



WATER QUALITY (WQ)
SCIENTIFIC ASSESSMENTS Part III



Commissioner
for Environmental
Sustainability
Victoria



Traditional Owners

The Commissioner for Environmental Sustainability proudly acknowledges Victoria's Aboriginal community and their rich culture and pays respect to their Elders past and present.

We acknowledge Aboriginal people as Australia's first peoples and as the Traditional Owners and custodians of the land and water on which we rely. We recognise and value the ongoing contribution of Aboriginal people and communities to Victorian life, and how this enriches us.

We embrace the spirit of reconciliation, working towards the equality of outcomes and ensuring an equal voice.

Water Quality

This chapter includes assessments of Victoria's surface-water quality, occurrence of algal blooms, reported inland water-pollution incidents and volume of sewage discharged to surface waters. Indicators for groundwater quality are included in the Water Resources chapter, and indicators associated with marine-water quality are included in the Marine and Coastal Environments chapter.

Background

Water quality is fundamental to the ecosystem services that inland waters provide, such as drinking water, cycling of nutrients, maintenance of biodiversity, and recreational and cultural opportunities. Poor water quality has serious implications for the ecological health of inland waters, biodiversity, and human and livestock health.

Water-quality pollution generally arises from point-source discharges (directly from industry and treatment plants) or diffuse sources (runoff from catchments). Regulatory improvements have reduced point-source water pollution. Diffuse sources, such as urban stormwater, are now the most significant contributor to pollution of Melbourne's rivers, creeks and wetlands. The projected increase in extreme rainfall events in Victoria is highly likely to amplify the effects of urban stormwater pollution unless practical solutions are implemented.

The main water-quality issues for Victoria have traditionally been salinity, turbidity, nitrogen and phosphorus. At a state and national level, these variables are considered the most significant river contaminants. However, there are numerous other variables that contribute to water quality, such as pH, pesticides, heavy metals and temperature, which may have local or regional significance. Water quality is also affected by interactions between these components. For example, salinity and temperature both affect the saturation concentration of dissolved oxygen.

When SoE 2013 was issued, the Department of Environment, Land, Water and Planning (DELWP) had not analysed the raw monitoring data that had been collected, and was unable to provide a statewide assessment of water quality. Consequently, SoE 2013 contained only a limited update of water quality from SoE 2008. The 2008 assessment showed that water quality was generally poor in much of Victoria, particularly in Victoria's lowlands and in the west of the state.

There has been an increased focus on the water quality sector since 2013. DELWP conducted an internal audit of its water-quality monitoring programs in January 2015, prior to a Victorian Auditor-General's Office (VAGO) audit into Victorian water-resource monitoring, completed in May 2016.

The VAGO audit made three recommendations in response to a central finding that, although some individual programs are coordinated and governed well, oversight of the individual long-term water-quality monitoring programs in the Port Phillip Bay and Western Port region is deficient. The deficiency was due to inadequate coordination across all programs among the three relevant agencies: DELWP, Melbourne Water and Environment Protection Authority Victoria (EPA Victoria). The issue is less prevalent in the nine other catchments where DELWP has the clear coordination role. Specific findings from the VAGO audit included agencies not having a formal cooperative approach to monitoring, reporting and evaluating the individual monitoring programs in the region, and agencies not sharing and using data efficiently to meet reporting needs.¹ The DELWP and VAGO audits informed the Victorian Government's water plan, *Water for Victoria*, released in October 2016.²

1. VAGO 2016, 'Monitoring Victoria's Water Resources', Melbourne, Victoria <https://www.audit.vic.gov.au/sites/default/files/20160525-Water-Resources.pdf> Accessed 3 December 2018.
2. DELWP 2018, 'Water for Victoria', East Melbourne, Victoria https://www.water.vic.gov.au/_data/assets/pdf_file/0030/58827/Water-Plan-strategy2.pdf Accessed 3 December 2018.

Other organisations that help to manage water quality are Catchment Management Authorities (CMAs), which develop and implement waterway management strategies, and EPA Victoria, which implements the *State Environment Protection Policy (Waters)* (SEPP (Waters)) and regulates water quality.

Victoria also contributed to the development of the *Basin Salinity Management 2030* strategy, which is responding to the environmental, social and economic risks posed by salinity in the Murray–Darling Basin.³

Water-quality monitoring has been a greater focus of state and departmental strategies since SoE 2013. Consequently, SoE 2018 is a significant update to water-quality information, due to the trend data that has been supplied by DELWP on a range of quality indicators measured at approximately 80 sites.

A warmer climate will lead to higher water temperatures, affecting the distribution of many aquatic species. Increased temperatures also have water-quality implications, including reduced concentrations of dissolved oxygen and therefore a potential increase in algal blooms. Increased bushfires will also impact on water quality and riparian vegetation.

Critical challenges facing Victoria's management of water-quality impacts now and in the future include:

- balancing the needs of catchment and waterway health with human and agricultural water consumption needs
- managing urban growth and its impact on urban waterway health
- ensuring that long-term water-quality monitoring is coordinated and shared among the lead agencies (a key recommendation of the 2016 VAGO audit)

- maintaining long-term water-quality monitoring data so that it is easily accessible and suitable for informing policy and strategy development
- ensuring a coordinated approach to 'citizen science' (which incorporates public participation in research) in the water-quality sector. Citizen science programs are more prevalent in water-quality than in other sectors. Ensuring that lead agencies design and target programs with a similar level of rigour will help to maximise the value of community participation.
- identifying strategies to tackle the likely increase in stormwater pollution incidents associated with more frequent and intense rainfall events.
- mitigating against:
 - increasing stormwater and wastewater discharges from urban areas
 - altered water regimes, salinity and algal blooms
 - an increase in catchment inflows from diffuse sources
 - localised events, in which individual water-quality stressors, including nutrients, sediments, toxicants and pathogens, exceed objectives.

Note that this chapter refers to surface water only: groundwater quality is covered in the Water Resources chapter.

3. Murray-Darling Basin Ministerial Council 2015, 'Basin Salinity Management 2030 (BSM2030)', Canberra, Australia https://www.mdba.gov.au/sites/default/files/pubs/D16-34851-basin_salinity_management_strategy_BSM2030.pdf Accessed 3 December 2018.

Current Victorian Government Settings: Legislation, Policy, Programs

In October 2016, the Victorian Government released *Water for Victoria*, a plan for the management of Victoria's water resources, now and in the future.⁴

The plan includes commitments to improve Victoria's existing waterway monitoring programs, invest in community partnerships and citizen-science initiatives, strengthen integrated catchment management, and deliver a new SEPP to protect water quality.

The plan invests \$222 million for catchment and waterway health, to better balance the needs of the environment with water consumption needs. This investment includes water for the environment, riparian restoration and other programs.

The government has also established a series of Integrated Water Management Forums across the state. In these forums, the water sector and the community work together to plan, manage and deliver water in towns and cities.

To help manage urban growth and its impact on urban waterway health, the government has developed a range of water policies, including *Water for Victoria*, the *Yarra River Action Plan*, the *Plan Melbourne Implementation Plan* and the *Port Phillip Bay Environmental Management Plan*.

Melbourne Water's responsibility is to create long-term plans that ensure the region's waterways are healthy, liveable and accessible. Melbourne Water's *Healthy Waterways Strategy 2018* is intended to address future urban waterway management needs.⁵ As part of the Melbourne Urban Stormwater Institutional Arrangements Review, DELWP is reviewing the arrangements

between Melbourne Water and local government authorities to clarify responsibilities for urban stormwater risk management, related assets and services in the Melbourne metropolitan area.⁶ The government has also established the Improving Stormwater Management Advisory Committee to provide independent advice on planning and development controls for improving stormwater management and strengthening the links between water management and urban planning.

The 2003 SEPP (WoV) was the government's primary water-quality policy. However, it did not provide clarity on the roles and responsibilities of the lead agencies involved in long-term water-quality monitoring.⁷ The government committed to ensuring that the water-quality standards and objectives that are the basis of policies reflect best-available science, and provide clear and relevant standards and obligations to protect and improve the health of Victoria's water environments. To do this, the government has updated and merged the Waters of Victoria SEPP and the Groundwaters of Victoria SEPP,⁸ to create the new SEPP (Waters).

4. DELWP 2018, 'Water for Victoria', East Melbourne, Victoria https://www.water.vic.gov.au/_data/assets/pdf_file/0030/58827/Water-Plan-strategy2.pdf Accessed 3 December 2018.

5. Melbourne Water Corporation 2018, 'Healthy Waterways Strategy 2018', Melbourne, Victoria <https://www.melbournewater.com.au/media/6361/download> Accessed 3 December 2018.

6. DELWP, 'Melbourne Urban Stormwater Institutional Arrangements Review', East Melbourne, Victoria <https://www.water.vic.gov.au/managing-floodplains/stormwater-review> Accessed 3 December 2018.

7. EPA, 'State Environment Protection Policy (Waters) review', Melbourne, Victoria <https://www.epa.vic.gov.au/our-work/setting-standards/environmental-standards-reform/water> Accessed 3 December 2018.

8. EPA, 'Water-related policies', Melbourne, Victoria <https://www.epa.vic.gov.au/about-us/legislation/water-legislation/water-related-policies> Accessed 3 December 2018.

Algal Blooms

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
WQ:01 Occurrence of algal blooms						 DATA QUALITY Fair (no suitable trend data)
Data Custodian DELWP						

An algal bloom is a rapid increase in the population of algae, often resulting in the discolouration of water from their pigments. In freshwater, the algae of greatest concern are cyanobacteria (blue-green algae).

Cyanobacteria are naturally present in Victoria's inland waters. Under certain conditions, cyanobacteria populations can increase, causing potentially toxic blooms. Low flows, combined with the availability of nutrients and higher water temperatures, have been identified as likely causes of algal blooms. SoE 2013 found high variability in algal bloom number and extent, to the point that it was not possible to determine any trends.⁹

Some species of blue-green algae can produce chemical compounds that can taint drinking water, often giving it a musty odour and taste. More significantly, some species can produce toxins that have serious health implications for humans and animals, including livestock, if they are consumed, inhaled or come into contact with skin.¹⁰ Even high levels of non-toxic algae can affect water quality and treatment through filter-clogging.¹¹

During the late 1980s and early 1990s there were widespread cyanobacteria blooms in several rivers in south-eastern Australia, most notably

a 1,000 km bloom along the Darling River. This prompted research that led to the conclusion that algal blooms, particularly of blue-green algae, were stimulated by high nutrient availability, and that phosphorus was the limiting nutrient.¹² More recent studies have indicated that the conditions that stimulate algal growth to bloom proportion are more complex, and involve many site-based factors. Furthermore, nitrogen seems to play an equally important role as phosphorus in controlling the biomass of these freshwater blooms.¹³

Once algal blooms exceed a certain level, they are reported in a coordinated database. The trigger level for reporting a cyanobacteria bloom is when cyanobacteria in any water body exceed 0.2 mm³/L. In 2017–18, 113 cyanobacteria blooms were reported, in water bodies throughout all Victorian regions. While algal blooms are more prevalent in the warmer months, they can occur in any season, and without warning. No data is available to report on trends in algal bloom occurrence.

9. Commissioner for Environmental Sustainability 2013, 'State of the Environment report 2013', Melbourne, Victoria <https://www.ces.vic.gov.au/sites/default/files/publication-documents/2013%20SoE%20report%20full.pdf> Accessed 3 December 2018

10. DELWP 2015, 'Blue-Green Algae Circular 2016-17', East Melbourne, Victoria https://www.water.vic.gov.au/_data/assets/word_doc/0033/65589/BGA-Circular-2016-17final_-_docx Accessed 3 December 2018.

11. Ibid.

12. Oliver R, Hart B, Olley J, Grace M, Rees C, Caitcheon G 1999, 'The Darling River: Algal growth and the cycling and sources of nutrients', *Murray-Darling Freshwater Research Centre*.

13. Davis JR, Koop K 2006, 'Eutrophication in Australian rivers, reservoirs and estuaries—a southern hemisphere perspective on the science and its implications', *Hydrobiologia*, 559(1) pp. 23–76.

Aquatic Ecosystem Health

Healthy aquatic ecosystems depend on the quality of water for critical processes such as nutrient cycling, primary production and the creation of suitable habitats to support diverse communities of aquatic animals and plants.

Water quality is influenced by a range of factors, including:

- climate (patterns of rainfall and drought)
- land use (adjacent to waterways, but also in the catchment)
- water-resource use (extraction of water for drinking and agriculture, and discharge of stormwater and wastewater)
- ecosystem processes (such as water-sediment interactions and nutrient cycling)
- extreme events such as bushfires.

There are many aspects to water quality, including physical properties such as temperature and water clarity, concentrations of chemical components (such as salinity and dissolved oxygen) and biological processes such as algal growth.

The assessment of water quality in this report focuses on five water-quality indicators: dissolved oxygen, salinity (electrical conductivity), nutrients (total nitrogen and total phosphorus), water clarity (turbidity) and alkalinity (pH).

No statewide data was available for suspended solid concentrations in rivers, or for water temperature and chlorophyll-a concentrations in rivers. These indicators are generally less relevant for Victoria's water quality, although they can inform specific water-quality issues on localised scales. For example, suspended solids can indicate impacts, such as erosion, from localised to catchment scale. Chlorophyll-a can indicate the potential for algal blooms and fish kills.

Data collected from 2010 to 2017 was used to inform the water-quality assessment for indicators in this theme. This period spans a range of climatic conditions, from the wet years of 2010 and 2011, to the dry years of 2014 and 2015. This enables an assessment of water quality over a period that resembles the projected climate for Victoria: generally hotter and drier, but interspersed with more extreme rainfall events. Data was sourced from the Water Measurement Information System and Melbourne Water.^{14,15,16} Most of the water-quality measurements were made on a monthly basis.

SEPP (WoV) provides water-quality objectives for Victorian surface waters. Measurements that attain the objective are indicative of good conditions; measurements that do not attain the objective are a warning of potentially poor conditions. In this report, attainment of SEPP (WoV) objectives has been used as an indicator of the state of water quality across Victoria. The number of sites in a region attaining SEPP (WoV) objectives was used to complete the SoE status assessment (Figure WQ.1).¹⁷

Many of the figures in the Aquatic Ecosystem Health theme display the average number of monitoring sites per region over an assessment period from 2010 to 2017. An average has been used because the number of monitored sites in a region can change each year.

14. DELWP, 'Water Measurement Information System', East Melbourne, Victoria <http://data.water.vic.gov.au/monitoring.htm> Accessed 3 December 2018.

15. Melbourne Water Corporation, 'Waterway water quality data', Melbourne, Victoria <https://www.melbournewater.com.au/water/health-and-monitoring/river-health-and-monitoring/waterway-water-quality-data> Accessed 3 December 2018.

16. Note that data from Melbourne Water sites was provided only as summary statistics for 2010 to 2015. Total 75th percentiles (2010 – 2017) were calculated by averaging the 75th percentiles of individual years.

17. Note that the SEPP (WoV) was the subject of a recent review and a new 2018 SEPP (Waters) has been released (<https://engage.vic.gov.au/seppwaters> Accessed 3 December 2018). This SoE 2018 assessment of water quality, however, was completed before the new SEPP was approved and has used the previous (2003) policy. It should be noted that the water quality objectives for rivers and streams have not changed substantially between the old policy and the new policy.

SEPP (WoV) rating	SEPP (WoV) criteria	SoE status
Excellent	> 70 % of sites attained SEPP (WoV) water-quality objectives	Good
Good	51–70% of sites attained SEPP (WoV) water-quality objectives	Good
Moderate	31–50% of sites attained SEPP (WoV) water-quality objectives	Fair
Poor	11–30% of sites attained SEPP (WoV) water-quality objectives	Poor
Very Poor	< 10% of sites attained SEPP (WoV) water-quality objectives	Poor

Figure WQ.1 Matching the SEPP (WoV) ratings to the SoE status

SEPP (WoV) attainment across all catchments and years of monitoring from 2010 to 2017 shows that inland water quality for pH and dissolved oxygen is generally rated as excellent, and salinity is rated as good. However, nutrients (total nitrogen and phosphorus) and water clarity (turbidity) are generally rated as poor in Victoria's inland waters. (These important assessments are possible due to improved data availability since SoE 2013, and illustrate the value of DELWP investments to align data availability with SoE reporting.)

In addition to this analysis, water-quality report cards for the catchment waterways of Port Phillip Bay, Western Port and Gippsland Lakes are available online at the *Yarra and Bay* website.¹⁸

18. State Government of Victoria, 'Report Card 2016–2017', Melbourne, Victoria <https://yarraandbay.vic.gov.au/report-card/report-card-2017> Accessed 3 December 2018.

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
WQ:02 Dissolved oxygen concentration in rivers						
Data Custodian DELWP, Melbourne Water						Good

Biota that access oxygen from the water column, such as fish, tadpoles and macroinvertebrates, are highly susceptible to decreases in dissolved oxygen. Dissolved oxygen vary considerably over short periods and is influenced by temperature, salinity and biological activity. In most aquatic systems, dissolved oxygen follows a diurnal (daily) cycle, with a longer-term pattern that is balanced by diffusion of oxygen from the atmosphere and consumption of oxygen by biota. While the dissolved-oxygen requirements of fish species and different life-stages can vary significantly, mortality can occur at concentrations lower than 3 mg/L, which is only fractionally lower than the SEPP attainment value of greater than or equal to 3.5 mg/L.¹⁹

Dissolved oxygen in Victorian rivers and streams for 2010 to 2017 was rated as excellent in the east and central regions of the state, and good in the western CMA regions (Figure WQ.2). The only river basin that ranked lower than good was the Murray-Riverina, which includes the main stem of the Murray River, and reflects water quality not only in Victorian rivers, but that flowing in from New South Wales systems into the mid-Murray.

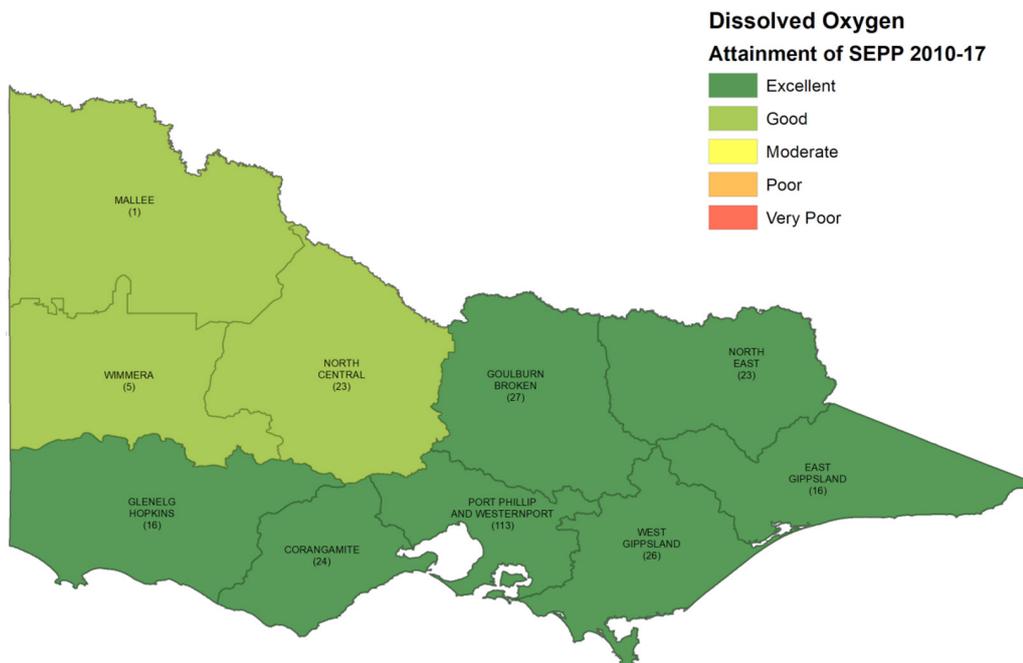


Figure WQ.2 SEPP (WoV) attainment of the dissolved oxygen threshold of ≥ 3.5 mg/L by CMA regions

Note: Numbers represent the average number of monitoring locations in each region used in the assessment. (Data source: DELWP, Melbourne Water, 2018)

19. Small K, Kopf RK, Watts RJ, Howitt J 2014, 'Hypoxia, blackwater and fish kills: experimental lethal oxygen thresholds in juvenile predatory lowland river fishes', *PLoS One*, 9(4).

Table WQ.1 Per cent attainment of SEPP (WoV) water-quality objectives for dissolved oxygen

CMA region (average number of sites)	2010	2011	2012	2013	2014	2015	2016	2017	All years
West Gippsland (27)	96	96	100	100	100	100	100	100	99
East Gippsland (17)	100	88	100	100	100	100	94	100	98
North East (24)	92	96	96	100	100	100	91	100	97
Glenelg Hopkins (16)	69	88	94	88	88	94	100	100	90
Corangamite (24)	67	75	88	83	83	83	79	75	79
Port Phillip & Western Port (114)	62	85	84	80	81	77	72	68	77
Goulburn Broken (27)	45	81	80	84	86	68	63	59	71
Mallee (1)	50	0	100	100	100				67
North Central (23)	38	55	77	87	75	71	64	71	67
Wimmera (5)	40	0	80	100	80	80	80	60	65

Note: Blank cells indicate no data available. The following cell colours in the table represent specific water quality ratings: dark green (excellent water quality), light green (good water quality), yellow (fair water quality), orange (poor water quality) and red (very poor water quality).
(Data source: DELWP, Melbourne Water, 2018)

Dissolved oxygen was generally worse in 2010 and 2011 than in subsequent years (Table WQ.1). This is most likely the result of large floods in late 2010 and early 2011, which inundated large parts of dry floodplains where organic matter had accumulated during the millennium drought. Floodplain inundation mobilised the carbon stored on the floodplain, and secondary productivity was stimulated in the rivers, depleting the water column of oxygen and leading to 'blackwater' events and low dissolved-oxygen concentrations.²⁰ Fish kills were reported in several major rivers.²¹ More recently, heavy rainfall in the Wangaratta region in January 2018 caused a blackwater event in One Mile Creek. The rainfall increased catchment runoff into the creek; however, this runoff, which included leaf litter and other debris, was not flushed through due to dry conditions upstream. The organic material decayed, giving the water a black appearance, lowering the concentration of dissolved oxygen and causing stress to fish and other aquatic animals.²²

Longer trends in dissolved oxygen show decreased dissolved oxygen in many river systems during drought years when water receded to residual pools and there was a lack of mixing. Data at longer-term monitoring sites is available from 1991, and shows variable trends in dissolved oxygen. This variability reflects both site-based factors, and the inherent difficulty in evaluating dissolved oxygen with spot measures. The diurnal variation in dissolved-oxygen concentrations is naturally large, so simple factors such as time of day, depth of sampling and fine-scale site attributes can obscure actual trends.

20. King AJ, Tonkin Z, Lieshcke J 2012, 'Short-term effects of a prolonged blackwater event on aquatic fauna in the Murray River, Australia: considerations for future events', *Marine and Freshwater Research*, 63(7), pp. 576–586.

21. Small K, Kopf RK, Watts RJ, Howitt J 2014, 'Hypoxia, blackwater and fish kills: experimental lethal oxygen thresholds in juvenile predatory lowland river fishes', *PLoS one*, 9(4).

22. EPA, 'Blackwater event at One Mile Creek, Wangaratta', Carlton, Victoria <https://www.epa.vic.gov.au/about-us/news-centre/news-and-updates/news/2018/january/31/wangaratta-blackwater-event> Accessed 3 December 2018.

Indicator	Status	Trend	Data Quality
	UNKNOWN POOR FAIR GOOD		
WQ:03 Salinity concentrations in rivers			
Data Custodian DELWP, Melbourne Water	Poor in the Glenelg Hopkins catchment, Fair in the Wimmera and Port Phillip and Westernport catchments, Good in the other catchments		DATA QUALITY Good

Salinity is a measure of the total concentration of inorganic salts in the water column. Electrical conductivity (the ability of water to conduct an electrical current) is typically used to measure salinity in waters where the concentration of salts is relatively low. Salinity is an important aspect of water quality and can have a profound effect on aquatic biota, either through direct toxicity or disruptions to ecosystem processes and functions.^{23,24} Animals and plants generally have a narrow salinity range they can tolerate for optimum growth and reproduction. Increased salinity in Australian freshwater systems can lead to:

- a reduction in the diversity of native fish, with eggs and larval stages more susceptible than adults in many instances
- decreased diversity and growth of freshwater aquatic and riparian vegetation
- reduced diversity of macroinvertebrate communities and negative impacts to frogs, particularly to eggs and tadpoles.²⁵

Salinity in Victorian rivers and streams for the period 2010 to 2017 was rated as excellent in four catchments and good in a further three (Figure WQ.3). The urbanised rivers of the Port Phillip and Western Port catchment were ranked as moderate, with poorer salinity found in the Maribyrnong and Moorabool river basins. The far west of the state also had lower ratings for salinity, although in the case of the Wimmera catchment, this was based on data from only four sites. Salinity was rated as poor for the Glenelg Hopkins catchment, with most sites in its river basins not meeting the SEPP (WoV) salinity objectives.

SEPP (WoV) attainment for salinity from 2010 to 2017 was generally consistent (Figure WQ.3). An assessment of longer-term trends in water quality indicated that while there had been increased salinity during the millennium drought of 1996 to 2010, increasing rainfall in recent years has led to decreased salinity in most river systems across the state.²⁶

With respect to the six long-term indicator sites, salinity has decreased in the Broken, Barwon, Ovens, Latrobe and Yarra rivers from the historical period, 1991 to 2010, to the current period, 2011 to 2016, but increased in the Wimmera River. It is likely that the reduced salinity levels at most sites in recent years will have beneficial environmental outcomes in the river systems.²⁷

The dominant factor influencing salinity at all sites was flow (water volume), with low flows in the Wimmera River in summer and during drought leading to increased salinity.²⁸ Rising groundwater levels can also affect salinity.

Some waterways are naturally more saline due to their geology. The new SEPP (Waters) guidelines, discussed earlier, have increased the target value of electrical conductivity in much of the Port Phillip and Western Port area, so waterways in that catchment will be more likely to meet the new SEPP (Waters) targets than the targets under the previous SEPP (WoV).

23. Kefford BJ, Schäfer RB, Liess M, Goonan P, Metzeling L, Nuggeoda D 2010, 'A similarity-index based method to estimate chemical concentration limits protective for ecological communities', *Environmental Toxicology and Chemistry*, 29(9), pp. 2123-31.

24. Schäfer RB, Bundschuh M, Rouch DA, Szöcs E, Peter C, Pettigrove V, Schulz R, Nuggeoda D, Kefford BJ 2012, 'Effects of pesticide toxicity, salinity and other environmental variables on selected ecosystem functions in streams and the relevance for ecosystem services', *Science of the Total Environment*, 415, pp. 69-78.

25. Hart BT, Lake PS, Webb JA, Grace MR 2003, 'Ecological risk to aquatic systems from salinity increases', *Australian Journal of Botany*, 51(6), pp. 689-702.

26. Ventia 2018, 'Victorian Water Quality Trends 1991-2016'.

27. Ibid.

28. Ibid.

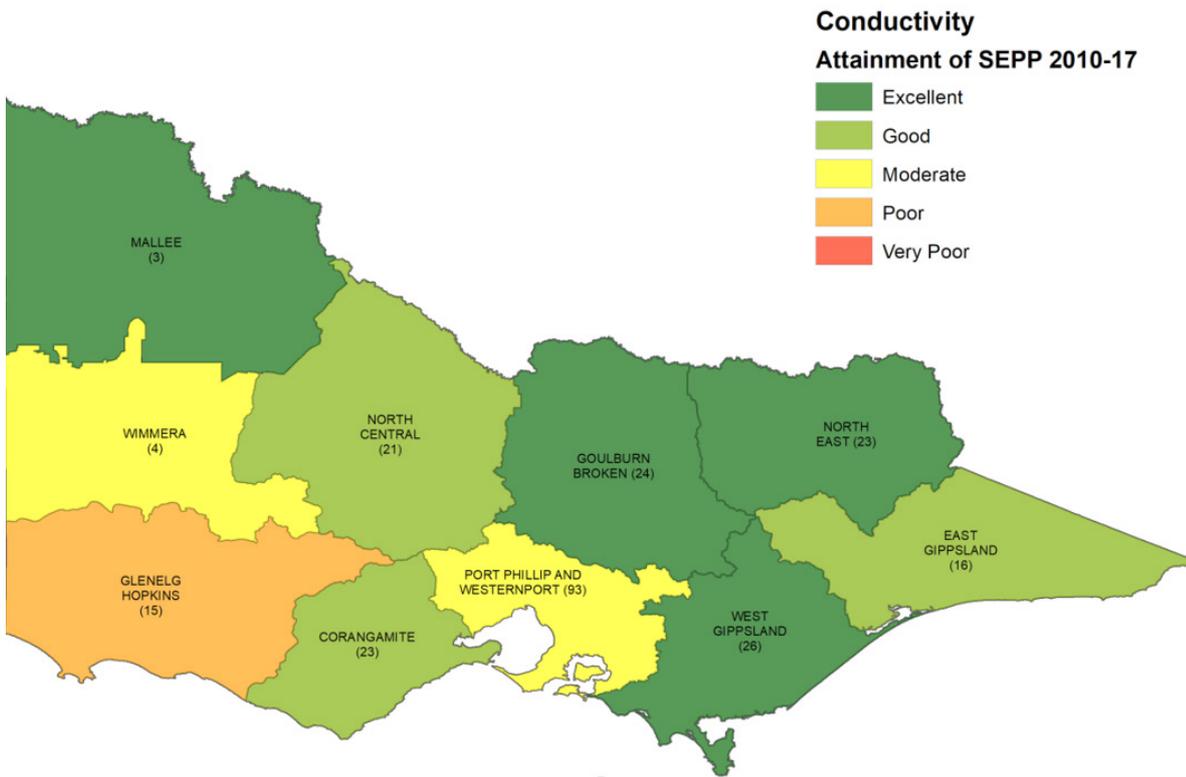


Figure WQ.3 SEPP (WoV) attainment of water-quality objectives for electrical conductivity (as an indicator of salinity) by CMA regions

Note: Numbers represent the average number of monitoring locations in each region used in the assessment.

(Data source: DELWP, Melbourne Water, 2018)

Table WQ.2 Per cent attainment of SEPP (WoV) water-quality objectives for electrical conductivity (as an indicator for salinity)

CMA region (average number of sites)	2010	2011	2012	2013	2014	2015	2016	2017	All years
Mallee (3)	100	100	100	100	100	100	100	100	100
North East (23)	92	96	100	96	96	91	96	96	95
Goulburn Broken (24)	93	95	95	90	92	91	73	76	88
West Gippsland (26)	81	78	85	74	81	72	72	72	77
North Central (21)	67	55	55	55	63	60	58	63	59
East Gippsland (17)	71	65	59	53	47	59	53	47	57
Corangamite (23)	57	50	63	55	59	63	55	50	56
Wimmera (4)	33	60	25	0	40	50	0	80	38
Port Phillip & Western Port (93)	35	41	37	33	20	26	28	26	33
Glenelg Hopkins (15)	21	19	25	20	20	21	21	19	21

Note: The following cell colours in the table represent specific water quality ratings: dark green (excellent water quality), light green (good water quality), yellow (fair water quality), orange (poor water quality) and red (very poor water quality).

(Data source: DELWP, Melbourne Water, 2018)

Indicator	Status	Trend	Data Quality
	UNKNOWN POOR FAIR GOOD		
<p>WQ:04 Total nitrogen concentration in rivers</p> <p>Data Custodian DELWP, Melbourne Water</p>	<p>Good in the North East and East Gippsland catchments, Fair in the Goulburn Broken and West Gippsland catchments, and Poor in other catchments. Unknown in the Mallee catchment.</p>		<p>DATA QUALITY Good</p>

Nutrients in aquatic ecosystems play a significant role in primary production, with nitrogen and phosphorus being two key nutrients in freshwater systems. Aquatic plants and phytoplankton take up nutrients in dissolved inorganic and organic forms. Measures of total nitrogen and total phosphorus include dissolved organic and inorganic particulate forms, as well as nutrients within the cells of phytoplankton and zooplankton. In the sediment, particulate forms of nitrogen and phosphorus can be broken down by micro-organisms. The processes of deamination, nitrification and denitrification can result in the release of ammonium into the water column, or the loss of nitrogen gas to the atmosphere. Phosphorus in the sediment can be released as bioavailable phosphate that allows algal growth. Sedimentary nutrient cycling is strongly influenced by the oxygen regime at the sediment water interface,²⁹ with a breakdown in the nutrient cycle likely to be associated with a lack of oxygen, causing fish kills or an overabundance of nutrients that can lead to algal bloom.

Attainment of SEPP (WoV) objectives for total nitrogen deteriorated from east to west – from excellent in Victoria’s east, to poor and very poor in the state’s west (Figure WQ.4). Attainment of SEPP (WoV) objectives for total nitrogen was achieved in fewer than 10% of sites in the urbanised catchment of Port Phillip and Western Port, as well as the Corangamite and Wimmera catchments in the west to south-west of the state. Conversely, SEPP (WoV) attainment was greater than 90% in the East Gippsland CMA region river basins of the Mitchell River and far-east Gippsland.

There was little evidence of a consistent temporal pattern across the 2010 to 2017 monitoring period, with ratings fluctuating from year to year. However, the spatial pattern of better nitrogen levels in the east, and poorer levels in the west, remained consistent (Figure WQ.4 and Table WQ.3). Longer-term trends in total nitrogen were influenced by rainfall and flow, with generally increased nutrient loads washing into streams during periods of heavy rainfall and floods.³⁰ Trends are also influenced by site factors, including surrounding land use, slope, soil types and stream-bank and bed stability. There was no significant trend in total nitrogen from historical (1991 to 2010) to current (2011 to 2016) conditions, although nitrogen levels at most sites were slightly higher after 2011.³¹ It is likely that this increase in nutrients at most sites is due to higher catchment runoff since the end of the millennium drought.³² Because there has been no discernible trend in temporal variations, the overall trend for this indicator has been classified as stable.

29. Harris GP 2001, 'Biogeochemistry of nitrogen and phosphorus in Australian catchments, rivers and estuaries: effects of land use and flow regulation and comparisons with global patterns', *Marine and Freshwater Research*, 52(1), pp. 139–149.

30. Ventia 2018, 'Victorian Water Quality Trends 1991-2016'.
 31. Ibid.
 32. Ibid.

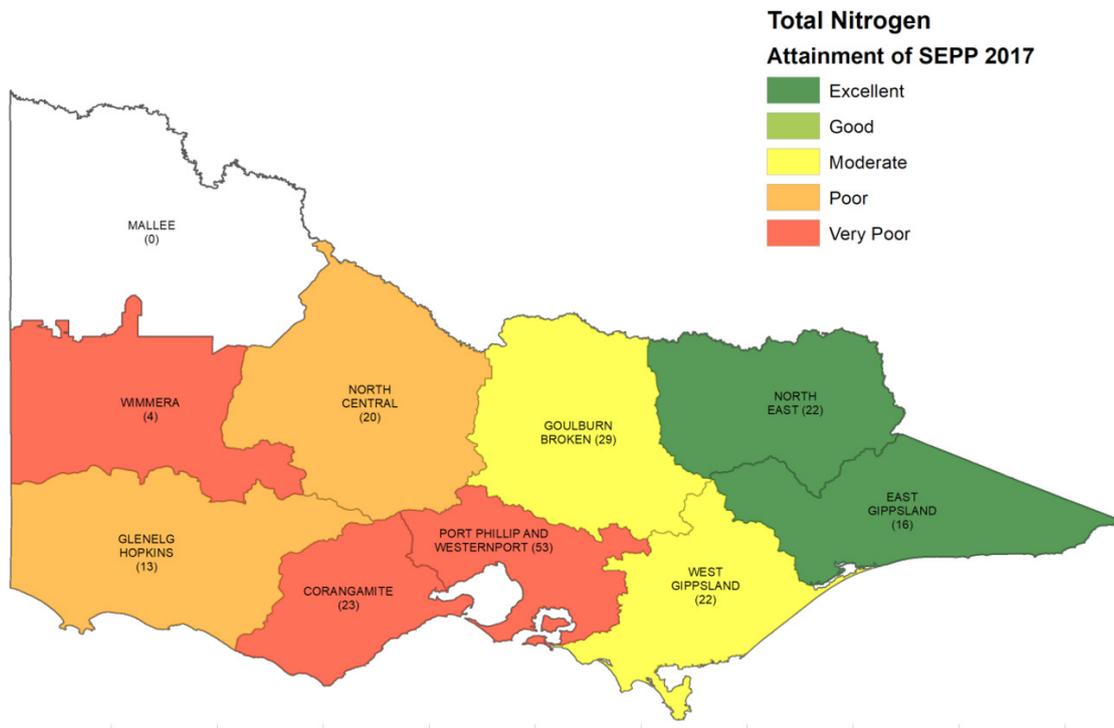


Figure WQ.4 SEPP (WoV) attainment of water-quality objectives for total nitrogen by CMA regions

Note: Numbers represent the average number of monitoring locations in each region used in the assessment.

(Data source: DELWP, Melbourne Water, 2018)

Table WQ.3 Per cent attainment of SEPP (WoV) water-quality objectives for total nitrogen

CMA region (average number of sites)	2010	2011	2012	2013	2014	2015	2016	2017	All years
East Gippsland (17)	82	59	59	88	59	76	69	94	73
North East (22)	55	55	59	68	64	82	50	77	64
West Gippsland (26)	44	26	30	37	41	52	41	41	39
Goulburn Broken (29)	14	28	38	41	44	50	27	45	36
Glenelg Hopkins (13)	15	8	23	15	15	38	23	23	20
North Central (22)	5	0	0	14	19	24	0	25	11
Port Phillip & Western Port (115)	4	5	5	8	9	9	2	4	6
Corangamite (23)	4	4	4	0	5	0	0	4	3
Wimmera (4)	0	0	0	0	0	0	0	0	0
Mallee (0)	No data								

Note: The following cell colours in the table represent specific water quality ratings: dark green (excellent water quality), light green (good water quality), yellow (fair water quality), orange (poor water quality) and red (very poor water quality).

(Data source: DELWP, Melbourne Water, 2018)

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
WQ:05 Total phosphorus concentrations in rivers Data Custodian DELWP, Melbourne Water						 DATA QUALITY Good
	Good in the East Gippsland catchment, Fair in the North East and West Gippsland catchments, and Poor in other catchments. Unknown in the Mallee catchment.					

Phosphorus plays an important role in freshwater systems. As for total nitrogen, attainment of SEPP (WoV) objectives for total phosphorus deteriorated from east to west – from excellent in the far-east of Victoria to very poor in the west of the state (Figure WQ.5). There were 10 river basins with less than 10% attainment of SEPP (WoV) water-quality objectives for total phosphorus. More than half of the river basins were considered poor or very poor (Table WQ.4).

There was little evidence of a consistent temporal pattern in the 2010 to 2017 monitoring period, with ratings fluctuating from year to year. However, the spatial pattern of better phosphorus levels in the east and poorer levels in the west remained consistent (Figure WQ.5 and Table WQ.4). Longer-term trends in total phosphorus were influenced by rainfall and flow, with generally increased nutrient loads washing into streams during periods of heavy rainfall and floods.³³ Trends are also influenced by site factors, including surrounding land use, slope, soil types and stream-bank and bed stability.

The majority of sites showed an increase in phosphorus levels after 2011, compared to the levels between 1991 and 2010.³⁴ The majority of sites in the east of the state showed increases in phosphorus that may be due to increased runoff since the end of the millennium drought.³⁵ As there is no trend in temporal variation, the overall trend for this indicator has been classified as stable

33. Ibid.

34. Ibid.
35. Ibid.

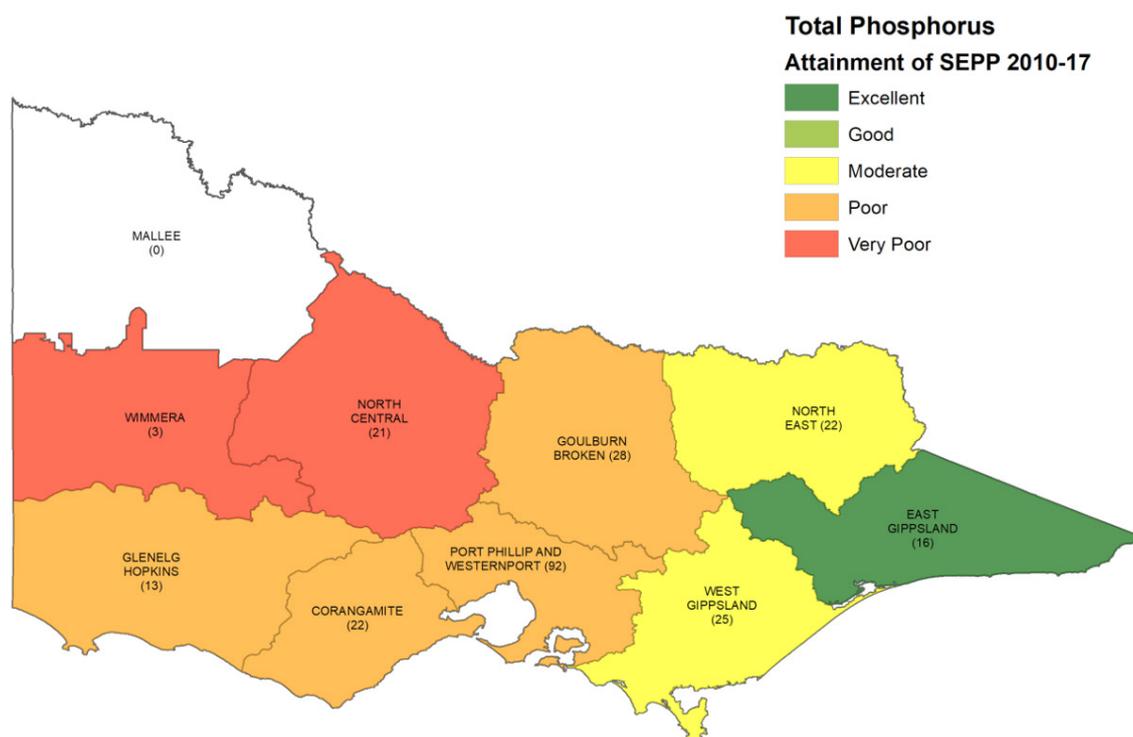


Figure WQ.5 SEPP (WoV) attainment of water-quality objectives for total phosphorus by CMA regions

Note: Numbers represent the average number of monitoring locations in each region used in the assessment. (Data source: DELWP, Melbourne Water, 2018)

Table WQ.4 Per cent attainment of SEPP (WoV) water-quality objectives for total phosphorus

CMA region (average number of sites)	2010	2011	2012	2013	2014	2015	2016	2017	All years
East Gippsland (17)	71	82	88	88	65	76	88	94	81
North East (22)	32	41	50	41	59	50	59	64	49
West Gippsland (26)	44	41	44	44	48	48	45	45	45
Goulburn Broken (29)	14	24	28	33	26	32	27	31	27
Glenelg Hopkins (13)	15	8	23	23	46	46	8	15	23
Corangamite (23)	17	4	17	14	14	32	10	26	17
Port Phillip & Western Port (115)	8	11	10	18	9	14	4	9	11
North Central (22)	0	0	4	10	10	14	11	14	8
Wimmera (4)	0	0	0	0	0	0	0	0	0
Mallee (0)	No data								

Table WQ.4 Per cent attainment of SEPP (WoV) water-quality objectives for total phosphorus

Note: The following cell colours in the table represent specific water quality ratings: dark green (excellent water quality), light green (good water quality), yellow (fair water quality), orange (poor water quality) and red (very poor water quality).

(Data source: DELWP, Melbourne Water, 2018)

Indicator	Status	Trend	Data Quality
	UNKNOWN POOR FAIR GOOD		
WQ:06 Turbidity levels in rivers	 Fair in the East Gippsland, North East and Glenelg Hopkins catchments, and Poor in other catchments.		 DATA QUALITY Good
Data Custodian DELWP, Melbourne Water			

Turbidity is a measure of the particulate matter (sediment particles, organic matter and phytoplankton) suspended within the water column. (In simple terms, turbidity is a measure of cloudiness.) Turbidity is not only influenced by the amount of suspended matter in the water column, but the size, shape and composition of the particles. For example, small amounts of fine particles such as clay will result in much higher turbidity (lower water clarity) than an equivalent amount of sand particles. Turbidity can affect aquatic ecosystems by:³⁶

- decreasing light penetration through the water column, which inhibits photosynthesis and reduces submerged plant growth

- reducing underwater visibility, which affects visual feeders, including some species of fish, turtle and waterbird
- physically impacting on the gills of fish and macroinvertebrates (in the case of very high levels of suspended matter in the water column).

Turbidity in Victorian rivers and streams from 2010 to 2017 was rated as moderate to very poor (Figure WQ.6). The Mallee and Wimmera catchments were both ranked as very poor, but this was based on a very small number of sites in each region, and may not reflect overall water turbidity across all rivers and streams in those catchments.

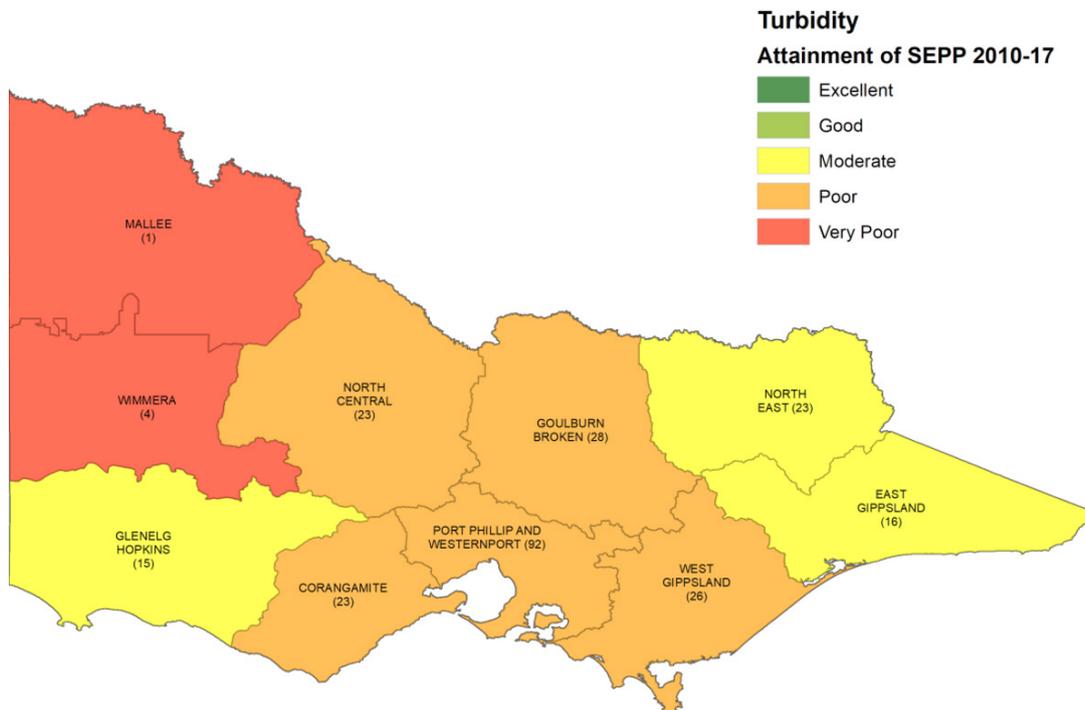


Figure WQ.6 SEPP (WoV) attainment of water-quality objectives for turbidity (as an indicator of water clarity) by CMA regions

Note: Numbers represent the average number of monitoring locations in each region used in the assessment.

(Data source: DELWP, Melbourne Water, 2018)

36. Davies-Colley RJ, Smith DG 2001, 'Turbidity, suspended sediment and water clarity: A review', *Journal of the American Water Resources Association*, 37(5), pp. 1085–1101.

Turbidity was excellent or good in a small number of river basins, including the Hopkins River and Portland coast basins in Glenelg Hopkins, the Mitchell River in East Gippsland, and the Moorabool River in Port Phillip and Western Port. There was little evidence of a temporal pattern across the eight years, although the drier years of 2014, 2015 and 2017 generally had lower turbidity than the wet years of 2010 and 2011 (Table WQ.5).

Longer-term trends in turbidity were influenced by rainfall and flow. Turbidity generally decreased in the drought years and increased during wet periods when run-off washed sediment from the surrounding landscape into the rivers.³⁷

Turbidity has increased in recent times (since 2011) compared to historical data (1991 to 2010) across most streams in Victoria, and the six long-term trend sites all exhibited increasing trends in turbidity related to increased streamflow and rainfall runoff.³⁸ Because of this, the overall trend for this indicator has been classified as deteriorating. In addition to climate, land use plays an important role in turbidity, with increased land-clearing, agricultural activities that lead to bank erosion (for example, livestock access to streams) and water-resource use all linked to increasing turbidity in Australian streams.³⁹

Table WQ.5 Per cent attainment of SEPP (WoV) water-quality objectives for turbidity (as an indicator of water clarity)

CMA region (average number of sites)	2010	2011	2012	2013	2014	2015	2016	2017	All years
Glenelg Hopkins (15)	36	38	50	40	60	93	36	44	49
East Gippsland (17)	35	24	35	59	35	35	33	93	43
North East (23)	29	29	29	39	52	52	35	61	41
North Central (24)	8	23	42	25	35	30	16	46	29
Corangamite (23)	17	0	17	23	23	54	23	33	24
West Gippsland (26)	22	19	15	19	30	28	20	36	23
Goulburn Broken (28)	3	3	10	15	24	41	8	34	17
Port Phillip & Western Port (92)	18	6	5	14	31	24	6	19	14
Wimmera (4)	0	0	25	0	0	0	0	0	3
Mallee (2)	0	0	0	0	0	0	0	0	0

Note: The following cell colours in the table represent specific water quality ratings: dark green (excellent water quality), light green (good water quality), yellow (fair water quality), orange (poor water quality) and red (very poor water quality).

(Data source: DELWP, Melbourne Water, 2018)

37. Ventia 2018, 'Victorian Water Quality Trends 1991-2016'.

38. Ibid.

39. Davis J, O'Grady AP, Dale A, Arthington AH, Gell PA, Driver PD, Bond N, Casanova M, Finlayson M, Watts RJ 2015, 'When trends intersect: The challenge of protecting freshwater ecosystems under multiple land use and hydrological intensification scenarios', *Science of the Total Environment*, 534, pp. 65–78.

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
WQ:07 pH						 DATA QUALITY Good
Data Custodian DELWP, Melbourne Water						

pH is a measure of the acidity or alkalinity of water. It is measured on a logarithmic scale from 0 (acidic) to 14 (alkaline), with a pH of 7 indicating neutral conditions.

Most natural freshwaters have a pH in the range of 6.5 to 8.0, depending on the soil and underlying geology of the catchment. Factors that influence the pH of river systems are land-use intensification, point-source pollution, exposure of acid sulfate soils via surface and groundwater flows, and the balance of buffering carbonates in the water column (a water body's pH can change as its carbonate concentrations keep an equilibrium with atmospheric concentrations).⁴⁰

Increases and decreases in pH can have ecological effects: water can be neither too alkaline nor too acidic. Altered pH disrupts physiological processes at a cellular level, with species that are confined to aquatic environments, such as fish, more exposed to pH changes. Juvenile stages of fish and frogs are highly susceptible to altered pH. In addition, increased acidity (lower pH) can affect the release of heavy metals from sediments and influence the toxicity of other chemicals such as ammonia.^{41,42}

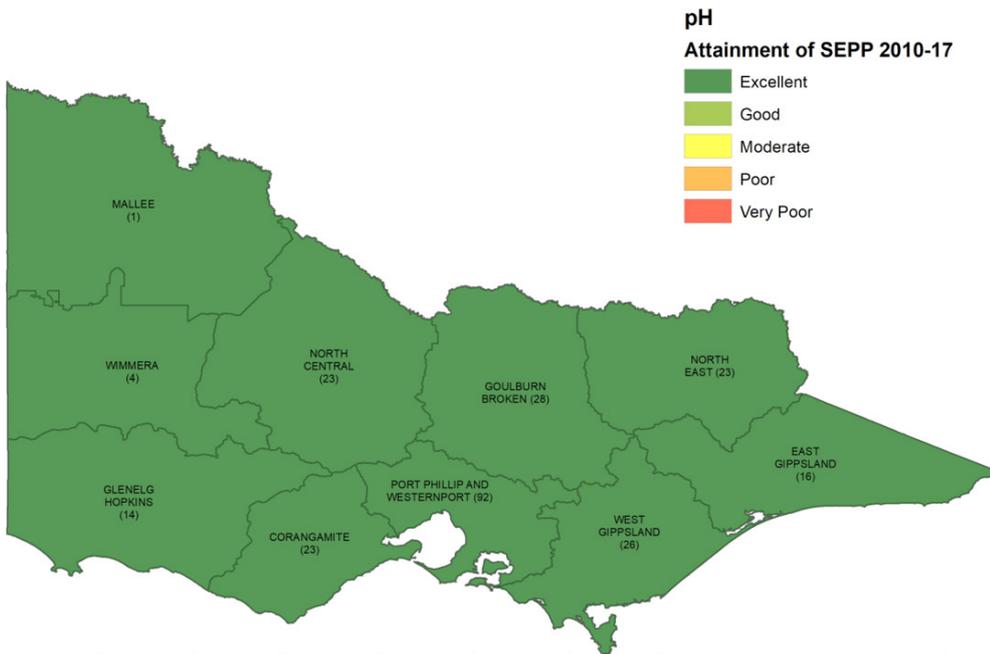


Figure WQ.7 SEPP (WoV) attainment of water-quality objectives for pH by CMA regions

Note: Numbers represent the average number of monitoring locations in each region used in the assessment. (Data source: DELWP, Melbourne Water, 2018)

40. Apte, S. and Batley, G. 2011, 'Water: Science and solutions for Australia', CSIRO Publishing, Collingwood, Victoria.

41. Emerson K, Russo RC, Lund RE, Thurston RV 1975, 'Aqueous ammonia equilibrium calculations: effect of pH and temperature', *Journal of the Fisheries Board of Canada*, 32(12), pp. 2379–2383.

42. Randall DJ, Tsui TKN 2002, 'Ammonia toxicity in fish', *Marine pollution bulletin*, 45(1–12), pp. 17–23.

Water quality with respect to pH in Victorian rivers and streams for 2010 to 2017 was rated as excellent across all catchment regions (Figure WQ.7) and river basins. SEPP (WoV) water-quality objectives for pH were attained at more than 80% of sites in all catchment regions, except the Port Phillip and Western Port catchment, where 72% of sites recorded attainment.

No temporal trends in pH were evident from 2010 to 2017 (Table WQ.6). There has been very little change in pH between current (since 2011) and historical periods (1991 to 2010).⁴³

Table WQ.6 Per cent attainment of SEPP (WoV) water-quality objectives for pH (as an indicator of alkalinity/acidity)

CMA region (average number of sites)	2010	2011	2012	2013	2014	2015	2016	2017	All years
Mallee (2)	100	100	100	100	100	100	100	100	100
West Gippsland (26)	96	100	100	89	100	100	92	100	97
North East (23)	88	100	88	100	100	96	100	100	96
North Central (24)	100	96	96	96	91	87	95	96	95
East Gippsland (17)	94	94	94	94	94	94	81	88	92
Corangamite (24)	96	92	88	96	91	88	95	79	90
Wimmera (4)	100	100	75	75	80	100	100	80	88
Glenelg Hopkins (14)	79	86	86	86	79	93	86	79	84
Goulburn Broken (28)	86	79	90	81	71	85	85	79	82
Port Phillip & Western Port (93)	65	74	84	84	68	62	60	58	72

Note: The following cell colours in the table represent specific water quality ratings: dark green (excellent water quality), light green (good water quality), yellow (fair water quality), orange (poor water quality) and red (very poor water quality).

(Data source: DELWP, Melbourne Water, 2018)

43. Ventia 2018, 'Victorian Water Quality Trends 1991-2016'.

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
WQ:08 Proportion of bodies of water with good ambient water quality						 DATA QUALITY Good
Data Custodian DELWP, Melbourne Water						Good

Victoria is moving to align its SoE reporting with the United Nations Sustainable Development Goals. As such, this indicator represents a way to use existing water-quality data to provide a statewide method of reporting on water quality in Victoria that is also applicable in a global context. The United Nations defines ‘good’ ambient water quality as water quality that does not damage ecosystem function and human health, according to core ambient water-quality parameters.⁴⁴

While the attainment of SEPP (WoV) water-quality objectives has been used to evaluate water-quality variables in the previous water-quality indicators, the methodology developed for calculating the water-quality component of the Index of Stream Condition (ISC) can be used to determine the overall water quality in Victoria for this indicator.

The primary aim of the ISC is to assess the environmental condition of Victoria’s major rivers and streams, and to provide statewide data for CMA regional waterway action-planning and priority-setting. Three statewide benchmark analyses have been undertaken, in 1999, 2004 and 2010.⁴⁵ The ISC method assigns scores that are integrated across water-quality indicators and ranked in five categories: very poor, poor, moderate, good and excellent. The good and excellent ISC categories are equivalent to the ‘good’ ambient water-quality assessed by this indicator.

The current assessment suggests that water quality is generally better in the east of the state than in the central and western regions (Figure WQ.8). The East Gippsland river basins of far-east Gippsland and the Snowy and Mitchell rivers all had good or excellent water quality, as did the North East catchment river basins of the Ovens, Kiewa and Upper Murray Regions (Figure WQ.9). The rest of the state was ranked as moderate or poor, with lower water quality in the urbanised river basins of the Port Phillip and Western Port catchment.

The general trend of better water quality in the east of the state and moderate to poor water quality in central and western regions has not changed from the previous ISC assessment from 2004-2009. Not enough data was collected in the Mallee catchment to provide a water-quality score and ranking for 2010 to 2017.

44. United Nations, ‘Indicator 6.3.2 – Water quality’, New York City, New York <http://www.sdg6monitoring.org/indicators/target-63/indicators632/> Accessed 3 December 2018.
45. DELWP, ‘Third Index of Stream Condition report’, East Melbourne, Victoria <https://www.watervic.gov.au/water-reporting/third-index-of-stream-condition-report> Accessed 3 December 2018.

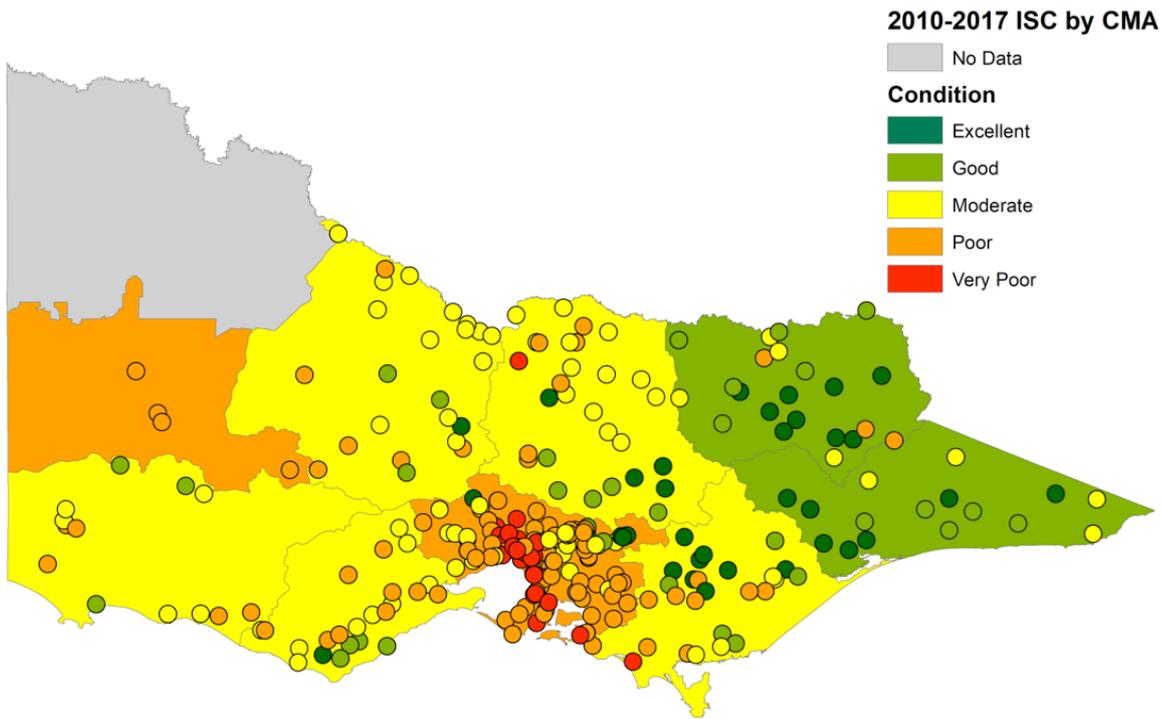


Figure WQ.8 Water-quality scores and rankings for Victoria (2010–17), based on the methodology developed to calculate the ISC

(Data source: DELWP, Melbourne Water, 2018)

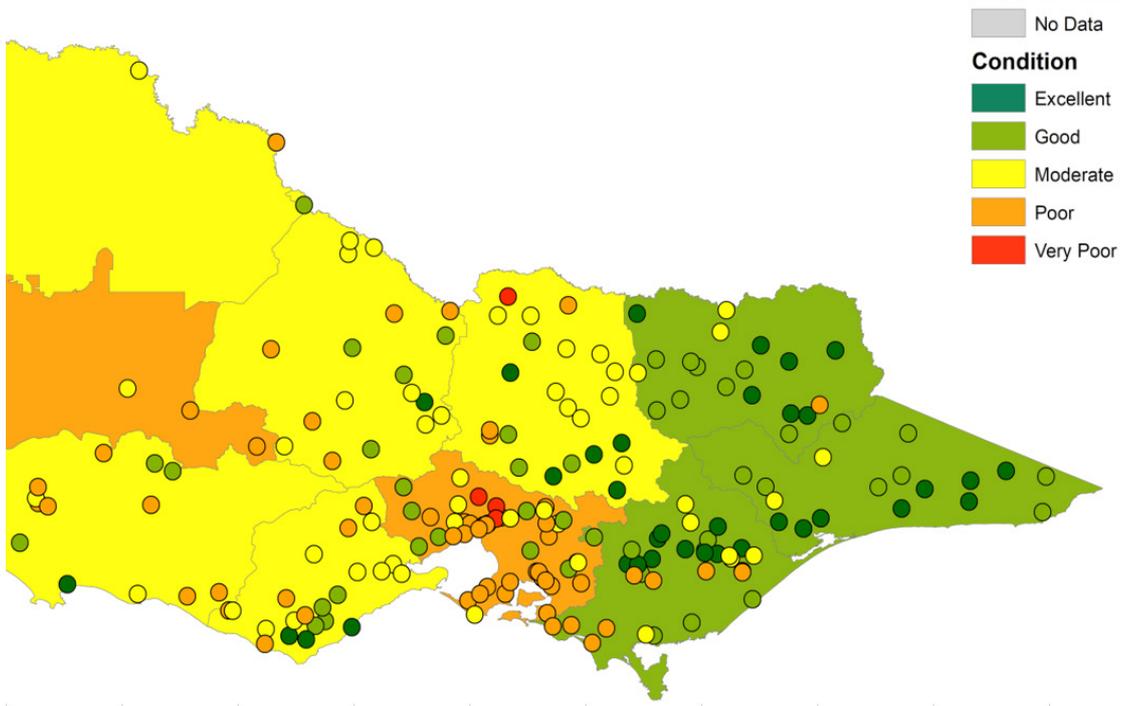


Figure WQ.9 ISC integrated water-quality scores for CMA regions, 2004–09, showing scores for individual sites

(Data source: DELWP, Melbourne Water, 2018)

Of the 27 river basins assessed from 2010 to 2017, seven (26%) rated as having good or better water quality. This represents a slight deterioration in water quality from the most recent ISC assessment (2004 to 2009) when 10 of the 27 river basins (37%) were rated as having good or better water quality.

Data for the 2010-17 reporting period shows a gradual deterioration of water quality at most sites (22 of 27), by an average score of 0.42, compared to the 2004-09 data. The most common ranking for river basins in both the current and previous period was moderate. The status assessment of poor for this indicator is based on fewer than one-third of all sites being rated as having good or better water quality for the current water-quality assessment period.

When assessing water-quality results over different periods, consideration must be given to changes in weather, particularly rainfall. Statewide rainfall maps covering some of the reported water-quality periods (2004 to 2009, and 2010 to 2017) have been included and are discussed below. However, most of the water-quality measurements are made monthly. Therefore, the data is not available at a sufficiently fine temporal resolution to properly compare individual samples with local rainfall at the specific time of the sampling. This means the impact of rainfall on water quality during the reporting periods is not well understood.

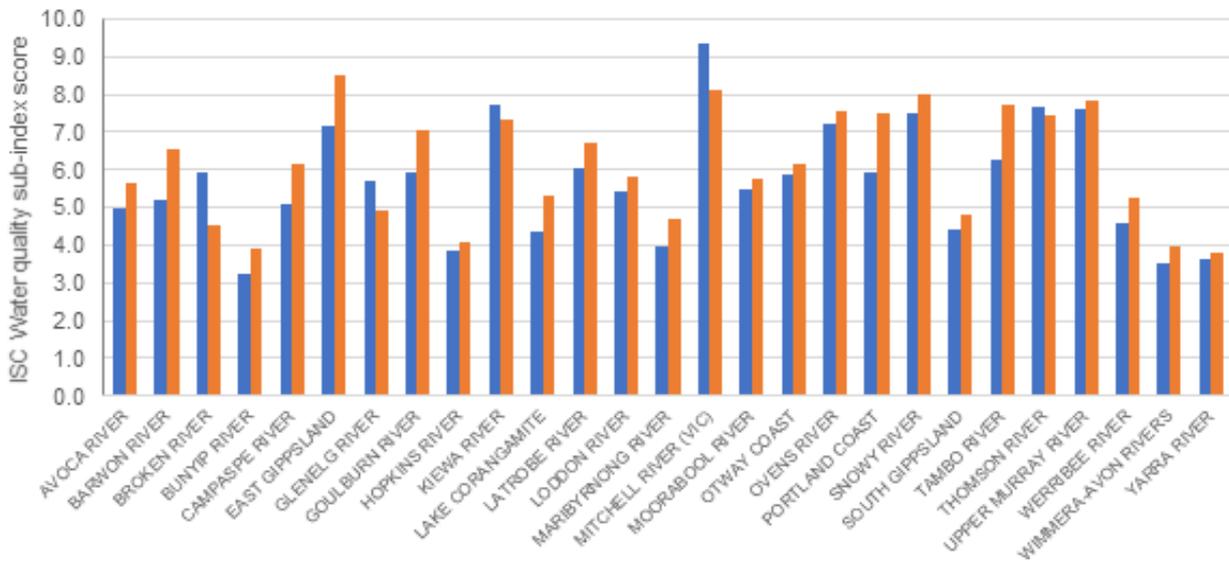


Figure WQ.10 ISC water-quality sub-index scores from the 2010 assessment (data from 2004-09) and the current assessment (data from 2010-17) for river basins

Note: ISC rankings are: excellent ≥ 9 ; good 8-9; moderate 6-7; poor 4-5; very poor ≤ 3 .

(Data source: DELWP, Melbourne Water, 2018)

The 2010 ISC assessment spans six years of drought conditions in Victoria, while the current period represents both dry years (2014 and 2015) and wet years (2011) (see Figure WQ.12 and Figure WQ.13). The current period certainly experienced greater rainfall and runoff. The impacts of drought on water quality include increased salinity (as water evaporates in streams and in channel pools) and decreased dissolved oxygen in residual pools.⁴⁶ Decreases in overland flow and runoff are also associated with drought, and decrease sediment and nutrient loads, leading to increased water clarity and lower nutrient conditions.⁴⁷ Conversely, heavy rainfall and flooding following a dry period can mobilise large loads of sediments and nutrients into the system, leading to higher turbidity and nutrient concentrations, particularly in lowland river sites.^{48,49}

The climatic conditions during the 2010 to 2017 assessment closely align with Victoria’s projected climate in the coming decades. That is, generally drier, but interspersed with more extreme rainfall events. Therefore, the assessment made in this indicator, that only 26% of Victoria’s monitored inland waterways have good or better water quality, is representative of what water quality will be expected to be like between now and 2030, without policy or management interventions.

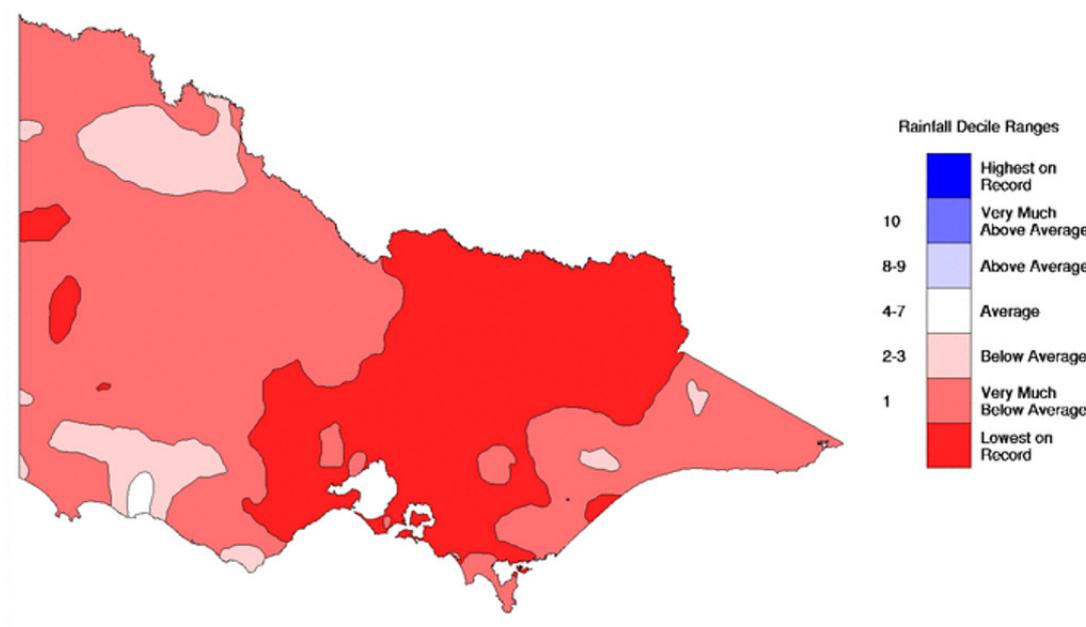


Figure WQ.11 Rainfall, 2006–09 (as an indicator of conditions during the current ISC assessment) compared to long-term averages

(Data source: BoM, 2018)

46. Bond NR, Lake PS, Arthington AH 2008, 'The impacts of drought on freshwater ecosystems: an Australian perspective', *Hydrobiologia*, 600(1), pp. 3–16.
47. Baldwin DS, Mitchell AM 2000, 'The effects of drying and re-flooding on the sediment and soil nutrient dynamics of lowland river-floodplain systems: a synthesis', *River research and applications*, 16(5), pp. 457–467.
48. Ibid.

49. Cook PL, Holland DP, Longmore AR 2010, 'Effect of a flood event on the dynamics of phytoplankton and biogeochemistry in a large temperate Australian lagoon', *Limnology and Oceanography*, 55(3), pp. 1123–1133.

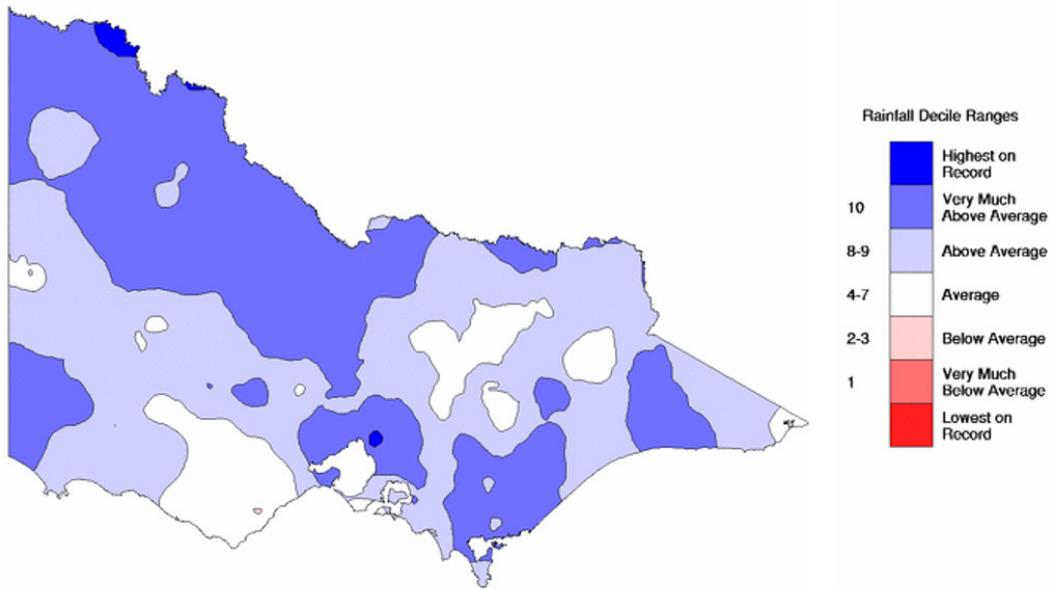


Figure WQ.12 Rainfall in 2011 (as an indicator of conditions during the current ISC assessment) compared to long-term averages

(Data source: BoM, 2018)

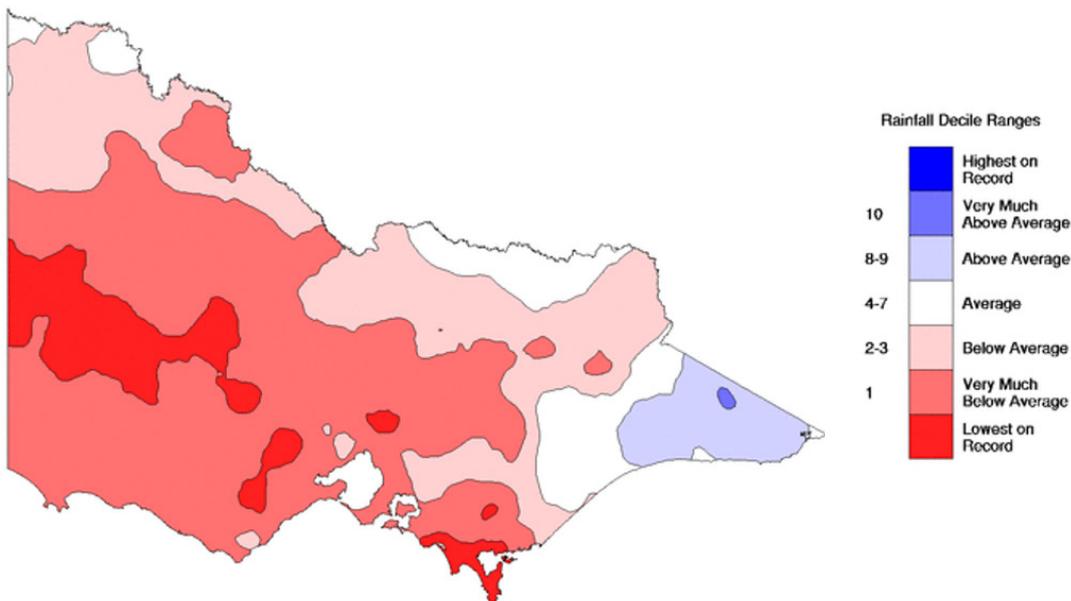


Figure WQ.13 Rainfall, 2014–15 (as an indicator of conditions during the current ISC assessment) compared to long-term averages

(Data source: BoM, 2018)

Discharges

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
WQ:09 Volume of sewage discharge to surface waters						 DATA QUALITY Poor (no data available to make an assessment)
Data Custodian EPA Victoria						

Point-source pollution is contamination that enters the environment through a single, identifiable emission source, such as a pipe or a drain. Point-source discharges to waterways are dominated by effluents from sewage treatment. These effluents tend to be the major source of contaminants that are potentially harmful to waterways and our use of them. These contaminants and their associated impacts include:

- pathogenic micro-organisms (such as bacteria and viruses) that may affect the health of in-stream fauna, animals drinking the water and people (through direct contact or piped water-supply systems)
- oxygen-demand substances (that is, substances that consume oxygen during decomposition) that may result in low oxygen levels in the water column. Low oxygen levels can damage the biota of receiving waters
- nutrients (especially nitrogen and phosphorus) that may result in a proliferation of algal and weed growth, change of species type and diversity, and a reduction in dissolved-oxygen levels. Some algal blooms may also be toxic.
- toxic substances (including ammonia, surfactants, heavy metals and biocides) that can be harmful to both in-stream life and users of the water. The greatest concern is persistent toxicants that bio-accumulate in the food chain.

In Victoria, high-risk point-source discharges are regulated by EPA Victoria, which specifies minimum acceptable environmental standards for treated effluent discharges to rivers and streams. Regulation of point-source sewage discharges has helped improve the quality of Victoria’s water environment over the past 40 years. Focus and effort is still needed to maintain and further improve these, particularly given the likelihood of significant climate changes.

Indeed, climate change will be one of the main challenges to sewage treatment systems in the future.^{50,51} Climate change projections indicate that Victoria’s average temperatures will increase, and rainfall and runoff will decline. Modelling also indicates that there will be an increase in the intensity of heavy rainfall events.^{52,53} These changes in climate will have multiple implications for sewage treatment plants and will accentuate existing discharge problems.

EPA Victoria holds data on all water pollutants that are discharged from its licensed sites; however, this information was not available to be extracted and analysed at a statewide level. Therefore, the status and trend assessments for this indicator are listed as unknown and unclear.

50. Tolkou A, Zouboulis A, 2015, 'Effect of Climate Change in Wastewater Treatment Plants: Reviewing the Problems and Solutions', in *Managing Water Resources under Climate Uncertainty*, Springer International Publishing, pp.197-220.

51. Tolkou A and Zouboulis A, 2016, 'Effect of Climate Change in WWTPs with a focus on MBR infrastructure', *Desalination and Water Treatment*, 57(5): pp. 2344-2354.

52. Hobday AJ, Lough JM 2011, 'Projected climate change in Australian marine and freshwater environments', *Marine and Freshwater Research*, 62, pp. 1000-1014.

53. Timbal B, Ekström B, Fiddes S, Grose M, Kirono D, Lim E-P, Lucas C and Wilson L 2016, 'Climate change science and Victoria: Bureau Research Report No. 14', *Report issued by the Bureau of Meteorology*.

Pollution Incidents

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
WQ:10 Reported inland water pollution incidents						
Data Custodian EPA Victoria						DATA QUALITY Fair (data provided not linked to water bodies)

EPA Victoria received 7,481 water-pollution reports for the five years from 2013 to 2017. Seventy-three per cent of the water-pollution reports were made in the Port Phillip and Westernport catchment, where a significant proportion of Victorians live.

Pollution reports can be categorised by the type of pollution; however, only 25% of reports contained some level of classification. Of the reports that were classified, industry, sewer overflow, fish death and residential construction were the main classifiers of pollution.

As well as reports for pollution in waterways, many reports are made for pollution before it reaches a waterway (such as pollution entering a stormwater drain). In EPA Victoria’s database, a single pollution event can be duplicated if more than one reporter makes a report.

The data for this indicator captures water-pollution reports from across the state, including coastal areas and estuaries. Most of the reports were for inland waters, with just 9% of pollution reports made for pollution within 200 m of the coast.

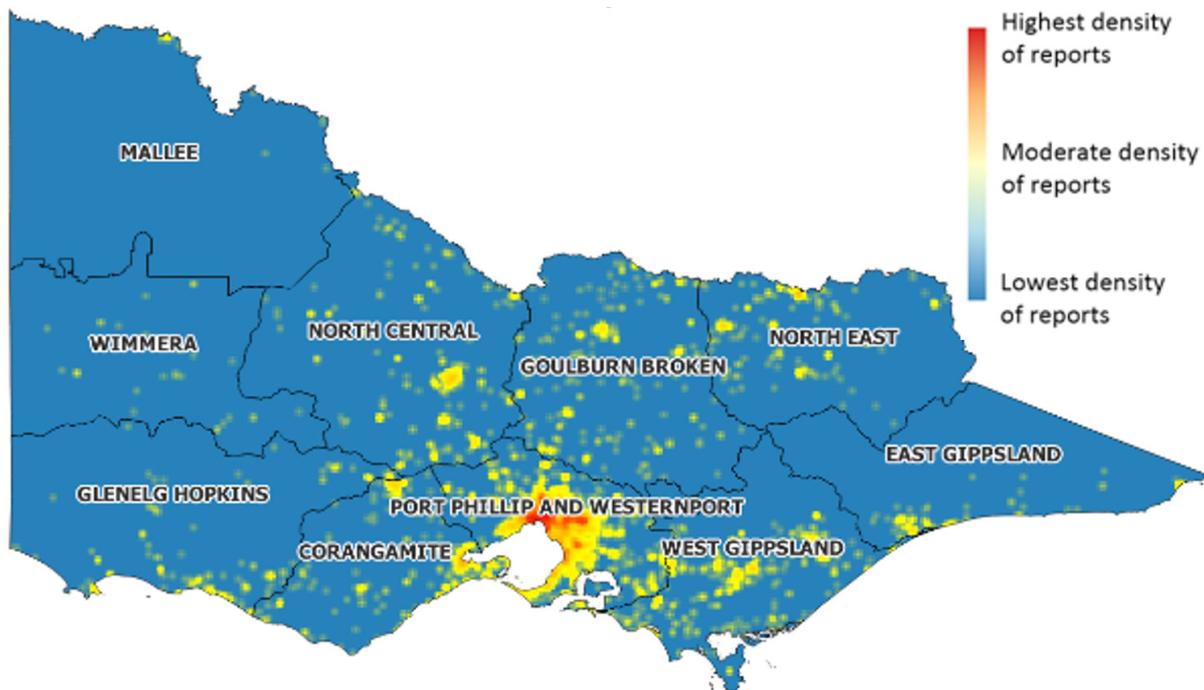


Figure WQ.14 Heat map of water pollution reports received by EPA Victoria, 2013–17

(Data source: EPA Victoria, 2018)

Table WQ.7 Water pollution reports received by EPA Victoria for each local government area (LGA) and locality, 2013–17

LGA	Total no.	Locality	Total no.
Melbourne	381	Yarraville	202
Darebin	363	Melbourne	118
Maribyrnong	321	Alphington	107
Moreland	307	Coburg North	101
Whitehorse	263	Dandenong South	97

(Data source: EPA Victoria, 2018)

The number of water-pollution reports to EPA Victoria was very stable between 2013 and 2015, then increased by 32% to 1,766 in 2016, and stabilised again in 2017. The increase in 2016 is likely to be associated with above-average annual rainfall. High rainfall increases runoff, which affects streams by decreasing water clarity and increasing the amount of pollutants that enter waterways. This, coupled with greater community awareness of the option to report water pollution to EPA Victoria, may explain pollution report numbers in 2016. In 2017, annual rainfall was below average: the number of reports in this year may be due primarily to increased public awareness of pollution reporting.

Water-pollution reporting is reasonably consistent within a given year, peaking slightly in late winter and early spring, when increased rainfall and runoff can exacerbate water-quality impacts.⁵⁴ Another slight peak occurs in late summer and early autumn, which is likely to be caused by heavy rainfall events and algal blooms.

Fish Deaths

As part of its pollution reporting database, EPA Victoria keeps records of pollution reports relating to fish deaths. For the five years from 2013 to 2017, EPA Victoria received 306 reports of fish deaths. There was no obvious trend in fish-death reports over the relatively short period, although the fewest fish-death reports were in the very dry years of 2014 and 2015 (Figure WQ.13). The location of fish-death reports was not as concentrated on Melbourne (as were reports for other water-pollution categories), with 39% of fish-death reports originating in the Port Phillip and Westernport catchment, compared to 73% for all water reports. The Corangamite catchment was responsible for the second-most fish-death reports (19% of all fish-death reports). Figure WQ.15 shows the locations of fish-death pollution reports received by EPA Victoria for 2013 to 2017.

Fish deaths in Victoria have a wide range of likely causes, and the exact cause of a fish death is often difficult to determine.⁵⁵ Some of the likely causes are:

- pollution from a contaminant entering a waterway (or as a result of a water intake or outfall)
- environmental stress, such as warmer waters, lower flows or water levels, and reduced dissolved oxygen
- changes in estuarine salinity due to high freshwater river flows or high tidal movements. These processes can rapidly change the salinity of the water, making it fresher or more saline, which can result in the death of freshwater, estuarine or marine fish.
- disease, most commonly associated with viruses, bacteria or parasites.

54. Agriculture Victoria, 'Rainfall', <http://vro.agriculture.vic.gov.au/dpi/vro/vrosite.nsf/pages/rainfall> Accessed 3 December 2018.

55. EPA 2007, 'Fish deaths reported to EPA Victoria, 1998–2007', Carlton, Victoria <https://www.epa.vic.gov.au/-/media/Publications/1175.pdf> Accessed 3 December 2018.

- algal blooms, including blue-green algae, which can grow prolifically in freshwater conditions, particularly when water temperatures and nutrient levels are high. The growth or the decomposition of algae can significantly deplete dissolved-oxygen levels in the water, which may cause fish death through suffocation.
- blackwater events, which occur when a high runoff event carries organic matter from the land into a waterway, or when highly organic water in billabongs or backwaters is flushed into another waterway. The organic matter stains the water black and decomposes, resulting in low dissolved-oxygen levels, which may cause fish death through suffocation. Black water events occur most often following rainfall after a dry period, when infiltration into the soil is low (that is, the soil absorbs rainfall at a slow rate) and waterway flows are also low.

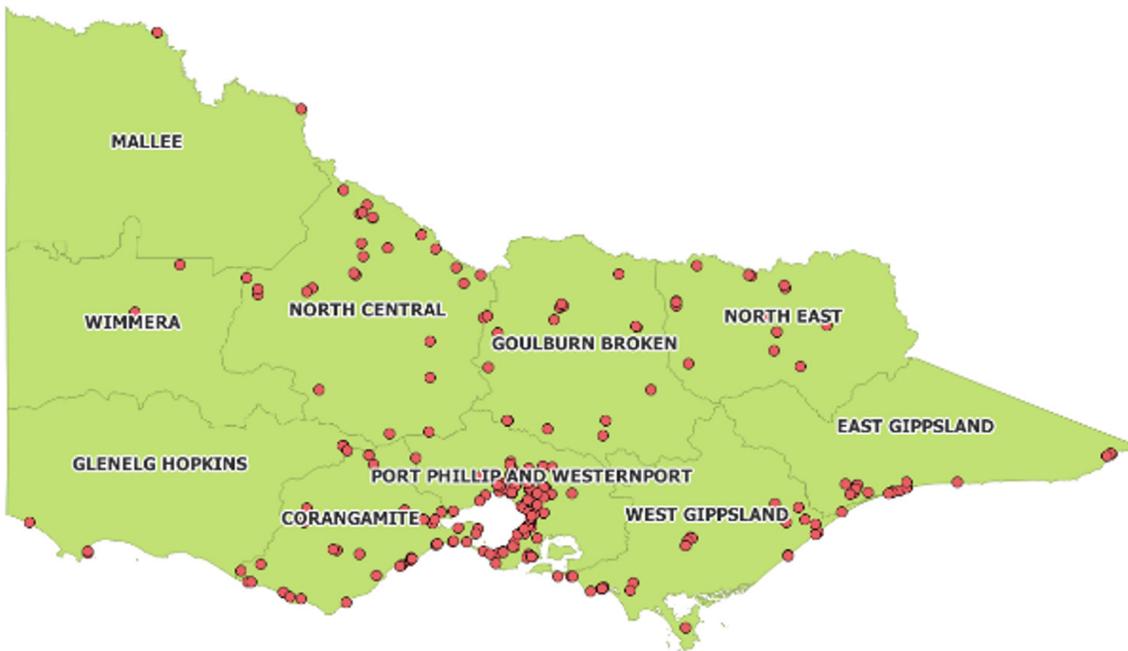


Figure WQ.15 The locations of fish death pollution reports in Victoria, 2013–17
(Data source: EPA Victoria, 2018)

Future Focus

Improvements in the availability of statewide water-quality data have meant a much more robust assessment of water-quality indicators in this report than in SoE 2013. This reflects steps undertaken since SoE 2013 to increase data availability, in line with that report's recommendations and subsequent VAGO and DELWP audits that identified a deficiency in data-usage and sharing. There are still considerable improvements to be achieved by coordinating monitoring programs and data between government agencies, industry and the community. Advances in monitoring will also need to be complemented by improvements to data, trend analysis and modelling.

Implement an agile Water-Quality Monitoring Framework

Future water-quality monitoring needs to include a network of long-term sites, complemented by targeted monitoring of water-pollution hotspots. Where and how this monitoring is completed, and who does it, needs to be determined in a transparent process, guided by evidence, and ultimately recommending clearly defined roles and responsibilities. The water-quality monitoring framework would be developed by DELWP with support from other agencies and the community. The framework would be a risk-based approach that uses threats and pressures on water quality to guide where and how monitoring is undertaken.

These reforms will support Victoria's progress in becoming a modern regulatory environment for water-quality protection. They align with recommendations 6.3 and 7.2 of the 2016 Ministerial Advisory Committee Inquiry into EPA Victoria to 'assess the adequacy of its air and water-monitoring networks, particularly in relation to air quality, and consider options to improve data-sharing and accessibility, and community communication' (recommendation 6.3) and to implement, through DELWP, statewide

environmental monitoring, a spatial data system and reporting on outcomes (recommendation 7.2).⁵⁶ The reforms will be essential for monitoring delivery of the *State Environment Protection Policy (Waters)* and the *Environment Protection Amendment Act 2018*.

Combining targeted monitoring of pollution hotspots with monitoring at priority long-term sites will help inform pollution-prevention interventions in hotspots and enable quantitative evaluations of those actions. Enhancements to EPA's pollution-reporting database would assist the determination of potential hotspot areas for monitoring.

Recommendation 12: That DELWP, working with its portfolio agencies, implement an agile water-quality monitoring framework that (i) clarifies the roles and responsibilities of all agencies and the community, (ii) improves monitoring of pollution hotspots, and (iii) builds on EPA Victoria's implementation of EPA Inquiry recommendations 6.3 and 7.2.

56. Ministerial Advisory Committee 2016, 'Independent inquiry into the Environment Protection Authority', http://www.epa-inquiry.vic.gov.au/_data/assets/file/0008/336698/inquiry-report-EPA_June.pdf

Accounting for the Environment

Under the System of Environmental-Economic Accounting (SEEA), there are water-quality accounts and water-emissions accounts, along with water-resources accounts (discussed in the Water Resources chapter).

Water-quality accounts are linked to water-resources accounts and describe the stocks of water at the beginning and end of an accounting period, according to their quality. Water quality is a key determinant of what water can be used for, and consequently is a key factor in determining the benefit of water resources to the economy.

In environmental-economic accounting, water pollution is categorised as a residual flow from the economy to the environment. A water-emissions account records this connection, recording both pollutants that enter the environment directly (either point-source emissions or non-point-source emissions such as urban and agricultural runoff) or through a treatment plant. Water-emissions accounts present information on the sectors (such as industry, government and households) responsible for emissions, the type and amounts of pollutants, and the destination of the emissions (for example, water resources or the sea). Water-emissions accounts should report emissions in line with industry classifications used by the Australian Bureau of Statistics.

Tracking water-pollution emissions over time, along with economic activity, can help highlight trends in the relative contributions of different sectors, including future levels expected with growth in economic activity. This type of account can also be used to assess efforts by government, industry and households to reduce water-pollution emissions.

Emissions to water resources can constitute a major environmental problem and cause the quality of water resources to deteriorate. Some substances are highly toxic (such as heavy metals); others, such as nitrogen and phosphorus, can lead to eutrophication. Organic substances can have effects on the oxygen balance, impacting the ecological status of a resource.

The impact of residual flows of water pollution on people and the environment already appears to some extent in Victoria's traditional economic accounts (the System of National Accounts). For example, these impacts would be included as expenditure in the health system from doctor visits and hospital admissions, or reductions in property values due to decreased amenity near water bodies. However, the amounts attributable to water pollution are not identified in the traditional accounts. Expenditure to prevent and manage the impacts of water pollution currently count towards Victoria's gross state product, rather than being recorded as a cost to the Victorian community.

Water-pollution emissions can affect the condition of assets, including water resources and freshwater and marine ecosystems. Emissions can impact on ecosystem functioning and the capacity of assets to support ecosystem services. Examples include provisioning services such as water supply; regulating services such as dilution/filtration of pollutants and water-cycle regulation; and cultural services such as recreation and tourism, and ecosystem capital for future generations.

The SEEA framework also recognises the benefit to the ecosystem of water purification by natural assets. An ecosystem account would record this connection by showing the quantity of water-pollutant emissions absorbed or diluted by natural assets, the impact of this on water quality and the corresponding benefit to the Victorian community in terms of avoided impacts.