
INFORMATION BULLETIN

WATER QUALITY OBJECTIVES FOR RIVERS AND STREAMS – ECOSYSTEM PROTECTION

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**WATER QUALITY OBJECTIVES FOR RIVERS AND STREAMS – ECOSYSTEM
PROTECTION**

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1 INTRODUCTION

1.1 Background

Water quality parameters such as pH, dissolved oxygen, turbidity and electrical conductivity (salinity) are important indicators of ecosystem health and can provide a measure of damage to Victorian waterways attributed to human activity. Significant deviation of these parameters from ‘natural’ levels can result in ecosystem degradation and may impact environmental qualities and beneficial uses.

Water quality objectives for individual indicators are set for defined segments in State Environment Protection Policy according to beneficial uses. Objectives are typically stated in terms of limits on individual, median and percentile indicator values over each year. The purpose of this report is to outline the process for developing the water quality objectives in the *State Environment Protection Policy (Waters of Victoria)*¹.

Historically, methodologies for setting and assessing water quality objectives have not generally accommodated the natural spatial and temporal variations that are inherent in aquatic ecosystems. Water quality varies naturally across the State according to processes related to soils, topography, meteorology and vegetation. Previously, the establishment of water quality objectives for broad based segments such as *General Surface Waters*² has resulted in the application of only one objective for each indicator, regardless of the underlying natural spatial variation in indicator levels across the State.

This has often resulted in comparison of a wide range of different environment types to just one objective.

Since 1988, programs of environmental monitoring and interpretation in both water quality and freshwater ecology have increased. There have also been considerable further developments in areas of environmental monitoring and assessment research.

While the intent behind setting water quality objectives has not changed, the amount of relevant, available data has. A major source of recently acquired data has been biological, chemical and physical habitat sampling undertaken by EPA as part of the federally funded National River Health Program. This has resulted in detailed data from approximately 900 sites across the State which enabled improved characterisation of regimes of water quality. These additions to our knowledge and information base were used to further develop and refine the water quality objectives.

1.2 Context and scope

Victoria has endorsed the National Water Management Strategy, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*³ which uses a risk based assessment approach for developing water quality guidelines. The *Guidelines*³ specify ‘trigger values’ (or alert levels) which initiate follow-up assessment when breached (refer to Appendix 1).

Historically, all guideline values were essentially ‘thresholds’ above which ecological health is likely to be compromised^{4,5}. The new risk based approach was

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used in the development of the water quality objectives, as it is more ecologically meaningful than the often simplistic use of thresholds.

The water quality objectives presented in this document are based on ecological goals. They are designed to protect the existing aquatic environment of healthy streams and provide goals for impacted streams. In many areas of the State a return to near-pristine conditions is neither practical nor achievable due to differing degrees of catchment disturbance, and major irreversible impacts on stream ecosystems. In these areas, the water quality objectives are representative of the better streams within a region, and provide realistic goals that accommodate regional constraints. In heavily urbanised areas, water quality objectives which would otherwise be applicable will not be met, and interim objectives which assist in partial rehabilitation must be determined, as for example in the *State Environment Protection Policy (Waters of Victoria) Schedule F7, Waters of the Yarra catchment*⁶.

The water quality objectives for freshwaters focus on a core indicator set that reflects their importance on a statewide scale. The core indicators pH, turbidity, electrical conductivity (salinity) and dissolved oxygen are addressed in this report. Nutrient and biological objectives for freshwater ecosystems, in addition to water quality objectives for marine waters, are discussed elsewhere^{7,8,9}.

While not designated as a core indicator, toxicants can be a locally important issue and generally affect sensitive species, rather than cause a reduction in overall ecosystem health. There are limited toxicants

data across the State, which precludes the development of specific regional objectives.

Accordingly, the *Guidelines*³ trigger values at the 99% protection level were adopted in the *State Environment Protection Policy (Waters of Victoria)*².

The setting of water quality objectives does not imply that streams with environmental quality better than these objectives can or should be allowed to decline. In these instances, the default objective is the background level for that stream or reach.

The regional approach adopted in this document is restricted to the range of environmental conditions over which data were available for examination. The water quality objectives therefore refer to:

- perennial rivers and streams;
- non-urban areas.

There is currently insufficient data available to derive objectives for intermittent/episodic streams, lakes, wetlands and estuaries.

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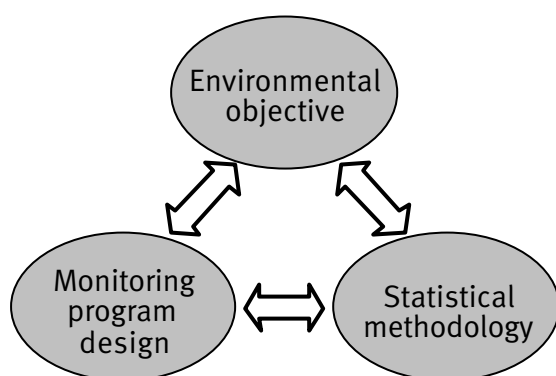
The water quality objectives are:

- aimed at protecting the health of the aquatic ecosystem;
- ecologically-based;
- for regions of relative homogeneity in water quality;
- not for heavily urbanised areas;
- applied to perennial rivers and streams;
- not developed for intermittent/episodic streams, lakes, wetlands, estuaries or marine waters;
- not to be used as a value to 'pollute up to'.

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2 GUIDING PRINCIPLES

A statistical verification of an environmental objective requires that the following three components be mutually consistent.



If any two of these components are specified without proper consideration for the third, the resulting inconsistency may preclude either the statistical assessment or its meaningful interpretation.

2.1 Environmental objective

The choice of an objective against which to compare water quality data is important in both a statistical and an environmental sense. In order for water quality objectives to have environmental significance, the objectives need to be linked to undesirable changes in environmental variables. The level at which an objective is set for an indicator should, ideally, be based on knowledge of the role of that indicator in the environmental process being monitored.

Hart et al. (1999)¹⁰ argue that the setting of environmental limits requires prior understanding of

the environmental system being monitored if the limits are to have meaning. However, they suggest that there is a role for professional judgement in instances where the detailed quantitative knowledge necessary to set a limit does not exist. Once objectives have been set, the statistical method then needs to be able to detect such changes with an acceptable degree of confidence.

2.2 Monitoring program design

The method of assessment of the objectives is restricted by practicable sampling frequency and, generally, an annual reporting requirement. The overall sampling intensity determined to be practicable over the statewide water quality monitoring network results in 12 observations per year per site.

Variations from this sampling frequency on the basis of power/sample size calculations on a per-site basis could be considered. However, the resulting logistical and cost implications would be difficult to accommodate and would be expected to vary from year to year. Another important reason for the current monthly sampling frequency is to satisfy the primary objective of the network, which is to allow tests for temporal trends. This objective would be compromised if variations in sampling frequencies between sites and between years were to be implemented.

2.3 Statistical methodology

The statistical methodology that is appropriate for assessing whether the objective has been met should

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be the simplest available. A confidence interval approach¹¹ has been found to be most appropriate for assessing water quality objectives over a very large number of sites given a monthly sampling frequency.

The use of percentiles

Water quality objectives need to relate to the statistical population being measured as it reflects the ‘true’ environmental quality. Given that whole populations cannot be measured, the use of sample percentiles provides the best estimates of the ‘true’ environmental quality. These estimates are subject to uncertainty. This uncertainty is expressed through the designation of confidence limits, within which there is an acceptable likelihood that the ‘true’ (statistical population) percentiles reside .

The intention in specifying a percentile objective for an indicator is to place lower and/or upper constraints on the distribution of the indicator values while avoiding the problems associated with absolute limits¹¹. Commonly, monitoring programs involve the collection of one sample per month, with an annual assessment against objective levels. It has been shown that the most extreme percentiles that can be estimated with 95 per cent confidence using 12 data values, and without making assumptions about the data distribution, are the 25th and 75th percentiles¹¹.

In Summary

- Objectives must be meaningful in an environmental sense and be assessable using the monitoring data.
- Monitoring must generate sufficient quality and quantity of data for assessing whether the objective has been met.
- The statistical method should be appropriate for assessing the objective using the monitoring data.

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3 APPROACH

3.1 Water Quality Regionalisation

EPA has an extensive database of aquatic invertebrates, water quality and habitat information, largely accumulated under the National River Health Program (NRHP). The availability of this information was essential for delineating water quality regions and developing water quality objectives. While the number of observations for each site is limited, this network has a large number of sites that spatially cover the entire State.

Sites within this network are classified as either 'reference' or 'test' sites. A reference site does not necessarily mean that the site is pristine but is a minimally impacted or best available site. This is in recognition that most streams in foothill and lowland areas in particular have been greatly modified by human activities, and few, if any, unaltered or pristine examples of streams exist. Reference sites were used to characterise best available stream condition. All other sites are designated 'test'.

The regionalisation process involved the classification of sites using a combination of numerical (multiple regression and clustering) and qualitative (expert judgement) methods. Electrical conductivity (salinity) and turbidity data were log transformed for the statistical analyses.

Regression equations for all reference sites were derived for each indicator in terms of catchment variables shown to be important predictors for ecosystem health¹³ (for example, latitude, longitude,

altitude, distance from source, slope). Better predictors were able to be derived when the State was divided into areas based on geographical features and individual regression equations derived for each area.

As an example, within the geographic area east of 146° longitude, the best predictors for pH were determined to be altitude, longitude and catchment area.

For each water quality indicator, all of the sites (reference and test) that had a similar range of the geographical variables (used within the regression equations) were used to predict the best expected water quality at those sites across the State. The reference sites used to generate the regression equations were also used (along with test sites) to predict best expected water quality. This was done to provide a spatial data set of sufficiently uniform variation to allow derivation of regions.

A cluster analysis was performed using these predicted data in an attempt to spatially group the sites of equivalent best expected water quality. This type of analysis groups sites with similar sets of indicator values. The analysis is performed by specifying the number of clusters required at the outset. For each indicator, the number of clusters was optimised based on how well each clustered model approximated its original predicted data.

Site locations were plotted onto Victoria base maps according to the cluster each site fell into. Four maps were produced, corresponding to the four water quality indicators, that approximated the spatial distribution of water quality across the State.

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The regional boundaries for each indicator were delineated and refined based on the cluster maps, physiographic features and the biological regions⁸.

Given that biota⁸ provide the most direct measure of ecological quality, the biological regionalisation was compared to the water quality regions to assess whether the data necessitated the defining of specific water quality regions. While a number of the water quality regional boundaries were not consistent with the biological regions, these were able to be adjusted to align with the biological regions without compromising the integrity of the water quality regionalisation.

management, the ‘ideal’ objectives were either adopted or refined.

3.2 Developing the objectives

Following the development of the boundaries, ‘ideal’ median and percentile objectives were calculated for each indicator for each region. These were based on the best estimates of water quality corresponding to the sites with the best ecological quality for each region.

The ‘ideal’ objectives were then compared to data from the Victorian Water Quality Monitoring Network (VWQMN)¹³. The VWQMN database contains monthly data, from approximately 200 sites, sampled over many years. The VWQMN database allowed a greater level of within-site temporal characterisation than did the NRHP database which had greater spatial coverage.

Based on knowledge of current conditions and what was likely to be achievable and sustainable in the long term given best practice environmental

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4 WATER QUALITY REGIONS AND OBJECTIVES

Regional water quality objectives were developed for dissolved oxygen saturation (%), turbidity (NTU), electrical conductivity ($\mu\text{S cm}^{-1}$) at 25°C and pH (pH units) for the protection of aquatic ecosystem values (Figures 1-4, Table 1).

The regional objectives are designed for ecosystem protection. They define concentrations or levels beyond which there exists a potential risk that adverse ecological effects will occur. A potential risk will trigger either further investigation or implementation of management actions (refer to Appendix 1 for a schematic diagram of the risk framework).

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4.1 Dissolved oxygen

Four 25th percentile objectives were determined for dissolved oxygen saturation (%), corresponding to:

- highlands areas above approximately 1000 m altitude (95%);
- forested areas in the north-east, Wilsons Promontory, the Strzeleckis, Otways and Grampians (90%);
- cleared hills, coastal plains and part of the Murray and western plains (85%);
- lowland reaches of the Wimmera, Mallee, Avoca, Campaspe and Loddon catchments, and the Victorian part of the Millicent Coast catchment (80%).

A maximum trigger of 110% for individual values was set due to concerns about the increased likelihood of nutrient enrichment above this level.

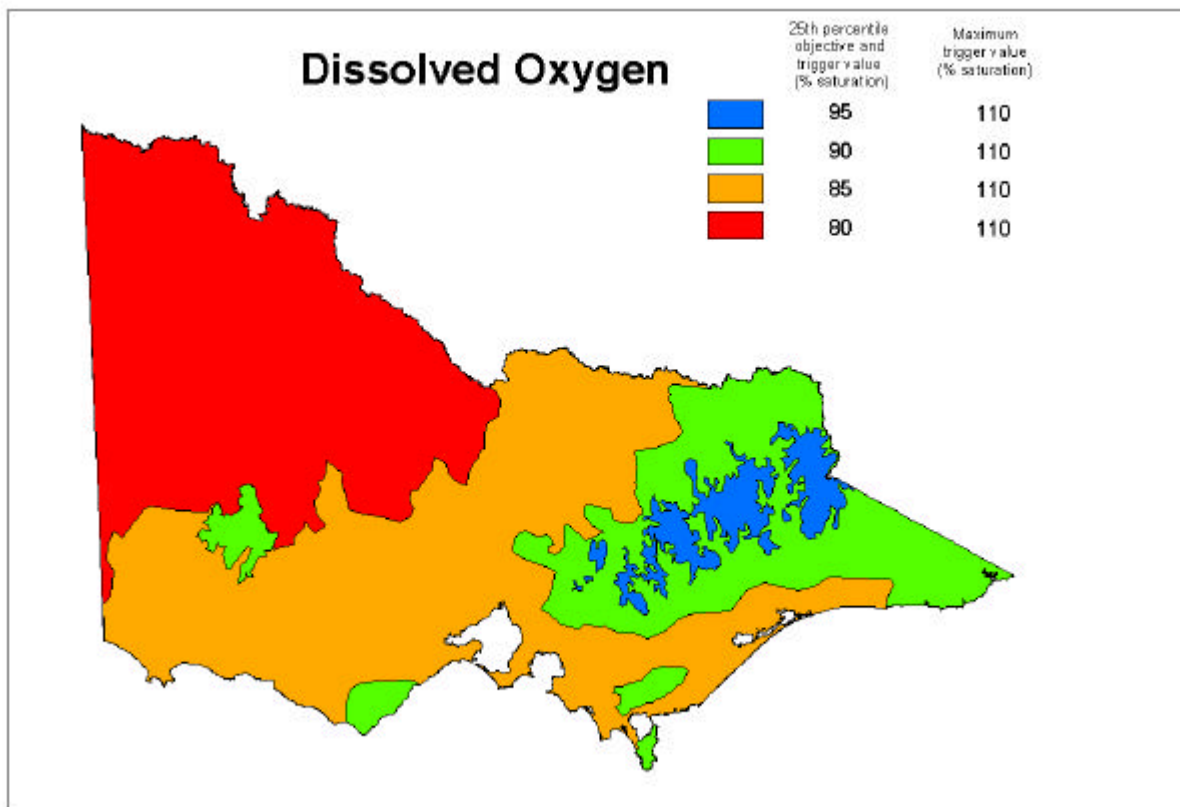


Figure 1: Water quality objectives for dissolved oxygen saturation (%) (SEPP WoV)

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4.2 Electrical conductivity

Three 75th percentile objectives were determined for electrical conductivity at 25 °C, corresponding to:

- forested areas in the north-east (100 $\mu\text{S cm}^{-1}$);
- Wilsons Promontory, the Strzeleckis, Otways, and Grampians, cleared hills and coastal plains including the Murray plains east of the

Goulburn/Campaspe catchment boundary, but excluding the western plains (500 $\mu\text{S cm}^{-1}$);

- western plains and Murray plains west of the Goulburn/Campaspe catchment boundary (1500 $\mu\text{S cm}^{-1}$).

Trigger levels equal to the 75th percentile objective values were adopted.

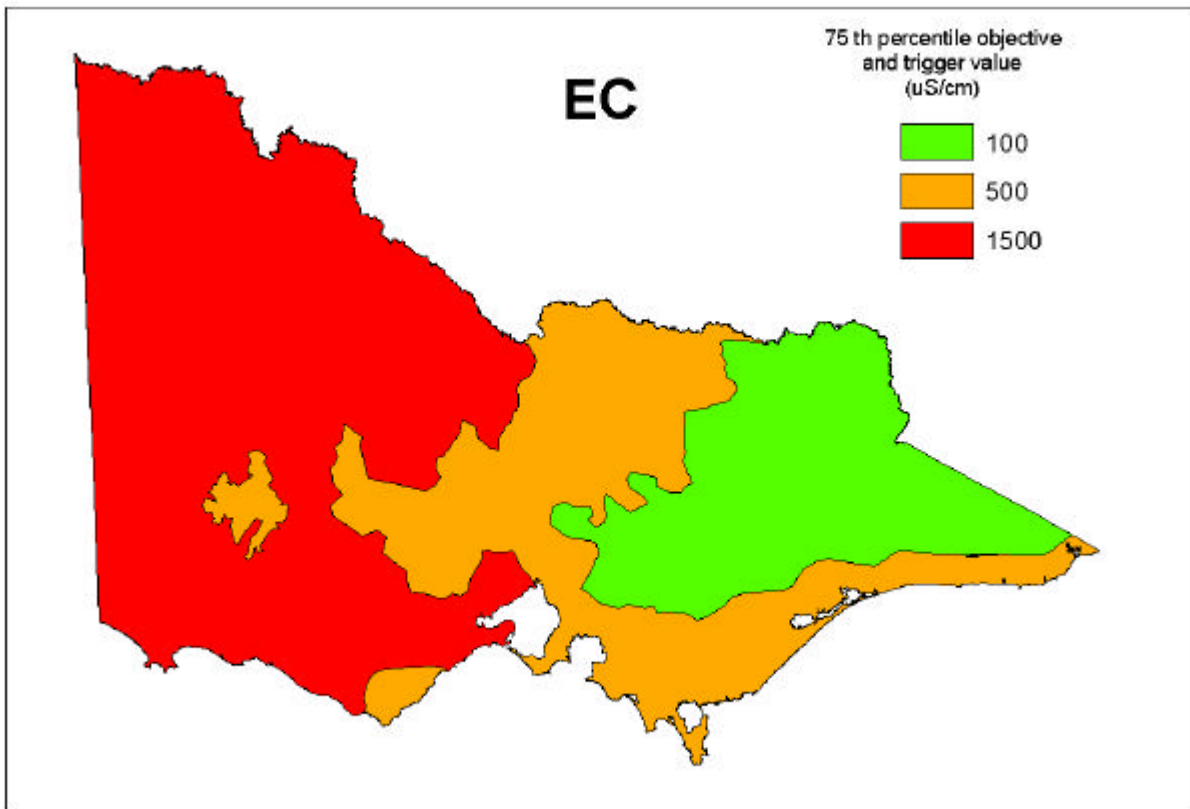


Figure 2: Water quality objectives for electrical conductivity ($\mu\text{S cm}^{-1}$) at 25 °C (SEPP WoV)

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4.3 pH

Two percentiles objectives, both the 25th percentile and 75th percentile, were determined for pH for each of two regions. These correspond to:

- all areas east of the Campaspe/Goulburn, Maribyrnong/Yarra, and Maribyrnong/Goulburn catchments boundaries, and the Grampians and the Otways (6.4 for the 25th percentile and 7.7 for the 75th percentile);

- all areas west of the Campaspe/Goulburn, Maribyrnong/Yarra, and Maribyrnong/Goulburn catchments boundaries, excluding the Grampians and the Otways (6.5 for the 25th percentile and 8.3 for the 75th percentile).

Trigger levels for each region equal to the corresponding 25th and 75th percentile objective values were adopted.

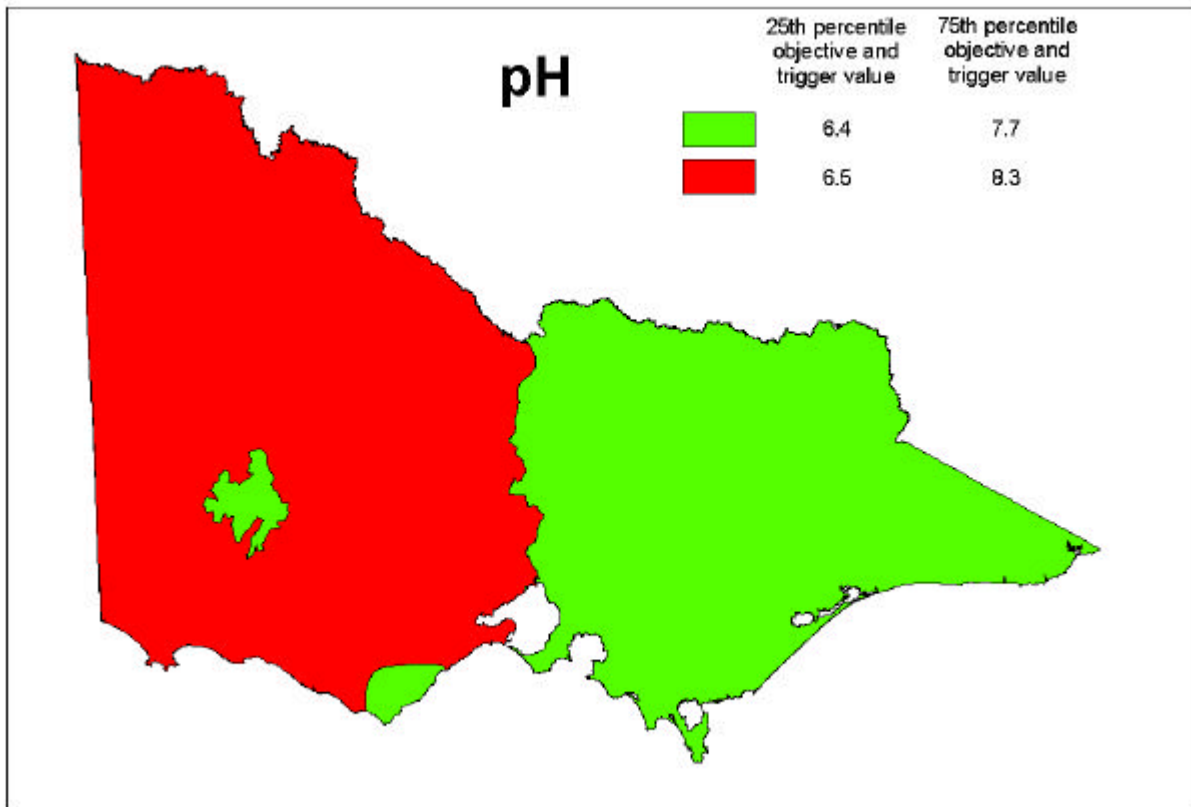


Figure 3: Water quality objectives for pH (SEPP WoV)

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4.4 Turbidity

Three 75th percentile objectives were determined for turbidity, corresponding to:

- forested areas in the north-east, Wilsons Promontory, the Strzeleckis, Otways and Grampians (5 NTU);
- cleared hills, coastal plains, Murray and western plains, excluding the lowland reaches of the Kiewa, Ovens, Goulburn, Campaspe, Loddon and Avoca catchments (10 NTU);
- lowland reaches of the Kiewa, Ovens, Goulburn, Campaspe, Loddon and Avoca catchments (30 NTU).

- Trigger levels equal to the 75th percentile objective values were adopted.

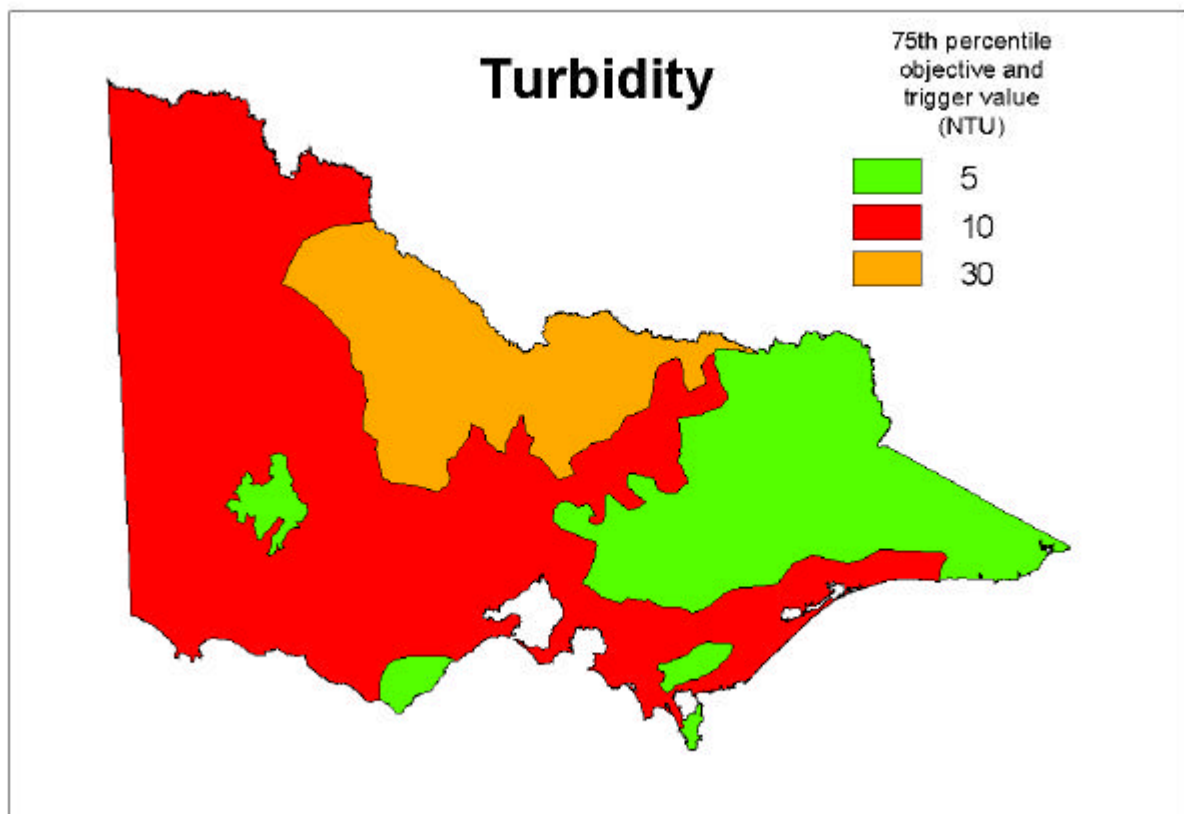


Figure 4: Water quality objectives for turbidity (NTU) (SEPP WoV)

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5 SEPP SEGMENTS AND WATER QUALITY OBJECTIVES

There is an obvious practical benefit in using a single set of regional boundaries across the State that is applicable for all indicators. It would minimise potential confusion and facilitate uptake of the objectives.

For the purpose of the *Policy*, the water quality objectives were incorporated within the segments representing the biological regions in the *State Environment Protection Policy (Waters of Victoria)*². The objectives are based on knowledge of current conditions and what is likely to be achievable and sustainable in the long term, given best practice environmental management.

Table 1: Water Quality Regions and Objectives (SEPP WoV)

SEGMENTS	Dissolved oxygen saturation	Turbidity	Electrical conductivity	pH	
	(25 th percentile / maximum)	(75 th percentile)	(75 th percentile)	(25 th /75 ^h percentiles)	
1 Highlands	Mountain reaches in the upper Murrav, Mitta Mitta, Kiewa, Ovens, Goulburn, Yarra, Latrobe, Thomson, Macalister, Mitchell, Tambo, and Snowy catchments	95/110	5	100	6.4/7.7
2 Forests A	Wilsons Promontory, Strezlecki Ranges, and far East Gippsland	90/110	5	500	6.4/7.7
	Upland reaches in the upper Murray, Mitta Mitta and Kiewa catchments	90/110	5	100	6.4/7.7
	The Grampians	90/110	5	500	6.4/7.7
	Upland reaches in Goulburn, Yarra, Latrobe and Thomson catchments	90/110	5	100	6.4/7.7

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Table 1: continued

	SEGMENTS	Dissolved oxygen saturation	Turbidity	Electrical conductivity	pH
		(25 th percentile / maximum)	(75 th percentile)	(75 th percentile)	(25 th /75 ^h percentiles)
3 Forests B	Otway Ranges	90/110	5	500	6.4/7.7
	Upland reaches in the Ovens, Broken, Goulburn, Macalister, Mitchell, Tambo and Snowy catchments	90/110	5	100	6.4/7.7
4 Cleared Hills and Coastal Plains	Lowland reaches in the Barwon, Moorabool, Werribee and Maribyrnong catchments	85/110	10	1500	6.5/8.3
	Lowland reaches in the Yarra, Western Port, Latrobe, Mitchell, Tambo and Snowy catchments	85/110	10	500	6.4/7.7
	Upland reaches in the Wimmera, Hopkins, Moorabool, Werribee, Maribyrnong, Campaspe, Loddon and Avoca catchments	85/110	10	500	6.5/8.3
	Mid reaches in the Ovens and Goulburn catchments	85/110	10	500	6.4/7.7

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Table 1: continued

	SEGMENTS	Dissolved oxygen saturation	Turbidity	Electrical conductivity	pH
		(25 th percentile / maximum)	(75 th percentile)	(75 th percentile)	(25 th /75 ^h percentiles)
5 Murray and Western Plains	Lowland reaches in the Kiewa, Ovens and Goulburn catchments	85/110	30	500	6.4/7.7
	Lowland reaches in the Campaspe, Loddon and Avoca catchments	80/110	30	1500	6.5/8.3
	Lowland reaches in the Wimmera catchment	80/110	10	1500	6.5/8.3
	Lowland reaches in the Glenelg, Hopkins, Portland and Corangamite catchments	85/110	10	1500	6.5/8.3

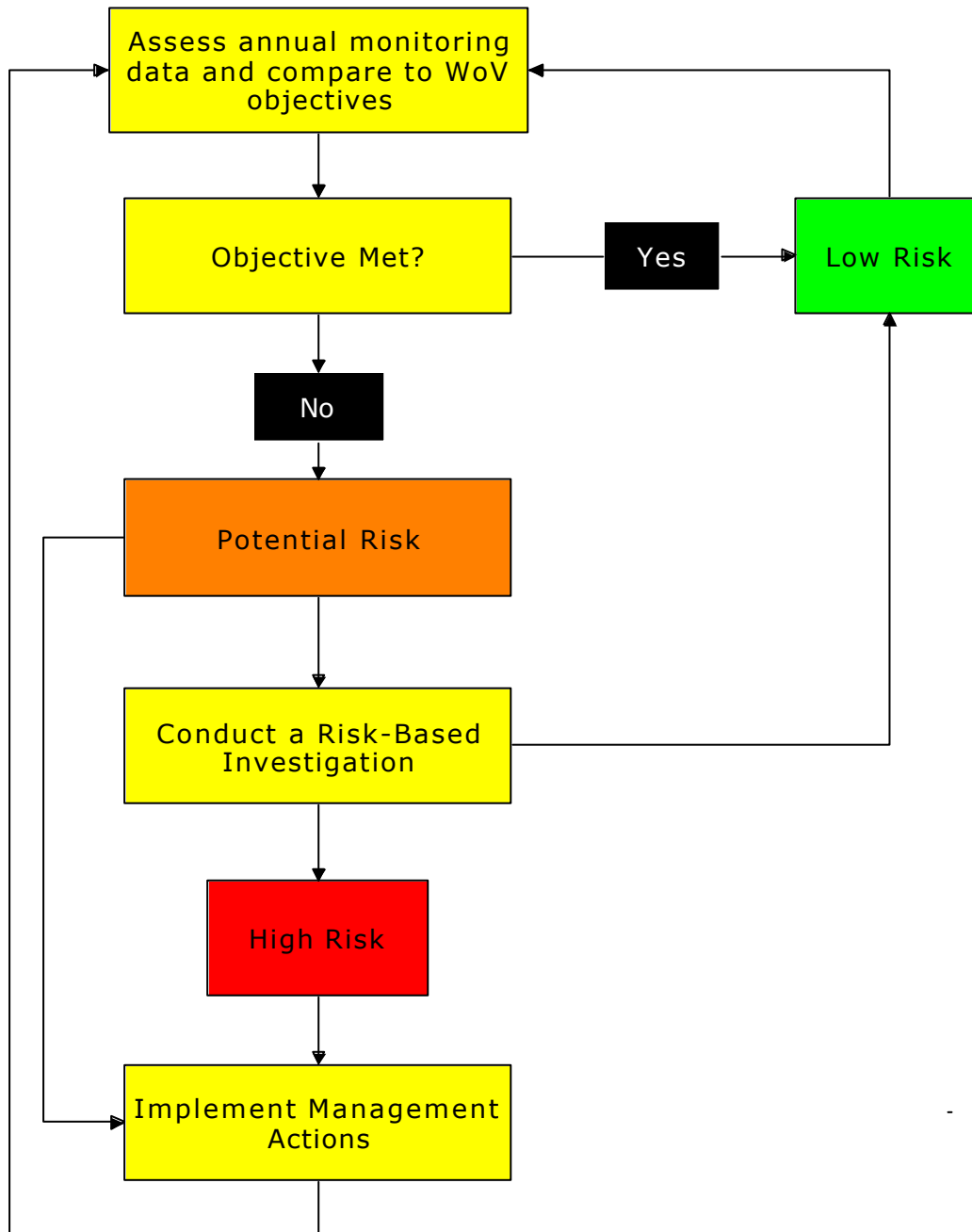
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- ¹³Victorian Water Resources Data Warehouse. <http://www.vicwaterdata.net>

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APPENDIX 1: RISK BASED DECISION FRAMEWORK (SEPP WoV)



For more details on the risk-based approach used by EPA, refer to: Environment Protection Authority Victoria, *Risk Assessment Approach – Ecosystem Protection*, Publication 790.1, 2003.