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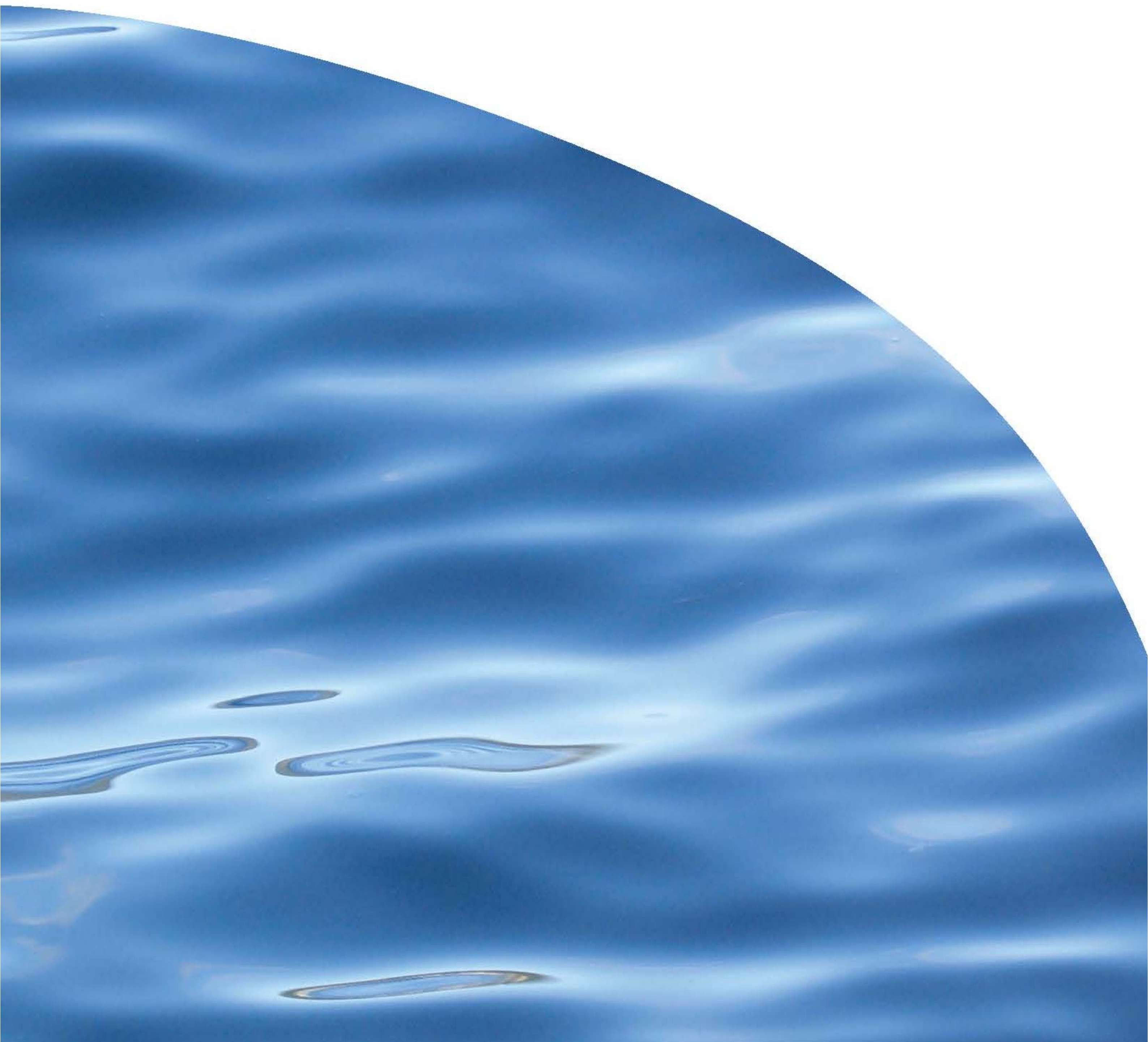
RECOMMENDED WATER QUALITY STANDARDS FOR REVIEW OF MARLBOROUGH'S RESOURCE MANAGEMENT PLANS



RECOMMENDED WATER QUALITY STANDARDS FOR REVIEW OF MARLBOROUGH'S RESOURCE MANAGEMENT PLANS

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Prepared for Marlborough District Council

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EXECUTIVE SUMMARY

Marlborough District Council (MDC) is currently reviewing their resource management framework. This includes combining the two existing resource management plans (Wairau / Awatere and Marlborough Sounds) into a comprehensive Resource Management Plan for the whole district. As part of this update, water resource units (WRU) have been identified. Through a comprehensive process of consultation with local stakeholders, the values of these zones are being determined. Information and expert advice is now sought to help inform appropriate water quality standards for these zones acknowledging the potentially different environmental types and values present.

This report makes recommendations relating to biological and water quality standards for waters managed for aquatic ecosystems, fishery purposes, fish spawning, natural state, contact recreation, aesthetics, water supply and irrigation values in streams and rivers. The report briefly reviews recent regional and national developments in water quality standards to make suitable recommendations for the Marlborough district.

This report recommends receiving water standards that maintain and improve the water quality of the Marlborough district. The scope of application of these limits in Marlborough's Resource Management Plan has yet to be defined. In particular, where and when each specific management purpose or value needs to be determined, so that the different receiving water standards recommended in this report can be applied to the relevant water resource units.

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1.1. Background

1.1.1. Current water quality standards

Current regional resource management plans (Marlborough Sounds Resource Management Plan [MSRMP] 2003; Wairau / Awatere Resource Management Plan [WARMP] 2008) contain water quality standards based on the guidelines as outlined in the Resource Management Act 1991 (RMA). Specifically, Schedule 3 outlines 11 water quality classes — water managed for the purposes of aquatic ecosystems, fisheries, fish spawning, edible shellfish gathering or cultivating, contact recreation, human drinking water supply, irrigation, industrial abstraction, natural water and aesthetic and cultural values. It also defines a suite of narrative or numerical water quality standards for each class. Furthermore, RMA Section 70 (1) sets five narrative standards in relation to consented or permitted discharges to water or land. These narratives relate to the potential impacts of discharges on aquatic life, visual aesthetics and odour, and suitability for consumption by farm animals. The existing regional plans adopt RMA narrative and numerical guidelines where relevant for all standards except water temperature (Appendix 1).

Water temperature is recognised as an important characteristic of Marlborough streams and rivers necessary for sustaining fisheries, which is currently the underlying class value of these ecosystems. Following consideration, Marlborough District Council (MDC) adopted temperature guidelines (“shall not exceed 20°C”) that were more stringent than those recommended in the RMA Third Schedule (“shall not exceed 25°C”).

Current water quality guidelines apply to receiving waters below point discharges after an area of ‘reasonable mixing’ (see Section 2).

1.1.2. Marlborough Resource Management Plan Review 2014

Since the implementation of MDC regional plans in 2003 and 2008, respectively, there have been advances in the practices used to assess water quality in fresh waters. These advances have generally improved the numerical interpretation of attributes making it easier to assess water quality. For example, RMA-based ‘standards’ for dissolved oxygen (DO) state “shall exceed 80% of saturation” and provides no guidance on the time period this value relates to, and does not take into consideration how diel fluctuations in DO affect aquatic ecosystems. Recent DO guidelines not only state the temporal limitations of numerical objectives but also provide improved definition of units and acknowledgement of the natural variability in DO in aquatic environments. For example, expert advice now recommends the numerical guideline for DO to be in concentration units (rather than % saturation) and takes into account daily variation (Davies-Colley *et al.* 2013). The review and adoption of relevant improvements in attribute assessment will be used to update the MRMP.

1.1.3. National Policy Statement for Freshwater Management

The National Policy Statement for Freshwater Management (NPS-FM) came into effect on 1 July 2011 as part of the 'Fresh Start for Fresh Water' package of reforms. The NPS-FM requires regional councils to:

- maintain or improve overall water quality within a region
- safeguard the life-supporting capacity, ecosystem processes and indigenous species (including their associated ecosystems) of fresh water
- set freshwater objectives and limits for all water bodies.

A discussion document, 'Amendments to the National Policy Statement for Freshwater Management 2011', was released for discussion in November 2013 and was open for submissions until 4 February 2014. In summary, the proposed amendments to the NPS-FM:

- require regional councils to account for all water takes and contaminant discharges
- include a national framework to support communities setting freshwater objectives
- provide explicit recognition of tangata whenua values for fresh water
- establish ecosystem and human health as compulsory values in regional plans
- introduce 'bottom lines' for ecosystem and human health that apply everywhere
- include restricted grounds for exceptions to 'bottom lines'
- require regional councils to identify a range of sites suitable for monitoring long-term trends in water quality.

The proposed amendment document also outlines a range of values for fresh waters. Compulsory national values include:

- Ecosystem health: The freshwater management unit supports a resilient ecosystem specific to that freshwater body type (river, lake, wetland, or aquifer).
- Human health (secondary contact recreation): The freshwater management unit will not present unacceptable risks to human health when used for wading or boating (except boating where there is high likelihood of immersion which would be classified as primary contact recreation).

Numerical limits are provided to assess national 'bottom lines' for a series of attributes in relation to the two identified national values. Specifically, numerical limits proposed for ecosystem health include:

- Chlorophyll-*a*, total nitrogen (TN), total phosphorus (TP) (for lakes)
- Nitrate toxicity, ammonia toxicity, dissolved oxygen (DO), periphyton (for rivers).

Numerical limits proposed for human health (secondary contact recreation) include:

- *E. coli*, cyanobacteria, suitability for recreation guide (for lakes and rivers).

Table 1. Examples of values and related attributes to be managed under the National Objectives Framework. The first two values are to be applied to all water bodies. Table adapted from information on the Ministry for the Environment (MfE) website in January 2014[1]. Attributes in bold are included in the current discussion document, 'Amendments to the National Policy Statement for Freshwater Management 2011'.

Value	Attributes
Ecosystem health and general protection for indigenous species	Temperature, **dissolved oxygen**, pH, **periphyton (slime)**, sediment, flows, connectivity, **nitrate (toxicity), ammonia (toxicity)**, fish, invertebrates, riparian margin
Human health for secondary contact	***E.coli*, cyanobacteria**
Electricity generation	Sediment, flows
Irrigation	Sediment, flows, *E. coli*
Stock watering	Sediment, flows, *E. coli*
Fisheries: for specific species (*e.g.* trout or inanga)	Flows, sediment, periphyton (slime), temperature, dissolved oxygen, nitrate (toxicity), ammonia (toxicity), invertebrates
Fish spawning: for specific species (*e.g.* inanga or trout)	Flows, sediment
Boating and navigation	Sediment, flows, periphyton (slime).
Natural form and character	Temperature, periphyton (slime), sediment, flows, connectivity
Indigenous species: protection for specific species	To be developed
Swimming	*E.coli*, periphyton, cyanobacteria, water clarity, flows
Drinking	*E.coli*, cyanobacteria, water clarity
Food gathering / mahinga kai	*E.coli*, cyanobacteria, water clarity, riparian margin
Food production / freshwater aquaculture	To be developed
Ceremonial uses	*E.coli*, clarity

[1] http://www.mfe.govt.nz/publications/water/freshwater-reform-2013/html/page6.html

An important component of the NPS-FM is the proposed management banding for different attributes. This provides a range of numbers that represent different states that an attribute may be managed for. For example, the numerical guidelines associated with Band A represent the best available or excellent state. Bands B and C gradients could be considered ‘good’ and ‘fair’ state. Whereas numerical guidelines associated with Band D could be considered to reflect non-supportive or ‘poor’ state. The national ‘bottom-lines’ component of the NPS-FM is represented numerically as the value delineating Bands C and D.

Some councils in New Zealand are moving towards implementation of management bands for different attributes by rating values. For example, in the Horizons One Plan, trout fishery value is rated as being ‘Outstanding’, ‘Regionally Significant’, or ‘Other Trout Fishery’. This could align to Bands A, B and C for establishing numerical limits for attributes to protect trout fisheries. In the absence of rated values, water quality guidelines could be seen as representative of a ‘bottom line’; the numerical standard of an attribute necessary to maintain the natural or human use value. For receiving waters in the Marlborough region, the site-specific water quality standard may be more conservative (or more lenient) than a catchment limit-setting ‘bottom line’ in consideration of the localised temporal and spatial effect of a discharge (see also Section 2). The regional ‘bottom line’ may also be more conservative than the national ‘bottom line’ in recognition of the natural character of the region.

Marlborough District Council have adopted a staged implementation programme whereby cumulative limits will be established in the medium to long term in line with the NPS-FM timeframe recommendations as outlined in Policy E2. Cumulative limit setting is not part of the current resource management plan review.

1.1.4. Scope

This report recommends water quality standards for receiving water bodies.
These will be standards that point-source discharges will be required to meet beyond a zone of reasonable mixing as opposed to a cumulative limit for a catchment.

1.2. Values

Marlborough District Council is currently reviewing its record of water body values to ensure that it is current. The outcome will be documented in a separate report and will directly inform the classification of water bodies. As part of the values review process, Marlborough has been divided into a series of WRU that are based on catchment boundaries. An assessment of the various natural and human use values of the waterways (ecological, habitat, recreational and natural character) in these water management units has been prepared and is being discussed with focus groups. Identified values include: Fishery purposes (F), fish spawning (FS), aquatic ecosystem purposes (AE), contact recreation (CR), irrigation (I), natural state (N), aesthetics (A) and water supply (WS). These interim values form the basis of developing water quality guidelines for Marlborough recommended in this report.

The aquatic ecosystem (AE) value recognises the need to safeguard the basic life supporting capacity of fresh waters. Ecosystems with life supporting capacity are resilient, stable and sustainable, maintaining characteristic composition, organization, and function over time. This objective of this value is to ensure the water quality requirements of New Zealand native aquatic ecosystems are being met, including but not limited to, fish and aquatic macroinvertebrates. This is a base value for waterways in the Marlborough region and aligns with the National Objectives Framework (NOF) aquatic ecosystem default value.

Fishery purposes (F) recognises the value the waterways hold as supporting populations of sporting fish, namely trout and other salmonids, with the primary objective being that fish are safe for human consumption. Additional objectives include that fish populations are healthy with adequate habitat and food, and that the waterway meets aesthetic, amenity and natural character expectations associated with the fishery. Similarly the fish spawning (FS) value recognises the importance of waterways for sport fish spawning with the primary objective being to ensure water quality requirements for trout egg survival. These two values are potential base values for the Marlborough region.

Contact recreation (CR) value recognises the importance of waterways for human recreation that involves body contact with the water. The primary objective of this value is to protect human health and additional objectives relate to recreational enjoyment, such as aesthetic, amenity and natural character expectations. There are two types of contact recreation, primary and secondary. Primary contact recreation includes swimming and other activities where there is frequent direct contact with the water, such as water skiing. Secondary contact recreation includes activities that generally have less-frequent body contact with the water, such as boating and fishing and is a NOF default value recommended to apply to all waterways.

The irrigation (I) value applies to waterways subject to demand for water for agricultural or stock drinking water purposes. The objectives of this value are to provide for crops or stock and indirectly human health.

The natural state (N) value applies to waterways with outstanding natural quality in terms of aquatic ecology, unaltered flows, recreation or aesthetic value. Applying to rivers located predominantly in natural vegetation landscapes, the objective of this value is to ensure the natural quality of water is not altered.

Aesthetics (A) recognises the special significance of clear waters in the Marlborough region and aims to protect the outstanding clarity of waterways.

The water supply (WS) value protects water for human consumption and would currently apply to only one WRU in the Marlborough region — Black Birch Stream in the Awatere catchment.

1.2.1. Values recommendations

We recommend that water quality guidelines associated with the base values of ‘aquatic ecosystem’, ‘fishery’ including ‘fish spawning’ are applied to all WRU and that additional water quality guidelines are applied where additional values are assigned. It may also be beneficial to MDC to consider rating these three base values for each WRU as this would aid in the development of future catchment limit setting.

We also recommend a reconsideration of the use of a ‘natural state’ value. It is difficult to determine numerical objectives to protect natural state without measuring the natural setting. Assignment of management bands may aid the application of numerical guidelines for WRU with natural state values. For example, Band A numerical guidelines could be applied to natural state waterways. In the absence of banding, regulatory tools (*e.g.* prohibited activity rules) should be applied to protect natural state.

Similarly, it is recommended that a value of ‘secondary contact recreation for human health’ value be assigned to all waterways. This would align the MDC Resource Management Plan with the NPS-FM, yet still allow for the assignment of primary contact recreation guidelines where applicable.

2. REASONABLE MIXING

The water quality guidelines stipulated in the existing WARMP and MSRMP apply to receiving waters below point discharges after an area of 'reasonable mixing'. The definition of reasonable mixing as defined in the current regional plans is:

> REASONABLE MIXING means for any point-source discharge the zone of reasonable mixing in the receiving water shall extend from the discharge point as follows:
>
> For rivers and streams, the lesser of:
> a) a distance downstream which equals seven times the width of the river or stream when the flow is at half the median flow; or
> b) 200 metres downstream.
>
> For rivers subject to tidal influence:
> As for rivers and streams plus a distance upstream equal to half of that allowed downstream when the width is taken at half the median river flow at mid-tide.
>
> For artificial watercourses (including farm drainage canals), the greater of:
> a) 200 metres downstream; or
> b) the property boundary.
>
> For lakes:
> Within a radius of 100 metres.
> A larger (or different shaped) reasonable mixing zone will be accepted where the applicant can demonstrate (to the satisfaction of the council) by physical or numerical modelling, and / or dispersion trials at the discharge point, that
> a) it is not practical to achieve reasonable mixing within the standard zone, and
> b) the objectives of the water quality classification(s) are not frustrated by a larger (or different shaped) zone, and
> c) adverse effects will not occur.

While it is desirable to have a clear definition of how reasonable mixing is to be interpreted, Norton and Snelder (2003) argue that it is not possible nor desirable to make a generic definition of reasonable mixing that is regionally applicable, because what is 'reasonable' in one situation, may not be reasonable in another. They recommend that rather than including a specific definition for reasonable mixing in the Canterbury Plan, instead it should provide guidance on how reasonable mixing will be assessed during a consent process. Guidance on how to define reasonable mixing on a case basis is provided by an MfE publication (Resource Management Ideas No. 10 — A Discussion on Reasonable Mixing in Water Quality Management — Rutherford *et al.* 1994), the ANZECC (2000) guidelines, and Norton and Snelder's (2003) review of numeric water quality standards for Environment Canterbury and MfE.

2.1. Rutherford *et al.* (1994)

Policy stipulating that standards or guidelines are to be met 'after reasonable mixing' (*e.g.* the RMA, and MDC's existing RMPs), implies that there is a zone in which the underlying standards need not be met. Rutherford *et al.* (1994) termed this the 'non-compliance zone'. They made a clear distinction between the 'near-field mixing zone', the point of 'complete mixing' and the non-compliance zone. The near-field mixing zone is the area close to the outfall where the effluent mixes rapidly with the receiving water due to momentum and/or buoyancy of the effluent and turbulence in the receiving water. Further away from the outfall transverse dispersion often takes a long time to completely mix contaminants across the entire flow (especially in wide, straight river channels). Complete mixing occurs once the effluent is completely dispersed through the receiving waters. The concept of complete mixing is only relevant in flows confined between banks (such as rivers and estuaries). In unbounded flows (such as lakes and the oceans) mixing continues more or less indefinitely. Rutherford *et al*. (1994) suggested that there was a common misconception that mixing is only 'reasonable' once it is complete. However, they stated that there is nothing in the legislation or the case law to support this notion.

The non-compliance zone, where the water quality standards are not always met, is the area of chief significance for water management (Rutherford *et al.* 1994). The size of this zone is partly dependent on the hydrodynamics of the receiving water (*e.g.* river flow, currents, depth, turbulence) and partly on the nature of the discharge (*e.g.* effluent flow, level of treatment, outfall design). Consequently, the discharger can control the size of the non-compliance zone, to some extent, by altering the effluent flow, concentration or outfall design.

2.2. Norton and Snelder (2003)

Norton and Snelder (2003) suggest that while the reasonable mixing zone requires a subjective judgement to define, the size of the non-compliance zone can be calculated for a specific situation based on:

- Effluent flow rate and concentration
- Design of the outfall, influencing dispersion
- Depth, velocity and rate of turbulent mixing of the receiving water

- Ambient concentrations in the receiving water
- Receiving water concentration limit or numeric 'standard' for contaminants.

Since these factors can vary over time, the size of the non-compliance zone is not fixed, but also varies over time. Norton and Snelder (2003) suggest that this point is commonly misunderstood, as well as the fact that the size of the non-compliance zone is potentially different for each contaminant due to differing concentrations and allowable standards for each contaminant. They go on to suggest that a specified maximum allowable zone of non-compliance would provide a good basis of classifying consent applications as permitted, controlled, discretionary, *etc.* based on the contaminant with the largest calculated zone of non-compliance.

As an alternative for rivers they suggest maximum allowable dilution ratio (MADR), or percentage of the flow that could be allowed to dilute a particular contaminant to meet a particular standard. This is based on an assumption that, in practice, the length of the non-compliance zone in a river will be closely related to the width of the zone and hence the percentage of flow used for mixing. They suggest that the maximum allowable dilution ratio could be varied according to the nature of the contaminant, *e.g.* "For a toxic contaminant (*e.g.* ammonia) the MADR could be only 10% of the river flow at the 7Q10 to ensure that the noncompliance zone would only occupy a small proportion (approximately 10%) of the channel width."

Key factors considered by Norton and Snelder (2003) when defining the maximum allowable zone of non-compliance and whether a non-compliance zone would compromise the management objectives of a water body included:

- The size (length, width and area) of the non-compliance zone relative to the size (length, width and area) of the receiving water body.
- The type of contaminant, and therefore the type of effect that occurs within the non-compliance zone (*e.g.* acute *vs* chronic effects).
- Whether the non-compliance zone could cause effects beyond the area of non-compliance with the standards (*e.g.* restricting the passage of fish to upstream waters).
- Any special localised use or value of the receiving water that the non-compliance zone intrudes into.
- The cumulative impact of more than one non-compliance zone on water bodies.

2.3. ANZECC (2000)

These points align with the ANZECC (2000) guidelines, which suggest that non-compliance zones are generally used in the management of discharges of soluble, non-bioaccumulatory toxicants whose impacts on local biota are primarily related to their concentration. They recommend that non-compliance zones should not be allowed for chemicals which bioaccumulate, unless it can be demonstrated that the discharge of these substances into the environment will not result in long-term adverse effects to biota. Also they should not be used to manage the bio-stimulant impacts of nutrients, since the stimulation of algae (*e.g.* phytoplankton) may occur at considerable distances away from the nutrient source, nor particulate substances.

The ANZECC (2000) guidelines also recommend that the mixing zone must be as small as practical and should not occupy a significant proportion of the receiving waters. The overall integrity of the ecosystem should not be compromised; for example, the entire width of a stream should not be obstructed by the zone, in order to allow migrating species to avoid the contaminated zone. In locations of high environmental significance, severe restrictions may be required for mixing zones, if they are allowed at all.

They go on to state that mixing zones should not generally be allowed for in waters which have values or characteristics which are not compatible with the existence of a plume of water which does not meet ambient management goals. Examples include waters which either:

- receive significant and regular use for primary contact recreation
- are recognised as of significant value as spawning or nursery areas
- are close to areas used for aquaculture
- are close to potable water supply intakes
- are of outstanding ecological or scientific importance
- have high conservation ecosystem values
- where the mixing zone plume is likely to hug the shoreline.

Even within the mixing zone the ANZECC (2000) guidelines suggest imposing limits to ensure that the discharge does not cause either:

- objectionable odours which would adversely affect the use of the surrounding environment
- objectionable discoloration at the surface of the mixing zone which could adversely affect the use of the surrounding environment
- visible floating foam, oils, grease, scum, litter or other objectionable matter
- acute toxicity to fish or other aquatic vertebrates
- significant irreversible harm within the mixing zone, including objectionable bottom deposits

- at levels which, when the size of the mixing zone is considered, may constitute a barrier to the migration of aquatic organisms
- the growth of undesirable aquatic life or dominance of nuisance species (algal blooms, for example).

2.4. Mixing zone recommendations

Some of the guidelines discussed above appear overly restrictive. However, they do highlight factors that should be considered with respect to discharges. The key point to consider is whether the non-compliance zone associated with a discharge impinges excessively on attaining the management objective for the WRU. We recommend a value-based consideration of the area of reasonable mixing. The current definition is likely to be suitable in most instances where base values are assigned.

3. WATER QUALITY GUIDELINES TO SUPPORT VALUES

3.1. Aquatic ecosystems

A range of water quality parameters can be applied to assess the life-supporting capacity of waterways. Fundamentally, aquatic organisms require suitable water quality in the form of water temperature, pH, dissolved oxygen, substrate, and an absence of toxicants. Deviation beyond a suitable range in these parameters can have detrimental effects on the ability of organisms to survive. Organisms also require food. Food availability and ability to feed can be assessed by nutrient concentrations, periphyton, and water clarity. Finally, the health of aquatic organisms can be assessed by direct measurements of individuals, populations and communities of periphyton, invertebrates and fish.

Several of the parameters currently measured by MDC as part of the state of the environment (SOE) monitoring network are suitable for assessing the life-supporting capacity of waterways (Appendix 2). These include: nitrate, dissolved reactive phosphorus (DRP), ammonia, suspended solids, DO, Macroinvertebrate Community Index (MCI) and / or Semi-quantitative Macroinvertebrate Community Index (SQMCI). Temperature and pH are also key parameters.

3.1.1. Temperature

Recommended temperature guideline to protect aquatic ecosystem value	**Parameter**	**Standard**	**Application**
	Temperature daily maximum	≤ 21°C	At all times
	Temperature change	± 3°C	At all times

Water temperature affects all aspects of freshwater ecosystems, from its influence on the solubility of oxygen through to regulating metabolic rates (and therefore the growth and activity) of most aquatic organisms. Consequently, it is critical to correctly manage this aspect of freshwater systems. Management of water temperatures for the protection of aquatic species should consider more than just the critical thermal limits and should be based on the thermal requirements of all life stages of the species in question.

Water temperature varies naturally on daily and seasonal cycles, largely driven by solar inputs. However, it can be influenced by discharges of water that is either warmer (*e.g.* industrial cooling water) or cooler (*e.g.* bottom release from dams) than ambient conditions.

Olsen *et al.* (2011) recently reviewed the thermal requirements of native biota and this review has subsequently helped inform thermal criteria for the NOF (Davies-Colley *et al.* 2013). Avoiding excessive elevation of temperature is the key management concern, because lethal temperatures for many species are only slightly above their optimal temperatures for growth and are close to the temperature range commonly experienced in streams during summer. While temperature reductions below optimal conditions tend to produce a gradual decline in growth and activity rates, temperatures above the growth optimum become increasingly stressful comparatively rapidly, because of effects on cellular function, with enzymes becoming denatured (Davies-Colley *et al.* 2013).

Theoretically, the optimum temperature for growth (T_{opt}) of keystone species provides a better criterion for temperature management than lethal temperatures, as suggested by Davies-Colley *et al*. (2013). This is because for long term (chronic) management the aim ought to be to avoid temperatures going into the 'stress zone' for organisms, let alone approaching acutely lethal temperatures. Unfortunately, because defining growth curves requires substantial effort for individual species (Olsen *et al.* 2011), less information is available on growth curves, from which to define T_{opt}, than for lethal temperatures. In fact, no such growth curve data has been developed for any native New Zealand aquatic organisms, although such data are available for several species of introduced salmonids, which support valued fisheries. Consequently, temperature guideline values are generally based on incipient lethal temperatures and incorporate a safety margin. Figure 1 shows thermal preferences and incipient lethal temperatures for some native species (from Olsen *et al.* 2011).

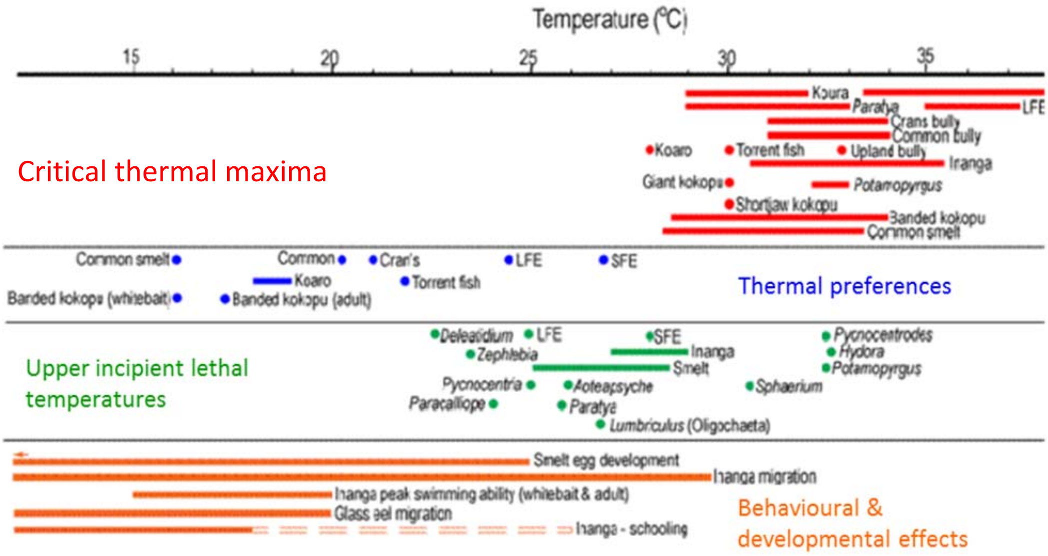

Figure 1. Summary of thermal tolerance of native fish and macroinvertebrates as expressed by critical thermal maxima (CTM; red), thermal preferences (blue), upper incipient lethal temperature (UILT; green) and behavioural and developmental effects (orange). Where CTM or UILT have been determined for multiple acclimation temperatures, the range is shown as a bar. Behavioural and developmental effects are shown as bars representing the range of temperatures when normal behaviour / development is apparent. Inanga schooling is dependent on acclimation temperature (from Olsen *et al.* 2011).

The temperature limits to protect aquatic ecosystem values from selected regional and national policy documents are tabulated below (Table 2). A key consideration in the limits suggested by Ausseil (2013a) and by Davies-Colley *et al*. (2013) was the "100 rivers study" finding that stoneflies (Plecoptera) were absent from rivers with annual maximum temperatures[2] over 19°C, and mayflies (Ephemeroptera) were absent from rivers with annual maximum temperatures over 21.5°C (Quinn & Hickey 1990). On this basis a maximum daily temperature of 21°C seems a reasonable default guideline to protect aquatic ecosystems. This would keep temperature close to the thermal preferences of many native fish and invertebrates and below incipient lethal limits for most (Olsen *et al*. 2011), while periphyton appear to be less sensitive to elevated water temperature. MDC SOE monitoring data show that exceedance of this guideline would currently be relatively rare (see Figure 14 in Tiernan 2011).

In the existing WARMP there is no temperature standard specified for water managed for aquatic ecosystems purposes, and in the MSRMP there is no aquatic ecosystems class specified. However, since the water managed for fishery purposes is applied as the underlying default class in both plans, the 20°C standard for that value would apply by default. The merits of this temperature threshold will be discussed below in relation to water managed for fishery values. However, in terms of protecting aquatic ecosystem values alone it could be seen as slightly over conservative.

A maximum temperature change of 3°C is probably reasonable, based on the precedent set in the RMA guidelines. This permitted temperature change is intended to be constrained by the maximum temperature guideline mentioned above (*i.e.* a discharge may increase water temperature by up to 3°C but should not be allowed to increase the daily maximum temperature to > 21°C). More stringent guidelines can be invoked for WMU with higher in-stream values, *e.g.* those with natural state value (see below).

Table 2. Examples of temperature guidelines to protect aquatic ecosystem values from selected regional and national policy documents.

Source	Parameter	Standard	Comment
Horizons One Plan (2013)	Temperature (max daily)	19°C–24°C	Applies at all times. Water management zone-specific target.
Canterbury Natural Resources Regional Plan (2010); Canterbury Land & Water Regional Plan (2014)	Temperature (max daily)	20°C	Objective
	Temperature (change)	2°C	Standard, applicable to consented activities

[2] Quinn and Hickey (1990) define annual maximum temperature or 'MAXTEMP' as mean annual daytime temperatures + half mean winter-summer range (°C).

Source	Parameter	Standard	Comment
Waikato Regional Plan (2007)	Temperature (change)	3°C	General 'Surface Water Class'. The Waikato Regional Plan also defines a number of narrative standards relative to changes in pH, water clarity, DO, deposited sediment and biological growths "if they have any significant adverse effects on aquatic ecosystems".
Ausseil 2013a recommendations to Greater Wellington Regional Council	Temperature (daily max)	19°C to 23°C	Applies at all times. FWENZ class dependent.
	Temperature change	±2°C to ±3°C	Applies at all times. FWENZ class dependent.
Davies-Colley *et al.* 2013 NOF proposed thresholds (Rivers in Eastern Dry Climates)	Temperature (Cox-Rutherford Index[3])	≤ 19°C Band A ≤ 21°C Band B ≤ 25°C Band C >25°C Band D	Summer period measurement of the Cox-Rutherford Index (CRI), averaged over the five (5) hottest days (from inspection of a continuous temperature record). Band A: No thermal stress Band B: Occasional thermal stress, particularly for sensitive species Band C: Some thermal stress on occasions, with risk of sensitive species being lost Band D: Significant stress, loss of ecological integrity.

Note: FWENZ = Freshwater Environments of New Zealand

3.1.2. Dissolved oxygen

Recommended dissolved oxygen guideline to protect aquatic ecosystem value	Parameter	Standard	Application
	DO mg/L (daily min)	≥ 6 mg/L	At all times
	DO mg/L (7-day mean)	≥ 7.5 mg/L	At all times

Dissolved oxygen (DO) is essential for almost all aquatic life. Reduced DO is of greater concern than elevated levels. Reduced levels can impair the growth and/or reproduction of aquatic organisms and very low or zero DO (anoxia) will kill organisms. However, there is comparatively little information in the published scientific literature regarding DO requirements or tolerance of New Zealand native fish and macroinvertebrates (Ausseil 2013a).

Dissolved oxygen in rivers generally varies on a daily cycle, increasing during the day due to photosynthesis and declining at night, since respiration continues but photosynthesis ceases. Dissolved oxygen is also mixed into the water column directly from the air, and this process of re-aeration increases in rate in steeper, shallower and more turbulent sections of streams.

[3] The average of the mean daily and daily maximum temperatures, and is a valuable metric because it permits direct application of constant temperature criteria from laboratory experiments. Animals respond to diurnally fluctuating temperatures in much the same way as if exposed to a constant temperature equal to the CRI.

The main way that discharges are likely to influence DO in streams is through introducing additional organic material (*e.g.* from wastewater treatment works, agricultural runoff *etc*.). Bacterial and fungal communities develop to break down this material and their respiration uses up the available oxygen (*i.e.* increases biological oxygen demand, BOD) in the water, potentially to the extent that waters can become severely depleted of oxygen or anoxic. Release of bottom waters from stratified dams can also introduce deoxygenated water. Increased nutrient loading can promote growth of aquatic plants and algae resulting in larger daily DO fluctuations.

The potential impacts of reduced DO are influenced by temperature. Water temperature controls the solubility of oxygen, with cooler water able to hold more oxygen, and also controls the metabolic demands of most aquatic organisms. So with elevated water temperatures biological oxygen demands tend to be higher, but DO concentrations tend to be lower. Davies-Colley *et al*. (2013) argue that this makes defining guideline levels based on concentration seem more appropriate than stipulating a percentage saturation, "*By defining a standard as a percentage of maximum saturation, the threshold dissolved oxygen concentration decreases as water temperature increases (i.e. 80% saturation at 10°C is 9.0 mg L^{-1} and at 25°C is 6.6 mg L^{-1}). This seems counter-intuitive for ecosystem protection purposes given that the oxygen demand of aquatic fauna generally increases with increasing temperature*".

Existing studies have generally concluded that, while some New Zealand native fish species are relatively tolerant of low levels of DO compared with trout, the most sensitive native fish species appear to be quite similar to trout (Davies-Colley *et al.* 2013). Consequently, United States Environmental Protection Agency (USEPA) water quality criteria for salmonid waters should adequately protect New Zealand aquatic fauna (Ausseil 2013a).

Table 3 shows the DO guidelines to protect aquatic ecosystem values from selected other sources. The DO concentration band limits recommended by Davies-Colley *et al*. (2013) can be compared with the saturation limits applied elsewhere for a given temperature. Assuming the 21°C temperature guideline suggested above is adopted the 7.5 mg/L A band limit would be equivalent to approximately 84% saturation at this temperature (6 mg/L equivalent to approximately 67% saturation), while the 5 mg/L B band lower limit would be equivalent to approximately 56% saturation. At lower temperatures these concentration limits would translate into lower percentage saturation, but oxygen demands of aquatic organisms also reduce with declining temperature (Franklin 2014). However, it is worth illustrating a lower temperature range if accepting a daily minimum parameter. For example, at a daily minimum temperature of 12°C adopting the 7.5 mg/L A band limit would be equivalent to approximately 70% saturation at this temperature (6 mg/L equivalent to approximately 56% saturation), while the 5 mg/L B band lower limit would be equivalent to approximately 46% saturation.

The existing WARMP does not stipulate a DO standard for waters managed for aquatic ecosystems, but for those managed for fishery values it stipulates that DO shall exceed 80% saturation, as does the MSRMP. The 80% saturation level suggested in the RMA has been widely adopted by other councils, but it is not clear what level of protection this guideline was intended to impart (Franklin 2014). By contrast, the intended level of protection associated with the DO concentration guidelines recommended by Davies-Colley *et al*. (2013) are explicitly stated. These levels are also closely aligned with recommendations made by Franklin (2014) specifically for New Zealand freshwater fish communities, discussed further in Section 3.2 with regard to maintaining fishery values.

Table 3. Examples of dissolved oxygen (DO) guidelines to protect aquatic ecosystem values from selected regional and national policy documents.

Source	**Parameter**	**Standard**	**Comment**
Horizons One Plan (2013)	DO% (min. daily)	60% to 80%	Applies at all times. Water management zone-specific target.
Canterbury Natural Resources Regional Plan (2010)	DO% (min daily)	70% to 90%	Numerical objective depends on water body class.
Ausseil 2013a recommendations to Greater Wellington Regional Council	DO% (daily min)	60% to 80%	Applies at all times. FWENZ class dependent.
Davies-Colley *et al*. 2013 NOF proposed thresholds (Rivers)	DO mg/L (daily min)	≥ 7.5 mg/L Band A ≥ 5 mg/L Band B ≥ 4 mg/L Band C < 4 mg/L Band D	Band A: To maintain near pristine ecosystems Band B: To maintain healthy ecosystems with slight stress, potential reduction of abundance of sensitive species Band C: Moderately stressed ecosystems, with risk of sensitive species being lost Band D: Persistent stress, loss of ecological integrity.
	DO mg/L (7-day mean)	≥ 9 mg/L Band A ≥ 8 mg/L Band B ≥ 6.5 mg/L Band C < 6.5 mg/L Band D	
	DO mg/L (7-day mean min)	≥ 8 mg/L Band A ≥ 7 mg/L Band B ≥ 5 mg/L Band C < 5 mg/L Band D	

3.1.3. pH

Recommended pH guideline to protect aquatic ecosystem value	**Parameter**	**Standard**	**Application**
	pH range	6.5 to 8.5	At all times
	pH change	± 0.5	

The acidity or alkalinity of water is measured by the concentration of hydrogen ions, which is referred to as pH (0–14). The pH of river water is often related to the underlying geology. Stream water tends to be circum-neutral (with a pH of 6.5–8.5), but can this can vary widely, for example streams draining peat can be quite strongly acidic (pH 4). During periods of base flow in streams with high plant or algal biomass pH often also displays a daily cycle, along with the DO driven by cycles in photosynthesis, due in part to flux in CO_2 availability. Daily variations in pH values of 1-2 are commonly observed during summer in streams with high plant or algal biomass (Davies-Colley 2013).

While fish and invertebrates in New Zealand appear to be able to tolerate a relatively broad range of pH, native fish species tested have exhibited a preference for a pH range of ~6–9 (Davies-Colley *et al.* 2013), and extreme values can be lethal. pH also mediates the effects of other variables, such as ammonia toxicity (Davies-Colley *et al.* 2013). Consequently, it is an important parameter to manage within a reasonable range.

There are no numeric pH standards for waters managed for aquatic values in either the WARMP or MSRMP. However, the WARMP does contain a narrative stipulation that there shall not be any adverse effect from pH change. Review of current pH guidelines from selected regional and policy documents in light of the values observed at MDC monitoring sites suggests a range of 6.5 to 8.5 would protect aquatic ecosystem health across the range of natural variability in pH observed in the region (Table 4). A change of ± 0.5 pH would be indicative of an adverse impact (Ausseil 2013a).

Table 4. Examples of pH guidelines to protect aquatic ecosystem values from selected regional and national policy documents.

Source	Parameter	Standard	Comment
Horizons OnePlan (2013)	pH	[7–8.2] to [7–8.5]	Applies at all times. Water management zone-specific target.
Canterbury Natural Resources Regional Plan (2010); Canterbury Land & Water Regional Plan (2014)	pH	6.5–8.5	Standard, applicable to consented activities
Ausseil 2013a recommendations to Greater Wellington Regional Council	pH range	5.8 to 8.9	Applies at all times. Upper and lower bounds are FWENZ class dependent.
	pH change	±0.5	Applies at all times
Davies-Colley *et al*. 2013 NOF proposed thresholds (Rivers)	pH range (summer 95th centile)	6.5 < pH < 8.0 Band A 6.5 < pH < 8.5 Band B 6.0 < pH < 9.0 Band C pH < 6 or pH >9.0 B and D	Band A: No stress on aquatic organisms Band B: Occasional minor stress on sensitive organism. Band C: Stress due to pH outside preference range for sensitive organisms for several hours each day. Band D: Significant, persistent stress on a range of organisms. Likely local extinctions and destabilisation of river ecosystems.

3.1.4. Biological oxygen demand

Recommended BOD guideline to protect aquatic ecosystem value	Parameter	Standard	Application
	$ScBOD_5$	< 2 mg/L	River flow < median

As discussed above, discharges high in organic matter can promote the growth of heterotrophic bacterial and fungal communities (commonly known as 'sewage fungus'), which can result in sags in DO through increased biological oxygen demand (BOD), as well as having potential adverse visual / aesthetic effects through formation of mats or plumose growths.

On the basis that sewage fungus growth is particularly promoted by the low molecular weight fraction of the available organic matter, and that the growth of sewage fungus will reflect ambient concentration during accrual periods with stable flow (but biomass is likely to be scoured or reset to low levels following a significant freshes), Ausseil (2013) recommended Greater Wellington Regional Council (GWRC) adopt a daily average maximum concentration of soluble carbonaceous BOD_5 [4]($ScBOD_5$) of 2 mg/L, applicable at flows below three times the median flow. This aligns with the existing WARMP stipulation that, "The daily average carbonaceous BOD_5 due to dissolved organic compounds (*i.e.* those passing a GF/C filter) shall not exceed 2 g/m^3" as part of the standards to avoid undesirable growths in waters managed for aquatic ecosystems values. As such we recommend the existing standard is retained.

Table 5. Examples of biological oxygen demand (BOD) guidelines to protect aquatic ecosystem values from selected regional policy documents.

Source	Parameter	Standard	Comment
Horizons One Plan (2013)	ScBOD5 (monthly average)	1.5 to 2 mg/L	Applies at flows < 20th percentile. Water management zone-specific target
Ausseil 2013a recommendations to Greater Wellington Regional Council	$ScBOD_5$ (max daily average)	2 mg/L	Year round. River flows < median

3.1.5. Particulate organic matter

Recommended particulate organic matter guideline to protect aquatic ecosystem value	Parameter	Standard	Application
	POM	4 mg/L	River flow < median

[4] *i.e.* BOD expressed in milligrams of oxygen consumed per litre of sample during five days of incubation at 20°C.

Particulate organic matter (POM) is a measure of the organic component of total suspended solids (TSS). Deposition of POM on the bed of streams downstream of point-source discharges has been shown to have adverse effects on macroinvertebrate communities (Quinn & Hickey 1993). A consistent reduction in the abundance of sensitive macroinvertebrate species was found when the average POM concentration increased by 6 mg/L or more downstream of point-source discharges. However, no significant adverse effects were observed at concentration increases below 4 mg/L. Background POM concentrations were in the order of 1 mg/L (McBride & Quinn 1993).

The existing WARMP stipulates that the daily average concentration of particulate organic matter shall not exceed 4 mg/L. On the basis of the studies described above a POM concentration limit of 5 mg/L ought to be sufficiently stringent to avoid significant adverse effects (*i.e.* since no significant adverse effects were observed with concentration increase of < 4 mg/L with background POM concentrations in the order of 1 mg/L). However, the existing 4 mg/L provides a conservative margin of safety.

By comparison, Ausseil (2013) recommended a maximum POM concentration limit of 5 mg/L, after reasonable mixing below point-source discharges to all streams and rivers for GWRC. He suggested that since this guideline was intended as an indicator of the potential for POM to settle on the stream / river bed and cause detrimental effects on benthic communities, the limit should apply only when the stream / river is under base flow conditions (*i.e.* below median flow). He also suggested it should be expressed as an average concentration over the base flow conditions (to reflect the timeframes required for deposited POM to accumulate and cause effects).

3.1.6. Water clarity and colour

Recommended clarity guideline to protect aquatic ecosystem value	**Parameter**	**Standard**	**Application**
	Visual clarity	≥ 0.5 m	River flow < median
	Visual clarity change	< 33%	
	Water hue change (Munsell units)	< 10	
	Reflectance change	< 50%	

The ability of water to transmit light is relevant to the photosynthesis and growth of aquatic plants and algae, as well as to the visual range of animals, such as visually foraging fish. Water clarity is influenced by the concentration of light scattering particles in the water column, such as sediment and phytoplankton. Consequently, it naturally varies with catchment geology and soils and with flow due to generally higher particulate concentrations during high flow events. It is typically measured in rivers as the horizontal distance over which a standard black disk remains visible (black disk measurement, m). This metric is also correlated with turbidity (measured in nephelometric turbidity units [NTU]), as well as with total suspended solids (TSS). The relationship between black disk clarity and NTU follows a power law, with very small increases in turbidity in relatively clear water having a marked influence on water clarity. At higher turbidity (> 20 NTU), there is less change in water clarity with increasing turbidity.

The ANZECC (2000) guidelines define default trigger values for visual clarity in upland (0.8 m) and lowland (0.6 m) rivers. These trigger values were determined using a very limited dataset, particularly for the lowland trigger value, and data from high flow events may not have been excluded during their development (Ausseil 2013) so they may be relatively permissive.

The existing WARMP does not stipulate water clarity standards for water managed for aquatic ecosystem values. However, both the WARMP and MSRMP stipulate that the "The natural clarity shall not be conspicuously changed due to sediment or sediment laden discharge originating from the site of a land disturbance operation" for water managed for fishery purposes (*i.e.* the underlying / default class). They also stipulate no more than a 33% reduction in visual clarity and no more than a 15% increase in turbidity (measured in NTU).

Ausseil (2013) recommended a minimum water clarity of 0.5 m, to approximate a maximum turbidity of 15 NTU, on the basis of a literature review of the effects of low water clarity, high turbidity or high TSS on native fish and macroinvertebrates (Ausseil & Clark 2007). The conclusions of that review were that turbidity above 17 to 25 NTU could cause behavioural changes in some native fish species, and that in highly turbid rivers the occurrence of several native fish species was significantly reduced, with banded kōkopu (*Galaxias maculatus*), common smelt (*Retropinna retropinna*) and redfin bully (*Gobiomorphus huttoni*) among the most sensitive species.

Davies-Colley (2009) recommends against the use of NTU for guidelines or standards for two key reasons. First, NTU is not a proper 'scientific' measurement amenable to absolute physical calibration, and second, measurement is appreciably instrument-specific. Davies-Colley suggests that turbidity measurement can be useful for measurements at night and for continuous monitoring, but should always be locally calibrated to the issue of real concern, which is usually visual clarity or suspended sediment concentration.

The RMA Sections 70 and 107 standards set that discharges of contaminants into water shall not give rise to "…any conspicuous change in the colour or visual clarity in the receiving waters". The Ministry for the Environment Water Quality Guidelines No. 2 (MfE 1994) provides guidance as to what degree of water clarity change constitutes a 'conspicuous change': 20% change in waters where visual clarity is an important characteristic of the water body, and 33% to 50% in other waters. Although these visual clarity change limits were originally defined for the protection of aesthetic values, in direct translation of the RMA S70/107 standards, such guidelines should also provide adequate protection for the habitat of sighted animals. Protection of the visual clarity of waters will also generally ensure that colour and light penetration (relevant to ecosystem values) are not degraded (MfE 1994). However, Davies-Colley (2009) recommends the ANZECC (2000) guidelines to maintain the spectral quality of the light field for aquatic life:

- Hue should be changed by no more than 10 Munsell units (protecting spectral quality)
- Reflectance should not be changed by more than 50% (protecting against large changes in brightness).

On this basis we recommend 0.5 m minimum visual clarity at flows below the median flow and a maximum percentage change in water clarity of 33% as sufficient guidelines to protect aquatic ecosystem health in the region. However, refer to following sections for comparison of visual clarity guidelines for the protection of fisheries (Section 3.2), contact recreation (Section 3.5.2) and aesthetic values (Section 0).

Table 6. Examples of water clarity guidelines to protect aquatic ecosystem values from selected regional policy documents.

Source	**Parameter**	**Standard**	**Comment**
Horizons One Plan (2013)	Water clarity	1.6 to 3.4m	Applies at flows < median. Water management zone-specific target
Canterbury Natural Resources Regional Plan (2010); Canterbury Land & Water Regional Plan (2014)	Water clarity change	20 to 35%	Class-specific standard, applicable to consented activities
Ausseil (2013) recommendations to Greater Wellington Regional Council	Visual clarity (min, default limit)	0.5m	Year round. River flows < 3 × median
	Visual clarity (min)	0.5 to 2.2m	Year round. River flows < median. FWENZ class dependent.
	Visual clarity change (max)	20% to 33%	Applies at all times. FWENZ class dependent.

3.1.7. Deposited fine sediment

Recommended deposited fine sediment (DFS) guideline to protect aquatic ecosystem value	**Parameter**	**Standard**	**Application**
	DFS cover DFS change	< 20% < 10%	At all times

Deposited fine sediment is defined as inorganic particles deposited on the streambed that are less than 2 mm in size. Sedimentation, or the deposition of fine sediment, occurs naturally, but human activities can accelerate the delivery of sediment to streams and increase the quantity of fine particles. Fine sediment alters the habitat of streams by clogging interstitial spaces used as refugia by benthic invertebrates and fish, and fine sediment can also alter the availability of food resources. As such, sediment can affect the diversity and composition of biotic communities.

Recent protocols and guidelines for assessing the effects of fine sediment deposition on stream biodiversity values recommend a maximum cover of 20% fine sediment or less than 10% increase in fine sediment cover in comparison to reference condition (Table 7). These guidelines were based on multiple lines of evidence where sediment cover was correlated with catchment land-use and indices of stream health, and the output of predicted sediment cover models were analysed. Clapcott *et al* (2011) note that there are likely to be lower limits at which in-stream values will be negatively affected by sediment but the error associated with methodology and the noise in correlative relationships with stream health metrics makes it difficult to determine lower limits, hence a comparison to reference will provide the most conservative guideline values.

There are few examples of the application of deposited fine sediment limits in New Zealand, possibly due to the lack of standardised protocols and guidelines prior to 2011 (Table 7).

Table 7. Examples of deposited fine sediment guidelines to protect aquatic ecosystem values from selected documents.

Source	**Parameter**	**Standard**	**Comment**
Sediment Assessment Methods (Clapcott *et al* 2011)	Fine sediment cover	< 20% OR within 10% cover of reference	Year round. Using SAM2 method
Horizons One Plan (2013)	DFS	< 20%	Applies to SOE sites
Canterbury Natural Resources Regional Plan (2010)	DFS	< 10% to < 40%	Depending on management class.

3.1.8. Nitrate

Recommended nitrate (toxicity) guideline to protect aquatic ecosystem value	**Parameter**	**Standard**	**Application**
	NO_3N	< 2.4 mg/L	At all times

Nitrate is an important bioavailable plant nutrient, but can also be toxic at high concentrations. Nitrate occurs naturally in the environment and is produced and consumed through the processes of the nitrogen cycle, and it is also produced by humans for agricultural use as a fertilizer. The major anthropogenic sources of nitrate

to surface waters are agricultural runoff, municipal and industrial wastewaters, urban runoff and groundwater inputs.
Guidelines to control potential adverse effects on aquatic ecosystems arising from nutrient enrichment with dissolved inorganic nitrogen, which is the sum of nitrate, nitrite and ammonia, are discussed together in Section 3.1.10. Guidelines to avoid toxic effects of nitrate are discussed below.

Hickey (2013) recently reviewed nitrate toxicity data and updated guidelines for nitrate monitoring/management. The dataset included recent toxicity information for two widespread New Zealand native species, inanga and *Deleatidium*. The guideline values recommended by Hickey (2013) were derived using procedures for deriving trigger values from ANZECC (2000). They comprise a two-number guideline based on:

1. Guideline derivation using chronic no observed effect concentration (NOEC) values to provide ecosystem protection for average long-term exposure — termed ‘grading’.
2. Threshold effect concentration (TEC) values for management of seasonal maximum concentrations — termed ‘surveillance’.

Hickey (2013) recommends that compliance with the NOEC value should be based on the annual median concentration, while compliance with the TEC value should be based on the annual 95th percentile of monitoring data.

The default guideline values are intended to provide 95% protection for chronic exposure in slightly-to-moderately disturbed systems. The values are 2.4 mg NO_3-N/L and 3.5 mg NO_3-N/L for the NOEC and TEC guidelines, respectively. More stringent values are given for 99% protection in pristine environments with high biodiversity and conservation values, with values of 1.0 mg NO_3-N/L and 1.5 mg NO_3-N/L for the NOEC and TEC guidelines, respectively. Less stringent values are also given for more highly disturbed systems.

Nitrate toxicity appears to be influenced by water hardness. Hickey (2013) reported that the overall trend for all species in both short-term and long-term exposures was for decreasing toxicity with increasing hardness. However, because of uncertainty in hardness-dependent short-term or long-term equations no hardness-modifying relationships were incorporated into the recent Environment Canada nitrate guideline derivation.

3.1.9. Ammonia

Recommended ammonia (toxicity) guideline to protect aquatic ecosystem value	**Parameter**	**Standard**	**Application**
	Ammonia-N (pH = 8.0, temp = 20°C)	< 0.32 mg/L	At all times

Like nitrate, ammonia can act as both an important bioavailable plant nutrient, and as a toxicant at high concentrations. Ammonia occurs naturally in the environment as a component of the nitrogen cycle. It is excreted as a waste product by animals and consequently is a common pollutant in raw or treated domestic, agricultural and industrial wastewater.

Guidelines to control potential adverse effects on aquatic ecosystems arising from nutrient enrichment with dissolved inorganic nitrogen (DIN), which is the sum of nitrate, nitrite and ammonia, are discussed together in Section 3.1.10. Guidelines to avoid toxic effects of ammonia are discussed below.

When in solution in the water, ammonia occurs as two main chemical forms: the ammonium cation (NH_4^+) and unionised ammonia (NH_3). The relative proportion of these two forms is determined by a chemical equilibrium, which is controlled by pH and temperature. Higher pH and temperature result in a higher the proportion of unionised ammonia. Unionised ammonia is much more toxic to aquatic life than ionised ammonia, thus the toxicity of total ammonia (being the sum of unionised and ionised forms) increases with pH and / or temperature (Ausseil 2013a). Many point-source discharges of dairy effluent and wastewater from community waste-treatment plants have elevated ammoniacal-N concentrations that, when coupled with high pH values in late afternoon, may cause ammonia toxicity to stream life if not diluted sufficiently (Davies-Colley *et al*. 2013). Consequently, the pH and temperature dependency of ammonia toxicity require careful consideration when setting guidelines.

Bivalves appear to be particularly sensitive to ammonia toxicity. The most sensitive indigenous species tested to date, is the larvae (glochidia) of the native freshwater mussel, kākahi (*Echyridella menziesii*), with an EC_{50}[5] of 9.4 mg NH_4-N/L (pH 8.0) at 48 hours (Clearwater *et al*. 2013 in review, cited in Davies-Colley *et al*. 2013). Kākahi are listed as 'at risk, declining', and are likely to be found in some Marlborough water bodies.

The existing WARMP and MSRMP both include pH and temperature dependent standards for ammonia for water managed for fishery values (the underlying / default class), though not specifically for water managed for aquatic ecosystems. There are examples of ammonia toxicity guidelines to protect aquatic ecosystem values in other policy documents (Table 8).

The recommended limit of 0.320 mg TNH_3-N/L at pH 8.0 and temperature 20ºC is the same as the 99% protection level trigger value of the ANZECC (2000) guidelines. ANZECC (2000) guidelines also provide tables to determine ammonia concentration at varying temperature and pH conditions, *e.g.* Table 9.

[5] The term half maximal effective concentration (EC_{50}) refers to the concentration of a drug, antibody or toxicant which induces a response halfway between the baseline and maximum

Table 8. Examples of ammonia guidelines to protect aquatic ecosystem values from toxic effects from selected regional and national policy documents.

Source	Parameter	Standard	Comment
Horizons One Plan (2013)	Total ammonia-N	0.320 to 0.400 mg/L	Average concentration, applies at all times
Waikato Regional Plan (2007)	Total ammonia-N	0.88 mg/L	In indigenous fisheries waters
Ausseil 2013a recommendations to Greater Wellington Regional Council	Total ammonia-N (chronic) (max average) At pH = 8.0, Temp = 20°C	0.32 to 0.9 mg/L	Applies at all times. FWENZ class dependent.
	Total ammonia-N (Acute) (max) At pH = 8.0, Temp = 20°C	4.3 to 7.5 mg/L	Applies at all times. FWENZ class dependent.
Proposed amendments to the NPS-FM 2011	Ammoniacal-N (mean) At pH = 8, Temp = 20°C.	Band A: < 0.03 mg/L Band B: 0.03–0.24 mg/L Band C: 0.24–1.30 mg/L Band D: >1.30 mg/L	Band A: 99% species protection level: No observed effect on any species tested Band B: 95% species protection level: Starts impacting occasionally on the 5% most sensitive species Band C: 80% species protection level: Starts impacting regularly on the 20% most sensitive species (reduced survival of most sensitive species) Band D: Starts approaching acute impact level (*i.e.* risk of death) for sensitive species

Table 9. Recommended chronic total ammonia-N concentration (mg/L) limit at different water pH and temperatures.

	Temperature			
pH	**15°C**	**20°C**	**25°C**	**30°C**
6.5	14.1	9.8	6.8	4.8
7.0	4.5	3.1	2.2	1.5
7.5	1.43	0.99	0.7	0.5
8.0	0.459	0.320	0.227	0.164
8.5	0.154	0.110	0.080	0.060
9.0	0.057	0.043	0.034	0.027

3.1.10. Dissolved nutrients (nitrogen and phosphorus)

Recommended dissolved nutrient guideline to protect aquatic ecosystem value	**Parameter**	**Standard**	**Application**
	DRP	< 0.015 mg/L	< median flow
	DIN	< 0.444 mg/L	

Periphyton forms the basis of stream food webs (along with terrestrial inputs of detritus) and can be likened to the grass on a farm. However, during periods of stable flow periphyton can proliferate to nuisance levels. Excessive periphyton biomass can smother habitat, alter benthic invertebrate communities, produce adverse daily fluctuations in dissolved oxygen and pH, impede flows, and block water intakes, as well as causing changes to water colour, odour, and making the substrate slippery, with detrimental impacts on aesthetics and human uses (Snelder *et al.* 2011). Excessive growths of long filamentous algae, in particular, are generally considered to be detrimental to the invertebrate community and to river users.

Factors controlling periphyton cover and biomass on river beds include sunlight, nutrient concentration, temperature, grazing by invertebrates and flow history (*i.e.* the history of bed disturbance). The primary control on periphyton growth that is likely to be influenced by effluent discharges is the concentration of bioavailable nutrients. In situations where other factors are favourable, particularly during periods of low/stable river flows, elevated nutrient concentrations increase the likelihood of undesirable periphyton proliferation. Setting nutrient concentration guidelines or standards is often used as a way of maintaining periphyton growth at acceptable levels. For example, Ausseil (2013a) recommended dissolved nutrient limits to attempt to control periphyton growth to specified levels in the Greater Wellington Region. He pointed out that using dissolved nutrient limits to attempt to control macrophyte growth in systems where they can become problematic is far more uncertain, due to macrophytes ability to take up nutrients from the sediment through their root systems.

Nitrogen and phosphorus are key nutrients required for periphyton growth. The forms of nitrogen that plants can assimilate directly (*i.e.* bioavailable) include oxides of nitrogen (nitrate- and nitrite- nitrogen) and total ammonia nitrogen, the sum of which is called dissolved inorganic nitrogen (DIN). Dissolved reactive phosphorus (DRP) is generally considered as the measurement of bioavailable phosphorus. The DIN:DRP ratio can be a useful indicator of whether DIN or DRP is the likely limiting nutrient for periphyton growth. A N:P ratio of approximately 7.5 is the theoretical limit between N-limited (ratio < 7.5) and P-limited (ratio > 7.5) conditions.

In principle, controlling the availability of the nutrient in shortest supply can control periphyton growth to acceptable levels. Where there is strong evidence for a particular nutrient being limiting, it may appear logical to put a greater emphasis on the control of that specific nutrient. This approach has recently been suggested in some regions (*e.g.* Canterbury). However, there are risks and uncertainties associated with managing only one nutrient to control periphyton growth. The limiting nutrient may change temporally or spatially, and the risk to downstream environments also needs to be assessed. Also, where one nutrient is in abundant supply periphyton growth is likely to react strongly if the controls on the other nutrient (the limiting nutrient) fail. Recent research has suggested a change in the species composition of benthic algae may also occur in response to changes in N:P ratios. For example, an increase in the presence of unfavourable cyanobacteria has been associated with increasing N (Heath *et al.* 2013). These risks and uncertainties were the primary reason for the recommendation by Wilcock *et al*. (2007) to generally control both nitrogen and phosphorus for the control of periphyton growth in the Manawatu-Wanganui region.

Horizons One Plan contained DIN and DRP targets (Table 10) defined for each management sub-zone. These were originally based on expert advice from Dr. Barry Biggs, the author of the New Zealand periphyton guidelines (Biggs 2000), but were modified to account for the current state of water quality in each water management sub-zone. The general targets recommended by Dr. Biggs were:

- 0.005 mg/L DRP and 0.070 mg/L DIN for upland areas with generally low nutrient levels and high potential for benthic biodiversity, where the maximum recommended periphyton biomass was 50 mg/m^2 chlorophyll-*a*
- 0.010 mg/L DRP and 0.110 mg/L DIN for hill countries areas with moderate nutrient levels and potentially high trout fishery values, where the maximum recommended periphyton biomass was 120 mg/m^2 chlorophyll-*a*
- 0.015 mg/L DRP and 0.165 mg/L DIN for lowland areas, naturally P-enriched catchments and soft-sediment geology in the catchment, where the maximum recommended periphyton biomass was 200 mg/m^2 chlorophyll-*a.*

The nutrient guidelines recommended by Ausseil (2013a) for the Greater Wellington region to protect aquatic ecosystem values (Table 10) are also based on attempting to avoid periphyton biomass exceeding 50, 120, or 200 mg/m^2, respectively, depending on the river category. They also aimed to avoid > 30% filamentous algae cover, and > 60% algal mat cover.

These values of periphyton biomass and cover are largely taken from Biggs (2000). The guideline to protect benthic biodiversity in that document was 50 mg/m^2 chlorophyll *a* for both mat forming and filamentous algae (120 mg/m^2 chlorophyll-*a* for filamentous algae was recommended for both aesthetics / recreation and for trout habitat and angling, along with 200 m^2 chlorophyll-*a* for mat-forming algae to protect trout habitat and angling).

The existing WARMP stipulates that, “The median concentration of dissolved reactive phosphorus (DRP) shall be less than 15 mg/m^3 [*i.e.* 0.015 mg/L] at low flows, unless other physical and / or biological factors prevent undesirable biological growths developing at higher DRP concentrations”, for water managed for aquatic ecosystem values. It does not stipulate any limit for DIN.

Based on assessment of current selected regional documents in light of current values observed in Marlborough we recommend 0.015 mg/L DRP and 0.444 mg/L DIN to restrict the effect of point-source discharges on periphyton biomass and to protect aquatic ecosystem values. We note that this is less restrictive than values for catchment limit-setting recommended elsewhere.

Table 10. Examples of dissolved nutrient (DIN and DRP) guidelines to protect aquatic ecosystem values from selected regional policy documents.

Source	Parameter	Standard	Comment
Horizons One Plan (2013)	DRP	0.006 to 0.015 mg/L	Applies at flows < 20th percentile. Water management zone-specific target
	DIN	0.070 to 0.444 mg/L	Applies at flows < 20th percentile. Water management zone-specific target
Canterbury Land & Water Regional Plan (2014)	DRP	0.005 to 0.025 mg/L	Water quality class — specific standards applicable to point-source discharges.
	DIN	0.080 to 1.500 mg/L	
Ausseil 2013b recommendations to Greater Wellington Regional Council	DRP	0.006 to 0.014 mg/L	River flows < 3 × median. FWENZ class dependent.
	DIN	0.07 to 0.3 mg/L	

3.1.11. Other toxicants

Recommended other toxicant guideline to protect aquatic ecosystem value	**Parameter**	**Standard**	**Application**
	Toxicants (protection level)	95%	At all times

Rather than listing and defining concentration limits for the large range of other toxicants, including metals and organic micro-contaminants (such as pesticides, hydrocarbons, *etc*.), that may be released and potentially cause toxic effects in aquatic ecosystems, we recommend using the trigger values provided in Table 3.4.1 of the ANZECC (2000) guidelines as water quality targets. However, as recommended in the ANZECC (2000) guidelines a direct toxicity assessment (DTA) should also be required on the effluent from discharges to aid development of site-specific criteria.

The ANZECC (2000) water quality guidelines define different protection levels, depending on the type of receiving environment, with the aim of protecting a pre-determined percentage of species. A 95% level of species protection is generally used, but the approach enables quantitative alteration of protection levels. The 95% protection level applies to 'slightly to moderately disturbed' ecosystems, and is generally recommended as the default limit for waters to be managed for aquatic ecosystem health. We recommend this level of protection for application to water managed for aquatic ecosystem purposes.

The ANZECC (2000) guidelines recommend the use of a higher (99%) protection level as the default trigger values for ecosystems with high conservation values. This protection level is recommended as the default limit for 'significant' aquatic ecosystems, and we recommend this level for waters managed to maintain their ‘natural state’ values (see Section 3.4).

This approach is consistent with that adopted elsewhere (Table 11). However, less stringent levels of protection could conceivably be applied on a case-by-case basis, for example in highly modified urban streams. Varying the desired level of protection is allowed in the ANZECC (2000) guidelines.

Table 11. Examples of general toxicant guidelines to protect aquatic ecosystem values from selected regional policy documents.

Source	Parameter	Standard	Comment
Horizons One Plan (2013)	Toxicants	95% to 99%	2000 ANZECC guidelines protection level
Canterbury Natural Resources Regional Plan (2010); Canterbury Land & Water Regional Plan (2014)	Toxicants	90% to 99%	2000 ANZECC guidelines protection level. Class-specific standard applicable to consented activities
Ausseil 2013a recommendations to Greater Wellington Regional Council	Other toxicants (protection level)	95% to 99%	Applies at all times. Dependent on ‘healthy’ or ‘significant’ value.

3.2. Fishery purposes

Recommended water quality guidelines to protect fishery purposes value	Parameter	Standard	Application
	Temperature daily maximum	≤ 19 °C	At all times
	Periphyton cover (filamentous algae > 2 cm long)	< 30 %	< median flow
	MCI	> 100	< median flow
	Visual clarity	> 1.4 m	< median flow
	Visual clarity change	< 20%	< median flow

Both native and introduced freshwater fish species support fisheries in the Marlborough region. There tends to be more information available on the water quality requirements to protect the introduced salmonids than for native fish species. Where information is available for native fish species (*e.g.* for temperature and DO) this has typically informed the selection of guidelines for maintenance of aquatic ecosystems values. Existing information suggests that water quality criteria derived to protect salmonids are likely to be adequate to also protect native fishery values, since trout tend to be more sensitive to water quality changes than most native fish.

Water temperature, dissolved oxygen, water clarity/ turbidity and food were recommended as the four key parameters for the protection of adult trout in the Horizons region (Hay *et al.* 2006). Temperature and DO have obvious direct effects on fish metabolism, while water clarity can influence foraging efficiency for drift feeding trout (the most common feeding behaviour of trout in New Zealand streams). Additional aspects of water quality affect the four parameters noted above including but not limited to pH, nitrogen, phosphorus, periphyton, faecal contamination and other toxicants. Hay *et al* (2006) recommended water quality values for key and supporting parameters to protect adult trout in outstanding/regionally significant fisheries and also for other significant trout fisheries; the former offers greater protection (Table 12).

Table 12. Recommended water quality values to maintain near optimal conditions for trout in rivers designated 'Outstanding' or 'Regionally significant' trout fisheries (adapted from Hay *et al.* 2006). *Guidelines intended to minimise adverse effects on trout in rivers designated 'other significant trout fisheries'. Standards apply to base flow conditions (< median flow) during all seasons.

Parameter	Stream type	Standard	Reference
pH	Upland	7.3-8.0	ANZECC 2000
	Lowland	7.2-7.8	
Temperature	All	19°C as daily maximum	Elliott 1994
	Other*	24°C as daily max	RMA 1991
	All	Shall not be changed by more than 3°C	
Dissolved oxygen	All	> 80% saturation	ANZECC 1992 & RMA 1991
Periphyton biomass	Lowland	Diatoms and cyanobacteria: 200 mg/m^2 chlorophyll-*a* 35 g/m^2 AFDW Filamentous algae: 120 mg/m^2 chlorophyll-*a* 35 g/m^2 AFDW	Biggs 2000
	Upland	50 mg/m^2 chlorophyll-*a* maximum 15 mg/m^2 chlorophyll-*a* mean monthly	Biggs 2000
Periphyton cover	All	30 % > 2 cm long for filamentous algae	Biggs 2000
MCI	All	> 120	Stark 1985
	Other*	> 100	
Soluble inorganic nitrogen	All	< 10 µg-N/L to < 295 µg-N/L depending on accrual period	Biggs 2000
Soluble reactive phosphorus	All	< 1 µg-N/L to < 26 µg-N/L depending on accrual period	Biggs 2000
Ammoniacal-N	Upland	10 µg-N/L	ANZECC 2000
	Lowland	21µg-N/L	
Clarity (black disk)	All	5 m	
	Other*	3.75 m	
Turbidity	All	0.5 NTU	
	Other*	0.7 NTU	
Faecal contamination	All	260 *E. coli* 100 mL	MfE 2003
Other toxicants	All	Level for protection of 99% of species	ANZECC 2000

Recently, Ausseil (2013b) recommended biological and water quality limits for trout fishery in the Wellington region (Table 13). Parameters relate directly to the trout's physiological requirements at different life stages (*e.g.* temperature, toxicants), their physical habitat (*e.g.* water clarity, deposited sediments), or food source (*e.g.* macroinvertebrates).

The guidelines recommended for Horizons (Table 12) are similar to those recommended for Wellington (Table 13), with both reports acknowledging the differences between stream classes, based on value or environment type. For example, both reports recommend an MCI limit of 120 for regionally significant fisheries and 100 for locally/other significant fisheries. In contrast, recommended values for clarity varies from 2.0 m to 3.0 m for differing rivers in the Wellington region, but varies from 3.75 m to 5 m depending on the level of significance of trout fishery in the Horizons region. (Note: Horizons did not adopt the water clarity guidelines suggested by Hay *et al*. (2006) because they were seen as overly conservative on the basis of existing water clarity in the region. Instead water clarity guidelines were developed on the basis of statistical analysis of SOE data).

Table 13. Recommended biological and water quality limits for waters managed for trout fishery and trout spawning purposes in the Wellington region (adapted from Ausseil 2013a).

Water quality parameter	**Trout fishery class**	**Recommended limit**	**Limit application**
MCI (minimum score)	Locally significant	100	Year round, all river flows
	Regionally significant	120	
QMCI change (maximum % change)	All	20%	Year round, all river flows
Periphyton biomass (mg chlorophyll-*a*/m^2)	All	120 mg/m^2	Year round, river flows < 3 × median
Periphyton cover (% stream bed, filamentous algae > 2 cm long)	All	30%	Year round, river flows < 3 × median
Temperature (°C, daily maximum)	Locally significant	24°C	Year round, all river flows
	Regionally significant	19°C	
Temperature change (°C, maximum change)	Locally significant	±3°C	Year round, all river flows
	Regionally significant	± 2°C	
pH (pH units, range)	Locally significant	6.0 to 9.0	Year round, all river flows
	Regionally significant	6.3 to 8.4	
pH change (pH units, maximum change)	Locally significant	± 0.5	Year round, all river flows
	Regionally significant	± 0.5	
DO (% saturation, daily minimum)	Locally significant	70%	Year round, all river flows
	Regionally significant	80%	
ScBOD$_5$ (mg/L, maximum daily average)	All	2 mg/L	Year round, river flows < median
POM (mg/L, maximum average)	All	5 mg/L	Year round, river flows < median
Visual clarity (m, minimum)	Locally significant	2.0 m	Year round, river flows < median
	Waikanae River	2.0 m	
	Wainuiomata River	2.0 m	
	Ruamahanga River	3.0 m	
	Waiohine River	2.5 m	
	Hutt River	2.1 m	

Water quality parameter	Trout fishery class	Recommended limit	Limit application
Visual clarity change (% change, maximum)	Locally significant	33%	Year round, all river flows
	Regionally significant	20%	
Total ammonia-N (**Chronic**) (mg/L, maximum average concentration at pH = 8.0, Temp = 20°C)	All	0.916 mg/L	Year round, all river flows
Other toxicants (protection level)	Locally significant	95%	Year round, all river flows
	Regionally significant	99%	

We suggest that for most parameters the values recommended to protect aquatic ecosystems value will also protect fisheries value. However, given that fish are visual predators, maintaining minimum water clarity is necessary to sustain fisheries populations. Based on the drift foraging model reported in Hay *et al* (2006) we recommend a minimum visual clarity of 1.4 m will allow mature fish to forage on small (12 mm) prey and maintain base fishery value. Greater visual clarity (*e.g.* 3.75 m) would allow fish to forage on larger invertebrate prey and may sustain a more productive trout fishery. This is an example of an alternative numerical guideline that could be applied if values were rated and management bands applied.

3.3. Fish spawning

Recommended water quality guidelines to protect fish spawning value	**Parameter**	**Standard**	**Application**
	Deposited fine sediment	< 15%	May–December
	Temperature (daily max)	< 11ºC	May–December
	Toxicants (protection level)	99%	May–December

For spawning and incubation the main issues for trout fisheries are temperature and DO, as well as maintaining a relatively low, fine sediment fraction in the substrate (Hay *et al.* 2006). These three key water quality factors are probably also relevant to many native fish species, although the parameter levels required are not as well studied. The eggs of some native fish species are known to incubate out of the water column (*e.g.* inanga and kōaro). Consequently, water quality parameters may be of limited relevance to spawning success for these species.

Parameter limits apply during the spawning season, which for brown trout is generally between May–October, but extends into November and December for native fish including bullies and kōaro. Again, recommended values are similar for the Horizons and Wellington regions with the exception of a higher year round MCI standard and a wider allowable pH range in Wellington compared to Horizons (Table 14). For Marlborough, the water quality guidelines to protect the aquatic ecosystems value will also protect fisheries value. Exceptions include the need for greater protection of substrate condition — Clapcott *et al* (2011) recommend a maximum fine sediment cover of 15% in run habitats where trout spawning occurs; seasonal temperature maximums to protect egg incubation; high level of protection from toxicants to protect egg incubation.

Table 14. Recommended water quality guidelines intended to maintain near optimal conditions for trout spawning and incubation in streams managed for spawning. Standards apply to base flow conditions (< median flow) during spawning season (May–October). *Standards apply all river flows all year round.

Source	Parameter	Standard
Hay *et al* 2006 recommendations to Horizons Regional Council	pH	7.3 to 8.0 upland streams 7.2 to 7.8 lowland streams
	Temperature	< 11°C as daily maximum
		Shall not be changed by more than 3°C
	Dissolved oxygen	> 80% saturation
	Periphyton biomass	For lowland streams, Diatoms and cyanobacteria: 200 mg/m^2 Chlorophyll-*a* 35 g/m^2 AFDW Filamentous algae: 120 mg/m^2 Chlorophyll-*a* 35 g/m^2 AFDW
		For upland streams, 50 mg/m^2 chlorophyll-*a* maximum 15 mg/m^2 chlorophyll-*a* mean monthly
	Periphyton cover	30 % > 2 cm long for filamentous algae
	MCI	> 100
	Soluble inorganic nitrogen	< 10 µg-N/L to <295 µg-N/L depending on accrual period
	Soluble reactive phosphorus	< 1 µg-N/L to < 26 µg-N/L depending on accrual period
	Ammoniacal N	10 µg-N/L in upland streams 21µg-N/L in lowland streams
	Clarity (black disk)	3.75 m
	Turbidity	0.7 NTU
	Other toxicants	Level for protection of 99% of species
Ausseil 2013a recommendations to Greater Wellington Regional Council	MCI*	> 120
	Temperature	< 11°C as daily maximum
		Shall not be changed by more than 3°C
	pH	6.3 to 8.4
		Shall not be changed by more than ±0.5°C
	Dissolved oxygen	> 80% saturation
	Other toxicants	Level for protection of 99% of species

3.4. Natural state

Recommended water quality guidelines to protect fish spawning value	Parameter	Standard	Application
	Toxicants (protection level)	99%	At all times

The management objective for natural state is to ensure that water bodies remain unchanged by human influences. Consequently, it may not be necessary to stipulate particular water quality standards for discharges to comply with. Instead policy could just preclude discharges to water in these catchments. This is in keeping with the existing plans, which simply state, 'natural quality', 'shall not be altered', and provide no numeric criteria.

Norton and Snelder (2003) discuss difficulties with using 'natural state' as a management objective. They point out that water quality standards to achieve specific management objectives are ultimately established by accepting existing guideline values for the protection of quite specific aspects of the ecosystem, which are applied in specific WMUs. For example, guideline values for certain water quality variables have been derived to protect specific species (*e.g.* salmonids) or human uses for which a desired environmental state has been established (*e.g.* algal cover for contact recreation). They argue that natural state as a purpose for management does not provide sufficiently specific criteria to be maintained in order to nominate values for setting standards.

We recommend that at minimum water quality guidelines to protect 'aquatic ecosystem', 'fishery' and 'fish spawning' values be applied to WMU with 'natural state' value, with the exception of a 99% species protection level from ANZECC for toxicants. More protective guidelines could be informed by a measurement of the current state of waterways in these areas and / or the continued use of a 'shall not be altered' narrative guideline. We further recommend that policy tools (*e.g.* prohibited activity rules) be the primary instrument to protect the natural state value.

3.5. Contact recreation

The ANZECC (2000) define two categories of contact recreational activities:

1. Primary contact: the activities in which the user comes into frequent direct contact with water, such as swimming and water-skiing.
2. Secondary contact: the activities that generally have less-frequent body contact with the water, such as boating and fishing.

Water quality guidelines to ensure primary contact activities (*e.g.* swimming, water-skiing) are generally seasonally specific, acknowledging the higher use and probability of contact during the warmer months. Secondary contact (*e.g.* fishing, boating) water quality guidelines are applicable all year round and are less stringent, based on lower probabilities of direct contact or emersion in water.

Key water quality parameters that may need more stringent guidelines in water managed for contact recreation than in water managed for aquatic ecosystem values include:

- Indicators of faecal contamination (*E. coli*), to avoid infection / illness
- Water clarity and colour, for safety and aesthetics
- Periphyton and other growths, for aesthetics, and to mitigate slipping risk
- Other toxicants / irritants, to avoid potential adverse effects on health.

The NPS-FM proposes that secondary contact recreation for human health water quality guidelines are applied to all waterways and currently suggest numerical guidelines for *E. coli* (Table 15) and planktonic cyanobacteria. The NPS-FM further notes that suitable attributes to protect swimming or primary contact recreation for human health values could include *E. coli*, periphyton, cyanobacteria, water clarity, and flows.

Here we review and recommend water quality guidelines to protect primary contact recreation values. At the end of this section we also recommend water quality guidelines to protect secondary contact recreation water quality guidelines; these could apply to all WMU should MDC choose to align to the NPS-FM and adopt human health secondary contact recreation as a base value.

Table 15. Examples of water quality guidelines to protect contact recreation values from selected regional and national policy documents.

Source	**Parameter**	**Standard**	**Comment**
Proposed amendments to the NPS-FM 2011	*E. coli*	Band A: < 260/100 mL Band B: 260–540/100 mL Band C: 540–1,000/100 mL Band D: > 1,000/100 mL	Band A: People are exposed to a very low risk of infection (less than 0.1% risk) from exposure to water used for wading or boating (except boating where there is high likelihood of immersion). Band B: between 0.1 and 1% risk Band C: between 1 and 5% risk Band D: greater than 5% risk.
Horizons One Plan (2013)	*E. coli*	260/100 mL 550/100 mL	All natural waterways, < median flow All natural waterways, < 20th %ile flow
	Periphyton cover	30% (filamentous > 2 cm) 60% (mats > 3 mm)	All natural waterways
	Water clarity	1.6 m	< median flow
Canterbury Natural Resources Regional Plan (2010)	Periphyton cover	10% to 30% (filamentous > 2 cm)	Numerical objective depends on water body class
	Periphyton biomass	50 to 200 mg/m^2 (chlorophyll-a)	Numerical objective depends on water body class
	Macrophyte cover	20% to 30% (emergent) 30% to 60% (total)	Numerical objective depends on water body class
	Deposited sediment	10% to 40% cover	Numerical objective depends on water body class
Waikato Regional Plan (2007)	*E. coli*	126/100 mL (median) 235/100 mL (max)	Based on 'dry weather' sampling. Set as a standard for Contact Recreation Class
	Sewage fungus	No visible growth	Set as a standard for Contact Recreation Class

Source	Parameter	Standard	Comment
	Periphyton cover	25% 40%	Set as a Policy (Policy 6) for Contact Recreation Class
	Periphyton biomass	100 mg/m^2 (chlorophyll-*a*)	Set as a standard for Contact Recreation Class
	Water clarity	1.6m	Set as a standard for Contact Recreation Class
	Other contaminants	Narrative standard	"The water shall not be rendered unsuitable for contact recreation activities by the presence of contaminants"
Recommended for GWRC Plan update by Ausseil 2013a	*E.coli*	260/100 mL 550/100 mL 550/100 mL	At flows < median during the main bathing season At flows between median and 3 × median during the main bathing season At flows < 3 × median flow outside the main bathing season
	pH	6.5 to 8.5	
	Water clarity	1.6 m 20% change 33% change	At flows < median At or near sites of high use In all other waters
	Periphyton cover	30% (filamentous > 2 cm) 60% (mats > 3 mm)	
	Macrophyte cover	30% (emergent) 60% (total)	
	Heterotrophic growths	Narrative standard	"no bacterial or fungal slime growths visible to the naked eye as plumose growths or mats"
	Other irritants / toxicants		Refer to ANZECC (2000) guidelines

3.5.1. *Escherichia coli*

Recommended *E. coli* guidelines to protect contact recreation value	Parameter	Standard	Application
	E. coli (mean)	< 126/100 mL	River flows < median November–April
	E. coli (max)	< 260/100 mL	River flows < median November–April

Both primary and secondary contact recreation water quality guidelines should be applied to WMU listed as having contact recreation value. The guideline values for safe freshwater recreational sites as determined by MfE (2003) are for a single sample:

- Acceptable < 260 *E. coli* / 100 mL — Highly likely to be uncontaminated.
- Alert > 260 < 550 *E. coli* / 100 mL — Potentially contaminated. Investigate likely causes.

- Action > 550 *E. coli* / 100 mL — Highly likely to be contaminated. Closure / public warnings and increased monitoring/ investigation of the source.

These levels are based on an estimate that approximately 5% of *Campylobacter* infections could be attributable to freshwater contact recreation (MfE 2003). These guidelines have been adopted in most regions, but have applied to various flow thresholds (Table 15). Generally, the acceptable level is required to be met at flows below the median flow, in recognition of the fact that microbiological contamination tends to increase with elevated flow, but that contact recreational use is generally concentrated in periods of fine weather and stable flow recessions.
The existing MSRMP has the following provisions for water managed for contact recreation to protect against microbiological contamination, "Median concentration of enterococci of at least 20 samples taken throughout the bathing season shall not exceed 33 per 100 mL [approximately equivalent[6] to 79 *E. coli* per 100 mL], nor shall any sample exceed 107 enterococci per 100 mL [approximately equivalent to 159 *E. coli* per 100 mL]", with the bathing season is defined as the period of 1 November to 1 April inclusive. These existing standards are substantially more conservative than the MfE (2003) 'acceptable' level, but align more closely with the 'Very good' suitability for recreation grade from Table E1 and Table 2 in those guidelines and are reasonably similar to the levels adopted by Waikato Regional Council. We recommend the seasonal median concentration of *E. coli* should not exceed 126/100 mL, and any given *E. coli* sample should not exceed 260/100 mL to protect primary contact recreation values. Monitoring protocols are provided in MfE (2003).

3.5.2. Water clarity and colour

Recommended clarity and colour guidelines to protect contact recreation value	**Parameter**	**Standard**	**Application**
	Visual clarity	> 1.6 m	River flows < median November–April
	Visual clarity change	< 33%	River flows < median November–April
	Colour hue change (Munsell units)	< 10	River flows < median November-April
	Colour reflectance change	< 50%	River flows < median November–April

Water clarity and colour are of critical importance for the protection of contact recreation values. They can be readily perceived by recreational water users, and directly affect the aesthetic quality of the water. Water clarity is also important for safety, so that swimmers can estimate depth and see subsurface hazards.

[6] These enterococci levels were converted to approximate *E. coli* concentrations based on the power expression relating faecal coliforms to enterococci as given by MfE/MoH (2003; H 12) and assuming that *E. coli* represent about 90% of the faecal coliform group of bacteria (following Davies-Colley 2009).

Water clarity

Both the ANZECC (2000) guidelines and the MfE (1994) Water Quality Guidelines No.2 recommend that the water clarity of recreational waters should not be less than 1.6 m. This limit has been widely used by councils in regional plans, resource consent processes and reporting (*e.g.* SOE), including the existing WARMP and MSRMP for water managed for contact recreation.

As discussed in Section 3.1.6, the RMA standards state that discharges of a contaminant into water shall not give rise to “any conspicuous change in the colour or visual clarity in the receiving waters”. Ministry for the Environment (1994) Water Quality Guidelines No. 2 provide guidance on what constitutes a ‘conspicuous change’ in water clarity, *i.e.* a 20% change in waters where visual clarity is an important characteristic of the water body, and 33% to 50% in other waters. Panel studies have shown that most people can detect a change of 30% in visual clarity (Davies-Colley & Smith 1990) and hence recreational value is only likely to be diminished beyond this level of change.

The existing WARMP and MSRMP both stipulate no greater than a 33% reduction in the visual clarity of the receiving water for water managed for fishery values (the underlying/default class), but a more stringent “no greater than 20% reduction in the visual clarity” for water managed for aesthetic purposes (WARMP) and for clear water managed for fishery purposes (MSRMP).

Water colour

People are also generally able to perceive hue (which relates to relates to the dominant wavelengths in the spectrum of light, and is interpreted by the human eye / brain as red, green, blue *etc*.) and tend to associate blue-violet with pure water, while generally associating yellow or orange hue with muddy or polluted waters (Davies-Colley 2009). In most cases water clarity and hue are likely to both be changed, but an important exception would be a highly coloured but non-turbid discharge, such as diversion of humic-stained wetland water to a clear river or the discharge from a kraft pulp mill. For example, the discharge of dark orange-coloured kraft pulp effluent from the Kawerau mill only slightly shifts the visual clarity of the Tarawera River after complete mixing, but noticeably shifts the river water hue (Davies-Colley 2009).

The MfE (1994) Water Quality Guidelines No. 2 provide guidelines for acceptable water colour change, for hue a maximum of 10 Munsell colour units and 50% change in reflectance. While the existing WARMP and MSRMP do not include colour change standards for water managed for contact recreation, they both stipulate that, “Hue shall not be changed by more than 10 points on the Munsell scale” in water managed for fishery values (which is the underlying / default class). We recommend that this standard should be applied to water managed for contact recreation.

3.5.3. Periphyton and cyanobacteria

Recommended periphyton and cyanobacteria guidelines to protect contact recreation value	**Parameter**	**Standard**	**Application**
	Periphyton (filamentous > 2 cm)	30%	River flows < median November–April
	Cyanobacteria (mat > 3 mm)	20%	River flows < median November–April

The DIN and DRP standards (see Aquatic values sections) should limit excessive growths of periphyton. However, a direct measure of periphyton cover/biomass can also be used to assess suitability for contact recreation. The existing WARMP and MSRMP stipulates that, "seasonal maximum cover of stream or river beds by periphyton as filamentous growths or mats (more than 3 mm thick) shall not exceed 40%, and the biomass on the bed shall not exceed 100 mg chlorophyll-*a* / m²" to protect contact recreation values. These numerical limits align with other regional and national policy documents to protect waters for secondary contact (Table 15). We recommend that long filamentous periphyton (> 2 cm) shall not cover more than 30% of the riverbed to protect primary contact recreational values. For periphyton and cyanobacteria (see below), recommended standards indicate a seasonal maximum. Recommended monitoring protocols are provided in Biggs *et al.* (2000) and Ministry for the Environment and Ministry of Health (2009), respectively.

The New Zealand Guidelines for Cyanobacteria in Recreational Fresh Waters: Interim Guidelines (Ministry for the Environment and Ministry of Health 2009) provide advice on how public health risk associated with cyanobacteria in recreational waters can be managed. Cyanobacteria (commonly known as blue-green algae) can multiply and form planktonic (suspended in the water column) blooms or dense benthic (attached to the substrate) mats in aquatic environments. Dog deaths associated with the consumption of benthic cyanobacteria have become increasingly common around New Zealand. The risk to animal and human and health is greatest at times when cyanobacteria mat coverage is widespread and when they detach from the substrate and accumulate along river edges. The interim guidelines propose an alert-level framework based on an assessment of the percentage of river bed that cyanobacterial mats cover at each site to be applied during the bathing season (Table 16).

Table 16. Alert-level settings framework for benthic cyanobacteria (adapted from Ministry for the Environment and Ministry of Health 2009). * The most common mat-forming benthic cyanobacteria genus in New Zealand is *Phormidium*.

Alert level	**Actions**
Surveillance (green mode) Up to 20% coverage of potentially toxigenic cyanobacteria* attached to substrate.	• Undertake fortnightly surveys between spring and autumn at representative locations in the water body where known mat proliferations occur and where there is recreational use.

Alert level	Actions
Alert (amber mode) 20−50% coverage of potentially toxigenic cyanobacteria* attached to substrate.	• Notify the public health unit. • Increase sampling to weekly. • Recommend erecting an information sign that provides the public with information on the appearance of mats and the potential risks. • Consider increasing the number of survey sites to enable risks to recreational users to be more accurately assessed. • If toxigenic cyanobacteria dominate the samples, testing for cyanotoxins is advised. If cyanotoxins are detected in mats or water samples, consult the testing laboratory to determine if levels are hazardous.
Action (red mode) *Situation 1:* Greater than 50% coverage of potentially toxigenic cyanobacteria* attached to substrate; **or** *Situation 2:* up to 50% where potentially toxigenic cyanobacteria* are visibly detaching from the substrate, accumulating as scums along the river's edge or becoming exposed on the river's edge as the river level drops.	• Immediately notify the public health unit. • If potentially toxic taxa are present then consider testing samples for cyanotoxins. • Notify the public of the potential risk to health.

In a recent examination of how the interim guidelines might apply in the NOF framework, which included the testing of proposed bands using monitoring data, Wood *et al*. (2013) recommended: sites where all sampling transects had less than 10% *Phormidium* cover be classified as Band A. Sites where all transects had less than 50% *Phormidium* cover be classified as Band B / C, and sites where any given sampling transect has more than 50% *Phormidium* cover be classified as Band D. Based on these reports we recommend to protect primary contact recreational values, cyanobacteria mats (> 3 mm) should not exceed 20% cover.

3.5.4. Secondary contact recreation

Recommended water quality guidelines to protect secondary contact recreation value	**Parameter**	**Standard**	**Application**
	E. coli (mean)	< 260 / 100 mL	< median flow
	E. coli (max)	< 550 / 100 mL	< median flow
	Cyanobacteria (mat > 3 mm)	< 50%	< median flow

3.6. Aesthetics

Recommended water quality guidelines to protect aesthetics value	**Parameter**	**Standard**	**Application**
	Visual clarity change	< 20%	At all times
	Colour hue change (Munsell units)	< 5	At all times

The aesthetics (A) value class recognises the special significance of clear waters in the Marlborough region and aims to protect the outstanding clarity of these waterways. The three WMU currently assigned aesthetic value are all within the Wairau catchment: Blenheim Springs, Spring Creek catchment and Wairau River tributaries. There are monitoring sites within the two former WMU and both have measured suspended solids and turbidity well within recommended guidelines to protect aquatic ecosystem and fishery values. Clarity is not currently routinely measured.

Key water quality parameters that may need more stringent guidelines in water managed for aesthetics than in water managed for aquatic ecosystem values include: water clarity, suspended solids, colour, reflectance and turbidity. Guideline values for these parameters are included in the existing WARMP:

- Hue (Munsell scale), change no more than < 5 points
- Clarity, narrative clause “shall not be conspicuously changed due to sediment”
- Clarity (black disk, m), change by no more than 20%
- Turbidity (NTU), change by no more than 10%
- Reflectance, change by no more than 50%.

There can be correlations between these measures, but the most direct measure of water clarity is the black disk method. However, the other criteria are also relevant to the management objective of maintaining the visual aesthetics of clear water streams. We note that the guideline for hue is more stringent than that recommended in the MfE (1994) Water Quality Guidelines No. 2 (*i.e.* no more than a 10-point change on the Munsell scale). However, this could be justified given the outstanding clarity that these water bodies are managed for. We also reiterate perceived limitations of turbidity (NTU) for prescribing standards and guidelines discussed by Davies-Colley (2009), see Section 3.1.6.

3.7. Water supply

Recommended water quality guidelines to protect water supply value	**Parameter**	**Standard**	**Application**
	Turbidity (NTU)	< 20	< median flow
	ScBOD$_5$	< 2 mg/L	< median flow
	Phytoplankton chlorophyll-*a*	< 0.02 mg/L	< median flow
	pH range	6.5–8.5	At all times

The water supply (WS) value is intended to protect water for human consumption and applies to only a single water management unit in the Marlborough district. Head works on the Black Birch Stream feed into a reticulation network that supplies water to much of the lower Awatere Valley, including Seddon township. Drinking water standards for New Zealand (DWSNZ; Ministry of Health 2008) stipulate water quality standards which water supplies must comply with, in order to protect public health. In this respect drinking water is different from the other water management objectives identified. While other objectives may have associated published guidelines, the quality of drinking water is controlled by a national standard.

The DWSNZ is primarily focused on protecting public health and to that end provides maximum concentrations of chemicals of health significance (maximum acceptable value, MAV) that are expected to constitute no significant risk to the health of a person who consumes 2 L of that water a day over their lifetime (usually taken as 70 years). However, they also provide aesthetic guidelines, since these influence public perception of their water supplies. The DWSNZ also stipulates sampling and testing protocols designed to give 95 percent confidence that no determinand in a supply has exceeded its MAV for more than five percent of the time.

However, the MAVs stipulated in the DWSNZ are intended to be applied post-treatment, whereas the quality of supply source water (*i.e.* raw, untreated water) is intended to be covered in Public Health Risk Management Plans developed for individual supplies serving over 500 people. As discussed by Norton and Snelder (2003) in advice to Environment Canterbury, it is difficult to set generic water quality guidelines for supply source water, in the absence of information on treatment.

Essentially, reducing the risk of contamination of the water source is a priority, since this reduces the treatment requirements. The first of four barriers to contamination of water to protect public health listed in the DWSNZ is “minimising the extent of contaminants in the source water that must be dealt with by the treatment process” (Ministry of Health 2008, p 3). This is likely to involve restricting human and livestock access to the catchment to reduce potential microbiological contamination, and restricting other potential contamination, such as excess nitrate and pesticides (ANZECC 2000).

The existing WARMP specifies a maximum turbidity limit (20 NTU) to ensure that water managed for water supply is fit of treatment (equivalent to coagulation, filtration, and disinfection). It also stipulates that pH shall be within the range 6–9, and includes BOD and phytoplankton (and DRP) limits to avoid excessive biological growths, which could presumably clog filters *etc*. A narrative clause is also included to avoid contamination, "Shall not be tainted or contaminated so as to make it unpalatable or unsuitable for human consumption after treatment…". The numerical criteria seem reasonable and we recommend that they are retained as water quality guidelines to protect water supply values.

Another policy action that could be applied to offer further protection to water managed for drinking water supply (suggested by Norton and Snelder [2003]) is to define any discharge to a 'human drinking water' WMU as a non-complying activity, so that a high level of discretion can be retained for case-by-case consideration. The consent process would include consideration of the raw water quality, the proposed discharge quality, the level of treatment of the drinking water supply, and the DWSNZ 2000.

3.8. Irrigation

The existing WARMP contains clauses specific to water quality guidelines irrigation water under the section defining standards for water managed for water supply purposes. Specifically, it states that water "Shall not be tainted or contaminated so as to make it unpalatable or unsuitable for human consumption after treatment, or unsuitable for irrigation", stipulates that water for irrigation shall comply with irrigation guidelines in ANZECC (1992). These irrigation water quality guidelines are attached as appendix P to the WARMP, and cover a broad range of parameters including metals and trace ions, pesticides and herbicides.

The ANZECC (2000) guidelines also covers irrigation water quality, and provides trigger values for a broad range of parameters, including differing trigger values for short term and long term exposures for some parameters. These more recent guidelines presumably provide updated information compared to the 1992 guidelines.

We recommend that MDC consider updating the reference in the plan to the ANZECC (2000) guidelines. However, it is important to remember that the intention of these guidelines is to provide trigger values (ANZECC 2000[7]), with breaches intended to prompt additional investigation, rather than definitive limit setting. This should be reflected in the wording of the Plan.

[7] See ANZECC 2000 section 2.2.1.8 Guidelines not standards: "The Guidelines recommend numerical and descriptive water quality guidelines to help managers establish water quality objectives that will maintain the environmental values of water resources. They are not standards, and should not be regarded as such."

The ANZECC (2000) guideline document also provides guideline values for stock drinking water (Section 4.3), covering contaminants including:

- Cyanobacteria (blue-green algae)
- Pathogens and parasites
- Major ions of concern (calcium, magnesium, nitrate and nitrite, sulphate, total dissolved solids (salinity)
- Heavy metals and metalloids
- Pesticides and other organic contaminants
- Radioactive contaminants.

The Ministry of Agriculture and Forestry's Farm Dairy Water Standard D106.2 (Ministry of Agriculture and Forestry 2002) covers water quality for water used in farm dairies for milking and cleaning equipment that comes in contact with milk.

4. RECOMMENDED STANDARDS

Table 17. Summary of recommended water quality guidelines for the protection of recognised values in the Marlborough district.

Parameter	Standard	Application	Base value
Temperature (daily max)	≤ 21°C	At all times	AE
Temperature (daily max)	≤ 19 ºC	At all times	F
Temperature (daily max)	< 11ºC	May–October	FS
Temperature change	± 3°C	At all times	AE
DO mg/L (daily min)	≥ 6 mg/L	At all times	AE
DO mg/L (7-day mean)	≥ 7.5 mg/L	At all times	AE
pH range	6.5 to 8.5	At all times	AE
pH change	± 0.5	At all times	AE
$ScBOD_5$	< 2 mg/L	River flow < median	AE
POM	< 4 mg/L	River flow < median	AE
Visual clarity	≥ 0.5 m	River flow < median	AE
Visual clarity	> 1.4 m	River flow < median	F
Visual clarity	> 1.6m	River flows < median November–April	CR
Visual clarity change	< 33%	River flows < median November-April	CR
Visual clarity change	< 20%	At all times	A
TSS			AE
DFS cover	< 20%	At all times	AE
DFS cover	< 15%	May–October	FS
DFS change	< 10%	At all times	AE
NO_3N (toxicity)	< 2.4 mg/L	At all times	AE
Ammonia-N (mean at pH = 8.0, Temp = 20°C) (toxicity)	< 0.32 mg/L	At all times	AE
DRP	< 0.015 mg/L	River flow < median	AE
DIN	< 0.444 mg/L	River flow < median	AE
Toxicants (protection level)	95%	At all times	AE
Toxicants (protection level)	99%	At all times	NS
Toxicants (protection level)	99%	May–October	FS
Periphyton cover (filamentous algae > 2 cm long)	< 30 %	River flow < median	F
MCI	> 100	River flow < median	F
E. coli (mean)	< 126 / 100 mL	River flows < median November-April	CR
E. coli (max)	< 260 / 100 mL	River flows < median November-April	CR
Colour hue change (Munsell units)	< 10	River flows < median	AE
Colour hue change (Munsell units)	< 10	River flows < median November–April	CR
Colour hue change (Munsell	< 5	At all times	A

Parameter	Standard	Application	Base value
units)			
Colour reflectance change	< 50%	River flows < median	AE
Colour reflectance change	< 50%	River flows < median November–April	CR
Periphyton (filamentous > 2 cm)	30%	River flows < median November–April	CR
Cyanobacteria (mat > 3 mm)	20%	River flows < median November-April	CR
Turbidity (NTU)	< 20	River flow < median	WS
Phytoplankton chlorophyll-*a*	< 0.02 mg/L	River flow < median	WS
pH range	6.5–8.5	At all times	WS

Table 18. Summary of recommended water quality guidelines for the protection of secondary contact recreation (SCR) as a base value in the Marlborough district.

Parameter	Standard	Application	Base value
E. coli (mean)	< 260 / 100 mL	River flow < median	SCR
E. coli (max)	< 550 / 100 mL	River flow < median	SCR
Cyanobacteria (mat > 3 mm)	< 50%	River flow < median	SCR

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6. APPENDICES

Appendix 1. Summary of water quality standards contained in the Marlborough Sounds Resource Management Plan 2003 (Appendix H) and Wairau / Awatere Resource Management Plan 2009 (Appendix J). Class F (primary objective being safe consumption of fish) is the underlying class for both plans.
* Note that to avoid repetition those Third Schedule Standards that are covered by, or exceeded by the underlying class, have been omitted.

Standard **(from RMA Third Schedule unless marked + in which case from RMA Section 70)**		**Numeric interpretation**
Class F: Water managed for fishery purposes		
+ Conspicuous oil or grease films, scums or foams, or floatable or suspended materials	Shall not be produced	No numeric interpretation available
+ Colour or visual clarity	Shall not change	Hue shall not be changed by more than 10 points on the Munsell scale
		The natural clarity shall not be conspicuously changed due to sediment or sediment-laden discharge originating from the site of a land disturbance operation. There shall be no greater than 33% reduction in the visual clarity of the receiving water as measured by the horizontal sighting of a black disk; and/or there shall be no greater than 15% increase in the turbidity of the receiving water as measured in NTU. Measurements are to be made immediately above or upstream of the discharge and below the discharge after reasonable mixing.
+ Objectionable odour	Shall not be emitted	No numeric interpretation available
+ Suitability for consumption by farm animals	Shall not be rendered unsuitable	No numeric interpretation available
+ Aquatic life	Shall not be any significant adverse effects	*Light penetration* In water deeper than half the euphotic depth, the euphotic depth shall not be changed by more than 10% In waters shallower than half the euphotic depth, the lighting at the bed shall not be reduced by more than 20% *Ammonia toxicity* The 4-day average concentration of total ammonia shall not exceed the following values:

<table>
<tr><th colspan="2">Standard
(from RMA Third Schedule unless marked + in which case from RMA Section 70)</th><th>Numeric interpretation</th></tr>
<tr><td></td><td></td><td>
<table>
<tr><td></td><td colspan="3">Total ammonia, NH_4--N (g/m^3)</td></tr>
<tr><td>pH</td><td>≤ 15°C</td><td>20°</td><td>25°</td></tr>
<tr><td>7.50</td><td>1.81</td><td>1.23</td><td>0.86</td></tr>
<tr><td>7.75</td><td>1.64</td><td>1.15</td><td>0.81</td></tr>
<tr><td>8.00</td><td>1.9</td><td>0.76</td><td>0.54</td></tr>
<tr><td>8.25</td><td>0.62</td><td>0.44</td><td>0.32</td></tr>
<tr><td>8.50</td><td>0.36</td><td>0.26</td><td>0.19</td></tr>
</table>
Note that daily average based on single sample taken 12:00–1400 (NZST)

Particulate organic material
The daily average concentration of particulate organic matter shall not exceed 4 g/m^3</td></tr>
<tr><td>Temperature</td><td>Shall not be changed by more than 3°C.
Shall not exceed 20°C
(Note that this is more stringent than the 25°C in the RMA Third Schedule)</td><td>N/A</td></tr>
<tr><td>Dissolved oxygen</td><td>Shall exceed 80% of saturation</td><td>N/A</td></tr>
<tr><td>Suitability of fish for human consumption</td><td>Shall not be rendered unsuitable by the presence of contaminants</td><td>No numeric interpretation available</td></tr>
<tr><td colspan="3">Class F1: Clear water managed for fishery purposes* (Marlborough Sounds RMP only)</td></tr>
<tr><td>+ Colour or visual clarity</td><td>Shall not change</td><td>Hue shall not be changed by more than 10 points on the Munsell scale</td></tr>
<tr><td></td><td></td><td>The natural clarity shall not be conspicuously changed due to sediment or sediment-laden discharge originating from the site of a land disturbance operation.
There shall be no greater than 20% reduction in the visual clarity of the receiving water as measured by the horizontal sighting of a black disk; and/or there shall be no greater than 15% increase in the turbidity of the receiving water as measured in NTU.
Measurements are to be made immediately above or upstream of the discharge and below the discharge after reasonable mixing.</td></tr>
<tr><td colspan="3">Class AE: Water managed for aquatic ecosystem purposes* (Wairau / Awatere RMP only)</td></tr>
<tr><td>Aquatic life</td><td>Shall not be any adverse effect from:
• pH change
• increase in the deposition of matter</td><td>Australian Water Quality Guidelines for Fresh and Marine Waters (ANZECC 1992)</td></tr>
</table>

Standard (from RMA Third Schedule unless marked + in which case from RMA Section 70)		**Numeric interpretation**
	on the bed • contaminants	
Biological growths	Shall be no undesirable growths	Bacterial and / or fungal slime growths shall not be visible to the naked eye as obvious plumose growths or mats
		The daily average carbonaceous BOD_5 due to dissolved organic compounds (*i.e.* those passing a GF/C filter) shall not exceed 2 g/m^3
		The median concentration of dissolved reactive phosphorus (DRP) shall be less than 15 mg/m^3 at low flows, unless other physical and/or biological factors prevent undesirable biological growths developing at higher DRP concentrations
Class FS: Water managed for fish spawning purposes* (Wairau / Awatere RMP only)		
Temperature	Shall not adversely affect spawning of specified fish species during the spawning season	Shall not exceed 14°C between April and October except where naturally occurring Species: trout, salmon, lamprey, giant kōkopu, kōaro, inanga
Biological growths	Refer Class AE	Refer Class AE
Class CR: Water managed for contact recreation purposes*		
Visual clarity	Shall not be so low as to be unsuitable for bathing	Horizontal sighting range of 200 mm black disk shall exceed 1.6 m during low flows
Contaminants	Shall not render water unsuitable for bathing	Median concentration of enterococci of at least 20 samples taken throughout the bathing season shall not exceed 33 per 100 mL, nor shall any sample exceed 107 enterococci per 100 mL. The bathing season is defined as the period of 1 November 10 to 1 April inclusive.
Biological growths	Shall be no undesirable growths	Refer Class AE Seasonal maximum cover of stream or river beds by periphyton as filamentous growths or mats (more than 3 mm thick) shall not exceed 40%, and the biomass on the bed shall not exceed 100mg chlorophyll-*a*/m^2
Class NS: Water managed in its natural state		
Natural quality	Shall not be altered	No numeric interpretation available
Class NS: Water managed for aesthetic purposes (Wairau / Awatere RMP only)		
Visual clarity		Hue shall not be changed by more than 5 points on the Munsell scale
		The natural clarity of any permanently flowing river, lake, wetland, or the sea shall not be conspicuously changed due to sediment or sediment laden discharge originating from the site of a land disturbance operation. There shall be no greater than 20% reduction in the visual clarity of the receiving water as

Standard **(from RMA Third Schedule unless marked + in which case from RMA Section 70)**		**Numeric interpretation**
		measured by the horizontal sighting of a black disk; and/or there shall be no greater than 10% increase in the turbidity of the receiving water as measured in NTU. Measurements are to be made immediately above or upstream of the discharge and below the discharge after reasonable mixing.
		Reflectance shall not be changed by more than 50%
Class SG: Water managed for the gathering or cultivation of shellfish for human consumption		
Temperature	Shall not be changed by more than 3°C	
Dissolved oxygen	Shall exceed 80% of saturation	N/A
Suitability of fish for human consumption	Shall not be rendered unsuitable by the presence of contaminants	Median faecal coliform concentration of not less than five samples, taken within any consecutive 30-day period, shall not exceed a most probable number (MPN) of 14 per 100 mL (or colony forming units per 100 mL). Not more than ten percent of samples taken within any consecutive 30-day period shall exceed and MPN of 43 per 100 mL (or 43 colony forming units per 100 mL) as a result of any discharge of a contaminant or water. Samples shall not be taken on the same or consecutive days.
Class WS: Water managed for water supply purposes* (Wairau / Awatere RMP only)		
pH	Shall be within the range 6.0–9.0	N/A
Suitability for treatment	Shall not be rendered unsuitable for treatment (equivalent to coagulation, filtration, and disinfection) by presence of contaminants	Turbidity, except that produced naturally under flood conditions, shall not exceed 20 NTU
Suitability for human consumption or irrigation	Shall not be tainted or contaminated so as to make it unpalatable or unsuitable for human consumption after treatment, or unsuitable for irrigation.	*Human consumption* Water treated by coagulation/filtration/ disinfection shall be able to comply with the Drinking-Water Standards for New Zealand 1995
		Irrigation Shall comply with irrigation guidelines in Australian Water Quality Guidelines for Fresh and Marine Waters (ANZECC 1992)
Biological growths		The daily average carbonaceous BOD_5 due to dissolved organic compounds (*i.e.* those passing a GF/C filter) shall not exceed 2 g/m^3
		Phytoplankton chlorophyll-*a* shall be less than 20 mg/ m^3 The median concentration of dissolved reactive phosphorus (DRP) shall be less than 15 mg/m^3 at low flows, unless other physical and/or biological factors prevent undesirable biological growths developing at higher DRP concentrations

Standard **(from RMA Third Schedule unless marked + in which case from RMA Section 70)**		**Numeric interpretation**
Class DW: Water managed for drinking water quality [Marlborough Sounds RMP only]		
Contaminates	Shall not render the water unsuitable for human consumption	• Faecal coliforms < 1 CFU/100 mls of sample • Ammonium < 1.5 mg/ • Iron < 0.2 mg/ • Nitrate < 50 mg/
pH	Shall be within the range 6.5–8.5	N/A

Appendix 2. Guideline values currently used to assess the state of surface water quality in the Marlborough District Council (adapted from Tiernan 2011).

Parameter	**Guideline value**	**Purpose**	**Reference**
Nitrate	1.7 mg/L 0.444 mg/L 0.167 mg/L	Aquatic ecosystem toxicity Prevent nuisance algal growth in lowland rivers Prevent nuisance algal growth in upland rivers	Hickey and Martin (2009) ANZECC (2000) ANZECC (2000)
DRP	0.01 mg/L 0.009 mg/ L	Prevent nuisance algal growth in lowland rivers Prevent nuisance algal growth in upland rivers	ANZECC (2000) ANZECC (2000)
Ammonia	0.9 mg/L* 0.021 mg/L** 0.01 mg/L**	Aquatic ecosystem toxicity Lowland river ecosystem health Upland river ecosystem health	ANZECC (2000) ANZECC (2000) ANZECC (2000)
E. coli	550 n/100 mL 260 n/100 mL 126 n/100 mL	Contact recreation (action level) Contact recreation (alert level) Contact recreation (median level for surface waters)	MfE (2003) MfE (2003) McBride *et al*. (1991)
Turbidity	5.6 NTU 4.1 NTU	Lowland rivers Upland rivers	ANZECC (2000) ANZECC (2000)
Suspended solids	10 mg/L	Ecological guideline	CCREM (1991)
Dissolved oxygen	80% saturation	Ecological guideline	RMA (1991)
Copper	0.0014 mg/L	95% protection of freshwater aquatic life (slightly to moderately disturbed systems)	ANZECC (2000)
Zinc	0.008 mg/L	95% protection of freshwater aquatic life (slightly to moderately disturbed systems)	ANZECC (2000)
MCI	> 119 100–119 80–99 < 80	Clean water Doubtful quality or possible mild pollution Probable moderate pollution Probable severe pollution	Stark 1998
SQMCI	> 5.99 5–5.99 4–4.99 < 4	Clean water Doubtful quality or possible mild pollution Probable moderate pollution Probable severe pollution	Stark 2007

* The ANZECC guidelines specify a toxic guideline level of 0.9 mg/L for total ammonia (NH_3 plus NH_4^+)

** In addition the guidelines give a limit for ionised ammonia (NH4+) of 0.01 mg/L for upland rivers and 0.021 mg/L for lowland rivers for the protection of ecosystem health.