant frogs)*		The key value state of the sub-catchment was applied to each wetland, this was adjusted for significant amphibians score. I.e. if all, or most, of the expected species of frog are found, the status was very high.	As for Streams frog value	

6.5.3 Setting scenarios

Forecast current trajectory under business as usual scenario

A long-term Business as Usual trajectory (current trajectory) was based on rules and assumptions around the likely impacts of significant future threats, particularly climate change and urbanisation. Predictions on the future trajectory for frog key value status ratings was based on the assumptions outlined in Table 82.

Table 82. BAU trajectory for wetland frog value

Value	Current trajectory assumptions
Frogs	Frog values at wetlands on the basalt plains are predicted to decline to very low due to reductions in water availability associated with reduced rainfall. At wetlands on the alluvial plains that are able to receive environmental water, have a stable water regime, and/or support significant frog species (such as Growling Grass Frog ponds), it was assumed that the water regime could be managed to maintain the frog community, with high potential for a water regime intervention program to be successful. At these sites, frog value current trajectory was expected to be

Value	Current trajectory assumptions
	maintained or improved to high/very high. Frog values at all other wetlands on the alluvial plains declined to low or very low.

Long term target setting

To set long term targets a set of assumptions were made about the potential for change into the future. It was assumed over the long term that;

- The target trajectory of frog values in wetlands on the basalt plains could improve (from current BAU trajectory) once programs to improve wetland buffers, vegetation condition and habitat form are implemented. Additionally frog values could improve further in the Werribee wetlands if threats such as decline in water regime and water quality are effectively mitigated.
- The target trajectory of frog values in wetlands on the alluvial plains could improve (from current BAU trajectory) once actions to reduce threats of changed water regime and altered wetland form are implemented in addition to programs to improve wetland buffers and vegetation condition. The Yarra catchment wetlands frog values are assumed to improve significantly from BAU current trajectory due to environmental watering of key billabongs.

6.5.4 Priority conditions, threats and management interventions

Priority conditions

The main condition targets and associated 10 year performance objectives which drive the long term frog value targets are:

- Water quality
- Hydrology (wetland hydroperiod)
- Vegetation – especially connecting habitat

Priority frog threats

A list of threats and threatening processes for native frogs was compiled during the frog value assessment for rivers (see Section 2.3.4). These were applied to the AVIRA framework using the following threat categories;

- Reduce wetland area
- Altered wetland form
- Degraded buffer vegetation
- Changed water regime
- Invasive fauna
- Invasive flora
- Livestock access

Priority management interventions for frogs

The main interventions that can be employed to protect or improve frog values in wetlands was based on the assessment in section 2.3.4 and include:

- Planning controls to preserve set-backs and areas of native vegetation.
- Reinstating meanders or billabongs.
- Revegetation of corridors to link habitat patches.
- Improving water quality.
- Revegetation to increase depth of riparian or wetland buffer zone.
- Controlling introduced fishes (e.g. Gambusia and carp).
- Environmental flow releases.
- Further research (e.g. frog responses to management and climate change).
- Constructing new habitat wetlands.
- Promoting natural regeneration of vegetation (as opposed to revegetation).
- Stock exclusion fencing.
- Installation of rocks, wood and other ground cover.
- Bank stabilisation to reduce silt loads.
- Building road underpasses near new wetlands.
- Cat and/or fox control.
- Community education, e.g. signboards and infrastructure such as boardwalks

- Controlling human (and dog) access or disturbance.
- Converting concrete channels to earthen drains.
- Herbaceous or aquatic weed control.
- Woody weed removal.
- Litter collection.

6.5.5 Relevant performance objectives

The 10-year performance objectives for wetland frog values were focused around protecting refuge habitats through the provision of appropriate water regimes.

- Protect refuge habitats through providing an appropriate wetland water regime and vegetation buffer.
- Deliver environmental water to key billabongs on the Yarra floodplain.

6.5.6 Key assumptions and improvement opportunities

The following key assumptions were made at the time of developing the Strategy:

- Our records provide an accurate picture of frog species' distribution and monitoring is sufficient to detect changes in frog community.
- Vegetation and water management will have positive effects on native species of frog and lead to greater persistence of species in modified environments than would otherwise be the case.
- On-ground works can counteract the effects of climate change.

Some of the improvement opportunities to be progressed over time for the Strategy:

- Explore opportunity to include frogs in the Habitat Suitability Models
- Utilise eDNA to obtain more accurate frog presence and absence data for a wider range of sites

Improvement opportunities will be developed through the HWS MERI Strategy and the associated Wetlands Monitoring and Evaluation Plan (MEP).

6.5.7 References

Refer to section 2.3.6

6.6 Fish

6.6.1 Defining Fish value

Wetlands that intermittently connect to creeks and rivers are used by some fish species such as Pygmy Perch (*Nannoperca* spp.) and Galaxiids (*Galaxiella* spp.) for feeding, breeding and refuge. In the Melbourne Water region, wetlands such as Spadonis Billabong, Willsmere Billabong, and Yarra Bridge Stream Side Reserve among others, have been known to support a range of fish species. Very little data exists for wetland fish on the basalt plains (western region) and a metric for fish in this region will be developed through the Strategy implementation.

6.6.2 Current state

The assessment of the current state of the wetland fish key value incorporated elements of the AVIRA rare or threatened species and measures of significant fish and landscape featured value categories (see Table 83 below).

Table 83 - Data used to determine the current state of the wetland fish key value.

AVIRA value category	AVIRA metric	Measure(s) used to determine current state	Data source / notes	Scoring
Rare or threatened species	Significant fish	• Listed on the International Union for Conservation of Nature Red List • Listed under the Environment Protection and Biodiversity Conservation (EPBC) Act 1999 • Listed on the Advisory List of Rare or Threatened Plants in Victoria (VROT)	• Victorian Biodiversity Atlas (VBA) records post-1980. • Available reports *Note: Many of the wetlands had no data.*	Very high – significant fish species = 5 High to very Low – metric to be developed

6.6.3 Setting scenarios

Forecast current trajectory under business as usual scenario

A long-term Business as Usual trajectory (current trajectory) was based on rules and assumptions around the likely impacts of significant future threats, particularly climate change and urbanisation. Predictions on the future trajectory for frog key value status ratings was based on the assumptions outlined in Table 84.

Table 84. Current trajectory for wetland fish

Value	Current trajectory assumptions
Fish	Where there were significant species (such as Yarra Pygmy Perch or Dwarf Galaxiids) it was assumed that the water regime could be managed to maintain the fish community, with high potential for a water regime intervention program to be successful. In particular, for those wetlands connected to regulated rivers (such as the Yarra Billabongs) as there is the potential for flow releases or for those with an environmental watering program already in place. No BAU trajectory was developed for wetlands on the basalt plains due to limited data available.

Long term target setting

To set long term targets a set of assumptions were made about the potential for change into the future. It was assumed over the long term that;

- No target trajectory was developed for fish in wetlands on the basalt plains due to limited data available.
- The target trajectory of fish values in wetlands on the alluvial plains could be maintained or improved (from current BAU trajectory) once actions to improve the water regime are implemented on the basis of the presence of a significant species (e.g. Yarra Pygmy Perch or Dwarf Galaxiids).

6.6.4 Priority conditions, threats and management interventions

Priority conditions

Several conditions interact to influence fish values in wetlands. The main condition targets and associated 10 year performance objectives which can be influenced to drive the long term fish value targets for estuaries are:

- Flow regime
- Water quality
- Wetland vegetation

Priority threats

The key threats to fish in estuaries that frequently were applied to AVIRA framework include:

- Degraded wetland vegetation
- Altered streamflow seasonality
- Reduced floodplain and wetland connectivity
- Degraded water quality
- Invasive fauna
- Livestock access

Priority management interventions

The main interventions that can be employed to protect or improve fish values include:

- Revegetation
- Pest plant and animal control
- Stock exclusion fencing
- Improving flow regimes

6.6.5 Relevant environmental condition targets and performance objectives

Relevant performance objectives

The 10-year performance objectives for wetland fish values were focused around protecting refuge habitats through the provision of appropriate water regimes and reducing the impact of invasive fauna.

- Protect refuge habitats through providing an appropriate wetland water regime and vegetation buffer.
- Protect and enhance water regimes in wetlands with significant fish species and other significant values.
- Re-engage key floodplain wetlands to protect habitat for significant wetland fish species
- Reduce the threat of invasive fish species on significant wetland fish populations
- Protect wetland vegetation that provides habitat for significant wetland fish populations.
- Deliver environmental water to key billabongs on the Yarra floodplain.

6.6.6 Key assumptions and improvement opportunities

Some of the improvement opportunities to be progressed over time for the Strategy:

- Monitoring program implemented for wetlands which includes collation of data on fish present
- Further development of the fish value metric to include assessment of very low to high condition.

Improvement opportunities will be developed through the HWS MERI Strategy and the associated Wetlands Monitoring and Evaluation Plan (MEP).

6.6.7 References

N/a

6.7 Amenity, Recreation and Community Connection

6.7.1 Defining social values for wetlands

Some wetlands in the region have high social values associated with their variety of landscapes as well as the aesthetic enjoyment and recreational opportunities they provide. For example, wetlands enable people to access nature for picnicking, walking and viewing wildlife.

While there has been an increased policy focus on social values at the state and regional level and social conceptual models (Jacobs, 2018b) developed for waterways in the region, there is limited information available for wetlands.

Consequently this lack of data meant that an AVIRA assessment was not viable due to the extent of data gaps. The focus of the Strategy is to collate data and information so social values of wetlands can be recorded. This is reflected in the performance objectives outlined below.

6.7.2 Relevant performance objectives

Performance objectives have been developed to fill knowledge gaps related to social values, particularly:

- The amenity, community connection and recreation values of wetlands are better understood. Performance objectives are developed to enhance these values (Region-wide performance objective RPO-20)
- Develop understanding of the amenity, community connection and recreation values of wetlands and develop performance objectives to enhance these values.
- Maintain existing high value facilities that support passive enjoyment and recreation.

6.7.3 Key assumptions and improvement opportunities

Undertaking an assessment of the social values of wetlands is an important improvement opportunity for the Strategy going forward. Improvement opportunities will be developed through the HWS MERI Strategy and the associated Wetlands Monitoring and Evaluation Plan (MEP).

7 Condition metrics for wetlands

7.1 Introduction

Wetland condition refers to the overall state of the wetland and the key processes that underpin well-functioning wetland ecosystems. Wetland conditions support the wetland values (environmental, social, cultural and economic). Improvements in wetland conditions in turn improve the wetland values and the benefits that can be derived from that wetland. AVIRA threat data was used as the basis for reporting on condition of wetlands. The conditions supporting environmental key values for wetlands are assessed on the following:

- **Water regime**: Considers changes to the wetland water regime, including those that impact the flow regime of the wetland water source, interfere with the natural connectivity of flow to the wetland, involve disposal of water into the wetland, extraction of water from the wetland and changed wetland depth.
- **Vegetation condition**: Refers to the extent that the 'natural' wetland vegetation is intact, displaced and modified.
- **Wetland buffer condition**: Wetland buffer is native vegetation located above the maximum inundation extent.
- **Wetland water quality**: Considers changed water properties within the wetland including nutrient levels, salinity regime and the disturbance of acid sulphate soils.
- **Wetland habitat form**: Considers the extent that the wetland area has been reduced through levees, diversions, etc., and the extent that the wetland bed has been altered through excavation and land-forming activities.

The metrics and measures underpinning these assessments are described in further detail in the following sections.

7.2 Water regime

7.2.1 Current state

The assessment of the current rating of the wetland water regime waterway condition was based on an element of the AVIRA altered water regimes threat category - changed water regime (see Table 85). Alternate data sources were required from those recommended in the AVIRA framework due to lack of data. Remote sensed data was a key input as described below.

Table 85. Data used to determine the current rating of the wetland water regime waterway condition.

AVIRA threat category	AVIRA metric	Measure(s) used to determine current rating	Data source / notes	HWS Scoring
Altered water regimes	Changed water regime	Presence of Melbourne Water physical assets that would impact water regime (dams, channels, levees etc.) Some Melbourne Water SoBS and Seasonal Herbaceous Wetlands data	• DEPI 2013 – Seasonal Herbaceous Wetlands report • Melbourne Water Sites of Biodiversity Significance database • Melbourne Water asset data GIS layers - structure, levee, connector, channel • Wetlands_Current GIS layer • *Data only available for a subset of wetlands*	• Very high – minor or no change • Moderate – moderate change • Low – Significant change

7.2.2 Setting scenarios

Forecast current trajectory under business as usual scenario

A long-term Business as Usual trajectory (current trajectory) was based on rules and assumptions around the likely impacts of significant future threats, particularly climate change and urbanisation. Predictions on the future trajectory for water regime condition ratings was based on the assumptions outlined in Table 86.

Table 86. BAU trajectory assumptions for water regime in wetlands.

Wetland condition	Current trajectory assumptions
water regime	Water regime at wetlands on the basalt plains is predicted to decline to very low due to altered hydrology, with rainfall decline to be exacerbated in the west under climate change. In the alluvial plains, water regime was predicted to improve at sites that can receive environmental water or have a stable water regime, with all others predicted to maintain their current water regime condition.

Long term target setting

To set long term targets a set of assumptions were made about the potential for change into the future. It was assumed over the long term that;

- The target trajectory of the water regime on alluvial plains could be maintained or improved (from current BAU trajectory) once actions to improve the water regime are implemented on the basis of the presence of a significant species (e.g. Yarra Pygmy Perch, Dwarf Galaxiids, frog species).
- The target trajectory of the water regime on the basalt plains could be maintained or slightly improved (from current BAU trajectory) however, the condition is anticipated to still be low due to pressures of climate change and urban development (see section 6.2).

7.2.3 10 year Performance Objective

Performance objectives are designed to support maintaining the water regime for wetlands. At a regional level the performance objective is:

RPO-11 – Understanding for groundwater dependent ecosystems is improved and opportunities to maintain or improve these continue to be investigated

RPO-12 – Water for the Environment continues to be managed and delivered to the region's rivers and wetlands and recovery options continue to be investigated.

RPO-29 – Programs, standards, tools and guidelines are in place to protect wetland vegetation communities from urban and rural threats, including adequate planning controls.

At a local level the performance objectives include:

- Investigate opportunities to improve the water regime of key wetlands to meet ecological watering objectives, improve ecosystem services and cultural and social value.
- Protect and enhance water regimes in wetlands with significant fish species and other significant values
- Protect refuge habitat through providing an appropriate wetland water regime and vegetation buffer.

7.2.4 Key assumptions and improvement opportunities

The following key assumptions were made at the time of developing the Strategy:

- On-ground works can counteract the effects of climate change.
- The assumptions in the wetland typology model used for determining future trajectory are reasonable.

Some of the improvement opportunities to be progressed over time for the Strategy:

- Improvement opportunities will be developed through the HWS MERI Strategy and the associated Wetlands Monitoring and Evaluation Plan (MEP).

7.2.5 References

DELWP (2015). Aquatic Value Identification and Risk Assessment (AVIRA) Manual, State of Victoria: Department of Environment, Land, Water and Planning.

7.3 Wetland habitat form

7.3.1 Current condition

The assessment of the current rating of the wetland habitat form was based on the AVIRA threat metrics reduced wetland area and altered wetland form (see Table 87). Alternate data sources were required from those recommended in the AVIRA framework due to lack of data. Remote sensed data was a key input as described below.

Table 87. Data used to determine the current rating of the wetland habitat form waterway condition.

AVIRA threat category	AVIRA metric	Measure(s) used to determine current rating	Data source / notes	Scoring
Altered physical form	Reduced wetland area	Analysed change in wetland area between Wetlands_1788 and Wetlands_Current layers.	• WC reduced wetland percentage - • IWC Physical Form Sub-Index - IWC DB and • GHD 2009 IWC report • Site data • MW SOBS DB • Aerial imagery	*Note that the highest threat level from two metrics applied*. • Very high – up to 5% reduction in wetland area OR 0-5% of wetland form altered by excavation or land forming activities • High - >5 to 25% reduction in wetland area OR >5-25% of wetland form altered by excavation or land forming activities • Moderate - >25 to 50% reduction in wetland area OR >25-50% of wetland form altered by excavation or land forming activities • Low - >50 to 75% reduction in wetland area OR >50–75% of wetland form altered by excavation or land forming activities • Very low - >75% reduction in wetland area OR >75% of wetland form

AVIRA threat category	AVIRA metric	Measure(s) used to determine current rating	Data source / notes	Scoring
				altered by excavation or land forming activities

7.3.2 Setting scenarios

Forecast current trajectory under business as usual scenario

A long-term Business as Usual trajectory (current trajectory) was based on rules and assumptions around the likely impacts of significant future threats, particularly climate change and urbanisation. Predictions on the future trajectory for wetland habitat form condition ratings was based on the assumptions outlined in Table 88.

Table 88. BAU trajectory assumptions for wetland habitat form condition

Wetland condition	Current trajectory assumptions
Wetland habitat form	Habitat form at wetlands on the basalt plains is predicted to maintain or decline due to altered hydrology, with rainfall decline to be exacerbated in the west under climate change and pressures from urbanisation. In the alluvial plains, habitat form was predicted to improve at sites that can receive environmental water or have a stable water regime, with all others predicted to maintain their current habitat form condition. The habitat form for Coastal wetlands in Western Port are predicted to improve or decline depending on the opportunity for the wetland to migrate inland due to climate change.

Long term target setting

To set long term targets a set of assumptions were made about the potential for change into the future. It was assumed over the long term that;

- The target trajectory of wetland habitat form on alluvial plains could be maintained or improved to moderate (from current BAU trajectory) once actions to improve the water regime, and increase wetland buffers is implemented.
- The target trajectory of the wetland habitat form on the basalt plains could be maintained or slightly improved (from current BAU trajectory) however, the condition is anticipated to still be low/moderate due to pressures of climate change and urban development (see section 6.2).

7.3.3 10 year Performance Objective

Performance objectives are designed to support maintaining habitat form for wetlands. At a regional level the performance objective is:

RPO-42 - Wetland condition information and prioritisation, with a focus on vulnerable wetlands, is understood and informs collaborative planning.

At a local level the performance objectives include:

- Prepare adaption pathways for climate change impacts, including opportunities to maintain water regime through prevention of activities that increase the altered wetland area and altered wetland form threats (e.g. construction of levees).
- Identify and assess management options for addressing risk to coastal wetland habitat from sea level rise and increasing coastal storm surge.
- Monitor threat levels from invasive species on growling grass frogs and mitigate risks if required.

7.3.4 Key Assumptions and Improvement Opportunities

The following key assumptions were made at the time of developing the Strategy:

- On-ground works can counteract the effects of climate change.
- The assumptions in the wetland typology model used for determining future trajectory are reasonable.

Some of the improvement opportunities to be progressed over time for the Strategy:

- Increased knowledge about current wetland form based on site inspections
- Improvement opportunities will be developed through the HWS MERI Strategy and the associated Wetlands Monitoring and Evaluation Plan (MEP).

7.3.5 References

DELWP (2015). Aquatic Value Identification and Risk Assessment (AVIRA) Manual, State of Victoria: Department of Environment, Land, Water and Planning.

7.4 Wetland buffer

7.4.1 Current condition

Wetland buffer condition was measured using the IWC Wetland buffer assessment score.

A buffer is defined as the native vegetation adjacent to the wetland (from the maximum inundation level outwards). Native vegetation is defined as vegetation in which native species make up more than 25% of the total understorey cover.

A buffer only includes vegetation contiguous with the wetland and it may extend beyond 50m.

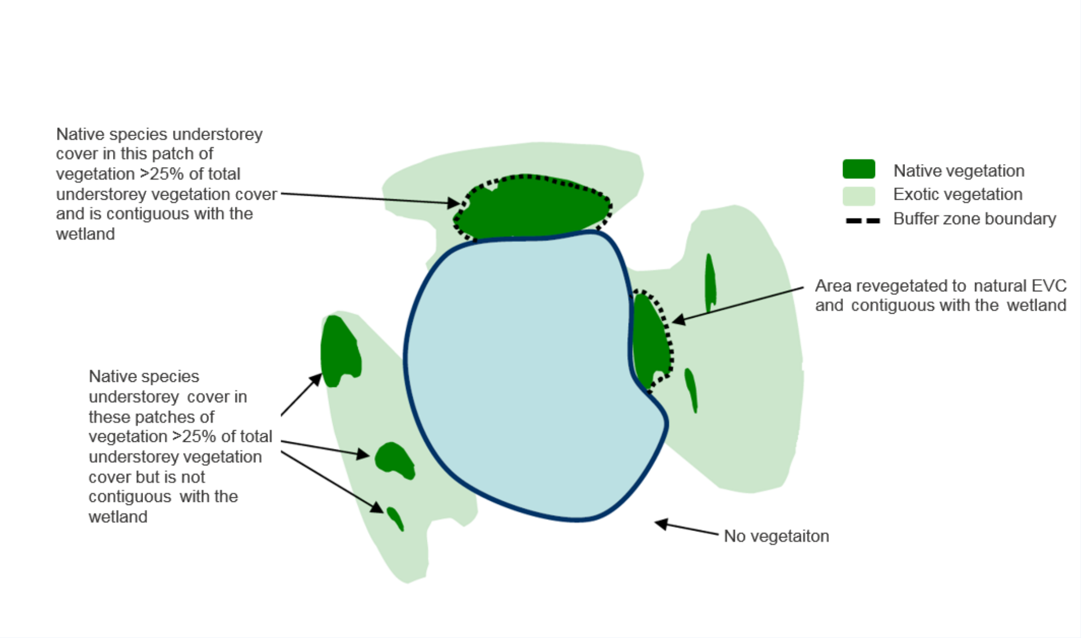


Figure 44. Conceptual diagram depicting native vegetation criteria required for the buffer zone (From DELWP, 2018)

The assessment of the current rating of the wetland buffer condition waterway condition was based on an element of the AVIRA degraded habitats threat category – degraded buffer vegetation (see Table 91). Alternate data sources were required from those recommended in the AVIRA framework due to lack of data. Remote sensed data was a key input as described in Table 89.

Table 89. Data used to determine the current rating of the wetland buffer condition waterway condition.

AVIRA threat category	AVIRA metric	Measure(s) used to determine current rating	Data source / notes	Scoring
Degraded habitats	Degraded buffer vegetation	IWC Wetland buffer assessment score	Manually assessing EVC mapping and imagery within 100 m of wetlands to determine buffer presence average width and percentage perimeter cover. Used IWC scoring accordingly based on	• Very high – IWC Wetland Buffer Assessment Score: >17-20 • High – IWC Wetland Buffer Assessment Score: >13-17

AVIRA threat category	AVIRA metric	Measure(s) used to determine current rating	Data source / notes	Scoring
			these two measures (as lack of IWC data for most wetlands).	• Moderate – IWC Wetland Buffer Assessment Score: >9-13 • Low – IWC Wetland Buffer Assessment Score: >5-9 • Very low– IWC Wetland Buffer Assessment Score: 0-5

7.4.2 Setting scenarios

Forecast current trajectory under business as usual scenario

A long-term Business as Usual trajectory (current trajectory) was based on rules and assumptions around the likely impacts of significant future threats, particularly climate change and urbanisation. Predictions on the future trajectory for wetland buffer condition ratings was based on the assumptions outlined in Table 90.

Table 90. BAU trajectory assumptions for wetland buffer condition

Wetland condition	Current trajectory assumptions
Wetland buffer condition	Wetland buffer condition at wetlands on the basalt plains was predicted to be maintained at or decline to very low. Wetland buffer condition at wetlands on the alluvial plains was predicted to improve at sites that can receive environmental water or are intensively managed for social or ecological values. All others are predicted to maintain their wetland buffer condition.

Long term target setting

To set long term targets a set of assumptions were made about the potential for change into the future. It was assumed over the long term that;

- The target trajectory of wetland buffer condition on alluvial plains could be improved to moderate/high (from current BAU trajectory) once actions to improve the water regime, and increase wetland buffers is implemented.

- The target trajectory of the wetland buffer condition on the basalt plains could be maintained or improved (from current BAU trajectory) depending on whether the sites could receive environmental water (e.g. Werribee catchment) and the extent of wetland buffer improvement planned.

7.4.3 10 year Performance Objective

Performance objectives are designed to support maintaining and extending the vegetation buffer for wetlands. At a regional level the performance objective is:

RPO–28 - Seasonal Herbaceous Wetland vegetation communities are identified and a management plan is in place to protect them on public and private land.

RPO-29 – Programs, standards, tools and guidelines are in place to protect wetland vegetation communities from urban and rural threats, including adequate planning controls.

RPO-30 – Climate change resilient revegetation management practices are understood and implemented by selecting plant species, provenances and vegetation communities that are suited to projected climatic conditions.

RPO-42 - Wetland condition information and prioritisation, with a focus on vulnerable wetlands, is understood and informs collaborative planning.

At a local level the performance objectives vary and are articulated in the Co-design Catchment Programs for each catchment. They typically refer to improving the condition of wetland buffers by either a condition class (i.e. low to moderate) or are quantitative (i.e. improve wetland buffer to 50% of wetland perimeter).

7.4.4 Key Assumptions and Improvement Opportunities

The following key assumptions were made at the time of developing the Strategy:

- On-ground works can counteract the effects of climate change.
- The assumptions in the wetland typology model used for determining future trajectory are reasonable.

Some of the improvement opportunities to be progressed over time for the Strategy:

- Increased knowledge about current wetland form based on site inspections
- Improvement opportunities will be developed through the HWS MERI Strategy and the associated Wetlands Monitoring and Evaluation Plan (MEP).

Wetland perimeter improvement

The perimeter of the wetland is measured as the distance around the wetland. In the case of wetland buffers, if they are only around part of the perimeter (for example 25 m of a 100m perimeter) then an improvement of wetland buffer to 50% of wetland perimeter would be equal to a total of 50m (25m existing + additional 25m). The buffer widths and perimeters of the 81 wetlands included in the HWS are represented in Melbourne Water GIS layers and provide a base case. Due to the rapid assessment being desktop based, it is recommended that they are verified and if needed updated, following an onground site assessment.

7.4.5 References

DELWP (2015). Aquatic Value Identification and Risk Assessment (AVIRA) Manual, State of Victoria: Department of Environment, Land, Water and Planning.

7.5 Vegetation

7.5.1 Current condition

The assessment of the current rating of the vegetation wetland condition was based on an element of the AVIRA naturalness value category - wetland vegetation condition (see Table 91). Alternate data sources were required from those recommended in the AVIRA framework due to lack of data. Remote sensed data was a key input as described below.

Table 91. Data used to determine the current rating of the wetland vegetation condition waterway condition.

AVIRA value category	AVIRA metric	Measure(s) used to determine current rating	Data source / notes	HWS Scoring
Naturalness	Wetland vegetation condition	Condition of wetland Ecological Vegetation Class	• IWC biota sub-index • SoBS database • Other literature • Aerial photography • DEPI 2013: SHW assessment - rule set development	• Very high – EVCs present intact, site near reference condition (veg condition excellent) • Moderate – EVCs present show some displacement, site moderately modified (veg condition mod - good) • Low – EVCs present completely displaced and site highly modified/ or no EVCs mapped

7.5.2 Setting scenarios

Forecast current trajectory under business as usual scenario

A long-term Business as Usual trajectory (current trajectory) was based on rules and assumptions around the likely impacts of significant future threats, particularly climate change and urbanisation. Predictions on the future trajectory for wetland vegetation condition ratings was based on the assumptions outlined in Table 92.

Table 92. BAU trajectory assumptions for wetland vegetation condition

Wetland condition	Current trajectory assumptions
vegetation condition	The current trajectory of vegetation condition in wetlands was predicted to decline to very low on the basalt plains and coastal wetlands, as a result of changed hydrology, including groundwater contributions, reduced rainfall and runoff and saline intrusion in coastal wetlands. Vegetation condition in most wetlands on the alluvial plains was also predicted to decline by one to two ranks with the exception of some billabongs in the Yarra catchment that are able to receive environmental water from the Yarra. These were predicted to improve in vegetation condition. In addition, wetlands that are expected to be intensively managed, such as Growling Grass Frog reserve wetlands or Blackburn Lake, are predicted to maintain their current condition rank.

Long term target setting

To set long term targets a set of assumptions were made about the potential for change into the future. It was assumed over the long term that;

- The target trajectory of vegetation on alluvial plains could be improved to moderate/high (from current BAU trajectory) once actions to improve the water regime, reduce threat of invasive plants and increase wetland buffers is implemented.
- The target trajectory of the vegetation condition on the basalt plains could be improved to moderate (from current BAU trajectory) depending on whether the sites could receive environmental water (e.g. Werribee catchment) and the extent of vegetation condition improvement is planned.

7.5.3 10 year Performance Objective

Performance objectives are designed to support maintaining and extending vegetation for wetlands. At a regional level the performance objective is:

RPO–28 - Seasonal Herbaceous Wetland vegetation communities are identified and a management plan is in place to protect them on public and private land.

RPO-29 – Programs, standards, tools and guidelines are in place to protect wetland vegetation communities from urban and rural threats, including adequate planning controls.

RPO-30 – Climate change resilient revegetation management practices are understood and implemented by selecting plant species, provenances and vegetation communities that are suited to projected climatic conditions.

RPO-42 - Wetland condition information and prioritisation, with a focus on vulnerable wetlands, is understood and informs collaborative planning.

At a local level the performance objectives include:

- Ensure appropriate aquatic macrophytes habitat is protected
- Reduce threat of invasive plant species, including the impact of salt tolerant species on significant coastal wetlands
- Reduce rabbit threat to salt marsh community
- Protect wetland vegetation that provides habitat for significant wetland fish populations.
- Implement the outcomes of the Melbourne Strategic Assessment on the Western Grassland Reserves, and associated management.

7.5.4 Key Assumptions and improvement opportunities

The following key assumptions were made at the time of developing the Strategy:

- On-ground works can counteract the effects of climate change.
- Data used to determine vegetation condition in wetlands across different time frames is representative of current condition
- The assumptions in the wetland typology model used for determining future trajectory are reasonable.

Some of the improvement opportunities to be progressed over time for the Strategy include:

- Undertake field assessment of vegetation condition of wetlands

Improvement opportunities will be developed through the HWS MERI Strategy and the associated Wetlands Monitoring and Evaluation Plan (MEP).

7.5.5 References

DELWP (2015). Aquatic Value Identification and Risk Assessment (AVIRA) Manual, State of Victoria: Department of Environment, Land, Water and Planning.

7.6 Water quality

7.6.1 Current condition

The assessment of the current rating of the wetland water quality waterway condition was based on elements of the AVIRA poor water quality and degraded habitats threat categories (see Table 93). Alternate data sources were required from those recommended in the AVIRA framework due to lack of data. Remote sensed data was a key input as described below.

Table 93. Data used to determine the current rating of the wetland water quality waterway condition.

AVIRA threat category	AVIRA metric	Measure(s) used to determine current rating	Data source / notes	HWS Scoring
Poor water quality	Changed Water Properties - Salinity	Altered salinity	• IWC Water Properties Sub-Index - IWC DB and GHD 2009 IWC report • Site specific information (literature review and Melbourne Water knowledge) • Melbourne Water SOBS DB *Most sites 'no data'*	**Very high** - No change Low to Very low land use intensity class Adjacent land does not contain Coastal Acid Sulfate Soils OR Inland waterway is not at high risk from acid sulfate soils **Moderate** medium land use intensity class **Low** Changed salinity of wetland High to Very high land use intensity class Adjacent land has the potential to contain Coastal Acid Sulfate Soils OR

AVIRA threat category	AVIRA metric	Measure(s) used to determine current rating	Data source / notes	HWS Scoring
				Inland waterway is at high risk from acid sulfate soils
	Changed Water Properties - Nutrients	Intensity of land use	• IWC Water Properties Sub-Index - IWC database and GHD 2009 IWC report • Melbourne Water SOBS database • Spatial analysis using use Land use severity classes (in IWC) as a surrogate for this metric where site specific data was not available	•
	Presence of Acid Sulfate Soil	Potential of adjacent land to contain Coastal Acid Sulphate Soils	• Coastal Acid Sulphate Soils (www.data.vic.gov.au)	•
Degraded habitats	Soil disturbance	Proportion of wetland with soil disturbance	• IWC Soils Sub-Index - IWC DB and GHD 2009 IWC report • Site specific information • HW report (DEPI 2013) • Melbourne Water SOBS DB • Imagery/ land use	•

7.6.2 Setting scenarios

Forecast current trajectory under business as usual scenario

A long-term Business as Usual trajectory (current trajectory) was based on rules and assumptions around the likely impacts of significant future threats, particularly climate change and urbanisation. Predictions on the future trajectory for wetland vegetation condition ratings was based on the assumptions outlined in Table 94.

Table 94. BAU trajectory assumptions for wetland water quality condition

Wetland condition	Current trajectory assumptions
wetland water quality	Wetland water quality at wetlands on the basalt plains and the alluvial flats declined to very low due to predicted reductions in inflows and increased nutrient runoff from stormwater. Cockatoo Swamp, a wetland being intensively managed for improved hydrology, was expected to have improved water quality.

Long term target setting

To set long term targets a set of assumptions were made about the potential for change into the future. It was assumed over the long term that;

- The target trajectory of water quality on alluvial plains could be improved to moderate (from current BAU trajectory) once actions to improve the water regime for some wetlands (i.e Yarra billabongs) is implemented.
- The target trajectory of the water regime on the basalt plains could be maintained or slightly improved (from current BAU trajectory) however, the condition is anticipated to still be low due to pressures of climate change and urban development (see section 6.2).

7.6.3 10 year Performance Objective

Performance objectives are designed to support maintaining the water quality for wetlands. At a regional level the performance objective is:

RPO-11 – Understanding for groundwater dependent ecosystems is improved and opportunities to maintain or improve these continue to be investigated.

RPO-17 – Water quality in waterways and bays is improved by reducing inputs of sediment and other pollutants from urban construction and development.

RPO-24 - Risk based program are in place to mitigate sources of urban pollution (licensed and unlicensed discharges) to protect bays and waterways.

RPO-25 – Programs, standard, tools and guidelines are in place to manage nutrients, sediments and other pollutants from rural land in priority areas.

At a local level the performance objectives include:

- Implement stormwater activities in the catchment as identified

- Implement rural land management program to reduce nutrient and sediment to the wetlands as identified for each sub-catchment.

7.6.4 Key Assumptions and Improvement Opportunities

The following key assumptions were made at the time of developing the Strategy:

- On-ground works can counteract the effects of climate change.
- The assumptions in the wetland typology model used for determining future trajectory are reasonable.

Improvement opportunities will be developed through the HWS MERI Strategy and the associated Wetlands Monitoring and Evaluation Plan (MEP).

7.6.5 References

DELWP (2015). Aquatic Value Identification and Risk Assessment (AVIRA) Manual, State of Victoria: Department of Environment, Land, Water and Planning.

8 Benefits to Bays

8.1 Introduction

Bays are broad inlets of the ocean where the land curves around to create a landscape feature that often supports unique environmental habitats. The two Bays in the Melbourne region are Port Phillip Bay and Western Port (Figure 45). Most of the Melbourne regions waterways terminate in one or other of these Bays so the protection of Bay environments in intrinsically linked to waterway management activities.

Figure 45. Port Phillip Bay and Western Port

Water quality in particular is an environmental condition that literally flows from waterways to bays, depositing some of the pollutants, nutrients or sediments that have been washed into waterways from the catchments into the bays.

Previous strategies have targeted water quality improvements that benefit both waterways and bays. (Better Bays and Waterways (2009), Environmental Management Plan for Port Phillip Bay (2017-2027), Melbourne Water Stormwater Strategy (2013). The inclusion of Bay actions and benefits into the HWS 2018 continues to be an important way to connect catchments and bays and articulate this connection to the community.

8.2 Bay-related Performance Objectives

Many of the actions required to protect bays are implemented in the catchments. Port Phillip Bay and Western Port are included in the HWS 2018 where targets for the protection of waterway values also have benefit for the bays.

The current Environmental Management Plan for Port Phillip Bay (DELWP, 2017) set the objective of no net increase of nutrient and pollutant loads to Port Phillip Bay over the next 10 years based on current (2017) baseline). A discussion paper on nutrient and sediment load targets for the Port Phillip Bay Environmental Management Plan was developed by Hart (et al, 2017) which determined that to achieve this target, an additional 300 t/y of Total Nitrogen (TN) and would have to be treated by approximately 2030 which, broken down further, gives a target of an additional 30 tonnes per year over a 10 year period. The load targets for Port Phillip Bay and sediment targets for Western Port are outlined in the draft State Environment Protection Policy (Waters) and are summarised in Table 95.

Table 95. Summary of draft SEPP (Waters) load targets for the bays

Location	Year	Total Nitrogen (tonnes / year)	Total Suspended Solids (tonnes / year)
Port Phillip Bay	Baseline (2017)	1,500-2,200	60,000 – 70,000
	Target (2027)	1,500-2,200	60,000 – 70,000
Western Port	Baseline (2017)	n/a	28,000
	Target (2027)	n/a	28,000

A number of Regional Performance Objectives (RPO's) set in the Health Waterways Strategy collectively contribute towards the load targets set for Port Phillip Bay and Westernport and the overarching aim of no net increase of pollutant and sediment loads. These are outlined in Table 96. Management actions that benefit in waterways, estuaries and wetlands for environmental and social value outcomes will also benefit bays. Examples of performance objectives that deliver multiple benefits are provided below.

Table 96. Summary of RPO's that contribute to Bay targets

RPO ID	Description
14	Standards, tools and guidelines are in place and implemented to enable re-use and infiltration of excess stormwater, and protect and/or restore urban waterways.
15	Victoria's planning system is used effectively to protect and enhance waterway values.

RPO ID	Description
16	Protection mechanisms are in place for headwaters to ensure that they are retained as features in the landscape for environmental, social, cultural and economic benefits.
17	Water quality in waterways and bays is improved by reducing inputs of sediment and other pollutants from urban construction and development.
18	Critical waterway health assets including stormwater treatment systems, fishways and erosion control structures, are maintained for their designed purpose or the same outcomes are delivered by alternative means.
24	Risk-based programs are in place to mitigate sources of urban pollution (licenced and unlicensed discharges) to protect bays and waterways.
25	Programs, standards, tools and guidelines are in place to manage nutrients, sediments and other pollutants from rural land in priority areas.
45	Research partnerships with universities and other research institutions are in place to address the key research areas and build our knowledge and capacity to efficiently and effectively achieve the HWS 2018 performance objectives and targets.

The performance objectives for rivers, wetlands and estuaries on a sub-catchment scale also contribute to the Bay load targets. There are too many to list individually but in general they include:

- Implementing stormwater harvesting to ensure DCI levels do not increase beyond current levels in priority sub-catchments
- Mitigating threats to physical form (e.g. erosion)
- Reducing nutrient, sediment and pesticide inputs to waterways and bays from rural land through improved land management
- Establishing and maintaining vegetated buffers around waterways. This can include establishing fencing to prevent stock from causing erosion in streams.
- Reducing nutrient inputs from septic tanks
- Reducing sedimentation from runoff associated with construction and urban development
- Maintaining current quality of discharges from sewage treatment plants
- Establishing vegetation buffer in headwater streams

- Monitor and reduce threat of catchment sediment impacts on estuaries
- Protecting water quality from industrial activity by mitigating sources of industrial pollution.
- Develop education programs and enforcement actions for industrial pollution
- Acid sulfate soils in estuaries

Melbourne Water and DELWP are in the process of building a Source catchments model for the PPB and WP catchment areas that will eventually be able to test our urban growth and renewal assumptions and the collective effectiveness of the performance objectives more explicitly.

8.3 Key assumptions and improvement opportunities

The calculation of the HWS performance objectives contribution towards the Bay targets is based on the following assumptions.

- All stormwater treatment wetlands previously built are maintained to their design intent (or equivalent) in alignment with target 3.1 in the EMP for Port Phillip Bay (2017-2021)
- All sewage treatment plants discharging to waterways remain at 2016 nutrient load levels in alignment to target 3.2 in the EMP for Port Phillip Bay (2017-2021)
- All Rural Land Program targets achieved previously are maintained into the future.
- That all future development will apply current stormwater BPEM as a minimum standard.
- No reduction has been attributed to riparian revegetation targets articulated in HWS.

Some of the improvement opportunities to be progressed over time for the Strategy include:

- Using the Source Catchments model (developed jointly by DELWP and MW in development) bay loads of nutrient, sediments and toxicants can be generated and reported annually.
- Modelled annual loads can be verified using monitoring data at regular intervals (defined by the HWS MERI).
- Potentially, "works" done to improve water quality can be integrated by the model to demonstrate combined effectiveness in achieving Bay load targets eg wetland maintenance, rural land program, IWM projects, erosion control projects.

8.4 References

DELWP (2017). Port Phillip Bay Environmental Management Plan (2017-2021)

Hart, B.T, Francey, M. and White, K. (2018) Discussion Paper on Load Targets for the Port Phillip Bay Environmental Management Plan – a report for Melbourne Water.

Victorian Government (1999), State Environment Protection Policy Schedule F7 (Waters of the Yarra catchment). S 89

Victorian Government (2003), State Environment Protection Policy (Waters of Victoria). S 107

Victorian Government (2018), State Environment Protection Policy Schedule (Waters) S 493 (in draft at the time) http://www.gazette.vic.gov.au/gazette/Gazettes2018/GG2018S499.pdf

9 Links to other strategies, plans and guidelines

A number of strategies and plans were in development during the period of the HWS 2018 development. This provided the opportunity to align objectives and targets across a number of areas including stormwater, water quality and traditional owner values. Some of the key plans and the links to the HWS 2018 are described below.

9.1 Yarra Strategic Plan

The Yarra River Protection (*Wilip-gin Birrarung Murron*) Act 2017 identifies the Yarra River and the many hundreds of parcels of public land it flows through as one living, integrated natural entity for protection and improvement and acknowledges the spiritual connection between the river and the descendants of the Woi-wurrung. Melbourne Water is the lead agency for developing a 50-year Community Vision for the Yarra River, which will become the foundation for an overarching Yarra Strategic Plan (YSP). The YSP focuses on a more specific geographical area to the HWS 2018, concentrating on the Yarra River Corridor (rather than the whole of the Yarra catchment) and considers public open space along the river, statutory planning, and the management of public land and infrastructure.

The *Healthy Waterways Strategy* vision for the Yarra Catchment builds on the Yarra River 50-year Community Vision developed as part of the *Yarra Strategic Plan* in early 2018. The outcomes of consultation undertaken by Melbourne Water on the YSP were also shared and incorporated into the HWS 2018.

The Yarra Strategic Plan will contribute to delivering the targets outlined in the HWS 2018 and build on the performance objectives outlined for the Yarra Catchment. The YSP will also contribute to delivering cultural value performance objectives related to the Yarra River with Traditional Owners and Aboriginal Victorians.

9.2 Waterways of the West

In late August 2018 the Victorian Government launched Waterways of the West (WoW) - a community-led approach to ensure iconic waterways in Melbourne’s West are protected for generations to come.

Over an 18-month period, a Ministerial Advisory Committee (MAC) was appointed to work with the community, Traditional Owners and industry to present a range of recommendations for the WoW to the Government. This work built on the strong community advocacy work that was already occurring across the region, along with other opportunities identified during the MAC's deliberations

It is envisaged that the Waterways of the West will intersect with the HWS 2018 and assist in achieving common goals for waterway protection and restoration.

9.3 IWM forums

Integrated Water Management Forums have been established by DELWP across the state in response to State government water policy, *Water for Victoria*. They aim to identify, prioritise and oversee the implementation of collaborative water opportunities. The Forums bring together all organisations with an interest in the water cycle, recognising that each has an important role to play in the management of our most vital resource.

Victoria's Integrated Water Management Forums have produced a Strategic Directions Statement that captures the regional context, shared vision and water-related outcomes for each of the Forum areas across metropolitan Melbourne and regional Victoria.

A Strategic Direction Statement has been produced for each of the five catchments in the HWS 2018 – Westernport, Dandenong, Maribyrnong, Yarra and Werribee. These statements have been developed collaboratively by the same partner organisations involved in the collaborative development of the HWS 2018.

Each Strategic Directions Statement includes a list of integrated water management opportunities collaboratively developed by the Forum to bring local community views, values and priorities into practice through integrated water management. The integrated management opportunities identified align with the performance objectives of the HWS 2018 and represent the opportunities to deliver the stormwater targets of the HWS 2018. In 2018-19, the Victorian Government co-funded 18 IWM projects in Melbourne that will improve regional water security, enhance waterway and landscape health, and build greater community connections to the environment (Figure 46).

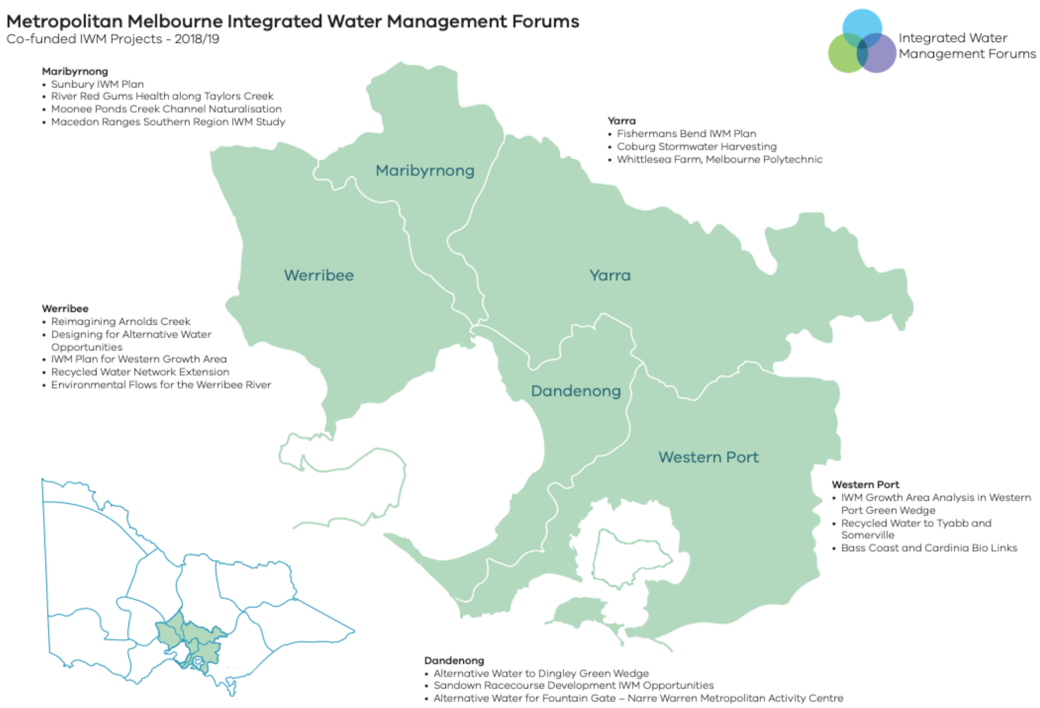


Figure 46. Co-funded IWM projects 2018/19

9.4 SEPP

The *State Environment Protection Policy (Waters of Victoria)* 2013 (*SEPP (WoV)*) and related schedules are the key statewide policy framework for water quality protection in Victoria. It provides a statutory framework for State and local government agencies, businesses and communities to work together to protect and rehabilitate Victoria's surface water environments.

The *SEPP (WoV)* identifies beneficial uses of water and sets the environmental quality objectives and policy directions required to address higher risk impacts and activities. The *SEPP (WoV)* was under review at the time of developing HWS 2018 and was released in 2018 after the Strategy was completed . As such, the environmental and recreational water quality objectives in SEPP WoV 2013 were utilised in strategy development process.

As the HWS strategy was finalising the revised *SEPP (Waters)* was released in draft form so load targets for Port Phillip Bay (that were derived from the PPB EMP (2017-2021) and sediment targets for Westernport were included in Table 95.

It is envisaged that the new objectives and targets stated in the *SEPP (Waters)* will be incorporated in to HWS MERI and be used for ongoing reporting.

Appendix 1 – List of lead authors

Section of document	Lead authors
1. Introduction	Trish Grant, Dr Belinda Lovell, Karen White
2. River Values	
2.1 Vegetation	Sharyn Rossrakesh
2.2 Riparian birds	Dr William Steele
2.3 Frogs	Dr William Steele
2.4 Platypus, fish and macroinvertebrates	Sharyn Rossrakesh, Dr Rhys Coleman, Trish Grant, Andrew Grant,
2.5 Amenity, Community Connection and Recreation	Michelle Ezzy, Rob Molloy, Dan Green
3. Condition metrics for rivers	
3.1 Stormwater	Sharyn Rossrakesh, Andrew Grant
3.2 Water for the environment	Sarah Gaskill
3.3 Vegetation extent	Sharyn Rossrakesh
3.4 Vegetation quality	Sharyn Rossrakesh
3.5 Water quality – environmental	Trish Grant
3.6 Instream connectivity	Trish Grant, Dr Rhys Coleman
3.7 Physical form	Trish Grant, Leigh Smith, Penny Rogers
3.8 Access	Michelle Ezzy
3.9 Water Quality – recreational	Trish Grant
3.10 Litter	Michelle Ezzy, Rob Molloy
3.11 Participation	Michelle Ezzy
4. Estuarine values (all)	Simone Wilkie, Karen White
5. Condition metrics for estuaries (all)	Simone Wilkie, Karen White
6. Wetland values (all)	Simone Wilkie, Karen White
7. Condition metrics for wetlands (all)	Simone Wilkie, Karen White
8. Benefits to bays	Trish Grant, Andrew Grant, Karen White

Appendix 2 - Summary of key value metrics

The following table presents the revised rating explanations and scores for the nine values used in the Healthy Waterways Strategy for rivers, estuaries and wetlands.

River value metrics

Key values	Description	Rating	Explanation
Amenity	Based on data from Melbourne Water community perceptions of waterways research on 'satisfaction with waterways' in relation to amenity related activities	Very High	Very high level of satisfaction that waterways provide amenity
		High	High level of satisfaction that waterways provide amenity
		Moderate	Moderate level of satisfaction that waterways provide amenity
		Low	Low level of satisfaction that waterways provide amenity
		Very Low	Very low level of satisfaction that waterways provide amenity
Community Connection	Based on data from Melbourne Water community perceptions of waterways research on 'satisfaction with waterways' in relation to community connection activities	Very High	Very high level of satisfaction that waterways support community connection
		High	High level of satisfaction that waterways support community connection
		Moderate	Moderate level of satisfaction that waterways support community connection
		Low	Low level of satisfaction that waterways support community connection
		Very Low	Very low level of satisfaction that waterways support community connection
Recreation	Based on data from Melbourne Water community perceptions of waterways research on 'satisfaction with waterways' in relation to recreation activities	Very High	Very high level of satisfaction that waterways support recreation
		High	High level of satisfaction that waterways support recreation
		Moderate	Moderate level of satisfaction that waterways support recreation
		Low	Low level of satisfaction that waterways support recreation
		Very Low	Very low level of satisfaction that waterways support recreation
Birds	Summed reporting rate of riparian bird species expected in that sub-catchment (from minimum of 40 appropriate surveys)	Very High	Almost all expected species are frequently recorded
		High	Many expected species are recorded often
		Moderate	Most expected species occur but some of these are only infrequently recorded
		Low	Few of the expected riparian bird species are recorded
		Very Low	Very few of the expected species are recorded and these in only low numbers
Fish	Based on habitat suitability models for native freshwater species and survey data	Very High	All or almost all native freshwater species recorded in the catchment likely to be present
		High	Most native freshwater species recorded in the catchment likely to be present
		Moderate	About half the native freshwater species recorded in the catchment likely to be present
		Low	Few freshwater native species recorded in the catchment likely to be present
		Very Low	Very few or no native freshwater species recorded in the catchment likely to be present
Frogs	Species richness (observed to expected) modified to reflect survey effort	Very High	All, or most, of the expected species of frog are found
		High	Many of the expected species of frog are found
		Moderate	Not many of the expected species of frog are found
		Low	Few of the expected species of frog are found
		Very Low	Very few of the expected species of frog are found
	Land Use Macroinvertebrate Response (LUMaR) index.	Very High	All or almost all macroinvertebrate families are predicted to be present, indicating very good stream health

Key values	Description	Rating	Explanation
Macroinvertebrates	LUMaR is an observed: expected index, that weights the observations of macroinvertebrate families by their sensitivity to forest loss and urbanisation	High	Most macroinvertebrate families are predicted to be present, indicating good stream health
		Moderate	Some macroinvertebrate families are predicted to be present indicating moderate stream health
		Low	Low number of macroinvertebrate families are predicted to be present, indicating poor stream health
		Very Low	Very low likelihood of sensitive aquatic macroinvertebrate families being found
Platypus	Based on habitat suitability models that indicate likelihood that waterways will support platypus	Very High	Very high likelihood that waterways will support platypus
		High	High likelihood that waterways will support platypus
		Moderate	Moderate likelihood that waterways will support platypus
		Low	Low likelihood that waterways will support platypus
		Very Low	Very low likelihood that waterways will support platypus
Vegetation	Based on vegetation quality and uniqueness derived from available surveys	Very High	High or very high naturalness and high or very high uniqueness
		High	Very high naturalness with very low to medium uniqueness or high naturalness and medium to high uniqueness
		Moderate	Medium to high naturalness and very low to low uniqueness, or medium naturalness and medium to high uniqueness, or very low naturalness and medium uniqueness
		Low	Low naturalness and very low to medium uniqueness
		Very Low	Very low naturalness and very low uniqueness

Estuary value metrics

Key values	Description	Rating	Explanation
Birds	Incorporated formally recognised significance as bird habitat, presences of significant species and condition of vegetation Ramsar site = Yes /Listed East Asian-Australasian = Yes / Listed Nationally Important Wetlands (DIWA) = Yes / Listed Wetland vegetation condition – adjusts score up or down	Very High	If 5 metrics meet criteria
		High	If 4 metrics meet criteria
		Moderate	If 2 or 3 metrics meet criteria
		Low	If one metric meets criteria
		Very Low	If no metrics meet criteria and/or vegetation condition is very poor
Fish	Wetland fish metric TBC Significant fish = 5	Very High	Significant fish species (5)
		High	TBC
		Moderate	TBC
		Low	TBC
		Very Low	TBC
Frogs	Key value status of the sub-catchment applied and adjusted for significant amphibians score	Very High	All, or most, of the expected species of frog are found
		High	Many of the expected species of frog are found
		Moderate	Not many of the expected species of frog are found
		Low	Few of the expected species of frog are found
		Very Low	Very few of the expected species of frog are found
Vegetation	Based on vegetation condition and uniqueness derived from available surveys	Very High	If all 3 metrics meet criteria (Score 5)
		High	If condition = 5 and one other metric meets criteria
		Moderate	If Condition = 3 and one other metric meets criteria or condition is 5
		Low	If condition = 3 (moderate) and meets one significance metric
		Very Low	If condition = 1 (Very poor or poor)

Wetland value metrics

Key values	Description	Rating	Explanation
Birds	Based on formally recognised significance (Ramsar, East Asian-Australasian Flyway Site, Nationally Important (DIWA)), supports significant bird species, Listed Important Bird Area and wetland vegetation condition. If vegetation condition is moderate, status reduces by one category	Very High	If 5 metrics meet criteria
		High	If 4 metrics meet criteria
		Moderate	If 2 or 3 metrics meet criteria
		Low	If one metric meets criteria
		Very Low	If no metrics meet criteria and/or vegetation condition is very poor
Fish	Incorporates significant fish, drought refuge and the Estuary Entrance Management Support System for Fish Asset Score	Very High	Records include listed fish species
		High	Records include estuarine dependent (Seasonal facultative and Seasonal obligate) species
		Moderate	Records of only non-estuarine dependent fish (marine or freshwater) species
		Low	N/A
		Very Low	No records of fish
Vegetation	Incorporates condition and rarity data Significant flora = 5 Significant EVC = 5 Vegetation condition	Very High	If all 3 metrics meet criteria (Score 5)
		High	If condition = 5 and one other metric meets criteria
		Moderate	If Condition = 3 and one other metric meets criteria or condition is 5
		Low	If condition = 3 (moderate) and meets one significance metric
		Very Low	If condition = 1 (Very poor or poor)
Frogs	Key value status of the sub-catchment applied and adjusted for significant amphibians score	Very High	All of most of expected species of frog are found
		High	Many of expected species of frog are found
		Moderate	Not many of the expected species of frog are found
		Low	Few of the expected species of frog are found
		Very Low	Very few of the expected species of frog are found

Appendix 3 – Summary of condition metrics

Waterway condition metrics

Condition	Description	Rating	Explanation
Stormwater condition	Directly connected imperviousness (DCI) is the proportion of the impervious surface that is directly connected to a stream through a conventional drainage connection	Very High	DCI <0.5% minimal or no threat from stormwater
		High	DCI 0.5-2% minor impacts to stream health from stormwater
		Moderate	DCI 2-5% stream health is impacted from stormwater
		Low	DCI 5-10% stream health is significantly impacted from stormwater
		Very Low	DCI >10% stream health is severely impacted from stormwater
Water for environment	Compliance with environmental flow components identified through FLOWS method. The FLOWS method is a state based approach for assessing flow requirements of freshwater river systems	Very High	Flow recommendations frequently achieved across all climate years, overall hydrological condition is considered excellent (81-100%)
		High	Flow recommendations often achieved across all climate years, overall hydrological condition is considered good (61-80%)
		Moderate	Flow recommendations often achieved in wet and average climate years and occasionally achieved in dry climate years. Overall hydrological condition is considered moderate (41-60%)
		Low	Flow recommendations occasionally achieved, mostly in wet and average climate years but not in dry climate years. Overall hydrological condition is considered poor (21-40%)
		Very Low	Flow recommendations rarely achieved, overall hydrological condition is considered very poor (<20%)
Vegetation quality	Description of quality of vegetation relative to Ecological Vegetation Classes (EVCs)	Very High	Riparian vegetation is intact with all structural components present and very high connectivity
		High	Riparian vegetation is relatively intact with structural elements present with high connectivity
		Moderate	Riparian zone consists of fragmented relevant EVC vegetation
		Low	Riparian vegetation is highly modified, fragmented
		Very Low	Riparian vegetation is highly modified, predominantly comprising exotic species
Physical Form	Potential of channels to erode (deepen and/or widen). Score is an 'on average' assessment across the sub-catchment	Very High	Very low erosion potential - geomorphically 'intact' channels, bedrock control or no known triggers for instability. Primarily source headwater streams.
		High	Low erosion potential - waterways with no known active erosion, some minor impacts from landuse, local disturbance etc. Also includes waterways that have been substantially modified.
		Moderate	Moderate erosion potential - waterways with no known active deepening, however susceptible to widening and bank erosion due to local landuse and disturbance.
		Low	High erosion potential - waterways with known active deepening and widening, and will continue to be susceptible to erosion processes.
		Very Low	Very high erosion potential - waterways with known active deepening and widening, in highly erodible soils, ongoing disturbance from adjacent landuse and susceptible to erosion processes.
Water quality - environmental	Compliance with SEPP (Waters of Victoria) environmental water quality objectives. EPA Water Quality Index	Very High	Near natural – high quality waterways. Meets SEPP water quality standards
		High	Meets SEPP water quality standards
		Moderate	Some evidence of water quality stress.
		Low	Under considerable stress

Condition	Description	Rating	Explanation
		Very Low	Under severe stress
Water quality - recreational	Compliance with SEPP (Waters of Victoria) recreational water quality objectives (swimming is considered as primary contact)	Very High	Meets primary contact objectives (good)
		High	Meets secondary contact objectives (fair)
		Moderate	NA
		Low	Does not meet secondary contact objectives (poor)
		Very Low	NA
Litter absence	Clean Communities Assessment Tool (CCAT) methodology provides a systematic assessment of littering behaviour, litter and key features of public places, including waterfronts	Very High	Very high proportion of waterways have an absence of litter. very unusual for people to do the wrong thing with litter
		High	High proportion of waterways have an absence of litter, majority of people do the right thing
		Moderate	Moderate proportion of waterways impacted by litter, but normally people do the right thing
		Low	Some waterways impacted by litter, low expectation for people to do the right thing
		Very Low	Most waterways highly littered, no expectation for people to do the right thing
Vegetation extent	Percentage or reach which has continuous vegetation canopy cover within 20m either side of the stream	Very High	80-100%
		High	60-80%
		Moderate	40-60%
		Low	20-40%
		Very Low	0-20%
Instream connectivity	Proportion of waterway length within the sub-catchment which is free from barriers to fish movement	Very High	80-100%
		High	60-80%
		Moderate	40-60%
		Low	20-40%
		Very Low	0-20%
Access	Proportion of stream corridors that have accessible waterways (paths) on at least one side	Very High	80-100%
		High	60-80%
		Moderate	40-60%
		Low	20-40%
		Very Low	0-20%
Participation	Percentage of population involved in grants and citizen science (related to waterways) over previous 3 years as a proportion of population within sub-catchment	Very High	> 2%
		High	1-2%
		Moderate	0.5-1%
		Low	0.1-0.5%
		Very Low	< 0.1%

Estuary condition metrics

Condition	Description	Rating	Explanation
Flow regime	AVIRA threat metric: based on level of alteration to flow regimes – magnitude and monthly and seasonal variability	Very High	Index score 8-10
		High	Index score 6-8
		Moderate	Index score 4-6
		Low	Index score 2-4
		Very Low	Index score 0-2
Tidal exchange	AVIRA threat metric: based on characteristics of estuary opening, manipulation required, and potential impact on ecology	Very High	No artificial openings or regular dredging or training walls
		High	< 25% artificial openings or regular dredging or training walls
		Moderate	NA
		Low	25-50% artificial openings or regular dredging or training walls
		Very Low	> 50% artificial openings or regular dredging or training walls
Longitudinal extent	AVIRA threat metric: based presence/absence of a barrier and distance of barrier downstream from the 'natural' head of the estuary	Very High	No artificial barriers exist
		High	1-25% of estuary affected by artificial barrier
		Moderate	25-50% of estuary affected by artificial barrier
		Low	>50% of estuary affected by artificial barrier
		Very Low	Artificial barrier can completely block movement of water
Water quality	AVIRA threat metric: EPA water quality guidelines for estuaries, frequency of algal blooms and excessive macrophyte growth	Very High	Very high level water quality - minimal stress
		High	High level of water quality - some stress
		Moderate	Moderate level of water quality and stress
		Low	Poor water quality
		Very Low	Very poor water quality
Estuarine vegetation	AVIRA threat metric: based on condition of fringing vegetation and extent of invasive plants	Very High	Vegetation is intact with all structural component present and very high connectivity
		High	Vegetation is relatively intact, most structural component present and high connectivity
		Moderate	Vegetation consists of fragmented relevant EVCs
		Low	Vegetation is highly modified and fragmented
		Very Low	Vegetation is highly modified, predominantly comprising invasive species
Estuarine wetland connectivity	AVIRA threat metric: based on level of restriction for estuarine biota that require connection with adjacent wetlands and floodplains	Very High	No restrictions - very high level of naturalness
		High	Minimal level of restriction - high level of naturalness
		Moderate	Moderate level of restriction
		Low	High level of restriction - low level of naturalness
		Very Low	Significant level of restriction - very low level of naturalness

Wetland condition metrics

Condition	Description	Rating	Explanation
 Flow regime	Simplified AVIRA threat metric – Changed water regime	Very High	Minimal or no threat Minor or no change
		High	N/A
		Moderate	Moderate change
		Low	N/A
		Very Low	Significant change
 Wetlands habitat form	AVIRA threat metrics – Reduced wetland area and altered wetland form	Very High	to 5% reduction in wetland area
		High	>5 to 25% reduction in wetland area
		Moderate	>25 to 50% reduction in wetland area
		Low	>50 to 75% reduction in wetland area
		Very Low	>75% reduction in wetland area
 Wetland buffer condition	AVIRA threat metric – Degraded buffer vegetation	Very High	IWC Wetland Buffer Assessment Score: >17 - 20
		High	IWC Wetland Buffer Assessment Score: >13 - 17
		Moderate	IWC Wetland Buffer Assessment Score: >9 - 13
		Low	IWC Wetland Buffer Assessment Score: >5 - 9
		Very Low	IWC Wetland Buffer Assessment Score: 0 - 5
 Vegetation condition	AVIRA value metric – Wetland vegetation condition	Very High	EVCs present intact, site near reference condition (veg condition excellent)
		High	N/A
		Moderate	EVCs present show some displacement, site moderately modified (veg condition mod - good)
		Low	N/A
		Very Low	EVCs present completely displaced and site highly modified/ or no EVCs mapped
 Wetland water quality	Wetland threat metrics – Changed water properties salinity, Changed water properties nutrients and disturbance of acid sulfate soils	Very High	No change, Low to Very low land use intensity class, Adjacent land does not contain Coastal Acid Sulfate Soils or inland waterway is not at high risk from acid sulfate soils
		High	N/A
		Moderate	Medium land use intensity class
		Low	N/A
		Very Low	Changed salinity of wetland, high to Very high land use intensity class, adjacent land has the potential to contain Coastal Acid Sulfate Soils or inland waterway is at high risk from acid sulfate soils

Appendix 4 - Habitat Suitability model scenarios explored in the HWS development

Table 97. List of actions/scenarios explored in the course of developing the Healthy Waterway Strategy. All candidate scenarios explore changes *relative* to the business-as-usual future (BAUF) conditions.

	Scenario Code	Description
5 Key Scenarios used to inform the HWS action prioritization process		
1	RV20	Like BAUF, but revegetate riparian zones on both stream sides, to 20m width along all streams in the MW region
2	SW2	Like BAUF, but treat all future impervious cover such that Attenuated Imperviousness is maintained at 2016 levels
3	SW1	Like BAUF, but treat all future *and* existing cover such that Attenuated Imperviousness is effectively zero
4	RV20_SW2	Like BAUF, but revegetate riparian zones on both stream sides, to 20m width along all streams in the MW region AND treat all future impervious cover such that Attenuated Imperviousness is maintained at 2016 levels
5	RV20_SW1	Like BAUF, but revegetate riparian zones on both stream sides, to 20m width along all streams in the MW region AND treat all future *and* existing cover such that Attenuated Imperviousness is effectively zero
1 'Action'		
6	RV10	Like BAUF, but revegetate riparian zones on both stream sides, to 10m width along all streams in the MW region
7	SW3	Like BAUF, but treat all future *and* some existing cover such that Attenuated Imperviousness in existing urban areas is reduced to 75% of 2016 levels
8	SW4	Like BAUF, but treat all future *and* some existing cover such that Attenuated Imperviousness in existing urban areas is reduced to 50% of 2016 levels
9	BAUF_NoDry	Like BAUF, but set Mean Annual Runoff Depth at 2016 values
2 'Actions'		
10	RV20_SW3	Like BAUF, but revegetate riparian zones on both stream sides, to 20m width along all streams in the MW region AND treat all future *and* some existing cover such that Attenuated Imperviousness in existing urban areas is reduced to 75% of 2016 levels
11	RV20_SW4	Like BAUF, but revegetate riparian zones on both stream sides, to 20m width along all streams in the MW region AND treat all future *and* some existing cover such that Attenuated Imperviousness in existing urban areas is reduced to 50% of 2016 levels

12	RV20_NoDry	Like BAUF, but revegetate riparian zones on both stream sides, to 20m width along all streams in the MW region AND set Mean Annual Runoff Depth at 2016 values
13	RV10_SW2	Like BAUF, but revegetate riparian zones on both stream sides, to 10m width along all streams in the MW region AND treat all future impervious cover such that Attenuated Imperviousness is maintained at 2016 levels
14	RV10_SW1	Like BAUF, but revegetate riparian zones on both stream sides, to 10m width along all streams in the MW region AND treat all future *and* existing cover such that Attenuated Imperviousness is effectively zero
15	RV10_SW3	Like BAUF, but revegetate riparian zones on both stream sides, to 10m width along all streams in the MW region AND treat all future *and* some existing cover such that Attenuated Imperviousness in existing urban areas is reduced to 75% of 2016 levels
16	RV10_NoDry	Like BAUF, but revegetate riparian zones on both stream sides, to 10m width along all streams in the MW region AND set Mean Annual Runoff Depth at 2016 values
3 'Actions'		
17	RV20_SW2_NoDry	Like BAUF, but revegetate riparian zones on both stream sides, to 20m width along all streams in the MW region AND treat all future impervious cover such that Attenuated Imperviousness is maintained at 2016 levels AND set Mean Annual Runoff Depth at 2016 values
18	RV20_SW1_NoDry	Like BAUF, but revegetate riparian zones on both stream sides, to 20m width along all streams in the MW region AND treat all future *and* existing cover such that Attenuated Imperviousness is effectively zero AND set Mean Annual Runoff Depth at 2016 values
19	RV20_SW3_NoDry	Like BAUF, but revegetate riparian zones on both stream sides, to 20m width along all streams in the MW region AND treat all future *and* some existing cover such that Attenuated Imperviousness in existing urban areas is reduced to 75% of 2016 levels AND set Mean Annual Runoff Depth at 2016 values
20	RV10_SW2_NoDry	Like BAUF, but revegetate riparian zones on both stream sides, to 10m width along all streams in the MW region AND treat all future impervious cover such that Attenuated Imperviousness is maintained at 2016 levels AND set Mean Annual Runoff Depth at 2016 values
21	RV10_SW1_NoDry	Like BAUF, but revegetate riparian zones on both stream sides, to 10m width along all streams in the MW region AND treat all future *and* existing cover such that Attenuated Imperviousness is effectively zero AND set Mean Annual Runoff Depth at 2016 values
22	RV10_SW3_NoDry	Like BAUF, but revegetate riparian zones on both stream sides, to 10m width along all streams in the MW region AND

		treat all future *and* some existing cover such that Attenuated Imperviousness in existing urban areas is reduced to 75% of 2016 levels AND set Mean Annual Runoff Depth at 2016 values
'Actions' that affect native Fish (and not Macroinvertebrates and Platypus)		
23	FW2	Like BAUF, but involves removing the following FULL Barriers in the: WERRIBEE catchment: ID 749 (Skeleton Ck) & ID 352 (Werribee R) MARIBYRNONG catchment: ID 840, 870 & 841 (Jacksons Ck) and 703 (Moonee Ponds Ck) YARRA catchment: ID 747 (Darebin Ck), 44 (Donnellys Ck), 361 (Grace Burn Ck), 358 (McMahons Creek) and 2 (Armstrong Creek) DANDENONG catchment: No FULL barriers removed WESTERNPORT catchment: ID 716 (Lang Lang R) And also the following PARTIAL Barriers in the: WERRIBEE catchment: ID 715, 759, 321, 879 & 880 (Koroit Ck), 750, 754 & 751 (Laverton Ck), 748 & 343 (Skeleton Ck), 881, 882, 883, 884, 885, 886, 887, 888, 889 & 354 (Werribee R), 344 & 347 (Toolern Ck), 891, 892, 893, 894 & 895 (Little R) MARIBYRNONG catchment: ID 706, 707 (Maribyrnong R), 842, 871, 872, 873 & 171 (Jacksons Ck), 702 & 733 (Moonee Ponds Ck) YARRA catchment: ID 684, 742, 741, 744, 745, 685 (Merri Ck), 760 (Darebin Ck), 763, 677, 678, 114 (Plenty R), 773, 40 & 39 (Diamond Ck), 164 (Yarra R), 829 (Sawpit Ck), 784, 782 & 783 (Corranderrk Ck), 8 (Big Pats Ck), 135 (Starvation Ck), 787, 11 & 788 (Britannia Ck) DANDENONG catchment: ID 387, 815, 241 (Dandenong Ck), 717 (Eastern Contour Drain), 266 (Kananook Ck) WESTERNPORT catchment: ID 836 (Main Ck), 856 (Bass R), 808 (Lang Lang R), 837 & 805 (Cannibal Ck), 249 (Diamond Ck), 301 & 803 (Toomuc Ck)
24	SW2_FW2	Like BAUF, but treat all future impervious cover such that Attenuated Imperviousness is maintained at 2016 levels AND remove Full and Partial Barriers as per FW2
25	RV20_SW2_FW2	Like BAUF, but revegetate riparian zones on both stream sides, to 20m width along all streams in the MW region AND treat all future impervious cover such that Attenuated Imperviousness is maintained at 2016 levels AND remove Full and Partial Barriers as per FW2

Appendix 5 - Development of unit costs for zonation analysis

Unit costs were developed for the main interventions used in the habitat suitability models, namely stormwater, revegetation and fishways. The approach and key assumptions for the vegetation costs are provided in Table 98 below.

Table 98. Methodology used to develop unit costs for vegetation

Type of action	Approach	Region	10 yr cost $/km	Comment
Woody weed removal (WdyWeedRemCost)	Costs were developed based on recent Melbourne Water capital works. They included removal costs, follow-up revegetation and on-going maintenance costs. Based on 20m wide buffer along both sides of the waterway Costed for 10 years – capex for first 3 years and 7 years of opex	South-east	$541,316	Generally easy access to sites. Based on recent costs for Gisborne and Allsops Creek
		Yarra	$735,144	Often no direct access, crews may have to walk a moderate distance. Based on recent costs for Bunyip River and Running Creek
		West	$1,439,380	difficult rocky terrain, making access difficult
		within UGB	$1,439,380	Costs within the Urban Growth boundary were equated to the 'west' costs as assigned a high
Riparian revegetation (RipRevegCost)	Costs were developed based on recent Melbourne Water capital works. They included site preparation, revegetation and on-going maintenance costs. Based on 20m wide buffer along both sides of the waterway. Costed for 10 years – capex for first 3 years and 7 years of opex	South-east	$233,392	Plants tend to establish easily (no supplementary watering required). Generally easy access to sites.
		Yarra	$427,220	No supplementary watering of plants required. Often no direct access, crews may have to walk a moderate distance. Based on recent costs for Macclesfield Creek and Diamond Creek.
		West	$933,064	Difficult rocky terrain which affects access and fencing. Drier conditions means supplementary watering over first summer required to aid plant establishment. Rabbit baiting required. Based on costs for Little River and Upper Maribyrnong.
		Within UGB	$933,064	Costs within the Urban Growth boundary were equated to the 'west' costs as assigned a high

The cost of stormwater treatment in greenfield development is based on data from Appendix C in the BPEM phase 3 report (DesignFlow, 2014). While there was no direct comparison to a cost of not increasing attenuated imperviousness, the scenario in this report which applied a requirement to achieve 8 surface days of runoff per year (considered equivalent to a 90% flow reduction) was considered the best scenario to use. The costs for all the different land use were averaged and the costs were converted to a $/impervious hectare. The data is based on

MUSIC modelling using Melbourne rainfall. Operational costs were also based on BPEM phase 3 report with 5% being the average figure that was applied. The modelling assumes 80% of stormwater from roofs is harvested. Low, medium and high costs were developed by multiplying the average cost by 0.5 for the low cost and 1.5 for the high cost.

The cost of treating stormwater in existing urban areas is known to be more expensive than in greenfield developments. Little Stringybark Creek and Dobson Creek retrofit projects provide examples of the increased costs within built up areas. As such the medium greenfield cost was used as the low cost for existing urban areas retrofit situations, the high cost for greenfield used as the medium for existing and for the high cost estimate an additional 25% was added to the medium cost.

For the purposes of estimating the most cost-effective action for each reach, the medium stormwater management cost estimate values for future and existing impervious cover were used (highlighted in yellow in Table 99). Ideally the low and high scenarios would have been assessed as well however timeframes did not allow for more detailed analysis.

Table 99. Summary of the low, medium and high cost estimates of effectively managing stormwater runoff per hectare of impervious area from future and existing impervious cover.

Impervious Cover Type	10 year cost/impervious ha		
	Low est	Med est	High est
Existing (SWExistingImpervAreaCost)	$423,400	**$712,310**	$890,388
Future (SWFutureImpervAreaCost)	$185,420	**$423,400**	$712,310

Costs for fishways were based on examples of fishways constructed by Melbourne Water. They were based on typical costs for different types of fishways and for varying heights as these were the main factors effecting cost. Some extrapolation was required to estimate costs for different heights and fishway types and this was based on expert opinion. Maintenance costs were based on the 17/18 proposed investment for the Maribyrnong Investment Plan. This generally included costs for regular inspection and maintenance and allowances for periodic corrective maintenance. Where height data was missing from the barrier database different sources of information (including imagery, plans, local knowledge) were used to estimate heights. Table 100 outlines the unit costs used for the various types of fish barriers across the region.

Table 100 Estimated costs of fishways by type (David Fisher, Melbourne Water)

		Estimated capital cost for a fishway of height		
Barrier type	**Typical fishway type**	<1 m (Category 1)	1-2 m (Category 2)	2-3 m (Category 3)
Artificial rock		10,000	20,000	30,000
Concrete channel		80,000	150,000	220,000
Crossing	Culverts	30,000	45,000	
Dam	Cone Fishway	400,000	641,740	1,000,000

Drop structure	Rock Ramp	61,300	146,483	171,033
Estuary mouth	Dredging?	100,000	120,000	140,000
Farm dam	Baffle/Cone Fishway	200,000	300,000	500,000
Gauging station	Rock Ramp	61,300	146,483	171,033
Gauging weir	Rock Ramp	61,300	146,483	171,033
Natural rock	NA	10,000	20,000	30,000
Pipe	Baffle	30,000	45,000	
Retarding basin	Baffle	80,000	150,000	220,000
Stormwater wetland	Cone Fishway	400,000	641,740	1,000,000
Weir	Rock Ramp	61,300	146,483	171,033

Notes on costs for maintenance of fishways (Leigh Smith, Melbourne Water):

1. One-off Condition Assessment (detailed): $500 per asset (usually only completed once every few years)
2. Periodic (currently set at monthly for fishways) preventative maintenance: $500 per asset per visit ($6000 per year per asset)
3. Corrective/breakdown maintenance (cost obviously varies) however, a small allowance of $10,000 per asset has been made. We have assumed that as a minimum, 5% of the entire asset portfolio (60+ fishways) would require CM/BM in any one year = 3 assets.
4. If major repairs are required, this would most likely trigger a capital renewal project.

Reference:

DesignFlow (2014) Modelling analysis for potential urban stormwater standards. A report for Melbourne Water and the Office of Living Victoria.

Appendix 6 - Overview of zonation application

Zonation is a set of methods implemented in a software tool to support large-scale systematic spatial conservation prioritisation and planning (Moilanen *et al*. 2005, 2014). The ultimate goal of conservation is to ensure the *persistence of biodiversity in the long term*. Below is a summary of the steps used to determine the most cost effective action by applying zonation methods. Further detail is available in Chee et al. (2020).

Determine the most cost-effective action

This is achieved through applying the unit costs (Appendix 4) to each reach (8,233 reaches in total). Determining a benefit score and dividing the benefit by the cost of achieving the benefit. The benefit score is the change in habitat suitability relative to the habitat suitability under the business as usual future (BAUF) scenario. Some of the key considerations include:

- Revegetation is required for at least 6km upstream from the reach which is being revegetated in-order for the benefit to be realized. The cost of this also needed to be considered.
- For reaches known to be naturally 'treeless' e.g. for a grassland ecological vegetation class, the scenario RV20 was 'disallowed'.
- As the results tended to favor single actions rather than combinations, it was decided that where RV20 was the most cost effective solution and the second most cost-effective action was RV20_SW2 *or* SW2, then we would select RV20_SW2 as the action to 'apply' for that reach. It made sense to combine these two actions as we know that addressing stormwater is important and required to protect the investment in revegetation.
- Figure 47 shows the resulting map of 'optimal' action for each of the 8,233 reaches after the process of identifying the most cost-effective action at each reach, and incorporating the various customisations described. Whilst Figure 47 shows *what* the 'optimal' action for each reach is according to cost-effectiveness and customisations, budget and resource limitations mean that we cannot afford to apply the 'optimal' action for every reach. Instead, we will need to prioritise *where* it would be most profitable to take action. The Zonation analysis is used to generate the quantitative spatial prioritisation 'solution'.

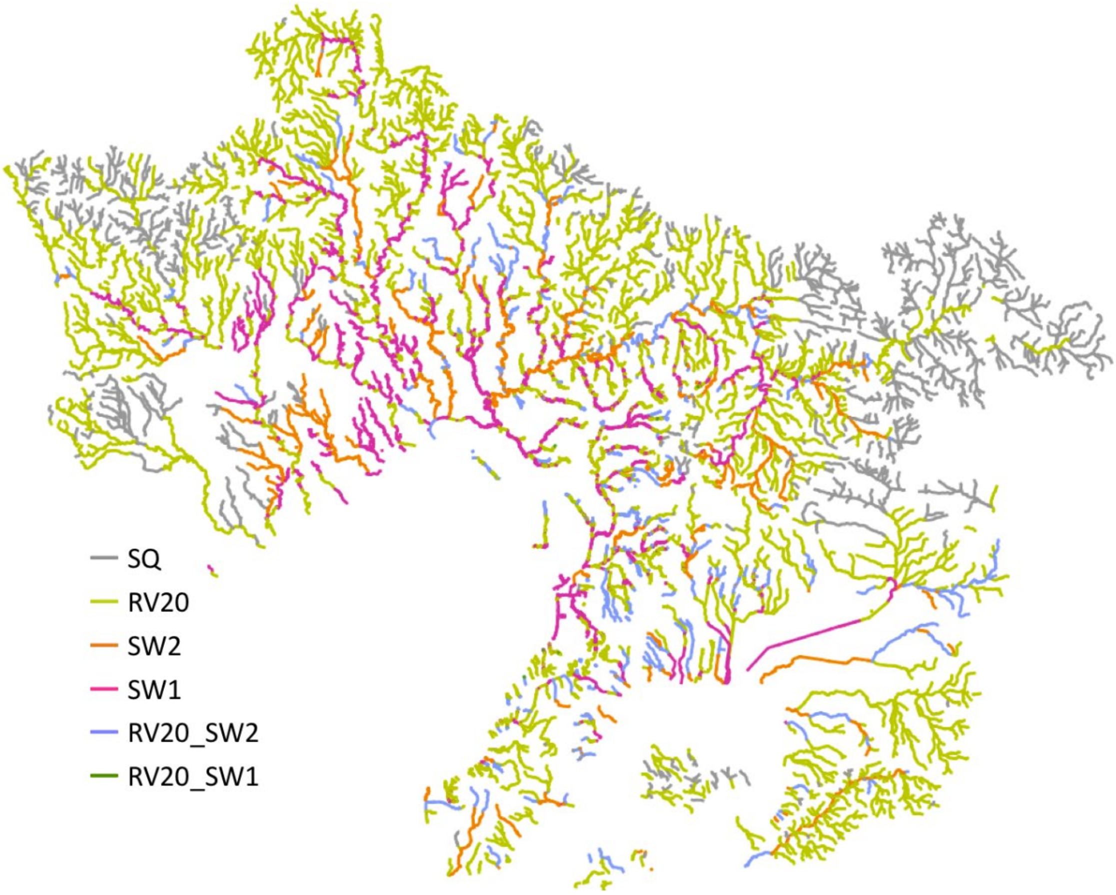


Figure 47. The ‘optimal’ action ‘applied’ at each of the 8,233 reaches in the MW region after identifying the most cost-effective action and including the various customisations.
Red lines represent low priority and blue lines represent high priority for investment. Refer to Table 101 for a description of each of the scenarios.

Table 101. Combination of interventions used in zonation analysis

Scenario code	Description
SQ	Status quo for variables as at 2016
SW1	Treat all *existing* and *future* impervious cover such that Attenuated Imperviousness is effectively zero
SW2	Treat all *future* impervious cover such that Attenuated Imperviousness is maintained at 2016 levels
RV20	Riparian Revegetation to 20 m width
RV20_SW1	Riparian Revegetation to 20 m width *and* treat all *existing* and *future* impervious cover such that Attenuated Imperviousness is effectively zero.
RV20_SW2	Riparian Revegetation to 20 m width *and* treat all *future* impervious cover such that Attenuated Imperviousness is maintained at 2016 levels,

Determine where to undertake the most cost effective action

The intent is to ensure that the Zonation solution will capture high-quality areas that are good for instream biodiversity in the context of the whole region (doing the analysis at just the catchment scale would have led to inefficiencies) *both at present and at the future timepoint,* while seeking to prioritise reaches where significant improvements can also be made. That is, we needed zonation to ensure the 'protect the best' principle played out rather than biasing large management gains from lower quality sites.

The key considerations in determining where to undertake an action included:

a) what's valuable at *present* (i.e. under CURR conditions)

b) what's predicted to be valuable under a business-as-usual-future (i.e. under BAUF conditions),

c) what's expected to produce the most cost-effective improvement in instream biodiversity (relative to BAUF).

Using the most cost effective action from the step above, zonation was applied to develop a zonation ranking map. The output spatially prioritises which reaches should be managed first according the most cost effective action for that reach. Figure 41 shows the priority for management actions across all waterways in the region where orange lines represent low priority and purple lines represent high priority for investment.

Once the zonation output is generated a process of sense checking was undertaken involving:

i) is the sub-catchment/reach dominated by a highly human-modified channel? e.g. a completely concrete-lined channel or underground pipe
ii) is there presence of levee or EVC constraints (eg grassland EVCs) where revegetation would be undesirable for flooding or native vegetation quality
iii) Other known constraints following consultation with internal and external stakeholders (eg buffer widths in highly urban areas)

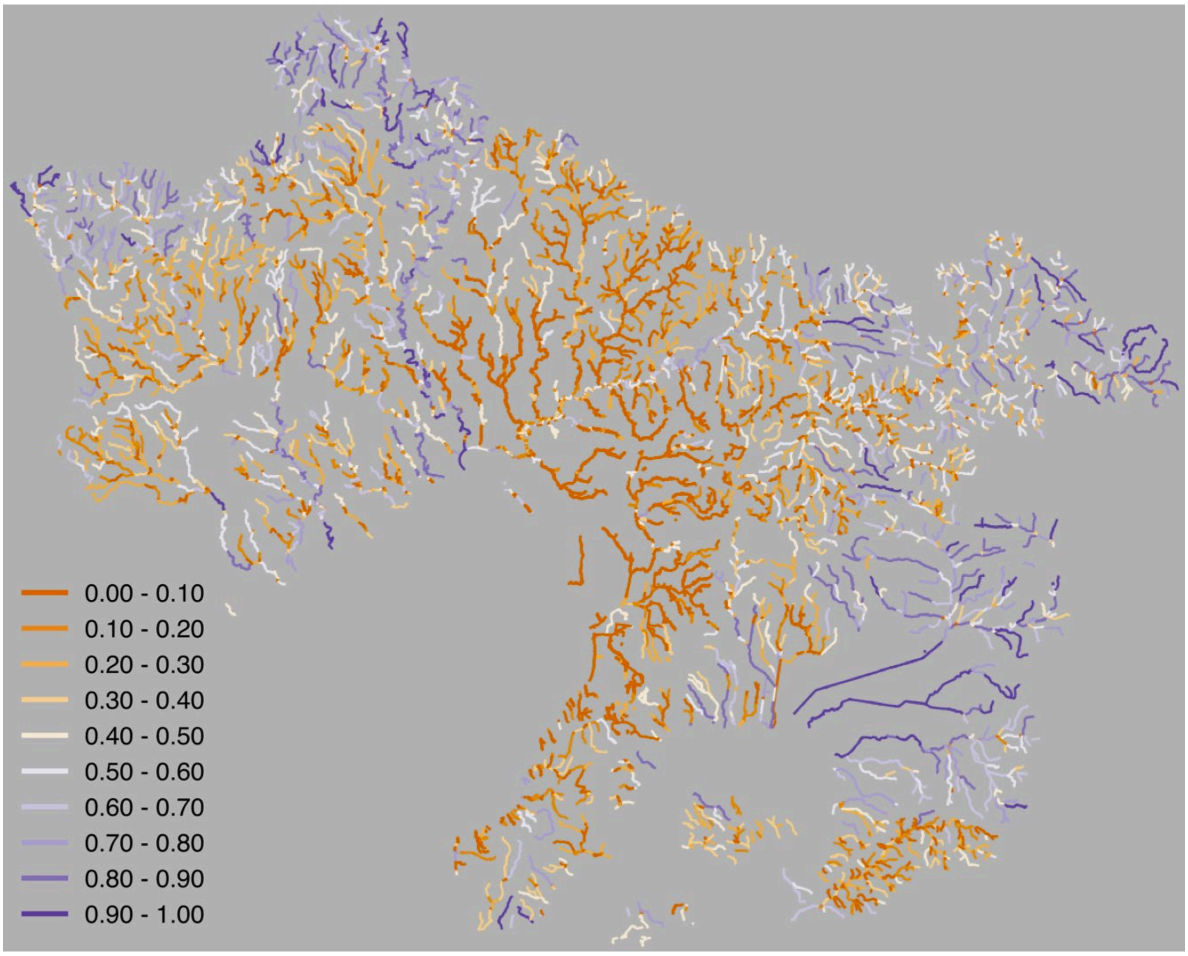


Figure 48. Map of the continuous ranking of spatial priorities (0-1) produced by the Zonation analysis in which the 'optimal' action was 'applied' at each of the 8,233 reaches in the MW region after identifying the most cost-effective action and including the various customisations.

Summary of zonation settings

The *CAZ* rule setting was used because it helps ensure that the core areas of individual taxa/species are retained even if they occur in species-poor regions (Moilanen *et al*. 2005).

The weighting of input features is an important, necessary and unavoidably subjective choice in a Zonation analysis. A top-down approach to weighting was used which involved starting with 100 weight points (an arbitrary choice), and dividing them between macroinvertebrates, fish, platypus in a 60:30:10 ratio. Macroinvertebrates were weighted the most as they are a good overall indicator of waterway health. Fish were weighted second as there are many species and as such Platypus as a single species was rated lowest. For further details see Chee et al.(2020).

Connectivity is important because it influences the ability of organisms to move between, disperse to, and colonise different sites. In streams, the loss of a reach results in a local loss as well as losses in the upstream and downstream neighbourhoods of that reach. In Zonation, the severity of upstream and downstream losses can be specified separately for each species.

The designation of upstream and downstream connectivity/neighbourhood loss response for macroinvertebrates, native fish and platypus was based on expert knowledge and judgement of taxa requirements (Associate professor Chris Walsh for macroinvertebrates; Dr Rhys Coleman for fish and platypus).

References:

Moilanen A, Franco AMA, Early RI, Fox R, Wintle B, Thomas CD. (2005) Prioritizing multiple-use landscapes for conservation: methods for large multi-species planning problems. Proceedings of the Royal Society of London: B. Biological Sciences 272:1885-1891.

Moilanen A, Montesino Pouzols F, Meller L, Veach V, Arponen A, Leppänen J, Kujala H. (2014) Zonation - Spatial Conservation Planning Methods and Software Version 4.0 User Manual. Conservation Biology Informatics Group (C-BIG), Department of Biosciences, University of Helsinki, Helsinki, Finland.

Chee, YE, Coleman, R, RossRakesh, S, Bond, N and Walsh, C (2020) Habitat Suitability Models, Scenarios and Quantitative Action Prioritisation (using Zonation) for the Healthy Waterways Strategy 2018: A Resource Document. Melbourne Waterway Research-Practice Partnership Technical Report 20.3, March 2020

Appendix 7 - impervious fraction for zone codes used for predicting ultimate urban development

The following planning scheme zones were assign Fraction imperviousness based on what was expected to be an ultimate urbanisation scenario for 20 -50 years. This provided the upper limit impact of urbanisation in the model scenarios.

The 113 ZONE_CODES we used, and their corresponding TI.Ultimate values are as follows:

ZONE_CODE ZONE_DESC TI.Ultimate

1 ACZ1 ACTIVITY CENTRE ZONE - SCHEDULE 1 0.90
2 ACZ2 ACTIVITY CENTRE ZONE - SCHEDULE 2 0.90
3 ACZ3 ACTIVITY CENTRE ZONE - SCHEDULE 3 0.90
4 B1Z COMMERCIAL 1 ZONE 0.90
5 B2Z COMMERCIAL 1 ZONE 0.90
6 B3Z COMMERCIAL 2 ZONE 0.90
7 B4Z COMMERCIAL 2 ZONE 0.90
8 B5Z COMMERCIAL 1 ZONE 0.90
9 C1Z COMMERCIAL 1 ZONE 0.90
10 C2Z COMMERCIAL 2 ZONE 0.90
11 CA COMMONWEALTH LAND NOT CONTROLLED BY PLANNING SCHEME 0.60
12 CCZ1 CAPITAL CITY ZONE - SCHEDULE 1 0.90
13 CCZ2 CAPITAL CITY ZONE - SCHEDULE 2 0.90
14 CCZ3 CAPITAL CITY ZONE - SCHEDULE 3 0.90
15 CCZ4 CAPITAL CITY ZONE - SCHEDULE 4 0.90
16 CCZ5 CAPITAL CITY ZONE - SCHEDULE 5 0.90
17 CCZ6 CAPITAL CITY ZONE - SCHEDULE 6 0.90
18 CDZ1 COMPREHENSIVE DEVELOPMENT ZONE - SCHEDULE 1 0.75
19 CDZ2 COMPREHENSIVE DEVELOPMENT ZONE - SCHEDULE 2 0.75
20 CDZ3 COMPREHENSIVE DEVELOPMENT ZONE - SCHEDULE 3 0.75
21 CDZ4 COMPREHENSIVE DEVELOPMENT ZONE - SCHEDULE 4 0.75
22 CDZ5 COMPREHENSIVE DEVELOPMENT ZONE - SCHEDULE 5 0.75
23 CDZ6 COMPREHENSIVE DEVELOPMENT ZONE - SCHEDULE 6 0.75
24 DZ1 DOCKLANDS ZONE - SCHEDULE 1 0.90
25 DZ2 DOCKLANDS ZONE - SCHEDULE 2 0.90
26 DZ3 DOCKLANDS ZONE - SCHEDULE 3 0.90
27 DZ4 DOCKLANDS ZONE - SCHEDULE 4 0.90
28 DZ5 DOCKLANDS ZONE - SCHEDULE 5 0.90
50 IN2Z INDUSTRIAL 2 ZONE 0.90
51 IN3Z INDUSTRIAL 3 ZONE 0.90
52 LDRZ LOW DENSITY RESIDENTIAL ZONE 0.30
53 LDRZ1 LOW DENSITY RESIDENTIAL ZONE - SCHEDULE 1 0.30
54 LDRZ2 LOW DENSITY RESIDENTIAL ZONE - SCHEDULE 2 0.30
55 LDRZ3 LOW DENSITY RESIDENTIAL ZONE - SCHEDULE 3 0.30
56 MUZ MIXED USE ZONE 0.70
57 MUZ1 MIXED USE ZONE - SCHEDULE 1 0.70
58 MUZ2 MIXED USE ZONE - SCHEDULE 2 0.70
59 MUZ3 MIXED USE ZONE - SCHEDULE 3 0.70
60 NRZ NEIGHBOURHOOD RESIDENTIAL ZONE 0.65
61 NRZ1 NEIGHBOURHOOD RESIDENTIAL ZONE - SCHEDULE 1 0.65
62 NRZ2 NEIGHBOURHOOD RESIDENTIAL ZONE - SCHEDULE 2 0.65
63 NRZ3 NEIGHBOURHOOD RESIDENTIAL ZONE - SCHEDULE 3 0.65
64 NRZ4 NEIGHBOURHOOD RESIDENTIAL ZONE - SCHEDULE 4 0.65
65 NRZ5 NEIGHBOURHOOD RESIDENTIAL ZONE - SCHEDULE 5 0.65
66 NRZ7 NEIGHBOURHOOD RESIDENTIAL ZONE - SCHEDULE 7 0.65
67 NRZ8 NEIGHBOURHOOD RESIDENTIAL ZONE - SCHEDULE 8 0.65
68 NRZ9 NEIGHBOURHOOD RESIDENTIAL ZONE - SCHEDULE 9 0.65
69 PDZ PRIORITY DEVELOPMENT ZONE 0.70
70 PDZ1 PRIORITY DEVELOPMENT ZONE - SCHEDULE 1 0.70
71 PDZ2 PRIORITY DEVELOPMENT ZONE - SCHEDULE 2 0.70
72 PPRZ PUBLIC PARK AND RECREATION ZONE 0.10
73 PUZ1 PUBLIC USE ZONE - SERVICE AND UTILITY 0.10
74 PUZ2 PUBLIC USE ZONE - EDUCATION 0.70
75 PUZ3 PUBLIC USE ZONE - HEALTH AND COMMUNITY 0.70
76 PUZ4 PUBLIC USE ZONE - TRANSPORT 0.70
77 PUZ5 PUBLIC USE ZONE - CEMETERY/CREMATORIUM 0.70
78 PUZ6 PUBLIC USE ZONE - LOCAL GOVERNMENT 0.70
79 PUZ7 PUBLIC USE ZONE - OTHER PUBLIC USE 0.60
80 PZ PORT ZONE 0.90
81 R1Z GENERAL RESIDENTIAL ZONE 0.80
82 R2Z GENERAL RESIDENTIAL ZONE 0.80
83 RGZ1 RESIDENTIAL GROWTH ZONE - SCHEDULE 1 0.80
84 RGZ2 RESIDENTIAL GROWTH ZONE - SCHEDULE 2 0.80

29 DZ6 DOCKLANDS ZONE - SCHEDULE 6 0.90
30 GRZ GENERAL RESIDENTIAL ZONE 0.80
31 GRZ1 GENERAL RESIDENTIAL ZONE - SCHEDULE 1 0.80
32 GRZ10 GENERAL RESIDENTIAL ZONE - SCHEDULE 10 0.80
33 GRZ11 GENERAL RESIDENTIAL ZONE - SCHEDULE 11 0.80
34 GRZ12 GENERAL RESIDENTIAL ZONE - SCHEDULE 12 0.80
35 GRZ13 GENERAL RESIDENTIAL ZONE - SCHEDULE 13 0.80
36 GRZ14 GENERAL RESIDENTIAL ZONE - SCHEDULE 14 0.80
37 GRZ17 GENERAL RESIDENTIAL ZONE - SCHEDULE 17 0.80
38 GRZ2 GENERAL RESIDENTIAL ZONE - SCHEDULE 2 0.80
39 GRZ3 GENERAL RESIDENTIAL ZONE - SCHEDULE 3 0.80
40 GRZ4 GENERAL RESIDENTIAL ZONE - SCHEDULE 4 0.80
41 GRZ5 GENERAL RESIDENTIAL ZONE - SCHEDULE 5 0.80
42 GRZ6 GENERAL RESIDENTIAL ZONE - SCHEDULE 6 0.80
43 GRZ7 GENERAL RESIDENTIAL ZONE - SCHEDULE 7 0.80
44 GRZ8 GENERAL RESIDENTIAL ZONE - SCHEDULE 8 0.80
45 GRZ9 GENERAL RESIDENTIAL ZONE - SCHEDULE 9 0.80
46 GWAZ1 GREEN WEDGE A ZONE - SCHEDULE 1 0.30
47 GWAZ2 GREEN WEDGE A ZONE - SCHEDULE 2 0.30
48 GWZ1 GREEN WEDGE ZONE - SCHEDULE 1 0.30
49 IN1Z INDUSTRIAL 1 ZONE 0.90
85 RGZ3 RESIDENTIAL GROWTH ZONE - SCHEDULE 3 0.80
86 RGZ4 RESIDENTIAL GROWTH ZONE - SCHEDULE 4 0.80
87 RGZ5 RESIDENTIAL GROWTH ZONE - SCHEDULE 5 0.80
88 RLZ1 RURAL LIVING ZONE - SCHEDULE 1 0.30
89 SUZ1 SPECIAL USE ZONE - SCHEDULE 1 0.50
90 SUZ11 SPECIAL USE ZONE - SCHEDULE 11 0.50
91 SUZ2 SPECIAL USE ZONE - SCHEDULE 2 0.50
92 SUZ3 SPECIAL USE ZONE - SCHEDULE 3 0.50
93 SUZ4 SPECIAL USE ZONE - SCHEDULE 4 0.50
94 SUZ5 SPECIAL USE ZONE - SCHEDULE 5 0.50
95 SUZ6 SPECIAL USE ZONE - SCHEDULE 6 0.50
96 SUZ7 SPECIAL USE ZONE - SCHEDULE 7 0.50
97 SUZ8 SPECIAL USE ZONE - SCHEDULE 8 0.50
98 TZ TOWNSHIP ZONE 0.50
99 UGZ URBAN GROWTH ZONE 0.50
100 UGZ1 URBAN GROWTH ZONE - SCHEDULE 1 0.50
101 UGZ10 URBAN GROWTH ZONE - SCHEDULE 10 0.50
102 UGZ11 URBAN GROWTH ZONE - SCHEDULE 11 0.50
103 UGZ13 URBAN GROWTH ZONE - SCHEDULE 13 0.50
104 UGZ14 URBAN GROWTH ZONE - SCHEDULE 14 0.50
105 UGZ15 URBAN GROWTH ZONE - SCHEDULE 15 0.50
106 UGZ2 URBAN GROWTH ZONE - SCHEDULE 2 0.50
107 UGZ3 URBAN GROWTH ZONE - SCHEDULE 3 0.50
108 UGZ4 URBAN GROWTH ZONE - SCHEDULE 4 0.50
109 UGZ5 URBAN GROWTH ZONE - SCHEDULE 5 0.50
110 UGZ6 URBAN GROWTH ZONE - SCHEDULE 6 0.50
111 UGZ7 URBAN GROWTH ZONE - SCHEDULE 7 0.50
112 UGZ8 URBAN GROWTH ZONE - SCHEDULE 8 0.50
113 UGZ9 URBAN GROWTH ZONE - SCHEDULE 9 0.50