



# Water quality and ecological attributes for rivers and lakes in the Bay of Plenty

## Report 1

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Revision #	Reviewers
1	Nicola Green, Michelle Lee, Rob Donald.
3	Ned Norton (Land Water People).

**Approved for publication by:** Paul Scholes, Water Quality Team Leader

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# Report summary

This extended report summary is provided as a stand-alone summary. It is written without references for ease of reading and interpretation, and is intended to provide enough information suitable for the needs of most readers, without the need to read the full report. Full descriptions of methods and technical information including references are provided in the main body of this report for those readers needing, or wanting, more technical detail on the attributes, selection and evaluation process.

## Introduction

As part of its implementation of the National Policy Statement for Freshwater Management (NPS-FM), Bay of Plenty Regional Council (BOPRC) has established a draft set of regional freshwater values which provide a consistent set of titles and definitions for the broad range of freshwater values that are commonly (but not always) relevant in freshwater bodies across the region. The draft regional values include all national values in the NPS-FM, and additional values identified from existing documents and engagement with tangata whenua and community groups. The next step is identifying attributes<sup>1</sup> for the values identified, and is the purpose of this report.

This report recommends appropriate physical, chemical, microbiological and ecological attributes for rivers and lakes. These attributes are to be used region-wide by BOPRC to help set measurable objectives to support key values with in-stream water quality or ecology requirements, and to measure their current state.

## Draft Freshwater Management Units

A significant challenge faced by councils is that both water quality and quantity naturally vary in water bodies throughout the region, as do the values that these water bodies support. Similarly, there is a large variation in balancing water resource use and the need to maintain other (often competing) values. The NPS-FM requires that regional councils subdivide water bodies within their region into freshwater management units (FMUs). The NPS-FM defines a FMU as “*a water body, multiple water bodies, or any part of a water body determined by a regional council as the appropriate spatial scale for setting freshwater objectives and limits and for freshwater accounting and management purposes*”.

BOPRC has divided the region into nine separate Water Management Areas (WMAs) to implement the NPS-FM. It has also developed a region-wide biophysical classification, and a draft objective setting spatial layer for the first two WMAs being considered: the Rangitāiki; and Kaituna, Maketū, Pongakawa and Waitahanui (Figure 1). The draft objective setting spatial layers are currently regarded as draft FMUs. The region-wide biophysical classification is an important component of the spatial framework supporting plan change development, and will be used to help set bands for different attributes where this is appropriate. The biophysical classification is particularly relevant for ecological attributes recommended in this report. The draft objective setting spatial layer will therefore be used later when setting objectives, targets and limits, using the attributes and options for bands recommended in this report; but it is not needed for developing the attributes and band options.

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<sup>1</sup> Attributes are components in water that can be measured to find out how healthy a waterway is (e.g. nutrients, bacteria, temperature).

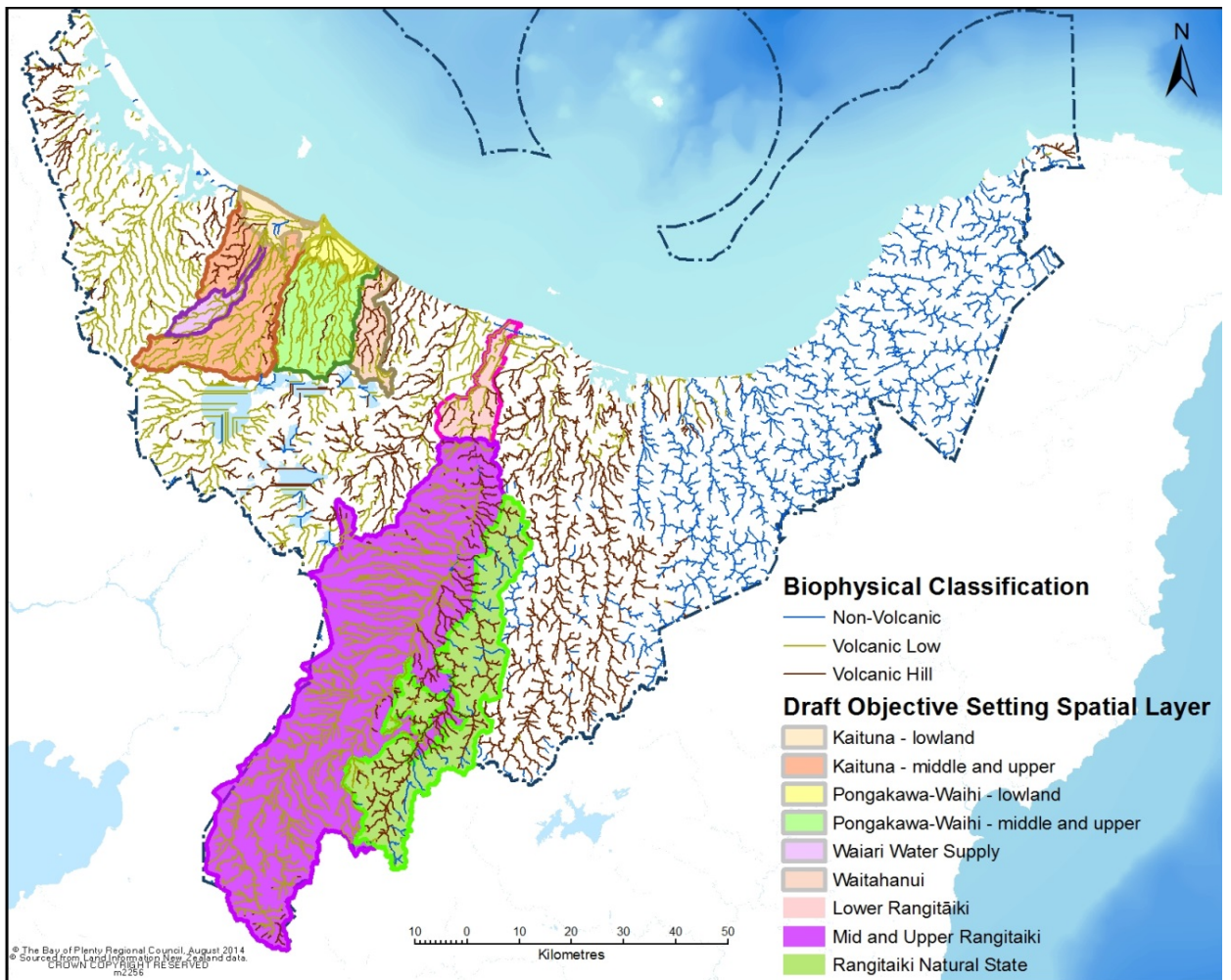


Figure 1 Regional biophysical classification and the draft objective setting spatial layer for the Rangitāiki and Kaituna, Maketū, Pongakawa and Waitahanui water management areas.

## Draft regional freshwater values

The draft regional freshwater values can be considered in terms of overarching Māori values which guide how Māori view and manage freshwater, in-river values that do not generally require consent or permission under the Resource Management Act (RMA) and RMA plans, and use values which do (i.e. take, use, damming, diversion, and discharge).

## Attributes

Attributes are specific parameters that can be measured using recognised/standardised methodology (e.g. nitrate, temperature, macroinvertebrates), and can help determine the extent to which specific values are provided for. There are many different physical, chemical, microbiological and ecological attributes that could be used to determine the extent to which different freshwater values are provided for, and one attribute may apply to more than one value. Although we have identified a range of attributes, we acknowledge that new scientific developments may result in creation of new attributes, or new ways to measure existing ones. As such this report should be seen as the first stage in presenting a definitive list of attributes, and that new ones may be adopted in future.



## River water quality attributes

The recommendations for physical, chemical and microbiological attributes for rivers are provided in two categories: recommended attributes with state bands, and recommended attributes without state bands. This recognises the importance of particular attributes to ecosystem health, and the challenges around defining attribute state bands at this time for some attributes.

Table 1 lists the recommended physical, chemical and microbiological attributes and corresponding state bands for rivers. Table 2 lists the recommended physical and chemical attributes without state bands.

Table 3 lists all the recommended ecological attributes and corresponding state bands for rivers.

All of the attributes from Appendix II of the NPS-FM are recommended for rivers, plus pH, temperature, benthic cyanobacteria, macrophytes and invertebrates.

## Lake water quality attributes

Table 4 lists the recommended physical, chemical, microbiological and ecological attributes for lakes and corresponding state bands. All of the attributes contained in the NPS-FM for lakes are recommended, plus lake Trophic Level Index (TLI)<sup>2</sup> and Lake Submerged Plant Index (SPI)<sup>3</sup>.

## Further considerations

There are a number of other factors that are considered important in the process of setting objectives/limits/targets, but were outside the scope of this report. Some of the relevant other considerations are briefly summarised here.

### Coastal receiving environments

Although the NPS-FM is focussed on freshwater quality and quantity, Policies A1 (a)(iii), B1(c) and C2(b) require Council to have regard to the connections between freshwater bodies and coastal water during freshwater quality and quantity objective setting, and in the integrated management of the effects of use and development of land<sup>4</sup>. When considering objective and limit setting for rivers, it is imperative that the cumulative impacts on the ultimate downstream receiving environment are actively considered and accommodated. This needs to be a focus for freshwater objective setting and attribute band development for contaminants that will impact on sensitive downstream receiving environments (like dissolved inorganic nitrogen and dissolved reactive phosphorus) and has been recognised by recommending these attributes without attribute state bands at this time.

### Drains

There is a large drainage network throughout the region, a large component of which is maintained and operated by Council. This network consists of a number of highly modified natural water courses, as well as artificial drains cut in the past as part of agricultural development of this area. Many of these drains are often below the water level of the river they discharge into, and are actively pumped into rivers during times when water levels are high. They often have poor water quality and ecological characteristics.

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<sup>2</sup> Lake TLI uses four key attributes: total nitrogen, total phosphorus, chlorophyll-a and water clarity (as Secchi depth) and gives an indication of how healthy a lake is. It ranges from 1 to greater than 7, where a score of 1 indicates very low nutrients in the lake and 7 is extremely high nutrients. The lower the Lake TLI, the better condition the lake is in.

<sup>3</sup> Lake SPI uses the type and amount of aquatic plants in a lake to give an indication of how healthy a lake is. It ranges from 0-100% where 0% is no plants in the lake, and >75% has excellent plant life. The higher the Lake SPI, the better the condition the lake is in.

<sup>4</sup>The New Zealand Coastal Policy Statement 2010 also requires integrated management and consideration of catchment and land use causes of effects on coastal environments (e.g. Objective 1 and Policies 4, 22 and 23).

Land drainage canals specified under Schedule 3 of the Regional Water and Land Plan *are* defined as water bodies and are therefore subject to the requirement for Council to set freshwater objectives under the NPS-FM. Other drainage channels and farm drains are defined as artificial watercourses, not rivers or water bodies, and consequently freshwater objectives will not be set for these under the NPS-FM. Discharges of contaminants from farm drains must be managed via discharge rules and contaminant generation may also potentially be managed by land use rules, limits and/or other methods in order to contribute to meeting fresh water and coastal receiving environment objectives of the water bodies they discharge into.

Table 1 Recommended physical, chemical and microbiological attributes and state bands for rivers. Shaded attributes are those from Appendix II of the NPS-FM (2014). Note the bottom of band C represents the “bottom line” except for *Escherichia coli* (*E.coli*) 95th percentile attribute states where the bottom of band B represents the “minimum acceptable state”.

Attribute	Statistic	Band	Numeric attribute state	Narrative attribute state	Value(s) supported
Nitrate-nitrogen	Annual median	A	≤ 1.0 mg/L	High conservation value system. Unlikely to be effects even on sensitive species.	Ecosystem Health (toxicity). Significant indigenous species and habitat. Mahinga kai. <sup>5</sup> Fishing.
		B	> 1.0 and ≤ 2.4 mg/L	Some growth effect on up to 5% of species.	
		C	> 2.4 and ≤ 6.9 mg/L	Growth effects on up to 20% of species (mainly sensitive species such as fish). No acute effects.	
		D	> 6.9 mg/L	Impacts on growth of multiple species, and starts approaching acute impact level (i.e. risk of death) for sensitive species at higher concentrations (>20 mg/L).	
	Annual 95 <sup>th</sup> percentile	A	≤ 1.5 mg/L	High conservation value system. Unlikely to be effects even on sensitive species.	
		B	> 1.5 and ≤ 3.5 mg/L	Some growth effect on up to 5% of species.	
		C	> 3.5 and ≤ 9.8 mg/L	Growth effects on up to 20% of species (mainly sensitive species such as fish). No acute effects.	
		D	> 9.8 mg/L	Impacts on growth of multiple species, and starts approaching acute impact level (i.e. risk of death) for sensitive species at higher concentrations (> 20 mg/L).	

<sup>5</sup> Refers to the safe collection of mahinga kai.



Attribute	Statistic	Band	Numeric attribute state	Narrative attribute state	Value(s) supported
<b>Ammonical nitrogen</b>	Annual median*	A	≤ 0.03 mg/L	99% species protection level: No observed effect on any species tested.	Ecosystem Health (toxicity). Significant indigenous species and habitat. Mahinga kai. <sup>5</sup> Fishing.
		B	> 0.03 and ≤ 0.24 mg/L	95% species protection level: Starts impacting occasionally on the 5% most sensitive species.	
		C	> 0.24 and ≤ 1.3 mg/L	80% species protection level: starts impacting regularly on the 20% most sensitive species (reduced survival of most sensitive species).	
		D	> 1.3mg/L	Starts approaching acute impact level (i.e. risk of death for sensitive species).	
	Annual maximum*	A	≤ 0.05 mg/L	99% species protection level: No observed effect on any species tested.	
		B	> 0.05 and ≤ 0.4 mg/L	95% species protection level: Starts impacting occasionally on the 5% most sensitive species.	
		C	> 0.4 and ≤ 2.2 mg/L	80% species protection level: starts impacting regularly on the 20% most sensitive species (reduced survival of most sensitive species).	
		D	> 2.2 mg/L	Starts approaching acute impact level (i.e. risk of death for sensitive species).	

Attribute	Statistic	Band	Numeric attribute state	Narrative attribute state	Value(s) supported
Dissolved oxygen	7-day summer mean minimum#	A	≥ 8.0 mg/L	No stress caused by low dissolved oxygen on any aquatic organisms that are present at matched reference (near-pristine) sites.	Ecosystem Health (toxicity). Significant indigenous species and habitat. Mahinga kai. <sup>5</sup> Fishing.
		B	≥ 7.0 and < 8.0 mg/L	Occasional minor stress on sensitive organisms caused by short periods (a few hours each day) of lower dissolved oxygen. Risk of reduced abundance of sensitive fish and macroinvertebrate species.	
		C	≥ 5.0 and < 7.0 mg/L	Moderate stress on a number of aquatic organisms caused by dissolved oxygen levels exceeding preference levels for periods of several hours each day. Risk of sensitive fish and macroinvertebrate species being lost.	
		D	< 5.0 mg/L	Significant, persistent stress on a range of aquatic organisms caused by dissolved oxygen exceeding tolerance levels. Likelihood of local extinctions of keystone species and loss of ecological integrity.	
	1-day summer minimum#	A	≥ 7.5 mg/L	No stress caused by low dissolved oxygen on any aquatic organisms that are present at matched reference (near-pristine) sites.	
		B	≥ 5.0 and < 7.5 mg/L	Occasional minor stress on sensitive organisms caused by short periods (a few hours each day) of lower dissolved oxygen. Risk of reduced abundance of sensitive fish and macroinvertebrate species.	
		C	≥ 4.0 and < 5.0 mg/L	Moderate stress on a number of aquatic organisms caused by dissolved oxygen levels exceeding preference levels for periods of several hours each day. Risk of sensitive fish and macroinvertebrate species being lost.	
		D	< 4.0 mg/L	Significant, persistent stress on a range of aquatic organisms caused by dissolved oxygen exceeding tolerance levels. Likelihood of local extinctions of keystone species and loss of ecological integrity.	

Attribute	Statistic	Band	Numeric attribute state	Narrative attribute state	Value(s) supported
<b><i>E.coli</i></b>	Annual median	A	≤ 260/100 mL	People are exposed to a very low risk of infection (< 0.1%) from contact with water during activities with occasional immersion and some ingestion of water (such as wading and boating).	Human Health for Recreation. Mahinga kai. <sup>5</sup>
		B	> 260 and ≤ 540/100 mL	People are exposed to a low risk of infection (<1%) from contact with water during activities with occasional immersion and some ingestion of water (such as wading and boating).	
		C	> 540 and ≤ 1,000/100 mL	People are exposed to a moderate risk of infection (<5%) from contact with water during activities with occasional immersion and some ingestion of water (such as wading and boating).	
		D	> 1,000/100 mL	People are exposed to a high risk of infection (>5%) from contact with water during activities with occasional immersion and some ingestion of water (such as wading and boating).	
	95 <sup>th</sup> percentile	A	≤ 260/100 mL	People are exposed to a low risk of infection (≤1%) when undertaking activities likely to involve full immersion.	
		B	> 260 and ≤ 540/100mL	People are exposed to a moderate risk of infection (<5%) when undertaking activities likely to involve full immersion.	
		>MAS	> 540/100 mL	People are exposed to a high risk of infection (>5%) when undertaking activities likely to involve full immersion.	

Attribute	Statistic	Band	Numeric attribute state	Narrative attribute state	Value(s) supported
<b>pH</b>	95 <sup>th</sup> summer percentile#	A	> 6.5 and < 8.0	No stress caused by acidic or alkaline ambient conditions on any aquatic organisms that are present at matched reference (near-pristine) sites.	Ecosystem Health (toxicity). Significant indigenous species and habitat. Mahinga kai. <sup>5</sup> Fishing.
		B	> 6.5 and < 8.5	Occasional minor stress caused by pH on particularly sensitive freshwater organisms (i.e. fish and insects).	
		C	> 6.0 and < 9.0	Stress caused on occasion by pH exceeding preference levels for certain sensitive insects and fish for periods of several hours each day.	
		D	< 6.0 or > 9.0	Significant, persistent stress caused by intolerable pH on a range of aquatic organisms. Likelihood of local extinctions of keystone species and destabilisation of river ecosystems.	
<b>Temperature</b>	Summer Cox-Rutherford Index# for upland areas	A	≤ 18.0°C	No thermal stress on any aquatic organisms that are present at matched reference (near-pristine) sites.	Ecosystem Health (toxicity). Significant indigenous species and habitat. Mahinga kai. <sup>5</sup> Fishing.
		B	≤ 20.0°C	Minor thermal stress on occasion (clear days in summer) on particularly sensitive organisms such as certain insects and fish.	
		C	≤ 24.0°C	Some thermal stress on occasion with elimination of certain sensitive insects and absence of certain sensitive fish.	
		D	> 24.0 °C	Significant thermal stress on a range of aquatic organisms. Risk of local elimination of keystone species with loss of ecological integrity.	

Attribute	Statistic	Band	Numeric attribute state	Narrative attribute state	Value(s) supported
	Summer Cox-Rutherford Index# for lowland areas	A	≤ 19.0°C	No thermal stress on any aquatic organisms that are present at matched reference (near-pristine) sites.	
		B	≤ 21.0°C	Minor thermal stress on occasion (clear days in summer) on particularly sensitive organisms such as certain insects and fish.	
		C	≤ 25.0°C	Some thermal stress on occasion with elimination of certain sensitive insects and absence of certain sensitive fish.	
		D	> 25.0 °C	Significant thermal stress on a range of aquatic organisms. Risk of local elimination of keystone species with loss of ecological integrity.	

\* based on pH 8 and temperature of 20°C.  
# summer period is 1 November to 30 April.

Table 2 Recommended physical and chemical attributes without state bands for rivers.

Attribute	Potential value(s) supported
<b>Sediment related attributes (TSS, deposited sediment, visual clarity, light penetration)</b>	Ecosystem health, significant indigenous species and habitat, human health for recreation, natural form and character, mahinga kai <sup>5</sup> , fishing, municipal and domestic water supply, treated wastewater discharge, urban storm water drainage and assimilation, transport and Tauranga waka, irrigation and cultivation, animal drinking water, commercial and industrial use, influence on other freshwater bodies, influence on coastal waters and receiving environments, influenced by geothermal water
<b>Dissolved inorganic nitrate and dissolved reactive phosphorus</b>	Ecosystem health, natural form and character, treated wastewater discharge, urban storm water discharge and assimilation, commercial and industrial use, influence on other freshwater bodies, influence on coastal waters and receiving environments, influenced by geothermal water.

Table 3 Recommended ecological attributes and state bands for rivers. Shaded attributes are from Appendix II of the NPS-FM (2014). Note also how the biophysical classification is currently only used for invertebrate monitoring. Note the bottom of band C represents the “bottom line”.

Attribute	Statistic	Band	Biophysical classification			Narrative attribute state	Value(s) supported
			Non-volcanic	Volcanic Gentle	Volcanic Steep		
Periphyton <sup>^</sup>	Exceeded no more than 8% of samples (default class)	A	≤ 50 mg chl-a/m <sup>2</sup>			Rare blooms reflecting negligible nutrient enrichment and/or alteration of the natural flow regime or habitat.	Ecosystem Health. Significant indigenous species and habitat. Mahinga kai. <sup>5</sup> Fishing. Human Health for Recreation.
		B	> 50 and ≤ 120 mg chl-a/m <sup>2</sup>			Occasional blooms reflecting low nutrient enrichment and/or alteration of the natural flow regime or habitat.	
		C	> 120 and ≤ 200 mg chl-a/m <sup>2</sup>			Periodic short-duration nuisance blooms reflecting moderate nutrient enrichment and/or alteration of the natural flow regime or habitat.	
		D	> 200 mg chl-a/m <sup>2</sup>			Regular and/or extended-duration nuisance blooms reflecting high nutrient enrichment and/or significant alteration of the natural flow regime or habitat.	
	Exceeded no more than 17% of samples (productive class)	A	≤ 50 mg chl-a/m <sup>2</sup>			Rare blooms reflecting negligible nutrient enrichment and/or alteration of the natural flow regime or habitat.	
		B	> 50 and ≤ 120 mg chl-a/m <sup>2</sup>			Occasional blooms reflecting low nutrient enrichment and/or alteration of the natural flow regime or habitat.	
		C	> 120 and ≤ 200 mg chl-a/m <sup>2</sup>			Periodic short-duration nuisance blooms reflecting moderate nutrient enrichment and/or alteration of the natural flow regime or habitat.	
		D	> 200 mg chl-a/m <sup>2</sup>			Regular and/or extended-duration nuisance blooms reflecting high nutrient enrichment and/or significant alteration of the natural flow regime or habitat.	



Attribute	Statistic	Band	Biophysical classification			Narrative attribute state	Value(s) supported
			Non-volcanic	Volcanic Gentle	Volcanic Steep		
<b>Cyanobacteria – Planktonic (lake-fed rivers)</b>	80 <sup>th</sup> percentile	A	≤ 0.5 mm <sup>3</sup> /L OR ≤ 500 cells/mL			Risk exposure from cyanobacteria is no different to that in natural conditions (from any contact with freshwater).	Human Health for Recreation. Ecosystem Health. Mahinga kai. <sup>5</sup>
		B	N/A			N/A	
		C	> 0.5 and ≤ 1.8 mm <sup>3</sup> /L (potentially toxic) OR > 0.5 and ≤ 10 mm <sup>3</sup> /L (all)			Low risk of health effects from exposure to cyanobacteria (from any contact with freshwater).	
		D	> 1.8 mm <sup>3</sup> /L (potentially toxic) OR > 10 mm <sup>3</sup> /L (all)			Potential health risks (e.g. respiratory, irritation and allergy symptoms) exist from exposure to cyanobacteria (from any contact with freshwater).	
<b>Benthic cyanobacteria</b>	80 <sup>th</sup> percentile	A	Cover < 20%.			Minimal risk exposure from benthic cyanobacteria for 80% of the time.	Ecosystem Health. Significant indigenous species and habitat. Mahinga kai. <sup>5</sup> Fishing. Human Health for Recreation.
		B	N/A				
		C	Cover 20 – 50%			Low risk of health effects or dog deaths from exposure to benthic cyanobacteria for 80% of the time.	
		D	Cover >50%, OR max dislodging and accumulating along river's edge.			Potential health risks from exposure to benthic cyanobacteria, potential risk to dogs walking along river margins.	
<b>Macrophytes</b>	Annual monitoring	A	<50% channel cross-sectional area or volume OR channel water surface area			Aquatic plants will have little adverse effects on recreational, drainage, aesthetic or ecological values.	Ecosystem Health. Significant indigenous species and habitat. Mahinga kai. <sup>5</sup> Fishing. Human Health for Recreation.
			No B band recommended.				
			No C Band recommended.				
		D	>50% channel cross-sectional area or volume OR channel water surface area			Aquatic plants likely to have significant adverse effects to one or more values for recreation, drainage, aesthetics or ecology.	

Attribute	Statistic	Band	Biophysical classification			Narrative attribute state	Value(s) supported
			Non-volcanic	Volcanic Gentle	Volcanic Steep		
<b>Invertebrate communities</b>	Annual monitoring: MCI <sup>6</sup> scores	A	> 120	> 124	> 115	MCI scores typical of healthy and resilient invertebrate communities, similar to natural reference conditions. Indicative of streams in “excellent” ecological condition.	Ecosystem Health.
		B	110 - 120	106 - 124	100 - 115	MCI scores show slight reductions, suggesting loss of some potentially sensitive taxa from what would be expected in a similar reference condition stream. Indicative of streams in “Good” ecological condition.	
		C	100 - 110	88 – 106	87 – 100	MCI scores show moderate impacts, with a more noticeable reduction in the majority of sensitive taxa from what would be expected in a similar reference condition stream. Indicative of streams in “Fair” ecological condition.	
		D	< 100	< 88	< 87	Reduction in MCI scores show large detrimental impacts, with a loss of all sensitive taxa from what would be expected in a similar reference condition stream. Indicative of streams in “Poor” ecological condition.	

<sup>6</sup> The Macroinvertebrate Community Index (MCI) ranks the presence and absence of different invertebrate species in river to give an indication of healthy the river is. MCI scores range from 20 to 200. Scores >120 represent streams in “excellent” condition, while scores < 80 indicate highly degraded streams.

Attribute	Statistic	Band	Numeric attribute state	Narrative attribute state	Value(s) supported	
	Annual monitoring: EPT <sup>7</sup> richness	A	> 12 EPT taxa	> 11 EPT taxa	> 9 EPT taxa	The number of sensitive EPT taxa typical of those found in reference condition streams.
		B	9 - 12 EPT taxa	7 – 11 EPT taxa	6 – 9 EPT taxa	Streams showing a slight reduction in the number of sensitive EPT taxa that are typically found in similar reference condition streams.
		C	6 – 9 EPT taxa	2 – 7 EPT taxa	3 – 6 EPT taxa	Streams showing a moderate reduction in the number of sensitive EPT taxa that are typically found in similar reference condition streams.
		D	< 6 EPT taxa	< 2 EPT taxa	< 3 EPT taxa	Streams showing a large reduction in the number of sensitive EPT taxa that are typically found in similar reference condition streams.
	Annual monitoring: BoP_IBI <sup>8</sup>	A	> 24	> 47	> 18	Streams supporting a range of invertebrate species that are very similar to those found in reference condition streams.
		B	16 - 24	36 - 47	7 - 18	Streams supporting a slightly reduced range of invertebrate species that would be expected in similar reference condition streams.
		C	7 – 16	26 - 36	3 - 7	Streams supporting a moderately reduced range of invertebrate species that would be expected in similar reference condition streams.
		D	<7	< 26	< 3	Streams supporting a greatly reduced range of invertebrate species that would be expected in similar reference condition streams.
<b>^based on monthly sampling over three years</b>						

<sup>7</sup> EPT richness refers to how many different types of invertebrates from the insect orders of mayflies, stoneflies, and caddis flies. Collectively these insects are known as EPT reflecting their scientific names of Ephemeroptera, Plecoptera and Trichoptera respectively. The higher the EPT richness, the healthier the stream is.

<sup>8</sup> The Bay of Plenty Index of Biotic Integrity (BOP\_IBI) is a regionally specific invertebrate index that gives an indication of how healthy a river is. It is a “summary” index that uses between four and six other indices (e.g. EPT richness, % worms, % snails) and is calculated for each biophysical class. It ranges from 0 to 54 (depending on biophysical class) and shows how different each site is to that of reference sites under natural, or “least disturbed” conditions.

Table 4 Recommended physical, chemical, microbiological and ecological attributes and state bands for lakes. Shaded attributes are from Appendix II of the NPS-FM (2014). Note the bottom of band C represents the “bottom line” except for *E.coli* 95<sup>th</sup> percentile attribute states where the bottom of band B represents the “minimum acceptable state”.

Attribute	Statistic	Band	Biophysical classification			Narrative attribute state	Value(s) supported
			Non-volcanic	Volcanic Gentle	Volcanic Steep		
Total nitrogen	Annual average	A	≤ 160 mg/m <sup>3</sup>			Lake ecological communities are healthy and resilient, similar to natural reference conditions.	Ecosystem Health (trophic state). Significant indigenous species and habitat. Mahinga kai. <sup>5</sup> Fishing.
		B	> 160 and ≤ 350 mg/m <sup>3</sup>			Lake ecological communities are slightly impacted by additional algal and plant growth arising from nutrients levels that are elevated above natural reference conditions.	
		C	> 350 and ≤ 750 mg/m <sup>3</sup>			Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrients levels that are elevated well above natural reference conditions.	
		D	> 750 mg/m <sup>3</sup>			Lake ecological communities have undergone or are at high risk of a regime shift to a persistent, degraded state, due to impacts of elevated nutrients leading to excessive algal and/or plant growth, as well as from losing oxygen in bottom waters of deep lakes.	

Attribute	Statistic	Band	Biophysical classification			Narrative attribute state	Value(s) supported
			Non-volcanic	Volcanic Gentle	Volcanic Steep		
	Annual median (polymictic)	A	$\leq 300 \text{ mg/m}^3$			Lake ecological communities are healthy and resilient, similar to natural reference conditions.	
		B	$> 300 \text{ and } \leq 500 \text{ mg/m}^3$			Lake ecological communities are slightly impacted by additional algal and plant growth arising from nutrients levels that are elevated above natural reference conditions.	
		C	$> 500 \text{ and } \leq 800 \text{ mg/m}^3$			Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrients levels that are elevated well above natural reference conditions.	
		D	$> 800 \text{ mg/m}^3$			Lake ecological communities have undergone or are at high risk of a regime shift to a persistent, degraded state, due to impacts of elevated nutrients leading to excessive algal and/or plant growth, as well as from losing oxygen in bottom waters of deep lakes.	
<b>Total phosphorus</b>	Annual median	A	$\leq 10 \text{ mg/m}^3$			Lake ecological communities are healthy and resilient, similar to natural reference conditions.	Ecosystem Health (trophic state). Significant indigenous species and habitat. Mahinga kai. <sup>5</sup>
		B	$> 10 \text{ and } \leq 20 \text{ mg/m}^3$			Lake ecological communities are slightly impacted by additional algal and plant growth arising from nutrients levels that are elevated above natural reference conditions.	
		C	$> 20 \text{ and } \leq 50 \text{ mg/m}^3$			Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrients levels that are elevated well above natural reference conditions.	
		D	$> 50 \text{ mg/m}^3$			Lake ecological communities have undergone or are at high risk of a regime shift to a persistent, degraded state, due to impacts of elevated nutrients leading to excessive algal and/or plant growth, as well as from losing oxygen in bottom waters of deep lakes.	

Attribute	Statistic	Band	Biophysical classification			Narrative attribute state	Value(s) supported
			Non-volcanic	Volcanic Gentle	Volcanic Steep		
<b>Ammoniacal nitrogen</b>	Annual median*	A	≤ 0.03 mg/L			99% species protection level: No observed effect on any species tested.	Ecosystem Health (toxicity). Significant indigenous species and habitat. Mahinga kai. <sup>5</sup> Fishing
		B	> 0.03 and ≤ 0.24 mg/L			95% species protection level: Starts impacting occasionally on the 5% most sensitive species.	
		C	> 0.24 and ≤ 1.3 mg/L			80% species protection level: starts impacting regularly on the 20% most sensitive species (reduced survival of most sensitive species).	
		D	> 1.3 mg/L			Starts approaching acute impact level (i.e. risk of death for sensitive species).	
	Annual maximum	A	≤ 0.05 mg/L			99% species protection level: No observed effect on any species tested.	
		B	> 0.05 and ≤ 0.4 mg/L			95% species protection level: Starts impacting occasionally on the 5% most sensitive species.	
		C	> 0.4 and ≤ 2.2 mg/L			80% species protection level: starts impacting regularly on the 20% most sensitive species (reduced survival of most sensitive species).	
		D	> 2.2 mg/L			Starts approaching acute impact level (i.e. risk of death for sensitive species).	



Attribute	Statistic	Band	Biophysical classification			Narrative attribute state	Value(s) supported
			Non-volcanic	Volcanic Gentle	Volcanic Steep		
<b><i>E.coli</i></b>	Annual median	A	≤ 260/100 mL			People are exposed to a very low risk of infection (< 0.1%) from contact with water during activities with occasional immersion and some ingestion of water (such as wading and boating).	Human Health for Recreation. Mahinga kai. <sup>5</sup>
		B	> 260 and ≤ 540/100 mL			People are exposed to a low risk of infection (<1%) from contact with water during activities with occasional immersion and some ingestion of water (such as wading and boating).	
		C	> 540 and ≤ 1,000/100 mL			People are exposed to a moderate risk of infection (<5%) from contact with water during activities with occasional immersion and some ingestion of water (such as wading and boating).	
		D	> 1,000/100 mL			People are exposed to a high risk of infection (>5%) from contact with water during activities with occasional immersion and some ingestion of water (such as wading and boating).	
	95 <sup>th</sup> percentile	A	≤ 260/100 mL			People are exposed to a low risk of infection (<1%) when undertaking activities likely to involve full immersion.	
		B	> 260 and ≤ 540/100 mL			People are exposed to a moderate risk of infection (<5%) when undertaking activities likely to involve full immersion.	
		>MAS	> 540/100 mL			People are exposed to a high risk of infection (>5%) when undertaking activities likely to involve full immersion.	

Attribute	Statistic	Band	Biophysical classification			Narrative attribute state	Value(s) supported
			Non-volcanic	Volcanic Gentle	Volcanic Steep		
Phytoplankton	Annual median	A	$\leq 2 \text{ mg chl-a /m}^3$			Lake ecological communities are healthy and resilient, similar to natural reference conditions.	Ecosystem Health (trophic state). Mahinga kai. <sup>5</sup> Fishing. Human Health for Recreation.
		B	$>2 \text{ and } \leq 5 \text{ mg chl-a /m}^3$			Lake ecological communities are slightly impacted by additional algal and plant growth arising from nutrient levels that are elevated above natural reference conditions.	
		C	$> 5 \text{ and } \leq 12 \text{ mg chl-a /m}^3$			Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrients levels that are elevated well above natural reference conditions.	
		D	$> 12 \text{ mg chl-a /m}^3$			Lake ecological communities have undergone or at high risk of a regime shift to a persistent degraded state, due to impacts of elevated nutrients leading to excessive algal and/or plant growth, as well as from losing oxygen in bottom waters of deep lakes.	

Attribute	Statistic	Band	Biophysical classification			Narrative attribute state	Value(s) supported
			Non-volcanic	Volcanic Gentle	Volcanic Steep		
	Annual maximum	A	$\leq 10 \text{ mg chl-a /m}^3$			Lake ecological communities are healthy and resilient, similar to natural reference conditions.	
		B	$> 10 \text{ and } \leq 25 \text{ mg chl-a /m}^3$			Lake ecological communities are slightly impacted by additional algal and plant growth arising from nutrient levels that are elevated above natural reference conditions.	
		C	$> 25 \text{ and } \leq 60 \text{ mg chl-a /m}^3$			Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrients levels that are elevated well above natural reference conditions.	
		D	$> 60 \text{ mg chl-a /m}^3$			Lake ecological communities have undergone or at high risk of a regime shift to a persistent degraded state, due to impacts of elevated nutrients leading to excessive algal and/or plant growth, as well as from losing oxygen in bottom waters of deep lakes.	
<b>Cyanobacteria – Planktonic</b>	80 <sup>th</sup> percentile	A	$\leq 0.5 \text{ mm}^3/\text{L}$ OR $\leq 500 \text{ cells/mL}$			Risk exposure from cyanobacteria is no different to that in natural conditions (from any contact with freshwater).	Human Health for Recreation, Ecosystem Health, Mahinga kai <sup>5</sup>
		B	N/A			N/A	
		C	$> 0.5 \text{ and } \leq 1.8 \text{ mm}^3/\text{L}$ (potentially toxic) OR $> 0.5 \text{ and } \leq 10 \text{ mm}^3/\text{L}$ (all)			Low risk of health effects from exposure to cyanobacteria (from any contact with freshwater).	
		D	$> 1.8 \text{ mm}^3/\text{L}$ (potentially toxic) OR $> 10 \text{ mm}^3/\text{L}$ (all)			Potential health risks (e.g. respiratory, irritation and allergy symptoms) exist from exposure to cyanobacteria (from any contact with freshwater).	

Attribute	Statistic	Band	Biophysical classification			Narrative attribute state	Value(s) supported
			Non-volcanic	Volcanic Gentle	Volcanic Steep		
<b>TLI (Burns TLI Classification)</b>		A	≤ 3			Lake ecological communities are healthy and resilient, similar to natural reference conditions.	Ecosystem Health (trophic state). Significant indigenous species and habitat. Mahinga kai. <sup>5</sup>
		B	> 3 and ≤ 4			Lake ecological communities are slightly impacted by additional algal and plant growth arising from nutrients levels that are elevated above natural reference conditions.	
		C	> 4 and ≤ 5			Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrients levels that are elevated well above natural reference conditions.	
		D	> 5			Lake ecological communities are at high risk of a regime shift to a persistent, degraded state, due to impacts of elevated nutrients leading to excessive algal and/or plant growth, as well as from losing oxygen in bottom waters of deep lakes.	
<b>Lake SPI</b>	Changes to calculated Lake SPI scores based on annual or biannual sampling	A	0 – 5 reduction in Lake SPI scores OR an increase in Lake SPI scores			Change to Lake SPI not indicated.	Ecosystem Health (trophic state). Significant indigenous species and habitat. Mahinga kai. <sup>5</sup> Fishing. Human Health for Recreation.
		B	> 5 – 10 change in Lake SPI scores			Change to Lake SPI possible.	
		C	> 10 - 15 change in Lake SPI scores OR new incursion of a more invasive species			Change to Lake SPI probable, OR introduction of new, potentially invasive species.	
		D	> 15 reduction in Lake SPI scores			Change to Lake SPI indicated.	

\*based on pH 8 and temperature of 20°C.

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# Part 1:

## Introduction

### 1.1 Background

The National Policy Statement for Freshwater Management 2014 (NPS-FM; Ministry for Environment, 2014) sets out environmental objectives and policies that direct regional councils (and other local government authorities) to sustainably manage fresh water in an integrated way that provides for use and development (take, use, damming, diversion, discharge of contaminants, land use and development) within water quality and quantity limits to meet clear water quality and quantity objectives.

The NPS-FM sets out two compulsory national values for freshwater: Ecosystem Health; and Human Health for Recreation. For each of these values, attributes are specified in Appendix II of the NPS-FM, which are measurable characteristics of fresh water that support particular values. Policy CA2 of the NPS-FM directs regional councils to identify other attributes that are appropriate for the compulsory national values, and any other national value or other value applied at regional level.

As part of its implementation of the NPS-FM, Bay of Plenty Regional Council (BOPRC) has established a draft set of regional freshwater values which provide a consistent set of titles and definitions for the broad range of freshwater values that are commonly (but not always) relevant in freshwater bodies across the region (Poutassi, 2016). The draft Regional Freshwater Value set includes all national values in the NPS-FM and additional values identified from existing documents and engagement with tangata whenua and community groups. The next step is identifying appropriate and applicable attributes for the values identified.

### 1.2 Purpose of report

The purpose of this report is to recommend an appropriate suite of measurable physical, chemical, microbiological and ecological attributes and, where possible, attribute state bands. These attributes are to be used region-wide by BOPRC to help set measurable objectives to support key values with in-stream water quality or ecology requirements, and to measure their current state.

This report is the first in a series of reports on attributes recognising that significant research is currently underway (both regionally and nationally) and subsequent recommendations for potentially new attributes will be possible as data and information becomes available.

### 1.3 Scope

This report covers freshwater attributes in rivers and lakes, and:

- 1 Identifies attributes in Appendix II of the NPS-FM that are applicable to each freshwater value;
- 2 Identifies other freshwater attributes that are appropriate for each value. Attributes are primarily water quality and ecology attributes.
- 3 Evaluates identified attributes and recommends a core set that will be appropriate to determine the extent to which a value is provided for.
- 4 For each recommended attribute, state bands and “bottom lines” are defined where possible, including both numeric and narrative descriptions wherever possible.
- 5 Considers the implications for monitoring, limit setting and accounting when identifying attributes.
- 6 Focuses on the following freshwater values as the highest priority:
  - (a) Freshwater *Ecosystem Health*.
  - (b) Freshwater requirements for *Significant indigenous species and habitat*.

- (c) *Mahinga Kai is safe to harvest and eat* (in freshwater), and *Fishing*.
- (d) *Human Health for Recreation* (in freshwater for both primary and secondary contact recreation).

Groundwater quality and wetland attributes are being addressed in separate reports. This report focusses solely on 'western' scientific physical, chemical, microbiological and ecological attributes and is one source of information the Council will be considering when setting objectives/limits/targets. Other sources of information being considered include (but not limited to) social, cultural, and economic attributes. The scope of the report only extends to recommending attributes for freshwater. However, consideration has been given to sensitive receiving environments (e.g. estuaries) in evaluating attributes and recommending attribute state bands. It is recognised that there are dynamic relationships between freshwater and estuaries and that estuaries can be sensitive receiving environments as they act as 'sinks' for contaminants. As such, the following sections outline how estuaries and other receiving environments have been considered in this process.

# Part 2:

# Draft Freshwater Management Units

## 2.1 Introduction

A significant challenge faced by councils is that both water quality and quantity naturally vary in water bodies throughout regions, as do the values that these water bodies support. Similarly, there is a large variation in balancing water resource use and the need to maintain other (often competing) values. The NPS-FM requires that regional councils subdivide water bodies within their region into Freshwater Management Units (FMUs). The NPS-FM defines a FMU as “*a water body, multiple water bodies, or any part of a water body determined by a regional council as the appropriate spatial scale for setting freshwater objectives and limits and for freshwater accounting and management purposes*”.

Implicit in this definition is the idea that FMUs are to be established based on how water bodies, or parts of water bodies, are valued. There is interdependence between establishing FMUs and determining the values (and associated objectives) for which they are to be managed. Another aspect of FMUs is that they would, ideally, contain water bodies with a similar capacity for resource use, making it easier to set limits on resource use to minimise adverse environmental effects. BOPRC has developed a biophysical classification of waterways to reflect natural factors that control natural processes in waterways, and a draft objective setting spatial layer to support objective and limit setting. These are discussed below.

BOPRC has divided the region into nine separate Water Management Areas (WMAs) to implement the NPS-FM, with two WMAs already underway: Rangitaiki; and Kaituna, Maketu, Pongakawa and Waitahanui.

## 2.2 Biophysical classification

Snelder et al. (2016) suggested a biophysical classification for water quality in the Bay of Plenty based on the dominant catchment geology and upstream catchment slope. The biophysical classification is comprised of three classes: Non-Volcanic, Volcanic+Steep and Volcanic+Gentle. Stream segments classified as Volcanic were assigned to the Steep category if the average slope of the upstream catchment was greater than 10 degrees and Gentle if the average slope was less than 10 degrees. This biophysical classification is composed of discrete sets of water bodies with similar environmental drivers that regulate the response of the river to resource use.

The advantage of the biophysical classification approach is that it is valid across the region, as it is based on the premise that geology and slope are the proximate driving variables influencing both water quality and ecology (Snelder et al. 2016). For example, catchments draining volcanic material will have more infiltration and lower flood flows than catchments draining non-volcanic material. Nutrient concentrations will also inherently be higher in volcanic catchments due to naturally higher levels of nutrients, particularly phosphorus. Streams draining steep catchments will generally be dominated by large substrate particles, whereas streams draining catchments with gentle slopes will usually have smaller substrates such as pumice. Stream slope and substrate size are likely to be key determinants for habitat and ecological diversity. Defined bands for many ecological attributes can thus be developed based on this biophysical classification, and this will give us greater certainty for developing acceptable bands for each attribute.

Snelder et al. (2016) also emphasised that some water bodies have specific values or management issues that are not discriminated by the management classifications but which may need to be provided for. In these cases, the creation of special FMUs would over-ride the objectives set for the underlying specific biophysical classes. Examples of water bodies requiring special management objectives may be sites of significance such as water bodies with estuary receiving environments, swimming spots, or sites of special cultural or ecological significance. The draft objective setting spatial layer is relevant in this regard.

## 2.3 Draft objective setting spatial layer

The biophysical classification was based on the need to identify water bodies with a similar biophysical response to resource use and does not consider other factors such as different downstream receiving environments, the presence of permanent features such as dams, drains and urban areas, certain land uses, or social and cultural boundaries that may influence current freshwater quality and objectives for freshwater quality. Because of this, a draft objective setting spatial layer has also been developed for water bodies in the Rangitāiki and Kaituna, Maketū, Pongakawa and Waitahanui WMAs. Within the Rangitāiki WMA, three separate draft objective setting spatial layers have been identified, whilst six have been identified in the Kaituna, Maketū, Pongakawa and Waitahanui WMA (Table 5). These draft objective setting spatial layers are presently regarded as draft FMUs.

*Table 5 Draft objective setting spatial layers for the Rangitāiki and Kaituna, Maketū, Pongakawa and Waitahanui WMA.*

WMA	Draft objective setting spatial layers (FMUs)
<b>Rangitāiki</b>	Lower (below Matahina Dam)
	Mid-Upper (above Matahina Dam)
	Natural state/unmodified
<b>Kaituna, Maketū, Pongakawa and Waitahanui</b>	Lower Kaituna/Maketū
	Mid-upper Kaituna/Maketū Estuary Catchment
	Waiari Catchment
	Lower Pongakawa/Waihi Estuary catchments
	Mid upper Pongakawa/Waihi Estuary catchments
	Waitahanui Catchment

The boundaries around each of these draft objective setting spatial layers were developed firstly using judgements by an in-house multi-disciplinary team, and then refined in discussions with community groups. These boundaries reflected a general consensus of where these units supported different ranges of freshwater values and uses. The general aim of the draft objective setting spatial layer is to provide a spatial basis for the community to contribute to setting objectives.

## 2.4 Use of spatial layers

BOPRC will use both the biophysical classification and the draft objective setting spatial layers together to develop their planning framework (refer Figure 1). The biophysical classification will be used to help set bands for different attributes where a distinction between classes is appropriate. Although the current NPS-FM has identified bands for a number of water quality attributes and the ecological attribute periphyton biomass, this report recommends additional attributes that are appropriate for objective setting and monitoring to indicate the extent to which values are supported. For each of these attributes, state/quality bands will be assigned (e.g. A, B, C or D (bottom line)). In some cases, desired attribute bands may differ in each of the biophysical classes, particularly for ecological attributes. An advantage of the biophysical classification approach is that data from throughout the region can be used to create the different bands, thus maximising the information gains from a region wide monitoring network.

Another advantage of this approach is that information from each of the three biophysical classes throughout the region is used to define the bands for those attributes which vary as a result of inherent differences in catchment geology and slope. These bands then form the basis of specific objectives for each FMU. A further advantage of this approach is that specific numerical freshwater objectives can be set for streams even if there is no local data about the current state.

A major challenge with this approach, however, is to ensure that there are enough monitoring sites in each of the potential combinations of the three biophysical classifications and draft FMUs (i.e. draft objective setting spatial layer). This has implications for the ongoing monitoring programme if, for example, there are only one or two monitoring sites in a combination of biophysical classification and draft FMU. In such circumstances, it may be necessary to undertake additional monitoring of extra sites to ensure that freshwater objectives are indeed being met.

# Part 3:

## Draft regional freshwater values

### 3.1 The draft regional freshwater value Set

The draft regional freshwater value set is shown in (Table 6). The full process for developing and compiling the draft regional freshwater values is reported separately (Green and Lee, unpublished). At the time of writing, proposed amendments to the NPS-FM were open for public submission and there may be revision to the draft regional value set based on amendments to the NPS-FM. This report focuses on key physical, chemical, microbiological and ecological attributes that measure the extent to which each of these values are supported.

Table 6 Draft regional freshwater value set. RPS = Regional Policy Statement (BOPRC, 2014), RMA = Resource Management Act (1991), RWLP = Regional Water and Land Plan (BOPRC, 2008).

#### DRAFT overarching Māori cultural values

**Mauri** The essential life force, energy or principle that tangata whenua believe exists in all things in the natural world, including people. Tangata whenua believe it is the vital essence or life force by which all things cohere in nature. When Mauri is absent there is not life. When Mauri is degraded, or absent, tangata whenua believe this can mean that they have been remiss in their kaitiakitanga responsibilities and this affects their relationship with the atua (Māori gods). Mauri can also be imbued within manmade or physical objects (p. 210, RPS).

**Wairua** Spirit (p.212, RPS).

**Mana.**

**Kaitiakitanga** means the exercise of guardianship by the tangata whenua of an area in accordance with tikanga Māori in relation to natural and physical resources; and includes the ethic of stewardship (s.2, RMA).

**Tikanga Māori** customary values and practices (s.2, RMA).

**Manaakitanga.**

**Matauranga.**

**Whanaungatanga.**

**Rangatiratanga.**

**Maramataka.**

These are overarching Māori values intrinsic to Māori society and how they perceive the world, and also defining their “ways of being” and approach to managing natural resources.

While they are much broader than freshwater values, they provide key context around the type of cultural relationship and connections Māori have with water and the wider natural world.

These do not easily lend themselves to being “water quality and quantity measures and state objectives”. However, they are significant in terms of implementation sections 6, 7 and 8 of the RMA and can be acknowledged through the NPS-FM implementation process and policy framework.

Some definitions are incorporated into the RMA, RPS and operative RWLP as noted. Others may be developed.



**DRAFT Regional Freshwater Values**  
*National values are highlighted in yellow (compulsory) and green (additional)*

*Yellow: compulsory national value.*

*Green: additional national value.*

*No highlight: regional value.*

**Te Hauora o te Wai/the health and mauri of water**

**Ecosystem health** – The freshwater management unit supports a healthy ecosystem appropriate to that freshwater body type (river, lake, wetland, or aquifer). In a healthy freshwater ecosystem ecological processes are maintained, there is a range and diversity of indigenous flora and fauna, and there is resilience to change.

Matters to take into account for a healthy freshwater ecosystem include the management of adverse effects on flora and fauna from contaminants, changes in freshwater chemistry, excessive nutrients, algal blooms, high sediment levels, high temperatures, low oxygen, invasive species, and changes in flow regime. Other matters to take into account include the essential habitat needs of flora and fauna and the connections between water bodies. The health of flora and fauna may be indicated by measures of macroinvertebrates.

**Significant indigenous species and habitat** – The freshwater management unit includes habitat for rare, endangered or otherwise significant species and habitat, for part or all their life cycle. This may include birds, plants or aquatic life. For example, native fish spawning sites.

**Te Hauora o te Tangata/the health and mauri of the people**

**Human health for recreation**

***Occasional immersion/secondary contact recreation***

As a minimum, the freshwater management unit will present no more than a moderate risk of infection to people when they are wading or boating or involved in similar activities that involve only occasional immersion in the water. Other contaminants or toxins, such as toxic algae, would not be present in such quantities that they would harm people's health.

***Frequent immersion/primary contact recreation***

In freshwater management units where a community values more frequent immersion in the water such as swimming, white-water rafting or water skiing, the risk of infection will be no more than moderate. In some freshwater management units, the risk of infection to people undertaking any activity would be no greater than what would exist there under natural conditions.

Flows, water clarity and other factors may also be important freshwater characteristics enabling the recreation activity. Activities may include kayaking, white-water rafting, boating and swimming.

**Te Hauora o te Taiao/the health and mauri of the environment**

**Natural form and character** – Where people value particular natural qualities of the freshwater management unit.

Matters contributing to the natural form and character of a freshwater management unit are its visual and physical characteristics that are valued by the community, including its flow regime, colour, clarity, morphology or location.

They may be freshwater management units with exceptional, natural, and iconic aesthetic features, such as iconic waterfalls and puna (springs).

### **Mahinga kai/food gathering, places of food**

**Mahinga kai** – Kai is safe to harvest and eat.

Mahinga kai generally refers to indigenous freshwater species that have traditionally been used as food resources that can be harvested or gathered.

Mahinga kai provide food for the people of the rohe and these sites give an indication of the overall health of the catchment.

For this value, kai would be safe to harvest and eat and knowledge transfer is present (intergenerational harvest). In freshwater management units that are highly valued for providing mahinga kai, the desired species are plentiful enough for long-term harvest and the range of desired species is present across all life stages.

Includes tuna (longfinned eels and shortfinned eels), koura (freshwater crayfish), whitebait, kahawai, watercress, kakahi (freshwater mussels).

**Mahinga kai** – Kei te ora te mauri (the mauri of the place is intact).

For this value, freshwater resources would be available and able to be used for customary use at some places (but not everywhere). In freshwater management units that are highly valued for providing mahinga kai, resources would be available for use, customary practices able to be exercised to the extent desired, and tikanga and preferred methods of harvest and husbandry are able to be practised.

**Fishing** – The freshwater management unit supports fisheries of species allowed to be caught and eaten.

For freshwater management units valued for fishing, the numbers of fish would be sufficient and suitable for human consumption. In some areas, fish abundance and diversity would provide a range in species and size of fish, and algal growth, water clarity and safety would be satisfactory for fishers. Attributes will need to be specific to fish species such as salmon, trout, eels, lamprey, or whitebait. Includes tuna, koura, whitebait, trout.

**Game birds** – the freshwater management unit provides habitat for game birds that are allowed to be harvested.

### **Wai Māori/municipal waters and domestic water supply**

**Municipal and domestic water supply** - The freshwater management unit can meet people's potable water needs.

Water quality and quantity would enable domestic water supply to be safe for drinking with, or in some areas without, treatment.

**Treated wastewater discharge** - the freshwater management unit accommodates receipt and transportation of treated municipal wastewater discharge from urban areas, directed to a water body, as part of a municipal wastewater network.

**Urban stormwater drainage and assimilation** – the freshwater management unit sustains the receipt and transportation of stormwater runoff from urban areas (particularly impervious surfaces), directed to a water body in order to protect the urban areas from flood nuisance and risk to public safety and infrastructure. This can affect the hydrology of water bodies downstream and also contribute contaminants typical of urban sources.

### **He ara haere/navigation**

**Transport and tauranga waka** – The freshwater management unit is navigable for identified means of transport.

Transport and tauranga waka – The freshwater management unit is navigable for identified means of transport.

Water quality and quantity in the freshwater management unit would provide for navigation. The freshwater management unit may also connect places and people including for traditional trails and rites of passage, and allow the use of various craft.

### **Mahi māra/cultivation**

**Irrigation and cultivation** – The freshwater management unit meets irrigation needs.

Water quality and quantity would be suitable for irrigation needs, including supporting the cultivation of food crops, the production of food from domesticated animals, non-food crops such as fibre and timber, pasture. Attributes will need to be specific to irrigation and food production requirements.

**Animal drinking water** – The freshwater management unit meets the needs of stock.

Water quality and quantity would meet the needs of stock, including whether it is palatable and safe.

### **Āu Putea/Economic or commercial development**

**Commercial and industrial use** – The freshwater management unit provides economic opportunities to people, businesses and industries.

Water quality and quantity can provide for commercial and industrial activities. Attributes will need to be specific to commercial or industrial requirements.

The freshwater management unit sustains water take, use, damming and diversion for commercial and industrial activities

The freshwater management unit sustains the receipt, dilution and transportation of contaminants from industrial and commercial point source discharges, including discharges from wash down associated with primary production. This applies to water bodies downstream of discharges.

**Hydro-electric power generation** – The freshwater management unit is suitable for hydro-electric power generation.

Water quality and quantity and the physical qualities of the freshwater management unit, including hydraulic gradient and flow rate, provides for hydro-electric power generation.

### **Flood water conveyance**

**Flood protection and control** – One or more flood protection and drainage scheme/s designed to reduce flood hazard or inundation of rural land or nearby settlements exists in the freshwater management unit.

### **Wai Tapu/sacred waters**

**Wai tapu** – Wai tapu are places where rituals and ceremonies are performed.

Rituals and ceremonies include, but are not limited to, tohi (baptism), karakia (prayer), waerea (protective incantation), whakatapu (placing of raahui), whakanoa (removal of raahui), and tuku iho (gifting of knowledge and resources for future generations).

In providing for this value, the wai tapu would be free from human and animal waste, contaminants and excess sediment, with valued features and unique properties of the wai protected to some extent. Other matters that may be important are that identified catchments have integrity (there is no artificial mixing of the wai tapu) and identified taonga in the wai are protected.

Accessibility is also a factor.

### **Korero tuturu/sites or areas of cultural and historical significance**

#### **Sites of cultural significance**

The freshwater management unit includes korero tuturu, taonga, heritage sites, archaeological sites and the like that are of particular cultural significance generally, or specifically to Maori, which may be affected by water quality or quantity.

### Kaitiakitanga/historical relationships

**Cultural heritage and connection** – including the likes of heritage connections, whakapapa, whanaungatanga, ngā taniwha, kinship significant specifically to Māori, or also to non-Maori. Some water bodies provide iwi/hapū a strong sense of identity and connection with the land and water.

Respective iwi/hapū understood the functional relationships with and between all parts of the rivers, spiritually and physically. Iwi strive to maintain and restore these relationships despite the past artificial modifications along the rivers.

Certain iwi and hapū (with mana whenua and ahi kaa) have a special kaitiaki relationship with the freshwater management unit. Treaty of Waitangi Settlement Claims in the Bay of Plenty region demonstrated many iwi and hapū have unique and intergenerational relationships with specific rivers/lakes/streams/waterfalls/wetlands/estuaries.

### Rawa Tuturu/Customary resources

**Rawa Tuturu** – Kei te ora te mauri (the mauri of the place is intact).

For this value, freshwater management unit includes (or used to include) important customary resources (other than food, commercial and industrial uses) at some places (but not everywhere) for tangata whenua. Such resources may include those needed for customary cleaning, rongoa (medicine), healing, waahi taonga mahi a ringa (arts and craft supply) and building. Resources would be available for use, customary practices able to be exercised to the extent desired, and tikanga and preferred methods, able to be practised.

### Influence on other freshwater bodies

**Base flow/quantity** - The freshwater management unit plays a natural role in sustaining flow/water levels of another water body including springs. For example groundwater discharging to a river, groundwater springs supplying a wetland, or wetlands moderating flood flows in a river.

**Water quality** - The freshwater management unit discharges to another freshwater body and can affect the water quality of that water body. For example groundwater discharging to a river, wetlands “cleaning” water before it flows into a river, rivers discharging to wetlands or lakes.

Where these values and connections are present, the freshwater management unit will need to be managed to achieve the objectives of the water body it influences.

### Moana/Influence on sensitive coastal waters and receiving environments

The freshwater management unit discharges to a coastal receiving environment that is sensitive to freshwater quantity and quality inputs. This includes estuaries and harbours. Sensitivity may relate to many values in the coastal water body. In particular:

Biological diversity and ecosystem health, including habitat for particular species (rare, endangered etc.), natural features and landscapes, water based recreational activities, natural character, cultural values including kai moana, (e.g. flounder and shellfish) and tauranga waka.

*The management of coastal waters and receiving environments is not within scope of the NPS-FM.* The focus here is on integrated management and managing the connections between freshwater and coastal water bodies, i.e. freshwater quality and quantity objectives at the point of discharge to an estuary/harbour would respond to objectives for that estuary/harbour.

### Influences on/by geothermal heat

Freshwater bodies in the freshwater management unit interact with a geothermal water body.

**Influences on geothermal heat:** Take and use of the freshwater may affect the heat of the geothermal resource.

**Influenced by geothermal water:** The freshwater bodies affected by geothermal inputs. *The management of geothermal water bodies is not within scope of the NPS-FM.* The focus here is on integrated management and managing the connections between freshwater and geothermal water bodies.

# Part 4:

## Attribute prioritisation process

### 4.1 Introduction

Attributes are defined in the NPS-FM as:

*“a measurable characteristic of freshwater, including physical, chemical and biological properties, which supports particular values.”*

The non-exhaustive list of attributes provided in the NPS-FM to meet compulsory national values are shown in Table 7. For all of the values contained in the draft regional freshwater value set (refer Table 6), including the values in the NPS-FM, BOPRC has considered a range of potential ‘western’ scientific attributes that could be used to indicate the extent to which the value is being provided for.

*Table 7 Compulsory National Values and attributes to determine the extent to which a value is supported (sourced from the NPS-FM, 2014).*

Value	Attribute	Water body type
<b>Ecosystem Health</b>	Phytoplankton (trophic state)	Lakes
	Total Nitrogen (trophic state)	Lakes
	Total Phosphorus (trophic state)	Lakes
	Periphyton (trophic state)	Rivers
	Nitrate (toxicity)	Rivers
	Ammonia (toxicity)	Rivers
	Dissolved Oxygen	Rivers (below point sources)
<b>Human Health for Recreation</b>	<i>Escherichia coli (E.coli)</i>	Lakes and Rivers
	Cyanobacteria – Planktonic	Lakes and lake-fed Rivers

## 4.2 Links between draft FMUs, values and attributes

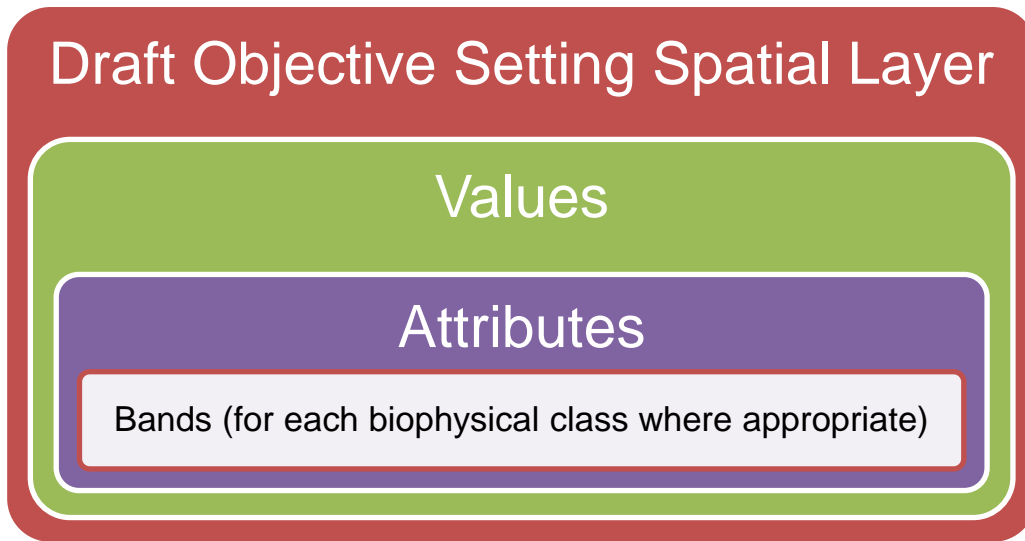


Figure 2 Relationship between draft FMUs, values and attributes.

## 4.3 Criteria for evaluating and prioritising attributes

Policy CA2 of the NPS-FM suggests that attributes laid out in its Appendix II are to be used to express “freshwater objectives” (e.g. periphyton biomass or planktonic cyanobacteria). Other attributes in the Appendix II of the NPS-FM are more useful to set specific limits (e.g. nutrients) to help achieve measurable freshwater objectives. We thus define two different attribute types: “objective-setting” and “limit-setting”. Differences between these attribute types are that objective-setting attributes define the “state” we want to meet to achieve a particular value, while limit-setting attributes are used as a one of several “means” or “levers” to achieve that state. For example, if we value “healthy waterways”, we can set specific objectives that aim to achieve a specific periphyton biomass, or a Macroinvertebrate Community Index (MCI) score that is appropriate for a stream’s biophysical class that meet this value. Other attributes such as nutrients (dissolved inorganic nitrogen and dissolved reactive phosphorus) are the “means” to help achieve a particular periphyton biomass, which in turn will maintain a healthy ecosystem. This emphasises that fact that, with the exception of very high levels of nutrients such as ammonia or nitrate at which toxic effects can occur, a stream’s nutrient concentration would be of little concern as long as periphyton biomass is not adversely affecting specific values. In these examples, the primary objective is the maintenance of healthy waterways which is determined by measuring periphyton and invertebrate communities, while setting specific numerical limits on nutrients is just one way of achieving this objective.

In addition to the compulsory attributes in Appendix II of the NPS-FM, many other attributes could be relevant for measuring the extent to which freshwater values are supported in rivers and lakes. Moreover, any particular attribute may be relevant for more than one value. Because it is not realistic to monitor all possible attributes, we developed a scoring criterion to rank and prioritise each attribute for the Bay of Plenty region.

All attributes (i.e. all those potentially useful for setting objectives and/or associated limits) were ranked according to the following seven criteria, where they were assigned a score ranging from 1 (low weighting) to 3 (high weighting). Individual scores were then summed to determine an overall ranking for each attribute.

**1 The number of values it relates to**

This criterion evaluated how relevant each attribute was to each value. Three levels of relevance were identified: directly related to a value (e.g. nitrate directly related to ecosystem health in terms of toxicity to aquatic organism); not related (e.g. nitrate is not related to hydro-electric power generation), or linked (e.g. nitrate is linked to transport and Tauranga waka because of the potential for nuisance aquatic plant growth, but it is not a direct measure for transport and Tauranga waka). The number of values each attribute was directly related to was assigned a rank score of 1 ( $\leq 10$  values); 2 (11 – 15 values); 3 ( $> 15$  values).

**2 Does the attribute respond in a predictable way to stressors/pressures and limit setting?**

This criterion evaluated whether the attribute responded in a predictable way to stressors/pressures (e.g. water temperature responds to climatic/seasonal changes and the amount of sunlight reaching the water body) and whether setting limits (to meet objectives) would directly influence the attribute (e.g. effective riparian management could increase shade across a water body and reduce peak summer water temperatures).

**3 Can the attribute be measured (both spatially and temporally)?**

This criterion evaluated how easy or difficult the attribute was to measure in both the spatial and temporal spheres. For example, electrical conductivity is easy to measure at different times and across the region with handheld water quality meters, and generally does not change over a diurnal period. In contrast, although dissolved oxygen can easily be measured with meters, it displays often pronounced natural diel cycles, and as such requires continually logging sensors to be deployed in water bodies for extended periods of time (i.e. days to months).

**4 Cost of measurement**

This criterion evaluated how expensive the attribute is to measure. For example, it is not expensive to obtain measurements of water clarity either by water sample and subsequent lab analysis, black disk or Secchi disk methods. Obtaining accurate suspended solid samples across a range of different flow conditions to generate accurate sediment loads is, in contrast, an expensive task requiring permanent structures, sensors and high levels of sampling and maintenance.

**5 Responds to factors that Council has a mandate to control**

This criterion is evaluated by the ability Council has to control (by way of objectives, policies, rules or methods in a plan) activities that could directly influence the attribute. For example, Council can implement rules, methods and action plans to improve riparian management to remove stock access to waterways and reduce direct contamination of animal waste (and *E. coli*) into waterways. In contrast, Council has no mandate to control the conductivity or salinity in a water body where it is influenced by natural factors (e.g. marine water), or to regulate recreational fishing activities, even though these may be having detrimental effects on fish stocks.

**6 Can be summarised by well-researched, clear and defensible thresholds/indices**

This criterion evaluated whether the attribute had well-researched, clear and defensible thresholds or indices to define it. For example, biotic indices such as the MCI have clearly defined thresholds/bands that indicate the health of an ecosystem on a scale from Poor to Excellent. Biochemical oxygen demand, however, only has a single recommended threshold for protection of aquatic organisms.

**7 Is defensible and transparent and the data is robust.**

This criterion evaluated how robust the Councils' monitoring data was for the attribute (both spatially and temporally) and the ability to defend the use of the attribute and associated bands in setting limits. For example, ammoniacal-nitrogen is an attribute prescribed in Appendix II of the NPS-FM for the protection of Ecosystem Health. This is also an attribute that is routinely measured at Council's water quality monitoring networks, with some records dating back to 1989. Ammoniacal-nitrogen is consequently a robust, transparent and defensible attribute.

Other attributes, such as deposited sediment, are only sporadically monitored by the Council, so the data is not robust. Moreover, although deposited sediment does have important ecological implications, little is known of the spatial and temporal dynamics of deposited sediment in unmodified streams, so it would be difficult to assess the effects of human activities on this attribute at this time. Attempting to create limits for this attribute at this stage would thus not be defensible.



# Part 5:

## Physical, chemical and microbiological attributes and bands

### 5.1 Introduction

This section outlines the potential physical, chemical and microbiological attributes that could be used, provides some examples of how the attributes have been used by (or recommended to) some other councils, and provides recommendations for physical, chemical and microbiological attributes for both rivers and lakes in the Bay of Plenty region. Whilst this review is not exhaustive, it highlights some of the major attributes and suggested limits that some other councils throughout the country have used.

The list of attributes was composed based on existing monitoring (Scholes and McIntosh, 2009, Scholes and Hamill, 2016, Scholes et al., 2016), current standards/guidelines (see Appendix 1), results from gap analyses (Suren et al., 2016, Carter et al., 2016), recommendations/usage by some other councils (e.g. Clapcott and Hay, 2014, Ausseil 2013a and 2013b, Horizons Regional Council, 2014, Gisborne District Council, 2015) and current research direction (e.g. Hickey et al., 2016, Robertson et al., 2016a and 2016b).

A summary of relevant existing water quality guidelines or standards that have been used as part of attribute evaluation is provided in Appendix 1.

### 5.2 Attribute evaluation

All the physical, chemical and microbiological attributes were considered as “limit-setting” attributes (refer Section 4.3), were assessed against the evaluation criteria developed in Section 4.3, and the results are shown in the Table 8 and Table 9 below.

As the scope of this report focussed on ‘western’ scientific attributes, five of the cultural values listed in Table 8 have not been evaluated, but should be evaluated in future by relevant specialists. If there is a future requirement to apply ‘western’ scientific attributes to cultural values, then this needs to be done in conjunction with our iwi and hapū partners.

Table 8 Relationship between attributes and freshwater values. Attributes shaded green apply to rivers and lakes. Attributes shaded orange apply to lakes only. Values shaded yellow represent cultural values which are outside the scope of this report. N=Not a direct measure of value, Y=a direct measure of value, L=linked to value but not a direct measure.

	Attributes																								
	Physical										Chemical								Biological						
Values	DO	BOD	pH	T	Conductivity/ Salinity	Colour	TSS	Turbidity	Clarity	Deposited Sediment	NO <sub>3</sub> -N	NO <sub>2</sub> -N	NH <sub>4</sub> -N	DRP	DIN	TN	TP	TLI	Metals	Pesticides	E. coli	Enterococci	Faecal Coliforms		
Overarching Māori values	<b>Te Hauora o te Wai/the health and mauri of water</b>																								
	Ecosystem health	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	L	L	L	
	Significant indigenous species and habitat	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	L	L	L	L	L	L	L	L	L	L	L	
	<b>Te Hauora o te Tangata/the health and mauri of the people</b>																								
	Human health for recreation (secondary contact)	L	L	N	N	N	N	L	L	Y	Y	Y	Y	Y	L	L	L	L	L	N	Y	Y	Y	Y	Y
	Human health for recreation (primary contact)	L	L	Y	Y	N	N	L	L	Y	Y	Y	Y	Y	L	L	L	L	L	N	Y	Y	Y	Y	Y
	<b>Te Hauora o te Taiao/the health and mauri of the environment</b>																								
	Natural form and character	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y
	<b>Mahinga kai/food gathering, places of food</b>																								
	Mahinga Kai – Kai is safe to harvest and eat	L	L	Y	Y	N	N	L	L	Y	L	Y	Y	Y	L	L	L	L	L	L	Y	Y	Y	Y	Y
	Mahinga Kai – Kei te or ate mauri (the mauri of the place is intact)																								
	Fishing	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	L	L	L	L	L	L	L	L	L	L	L
	Game birds	N	N	L	L	N	N	L	L	L	L	L	L	L	L	L	L	L	L	L	L	N	N	N	N

Values	Attributes																								
	Physical										Chemical								Biological						
	DO	BOD	pH	T	Conductivity/ Salinity	Colour	TSS	Turbidity	Clarity	Deposited Sediment	NO <sub>3</sub> -N	NO <sub>2</sub> -N	NH <sub>4</sub> -N	DRP	DIN	TN	TP	TLI	Metals	Pesticides	E. coli	Enterococci	Faecal Coliforms		
<b>Wai Māori/municipal waters and domestic water supply</b>																									
Municipal and domestic water supply	N	N	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	N	N	N	N	N	Y	Y	Y	Y	Y	L	
Treated wastewater discharge	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
Urban stormwater drainage and assimilation	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
<b>He ara haere/navigation</b>																									
Transport and Tauranga waka	N	N	N	N	N	N	L	L	N	Y	L	L	L	N	N	N	N	N	N	N	N	N	N	N	
<b>Mahi mara/cultivation</b>																									
Irrigation and cultivation	N	N	Y	Y	Y	N	L	Y	N	N	L	L	L	L	L	L	L	L	L	L	Y	Y	Y	L	L
Animal drinking water	N	N	Y	N	Y	N	Y	N	N	N	Y	Y	Y	N	N	N	N	N	N	Y	Y	Y	L	Y	
<b>Au Putea/Economic or commercial development</b>																									
Commercial and industrial use	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
Hydro-electric power generation	N	N	L	L	L	N	L	N	N	L	L	L	L	L	L	L	L	L	L	L	N	N	L	L	L
<b>Flood water conveyance</b>																									
Flood protection and control	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
<b>Wai tapu/sacred waters</b>																									
Wai tapu																									

Values	Attributes																							
	Physical										Chemical								Biological					
	DO	BOD	pH	T	Conductivity/ Salinity	Colour	TSS	Turbidity	Clarity	Deposited Sediment	NO <sub>3</sub> -N	NO <sub>2</sub> -N	NH <sub>4</sub> -N	DRP	DIN	TN	TP	TLI	Metals	Pesticides	E. coli	Enterococci	Faecal Coliforms	
<b>Kōrero tuturu/sites or areas of cultural and historical significance</b>																								
Sites of cultural significance																								
<b>Kaitiakitanga/historical relationships</b>																								
Cultural heritage and connection																								
<b>Rawa Tuturu/customary resources</b>																								
Rawa tuturu																								
<b>Influence on other freshwater bodies</b>																								
Base flow/quantity	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Water quality	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
<b>Moana/influence on sensitive coastal waters and receiving environments</b>																								
	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
<b>Influences on/by geothermal heat</b>																								
Influences on geothermal water	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Influenced by geothermal water	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Number of values attribute appropriate to	10	10	15	14	13	9	12	12	13	14	15	15	15	8	8	8	8	7	14	13	12	10	10	
Scoring of values	2	2	3	2	2	1	2	2	2	2	3	3	3	1	1	1	1	1	2	2	2	2	2	

Table 9 Evaluation of attributes against assessment criteria. Attributes shaded orange apply to lakes only. Values shaded yellow represent cultural values which are outside the scope of this report. Scoring system: 1 = Low/Expensive/Poor, 2 = Medium/Moderate/Fair, 3=High/Cheap/Good.

	Attributes																						
	Physical										Chemical										Biological		
	DO	BOD	pH	T	Conductivity/ Salinity	Colour	TSS	Turbidity	Clarity	Deposited Sediment	NO <sub>3</sub> -N	NO <sub>2</sub> -N	NH <sub>4</sub> -N	DRP	DIN	TN	TP	TLI	Metals	Pesticides	E. coli	Enterococci	Faecal coliforms
Values	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Responds	2	3	2	3	2	1	2	2	3	2	3	3	3	3	3	2	2	3	2	2	3	3	3
Ease	2	2	2	2	3	3	3	3	3	2	3	3	3	3	3	3	3	3	3	2	3	3	3
Cost	2	3	3	3	3	3	3	3	3	1	3	3	3	3	3	3	3	2	2	2	3	3	3
Mandate	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Indices	3	1	2	2	1	1	1	1	2	1	3	2	3	1	2	3	3	3	3	2	3	3	1
Defensible	2	1	2	2	2	3	1	2	2	1	3	1	3	2	2	3	3	3	2	2	3	3	3
<b>SUM</b>	<b>14</b>	<b>13</b>	<b>14</b>	<b>15</b>	<b>14</b>	<b>14</b>	<b>13</b>	<b>14</b>	<b>16</b>	<b>10</b>	<b>18</b>	<b>15</b>	<b>18</b>	<b>15</b>	<b>16</b>	<b>17</b>	<b>17</b>	<b>17</b>	<b>15</b>	<b>13</b>	<b>18</b>	<b>18</b>	<b>16</b>

## 5.3 Physical attributes

### 5.3.1 Dissolved oxygen (DO)

Dissolved oxygen (DO) is a measure of how much oxygen is dissolved in the water. Oxygen is needed in aquatic ecosystems to support life. Stream ecosystems both produce and use oxygen, and this occurs on a diel (daily) cycle. Oxygen is provided to streams from the air, and also from aquatic plants as a by-product of photosynthesis. Consequently, during the day oxygen levels reach their peak with peak photosynthetic activity. Conversely, oxygen is consumed within a stream by aquatic animals and plants as they respire, and as organic matter (e.g. leaves, twigs) decompose. Additionally, waste that is discharged into a river (e.g. from industry, urban or agricultural stormwater) can also contain contaminants that consume oxygen. Subsequently, during the night (when there is no photosynthesis to replenish oxygen levels), oxygen levels reach their minimum levels just before dawn.

In lakes, DO levels often change dramatically with depth when a lake stratifies during warmer summer months. When a lake is stratified, the top water layer (called the epilimnion) and the bottom layer (called the hypolimnion) are separated by a thermocline. If the hypolimnion becomes devoid of oxygen in monomictic (stratified) lakes, nutrients (nitrogen and phosphorus) can be released from sediment into the water column, diffusing throughout the whole lake when mixing occurs at the onset of winter. The rate at which oxygen is lost, the Hypolimnetic Volumetric Oxygen Depletion rate (HVOD) is a measure of lake quality. If a lake becomes more productive (eutrophic), organic enrichment of lake sediments can occur which in turn can increase the oxygen demand of a lake or HVOD. To date HVOD has not been used as a targeted measure in New Zealand but has been used in tandem for other measures such as the trophic level index to assess lake water quality. HVOD or oxygen degradation rate could be used as a measure of lake health and could be aligned to the trophic level index classification. In the case of more eutrophic lakes this could require intensive or continuous monitoring to evaluate. Changes to the HVOD are linked to eutrophication of the lake and hence are linked to the TLI parameters of TN, TP and chlorophyll-a. As changes in dissolved oxygen are primarily a result of changes to these stressors, lake health would be better served by setting limits on these TLI parameters.

Table 10 summarises how the DO attribute has been used by some other councils around New Zealand.

*Table 10 Examples of DO attribute and numeric thresholds/guidelines from some other councils.*

Attribute	Numeric Threshold/ Guideline	Water body	Council
<b>DO (daily min)</b>	≥ 6 mg/L at all times	Rivers	Recommended to Marlborough District Council (Clapcott and Hay, 2014).
<b>DO (7-day mean)</b>	≥ 7.5 mg/L at all times	Rivers	
<b>DO</b>	Overall range > 60-80%*	Rivers	Horizons Regional Council, (2014).
<b>DO (1 day min from 1 Nov to 30 Apr)</b>	Band A: ≥ 7.5 mg/L Band B: ≥ 5.0 < 7.5 mg/L Band C: ≥ 4.0 < 5.0 mg/L Band D: <4.0 mg/L	Rivers	Gisborne District Council (2015).
<b>DO (daily min from 1 Nov to 30 Apr)</b>	Overall range 7-8 mg/L*	Rivers	Northland Regional Council (2016).
<b>DO (7-day mean min from 1 Nov to 30 Apr)</b>	Overall range 5-8 mg/L*	Rivers	
<b>DO (minimum 95<sup>th</sup> percentile)</b>	Overall range 80-90%* Overall range 6.2-7.3 mg/L	Coastal waters	
<b>DO (daily min)</b>	Overall range 60-80%*	Rivers	Recommended to Greater Wellington Regional Council (Ausseil 2013b).

\* Target/standard varies for different zones/units/water bodies/classifications\.

DO is currently an attribute contained in Appendix II of the NPS-FM for protecting the value of Ecosystem Health in rivers (MfE, 2014), and is to be measured downstream of point-source discharges. This recognises the higher demand on oxygen that can result from organic matter in discharge water (Davies-Colley et al., 2013). The numeric attribute state bands for DO in the NPS-FM are based on documented observations of impacts to fish species (Davies-Colley et al., 2013). The NPS-FM statistics for DO are Daily Minimum concentration, and a 7-day Mean Minimum concentration in recognition of short-term exposure/acute impacts and long-term exposure/chronic impacts respectively (Davies-Colley et al., 2013). The monitoring period for DO applies during the warmest part of the year when DO variations are likely to be at their greatest (1 November to 30 April). It is recommended that this attribute be applied to all rivers and streams in the Bay of Plenty. This could require more extensive use of continuous DO monitoring in the region, however sites could be prioritised based on a comprehensive risk assessment and use of modelling.

Recommendation: Use the DO attribute as specified in Appendix II of the NPS-FM for the protection of Ecosystem Health, Significant Indigenous Species and Habitat, Mahinga Kai (collection only) and Fishing values in rivers, and extend coverage to all rivers. Note that a risk assessment could be undertaken to determine rivers at high-risk for low DO in order to prioritise where sensors should be located. This makes best use of resources by prioritising to high-risk waters.

### 5.3.2 Biochemical Oxygen Demand (BOD)

The biochemical oxygen demand (BOD) is the amount of oxygen needed by aerobic organisms to break down the organic material in a water sample. The BOD is often expressed as the amount of oxygen consumed per litre of sample during five days incubation at 20°C. The BOD can give an indication of organic enrichment in streams. Table 11 summarises how the BOD attribute (as soluble carbonaceous BOD<sub>5</sub>) has been used by some other councils around New Zealand.

Table 11 *Examples of biochemical oxygen demand attribute and numeric thresholds/guidelines from some other councils.*

Attribute	Numeric Threshold/Guideline	Water body	Council
scBOD <sub>5</sub>	<2 mg/L river flows < median	Rivers	Recommended to Marlborough District Council (Clapcott and Hay, 2014)
scBOD <sub>5</sub> (monthly average)	1.5-2 mg/L* river flows <20 <sup>th</sup> percentile	Rivers	Horizons Regional Council, (2014)
scBOD <sub>5</sub> (max daily average)	2 mg/L river flows < median (year round)	Rivers	Recommended to Greater Wellington Regional Council (Ausseil 2013b)

\* Target/standard varies for different zones/units/water bodies/classifications

BOD concentrations in most Bay of Plenty rivers were found to be below the detection limit of 2 mg/L. As such this measure was not found to be very useful under normal flow conditions and was removed from the NERMN programme in 2009 with the exception of the Tarawera and Kaituna rivers.

As the environmental risk from toxicants is often associated with point source discharges, or controlled as an infrastructure based activity where multiple contaminants might be found (i.e. stormwater discharges), BOD should only be considered where point source discharges with potential for elevated BOD loads in the discharge occur, and as such, the status quo planning approach could be maintained, which is to address BOD on a case by case basis through discharge consenting.

### 5.3.3 pH

The variable pH is a measure of the concentration of hydrogen ions in water and defines how acidic or alkaline conditions are, as well as regulating the toxicity of many other pollutants (e.g. ammonia). The pH scale is logarithmic (base 10) and ranges from 0 to 14, low pH being acidic and high pH being alkaline; pH of 7 is neutral. Freshwater lakes, ponds and streams usually have a pH of 6 - 8 depending on the surrounding soil and bedrock (Lenntech, 2013). In deeper lakes where stratification (layering) occurs, the pH of water is generally higher (7.5 - 8.5) near the surface and lower (6.5 - 7.5) at greater depths. A slight change in the pH of water can increase the solubility of phosphorus and other nutrients, making them more accessible for plant growth. With more accessible nutrients, aquatic plants and algae thrive, increasing the demand for dissolved oxygen.

Like temperature and DO, pH can exhibit appreciable change over 24 hours (diel variation) in response to changes in water temperature, photosynthetic uptake of carbon dioxide by aquatic plants and decay of organic substances. In freshwater, pH and DO maxima occur with the maximum photosynthetic activity in the late afternoon, and minimum pH levels occur in the early morning, due to the dominance of plant respiration (Davies-Colley et al, 2013).

The range of tolerances of aquatic species to pH has been tested in several studies internationally and for native New Zealand species (West et al, 1997; Collier et al, 1990; Winterbourne and Collier, 1987). While some species of fish and aquatic insects are found in low pH water of humic-stained streams, laboratory tests indicate adult fish avoid water below pH of 6.5 and above 9.5 (with the exception of inanga). Table 12 summarises how the pH attribute has been used by some other councils around New Zealand.

*Table 12 Examples of pH attribute and numeric thresholds/guidelines from some other councils.*

Attribute	Numeric Threshold/Guideline	Water body	Council
<b>pH range</b>	6.5 - 8.5 at all times	Rivers	Recommended to Marlborough District Council (Clapcott and Hay, 2014)
<b>pH change</b>	± 0.5 at all times	Rivers	
<b>pH range</b>	Overall range 7 - 8.5*	Rivers	Horizons Regional Council, (2014)
<b>pH change</b>	0.5 for all sub-zones	Rivers	
<b>pH</b>	Band A: 6.5 - 8.0 Band B: 6.5 - 8.5 Band C: 6 - 9 Band D: < 6 or > 9		Gisborne District Council (2015)
<b>pH</b>	Overall range: 7 - 8.5*	Coastal waters	Northland Regional Council (2016)
<b>pH</b>	Overall range 5.8 - 8.9*	Rivers	Recommended to Greater Wellington Regional Council (Ausseil 2013b)

\* Target/standard varies for different zones/units/water bodies/classifications.

Monitoring shows Bay of Plenty streams ranging from an average pH of 6.7 to 8.1 (2011-2016 data). Geothermal influences and areas dominated by algae or aquatic vegetation will also influence pH, with geothermal water being less than pH 6, and littoral zones during aquatic vegetation growth reaching pH greater than 11.



Prior to the Resource Legislation Amendment Act (2017), a pH range of 6 to 9 was required to meet the Schedule 3 Resource Management Act (1991) water supply class, and no change in pH is the standard for aquatic ecosystem purposes. Davies-Colley et al (2013) has built on this framework to represent an increasing gradient of ecological stress from a no stress band 'A', to significant, persistent stress in 'D' band. The framework should apply throughout the diel (24-hour) regime of pH measurements and not just to the narrower range of daytime 'spot' measurements that are commonly reported and is recommended for the Bay of Plenty (Table 13). This could require more extensive use of continuous pH monitoring in the region, however sites could be prioritised based on a comprehensive risk assessment and use of modelling.

*Table 13 Attribute table for pH regimes in rivers and streams, recommended for inclusion in the NPS-FM. The term regime refers to the diel fluctuation of pH (and co-variation with temperature and dissolved oxygen) around the daily mean (from Davies-Colley et al., 2013). Note that a risk assessment could be undertaken to determine rivers at high-risk for pH extremes in order to prioritise where sensors should be located. This makes best use of resources by prioritising to high-risk areas.*

Value (use)		Ecological Health
Attribute		<b>pH regime</b>
Environment river, lake, groundwater, estuary, wetland		Rivers
Measurement unit		pH units are dimensionless
Summary statistic		Summer monitoring data upper 95 <sup>th</sup> percentile
Band descriptors	A	No stress caused by acidic or alkaline ambient conditions on any aquatic organisms that are present at matched reference (near-pristine) sites.
	B	Occasional minor stress caused by pH on particularly sensitive freshwater organisms (viz. fish and insects).
	C	Stress caused on occasion by pH exceeding preference levels for certain sensitive insects and fish for periods of several hours each day.
	D (unacceptable/doesn't provide for value)	Significant, persistent stress caused by intolerable pH on a range of aquatic organisms. Likelihood of local extinctions of keystone species and destabilisation of river ecosystems.
Band boundaries (numeric)	A/B	6.5 < pH < 8.0
	B/C	6.5 < pH < 8.5
	C/D	6.0 < pH < 9.0
	D (unacceptable/doesn't provide for value)	pH < 6 or pH > 9
Are there circumstances where a water body could naturally fall into the D band?		Natural humic-stained streams may also have pH values <5.
Limitations/gaps/risks		These criteria do not apply to humic-stained streams. There is a wide range of sensitivities of freshwater fish and invertebrates to pH that is hard to capture with single criteria for each class. Special consideration is needed for (i) naturally acid waters (e.g., humic-stained streams), and (ii) where there are substances for which toxicity is affected by pH (viz. ammonia, toxic metals and sulphide and certain organic contaminants).
Notes:		Summer pH maxima data may need to be used if only limited data are available for a site. Continuous monitoring of pH in summer is required to provide reliable data on the diel pH variability.
Key references:		Alabaster and Lloyd (1982); West et al. 1997)

In a eutrophic lake, other organisms living in the water can become stressed, even if pH levels remain within the optimum range. As pH can be affected by lake eutrophication the limiting nutrient remains the key focus hence it is recommended that pH is not an appropriate attribute for lakes.

Recommendation: Use the pH attribute as specified in Table 13 for the protection of Ecosystem Health, Significant Indigenous Species and Habitat, Mahinga Kai (collection only) and Fishing values in rivers.

Note that a risk assessment could be undertaken to determine rivers at high-risk for pH extremes in order to prioritise where sensors should be located. This makes best use of resources by prioritising to high-risk areas.

### 5.3.4 Temperature

Temperature not only influences water composition, such as solubility of DO and ammoniacal-nitrogen (NH<sub>4</sub>-N), but when elevated, can cause thermal stress in aquatic organisms. Lethal temperatures can be reached not much beyond optimum growth temperatures (Davies-Colley et al, 2013). Management of temperature in freshwaters is not only a matter of avoiding elevated temperatures, but should also be based on thermal requirements of all life stages. Table 14 summarises how the temperature attribute has been used by some other councils around New Zealand.

Table 14 Examples of temperature attribute and numeric thresholds/guidelines from some other councils.

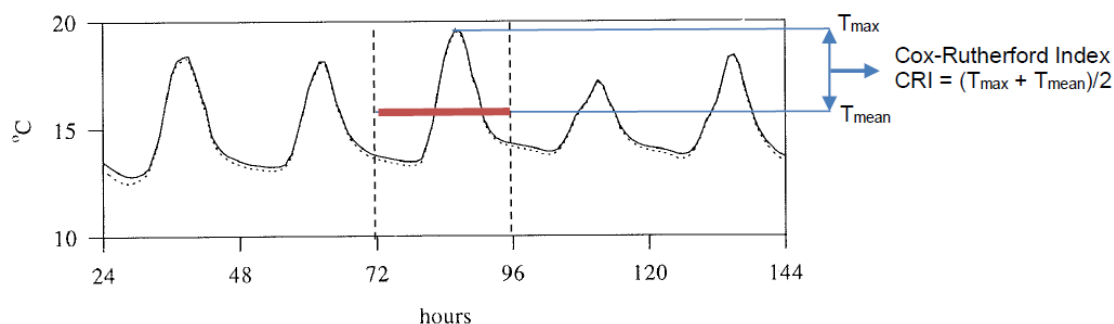
Attribute	Numeric Threshold/Guideline	Water body	Council
<b>Temperature (daily max.)</b>	Overall range ≤ 19-21°C at all times~ <11°C (May-December) ~	Rivers	Recommended to Marlborough District Council (Clapcott and Hay, 2014)
<b>Temperature (change)</b>	± 3°C at all times	Rivers	
<b>Temperature</b>	Overall range 19-24°C*~ <11°C (May-December) ~	Rivers	Horizons Regional Council, (2014)
<b>Temperature change</b>	Overall range 2-3°C*~	Rivers	
<b>Temperature (daily summer max.)</b>	Band A: ≤19°C Band B: 19-21°C Band C: 21-25°C Band D: > 25°C	Rivers	Gisborne District Council (2015)
<b>Temperature (change)</b>	± 3°C	Coastal waters	Northland Regional Council (2016)
<b>Temperature (daily max.)</b>	Overall range 19-23°C*	Rivers	Recommended to Greater Wellington Regional Council (Ausseil 2013b)
<b>Temperature (change)</b>	Overall range 2-3°C*	Rivers	

\* Target/standard varies for different zones/units/water bodies/classifications.

~ different thresholds apply for different values.

Davies-Colley et al (2013) recommended an attribute table for inclusion in the NPS-FM for temperature in rivers based on a gradient of increasing thermal stress from a no thermal stress 'A' band to significant thermal stress at 'D' band. Temperature bands have been based on a review of temperature criteria (Olsen et al, 2012). It is also noted that diel fluctuations must be accounted for especially during mid to late summer when annual maxima are reached and diel fluctuations can be greatest. Temperature is not considered a key attribute for lakes.

The proposed attribute state banding regimes use the Cox-Rutherford Index (CRI) which is defined as the average of the mean daily and daily maximum temperatures (Figure 3). The Cox-Rutherford Index ( $CRI = (T_{max} + T_{mean})/2$ ) permits application of (constant) temperature criteria to temperature regimes varying over a diel cycle in rivers. The CRI will generally be greatest (i.e. the likelihood of thermal stress is greatest) on clear (cloud-free) days when solar insolation is maximal and the amplitude of diel fluctuation is greatest. In Figure 3 a clear day is selected to illustrate the calculation of this index (Davies-Colley et al, 2013).



**Figure 3** Accounting for diel temperature fluctuations in streams and rivers. An index accounting for diel temperature fluctuations based on the work of Cox and Rutherford (2000a, b) is illustrated for the temperature profile fluctuation of a clear day. The Cox-Rutherford index, in this case, is  $(19.5 + 16)/2 = 17.75$  °C. From Davies-Colley et al (2013) based work by Rutherford et al. (1999).

The CRI is dependent on a continuous temperature monitoring record and is most relevant to the summer period defined as 1 December to 31 March. Traditionally discrete measures of temperature have been made in water quality monitoring programmes, but such monitoring fails to capture minimum and more importantly maximum temperatures that potentially result in thermal stress.

The CRI is argued to be a robust measure for temperature thresholds as thermal stress is accounted for by the diurnal fluctuation of temperatures measured, permitting direct comparison with temperature extremes collected from laboratory experiments with aquatic organisms. It would be measured on an average of the five hottest days based on the continuous data record.

Attribute state bands for temperature as recommended by Davies-Colley et al (2013) are listed in Table 15 and Table 16. A third table for temperature increments is also given by Davies-Colley et al., (2013) to use as a site-specific approach for comparison with reference data. This method requires adequate reference sites and collection of reference data for multiple years to demonstrate 'good ecological health'. Having adequate reference sites is dependent on categorisation of a spatial rivers framework within the landscape, which will be dependent on fresh water management unit definition. As both reference sites and data for sites are limited, the preferred approach would be the banding approach listed in Table 15 and Table 16, where lowland areas in the Bay of plenty would fall into the 'Eastern Dry' and upland areas would fall into the 'Maritime' climate boundaries.

**Recommendation:** Use the banding approach listed in Table 15 and Table 16 for the protection of Ecosystem Health, Significant Indigenous Species and Habitat, Mahinga Kai (collection only) and Fishing values in rivers. Temperature ranges based on climate class would be developed based on respective draft FMUs. For example, lowland areas in the Bay of Plenty could fall into the 'Eastern Dry' and upland areas could correspond to 'Maritime' climate boundaries. Note that a risk assessment could be undertaken on exposed rivers to determine where temperature sensors should be located. This makes best use of resources by prioritising to high-risk areas.

Table 15 Attribute table for temperature regime in rivers and streams in 'Maritime' regions of New Zealand (Davies-Colley et al, 2013), as recommended for inclusion in the NPS-FM within the NPS-FM.

Value (use)		Ecological Health
Attribute		<b>Temperature regime</b>
Environment (river, lake, GW, estuary, wetland)		Rivers (Maritime climates)
Measurement unit		Degrees Celsius ( <sup>0</sup> C)
Summary statistic		Summer period measurement of the Cox-Rutherford Index (CRI), averaged over the five (5) hottest days (from inspection of a continuous temperature record).
Band descriptors (narrative – what will people notice as the impact on the value)	A	No thermal stress on any aquatic organisms that are present at matched reference (near-pristine) sites.
	B	Minor thermal stress on occasion (clear days in summer) on particularly sensitive organisms such as certain insects and fish.
	C	Some thermal stress on occasion, with elimination of certain sensitive insects and absence of certain sensitive fish.
	D(unacceptable/does not provide for value)	Significant thermal stress on a range of aquatic organisms. Risk of local elimination of keystone species with loss of ecological integrity.
Band boundaries (numeric)	A/B	≤18 <sup>0</sup> C
	B/C	≤20 <sup>0</sup> C
	C/D	≤24 <sup>0</sup> C
	D(unacceptable/does not provide for value)	>24 <sup>0</sup> C

Table 16 Attribute table for temperature regime in rivers and streams in 'Eastern Dry' regions of New Zealand (Davies-Colley et al, 2013), as recommended for inclusion in the NPS-FM within the NPS-FM.

Value (use)		Ecological Health
Attribute		<b>Temperature regime</b>
Environment (river, lake, GW, estuary, wetland)		Rivers (Eastern Dry climates)
Measurement unit		Degrees Celsius ( <sup>0</sup> C)
Summary statistic		Summer period measurement of the Cox-Rutherford Index, averaged over the five (5) hottest days (from inspection of a continuous temperature record).
Band descriptors (narrative – what will people notice as the impact on the value)	A	No thermal stress on any aquatic organisms that are present at matched reference (near-pristine) sites.
	B	Minor thermal stress on occasion (clear days in summer) on particularly sensitive organisms such as certain insects and fish.
	C	Some thermal stress on occasion, with elimination of certain sensitive insects and absence of certain sensitive fish.
	D(unacceptable/does not provide for value)	Significant thermal stress on a range of aquatic organisms. Risk of local elimination of keystone species with loss of ecological integrity.
Band boundaries (numeric)	A/B	≤19 <sup>0</sup> C
	B/C	≤21 <sup>0</sup> C
	C/D	≤25 <sup>0</sup> C
	D(unacceptable/does not provide for value)	>25 <sup>0</sup> C

### 5.3.5 Conductivity and salinity

Conductivity and salinity are measures of the ability of water to conduct electricity, which provides a measure of what is dissolved in the water. The more dissolved salts in the water the higher the conductivity (or salinity). The degree to which mineral salts dissociate into ions, the amount of electrical charge on the ions, and the temperature all have an influence on the conductivity. Conductivity is measured by electrical probe usually in seimens per unit length (e.g. mS/m), and salinity is most often measured in parts per thousand.

Salinity is typically monitored to understand the influence of marine water on freshwaters and vice versa. As such, is not a useful attribute for freshwater, but is a useful measure at the junction of fresh and marine environments. Likewise, thresholds are not often set for water quality using conductivity. The exception is where conductivity is sometimes used to monitor point source discharges, usually continuously and after a relationship has been determined between conductivity and the concentrations of contaminants known to be in the discharge.

Other councils have not set regional thresholds using these parameters and they are not considered key attributes for rivers or lakes.

### 5.3.6 Total Suspended Solids (TSS)

Suspended solids are fine particles (clay or silt categories of 0.2 - 63µm diameter; Davies-Colley et al., 2015) that travel in suspension in water, and generally represent the fine sediment that is suspended in the water column. Suspended solids impact on ecosystem health by reducing visual clarity and light penetration, or clogging gills and smothering habitat. The amount of sediment suspended in a water column depends on the size, shape and composition of the sediment, and the flow of the river. The faster a river/stream flows, the more suspended solids it can transport. Once stream flow slows down, some of these suspended solids settle to the bottom of the river/stream and become deposited sediment (see section 5.3.10). Suspended solids are measured and reported as the Total Suspended Solids (TSS) in a known volume of water. Table 17 summarises how the TSS attribute has been used by some other councils around New Zealand.

*Table 17 Examples of total suspended solids attribute and numeric thresholds/guidelines from some other councils.*

Attribute	Numeric Threshold/Guideline	Water body	Council
<b>Suspended solids</b>	Annual median (g/m <sup>3</sup> ) Band A: ≤ 10. Band B: >10 and ≤ 20 Band C: >20 and ≤ 50 Band D: >50	Rivers	Gisborne District Council (2015)

Sediment has been recognised as an important attribute for the protection of ecosystem health (MfE, 2016, Davies-Colley et al., 2015, Hicks et al., 2016) and aquatic recreation (MfE 1994, Davies-Colley et al., 2015, BOPRC, 2008) in rivers and estuaries. TSS has not been included as an attribute in the NPS-FM to date largely because of the complex relationships between physical sediment characteristics (particle size, shape and composition), interactions with other contaminants (like nutrients and temperature), the impacts these aspects have on visual clarity, light penetration and settling velocity, and the subsequent environmental effects (e.g. reduced predation, altered or smothered habitat). The impacts of sediment on ecosystem health can be quantified broadly by four key attributes (Davies-Colley et al., 2015, Hicks et al., 2016):

- 1 Suspended sediment concentration (silt and clay particle size),
- 2 Deposited fine sediment (sand, silt and clay particle size),
- 3 Visual clarity, and
- 4 Light penetration.

Davies-Colley et al., (2015) presented a summary of national and international literature on these four attributes, and Hicks et al., (2016) summarised research on transforming catchment sediment loads to these four attributes. The process of transforming catchment sediment loads into these four attributes is arguably useful to determine how much change in sediment load (such as by reducing discharges and/or bank erosion for example) is needed to achieve any targets/limits expressed using the four attributes. Transforming catchment sediment load into the four identified attributes is based on developing a sediment rating curve – this is the relationship between suspended sediment concentration and river/stream discharge. Because of the complex composition and response of sediment in rivers/streams, there is not a uniform relationship between suspended sediment concentration, visual clarity and light penetration, and sediment particle size distribution is the main factor influencing these relationships (Hicks et al., 2016).



Understanding the particle size distribution can improve understanding of regional variations in these relationships, however there is a paucity of data on particle size distribution both regionally and nationally. Hicks et al. (2016) developed analytical frameworks to link the four attributes to the catchment sediment load. They found that the frameworks were not overly robust when trying to predict absolute values of each of the attributes in relation to changes in sediment load. However, they noted that the robustness improved when trying to predict *changes* in the attributes (from a known state) relative to changes in sediment load.

Based on these findings, there is significant research currently underway nationally to develop thresholds for a national suspended sediment attribute. This research includes the use of sites from the Bay of Plenty. Sediment is an important attribute for ecosystem health in freshwater and coastal water and should be part of a comprehensive water quality framework in future. However, it is recommended that Council awaits the results of the national research, before considering how thresholds/bands could be developed.

Recommendation: Recognise sediment and related attributes (visual clarity, deposited sediment, turbidity, light penetration) as important for the protection of ecosystem health in freshwater and marine water and prioritise investigation into relevant attributes (and state bands) for sediment, in line with results from national research. Note that the further attribute recommendations are likely to include some, not all, of the sediment related attributes.

### 5.3.7 Colour

Water colour can be due to backscattering and/or absorbance of light in water. Colour is often a result of scattering of photons from sunlight travelling back to the observer to give rise to water colour in combination with reflected light (MfE, 1994). Like visual clarity, colour can be affected by variations in the quantity and quality of substances such as dissolved constituents, suspended solids, mineral solids, and phytoplankton. These other constituents are also often monitored in waterways.

Colour can be measured in terms of hue (the wavelength distribution of light), and by comparison with the Munsell scale, coloured solutions or calibrated glass colour disks. It can also be measured as brightness using the reflectance ratio (R) (MfE, 1994).

Colour is often measured on industrial discharges (particularly from pulp and paper industry) using the platinum-cobalt method which expresses colour in terms of the equivalent concentration of the chloroplatinate ion. Colour can be pH dependant and is also interfered by turbidity. Environmental laboratories more regularly use a spectrophotometric method with a single wavelength to determine brightness and hue (Rice et al. 2012).

Colour is often an aesthetic concern and can also interfere with light penetration, limiting plant growth and habitat for aquatic organisms. Water bodies which obtain their colour from natural organic matter (e.g. tannins) usually pose no health hazard. However, because of the yellowish brown appearance observers may not find the water aesthetically acceptable. Table 18 summarises how the colour attribute has been used by some other councils around New Zealand.

*Table 18 Examples of colour attribute and numeric thresholds/guidelines from some other councils.*

Attribute	Numeric Threshold/Guideline	Water body	Council
<b>Colour hue changes (Munsell units)</b>	Overall range < 5 - 10 when river flow < median~	Rivers	Recommended to Marlborough District Council (Clapcott and Hay, 2014)
<b>Colour reflectance change</b>	< 50% when river flow < median	Rivers	

~ different thresholds apply for different values.

The perception of colour is difficult to measure and it is therefore recommended that colour not be used as an attribute for either rivers or lakes. In some cases colour may continue to be an important parameter that is managed in the Bay of Plenty (e.g. as is the case in the Regional Plan for the Tarawera River Catchment) but it is not recommended for wider use. Colour may be used on a case by case basis as warranted for relevant point source discharges.

### 5.3.8 Turbidity

Turbidity is a measure of how 'cloudy' water is and is determined by measuring the scattering of light by fine particles suspended in the water. Turbidity monitoring can be undertaken by analysing a water sample, or by using an automated sensor to log turbidity levels continuously. Turbidity monitoring is relatively cost effective and often used as a surrogate for suspended solid monitoring. Table 19 summarises how the turbidity attribute has been used by some other councils around New Zealand.

Table 19 Examples of turbidity attribute and numeric thresholds/guidelines from some other councils.

Attribute	Numeric Threshold/Guideline	Water body	Council
<b>Turbidity</b>	< 20 NTU when river flow < median flow	Rivers	Recommended to Marlborough District Council (Clapcott and Hay, 2014)
<b>Turbidity</b>	Overall range 3-5 NTU * <sup>∞</sup>	Rivers and lakes	Otago Regional Council (2016)
<b>Turbidity (annual median)</b>	Overall range 2.2-10.8 NTU*	Coastal waters	Northland Regional Council (2016)

\* Target/standard varies for different zones/units/water bodies/classifications.

<sup>∞</sup> achieved when 80% of samples collected when river flow ≤ median over a rolling 5-year period meet limit.

The Australia New Zealand Environment and Conservation Council (ANZECC, 2000) guidelines contain a default trigger value for turbidity in lowland rivers in New Zealand of 5.6 NTU. Turbidity is not considered a key attribute for rivers or lakes as other attributes relating to suspended sediment and visual clarity are considered more appropriate. Davies-Colley et al., (2011) argue that turbidity is generally not suitable for enumerating guidelines as it is only a relative, arbitrary index of the concentration of light scattering particles. Water clarity is more suitable for such standards. Turbidity is also one of the four key attributes that is being investigated for potential inclusion of a sediment attribute into the NPS-FM. Any regional recommendations would be premature given extent of research underway at a national level presently. Once results from the national research are available, any proposed thresholds (or bands) will be considered and subsequent recommendations made.

### 5.3.9 Visual clarity

Visual clarity is affected by the transmission of light through water. Visual clarity is generally measured either in a horizontal plane by black disk (in rivers/streams), and in the vertical plane by Secchi disk (in lakes). Water can also be removed from a water body and tested by a light and sensor array known as a beam transmissometer, or in-situ by measuring light penetration.

Table 20 summarises how the visual clarity attribute has been used by some other councils around New Zealand.

Table 20 Examples of visual clarity attribute and numeric thresholds/guidelines from some other councils.

Attribute	Numeric Threshold/Guideline	Water body	Council
Water clarity	Overall range $\geq 0.5 - 1.6$ m when river flow < median~	Rivers	Recommended to Marlborough District Council (Clapcott and Hay, 2014)
Visual clarity change	Overall range < 20 - 33% ~	Rivers	
Visual clarity (change)	Overall range 20 - 30% change*	Rivers	Horizons Regional Council, (2014)
Visual clarity	Overall range when river flow < median is 1.6 - 3.4 m*	Rivers	
Visual clarity (change)	20% change	Lakes	
Visual clarity	Overall range when river flow < median is 0.8 - 2.8 m*	Lakes	
Visual clarity	Short-term target range: 0.3 - 3.8 m 80-year target range: 1.0 - 3.8 m	Rivers	Waikato Regional Council (2016)
Visual clarity	80-year target: 1 m	Lakes	
Visual clarity (Minimum 95 <sup>th</sup> percentile)	Overall range 0.7 - 2.9 m*	Coastal waters	Northland Regional Council (2016)
Visual clarity (minimum)	0.5 m when river flow < 3 x median	Rivers	Recommended to Greater Wellington Regional Council (Ausseil 2013b)
Visual clarity (minimum)	Overall range 0.5 - 2.2 m* when river flow < median	Rivers	
Visual clarity change	Overall range 20-33%*	Rivers	
Euphotic depth	10% change	Lakes	Horizons Regional Council, (2014)

\* Target/standard varies for different zones/units/water bodies/classifications.  
~ different thresholds apply for different values.

The RMA Sections 70 and 107 standards set out 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) provide 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.

Visual clarity change limits were originally designed to protect aesthetic and recreational values, based on the RMA S70/107 standards. There is the added benefit that these guidelines should protect the habitat of sighted animals, maintaining foraging distances. 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).



To protect the visual clarity of waters used for recreation (ANZECC, 2000 & MfE, 1994), the horizontal sighting of a 200 mm diameter black disk should exceed 1.6 m. Other measures are based on visual clarity changing where the visual clarity shall not change by a certain percentage, usually 20% for Class A waters (water managed for aesthetic purposes). The assumption here is that a point source discharge is impacting clarity initially, and after *reasonable mixing*, the test should be applied. It does not appear to be the intention to apply this to the natural state of water measured at a site over time, but is something that could be considered. This would need to be considered against some reference state, which will be different for different rivers and sites.

Visual clarity change limits for the protection of aquatic ecosystem values could be set based on the biophysical classification (see section 2.2). This would require developing a water clarity scale taking into account flow conditions and physiographic drivers. Visual clarity is also one of the four key attributes that is being investigated for potential inclusion of a sediment attribute in the NPS-FM (see section 5.3.9). Visual clarity is potentially an important attribute and one that is monitored both regionally and nationally. It should be part of a comprehensive water quality framework, however it is recommended that Council awaits the results of the national research before considering how thresholds/bands could be developed.

Visual clarity in lakes is captured as part of the recommended TLI attribute (refer Section 5.4.6).

### 5.3.10 Deposited sediment

Deposited sediment refers to the fine sediment (< 2 mm diameter) that accumulates on the bed of a waterway (Clapcott et al., 2011). The composition of the streambed depends on slope, stream size, rainfall, catchment land use, vegetation and geology. Streams are often classified as 'hard-bottomed' (composed of gravel or larger substrate) or 'soft-bottomed' (composed of sand, silt or clay) reflecting the bed composition. In the absence of human influence, classification systems (i.e. Freshwater Ecosystems of New Zealand (FENZ)) and GIS models estimate that the majority of streams in New Zealand would be hard-bottomed (Clapcott et al., 2011). Deposited sediment can impact on ecosystem health by smothering organisms or changing the available habitat. Table 21 summarises how the deposited sediment attribute has been used by some other councils around New Zealand.

*Table 21 Examples of deposited sediment attribute and numeric thresholds/guidelines from some other councils.*

Attribute	Numeric Threshold/Guideline	Water body	Council
<b>Deposited fine sediment cover</b>	<20% at all times~ <15% May-December~	Rivers	Recommended to Marlborough District Council (Clapcott and Hay, 2014)
<b>Deposited fine sediment change</b>	<10% at all times	Rivers	
<b>Deposited sediment cover</b>	Overall range 15 - 25% for sediment < 2 mm diameter*	Rivers	Horizons Regional Council (2014)
<b>Deposited fine sediment cover (wadeable streams)</b>	Overall range 10 - 30%*~	Rivers	Environment Canterbury (2017)

\* Target/standard varies for different zones/units/water bodies/classifications.  
~ different thresholds apply for different values.

Methods for quantifying deposited sediment and recommended sediment guidelines were proposed by Clapcott et al., (2011), largely for hard-bottomed streams. In their review of fine sediment effects on freshwaters, Davies-Colley et al., (2015) concluded that national and international criteria for deposited sediment varied greatly. The authors recommended that sufficient data from streams representing reference conditions (both hard and soft-bottomed) be gathered as well as dose-response relationships with benthic communities. There is significant research currently underway nationally to develop thresholds for a national suspended sediment attribute (of which deposited sediment may be included). This research includes monitoring deposited sediment and the impacts on benthic invertebrates at a range of streams as recommended by Davies-Colley et al., (2015).

Recent research by Hicks et al., (2016) to determine a relationship between catchment sediment load and deposited sediment only showed a very weak relationship between these two variables. The authors concluded that this is likely a result of large sediment delivery during flood events when sediment is likely to be flushed through the stream and into receiving environments.

Deposited sediment is an important attribute for ecosystem health in rivers and estuaries, and one that should be prioritised for further development. Deposited sediment is not currently monitored within the Bay of Plenty, and it is recommended that a monitoring programme for deposited sediment be developed in the Bay of Plenty as per the protocols developed by Clapcott et al., (2011). This monitoring programme should include adequate 'reference' sites in both hard and soft-bottomed streams, and include analysis of particle size distribution. In the absence of any monitoring data, and with extensive national research underway, it is recommended that Council awaits the results of the national research before considering how thresholds/bands could be developed.

Recommendation: Recognise deposited sediment as an important sediment related attribute for the protection of ecosystem health and prioritise investigation into its applicability as an attribute and development of attribute state bands for the Bay of Plenty. This should be done in line with results from national research.

## 5.4 Chemical attributes

### 5.4.1 Nitrate-nitrogen (NO<sub>3</sub>-N)

Nitrogen occurs naturally and cycles through different forms as it moves through the environment. The concentrations of nitrogen (and phosphorus) in water give an indication of the potential for undesirable biological growths. Excessive concentrations of these nutrients can lead to prolific growths of periphyton (attached algae), phytoplankton (free-living algae) and macrophytes (attached aquatic plants).

Nitrate-nitrogen (NO<sub>3</sub>-N) is one form of nitrogen that is highly soluble in water and is an important nutrient for plant growth. Anthropogenic sources of NO<sub>3</sub>-N in the environment include fertilisers, leaking sewage systems, and animal wastes. At high concentrations, nitrate is also toxic to aquatic organisms and humans. It is often reported as nitrate-nitrite-nitrogen (NNN). NNN is the sum of nitrate (NO<sub>3</sub>) and nitrite (NO<sub>2</sub>). NO<sub>2</sub> concentrations are normally low in comparison to NO<sub>3</sub> concentrations, and this is often why NO<sub>3</sub> is reported as NNN.

Table 22 summarises how the NO<sub>3</sub> attribute has been used by some other councils around New Zealand. The values defined by some other councils ranged from toxicity to aquatic biota through to maximum values for drinking water, and some councils listed more than nine values for this attribute. As such, there is a large range of numeric thresholds in the table below.

Table 22 Examples of NO<sub>3</sub> attribute and numeric thresholds/guidelines from some other councils.

Attribute	Numeric Threshold/Guideline	Water body	Council
<b>Nitrate toxicity NO<sub>3</sub>N toxicity</b>	< 2.4 mg/L at all times	Rivers	Recommended to Marlborough District Council (Clapcott and Hay, 2014)
<b>Nitrate nitrite nitrogen (NNN)</b>	Overall range 0.075 - 0.444 mg/L <sup>∞*</sup>	Rivers	Otago Regional Council (2016)
<b>Nitrate (annual median)</b>	Short-term target range: 0.004 - 2.760 mg/L* 80-year target range: 0.004 - 2.4 mg/L *	Rivers	Waikato Regional Council (2016)

Attribute	Numeric Threshold/Guideline	Water body	Council
<b>Nitrate (annual 95<sup>th</sup> percentile)</b>	Short-term target range: 0.062 - 4.40 mg/L* 80-year target range: 0.062 - 3.5 mg/L *	Rivers	
<b>Nitrate toxicity (annual median)</b>	Band A: ≤ 1.0 mg/L Band B: > 1.0 ≤ 2.4 mg/L Band C: > 2.4 ≤ 6.9 mg/L Band D: > 6.9 mg/L	Rivers	Gisborne District Council (2015)
<b>Nitrate toxicity (annual 95<sup>th</sup> percentile)</b>	Band A: ≤ 1.5 mg/L Band B: > 1.5 ≤ 3.5 mg/L Band C: > 3.5 ≤ 9.8 mg/L Band D: > 9.8 mg/L	Rivers	
<b>Nitrate toxicity (annual median)</b>	≤ 1.0 mg/L	Rivers	Northland Regional Council (2016)
<b>Nitrate toxicity (annual 95<sup>th</sup> percentile)</b>	≤ 1.5 mg/L	Rivers	
<b>Nitrate nitrite nitrogen (NNN; annual median)</b>	Overall range 0.005 - 0.580 mg/L*	Coastal waters	
<b>Nitrate toxicity (95<sup>th</sup> percentile)</b>	1.5 mg/L 99% protection level 3.5 mg/L 98% protection level 5.6 mg/L 97% protection level 9.8 mg/L 96% protection level	Rivers	Environment Canterbury (Kelly, 2015)
<b>Nitrate toxicity (max. acceptable value – drinking water)</b>	11.3 mg/L	Rivers	

\* Target/standard varies for different zones/units/water bodies/classifications.

∞ achieved when 80% of samples collected when river flow ≤ median over a rolling 5-year period meet limit.

NO<sup>3</sup>-N is currently an attribute in the NPS-FM for protecting the value of Ecosystem Health (toxicity) in rivers (MfE, 2014). The attribute state bands for NO<sup>3</sup>-N are based on the 'no observed effect concentration' (NOEC) and 'threshold effect concentration' (TEC) values for 22 species which includes fish, and invertebrate species listed in Appendix 2 (Hickey, 2013). The NPS-FM statistics for nitrate are Annual Median and 95<sup>th</sup>ile in recognition of the average long-term exposure and seasonal peak concentrations respectively (MfE, 2015). NO<sub>x</sub> (sum of NO<sup>3</sup> and NO<sup>2</sup>) is currently measured monthly at all NERMN river water quality monitoring sites. NO<sup>2</sup> is generally in very low concentrations in comparison to NO<sup>3</sup>, as such NO<sub>x</sub> results are compared directly to the nitrate statistics in the NPS-FM. NO<sup>2</sup> and NO<sup>3</sup> are not measured separately in routine NERMN analysis.

The Maximum Acceptable Value (MAV) for nitrate-nitrogen in the Drinking Water Standards for New Zealand (DWSNZ) is ~11.3 mg/L NO<sup>3</sup>-N. This highlights how different thresholds apply for the protection of different values. For protection of multiple values, it is recommended that the most sensitive value be used to provide the highest level of protection.

Nitrate-nitrogen is not considered a key attribute for lakes, as other attributes, such as total nitrogen (TN) and total phosphorus (TP), are better indicators of lake nutrient enrichment (see section 5.4.5).

Recommendation: Use the nitrate-nitrogen attribute as specified in Appendix II of the NPS-FM for the protection of Ecosystem Health (toxicity), Significant Indigenous Species and Habitat, Mahinga Kai (collection only) and Fishing values in rivers.

#### 5.4.2 Nitrite-nitrogen (NO<sub>2</sub>-N)

At high concentrations, nitrite-nitrogen (NO<sub>2</sub>-N) can be toxic to animals and humans. However, NO<sub>2</sub>-N concentrations in the environment are normally low compared to NO<sub>3</sub>-N and ammoniacal-nitrogen (NH<sub>4</sub>-N). For this reason, NO<sub>2</sub>-N is not specifically measured by BOPRC in surface water, and is not recommended as a key attribute.

#### 5.4.3 Ammoniacal-nitrogen (NH<sub>4</sub>-N)

Ammoniacal-nitrogen (NH<sub>4</sub>-N) covers two forms of nitrogen: ammonia (NH<sub>3</sub>) and ammonium (NH<sub>4</sub>). NH<sub>4</sub>-N is an important nutrient for plant growth. At high concentrations it is also toxic to aquatic organisms and humans. Anthropogenic sources of ammoniacal-nitrogen in the environment include point source discharges (e.g. domestic, agricultural and industrial wastewater).

Table 23 summarises how the NH<sub>4</sub>-N attribute has been used by some other councils around New Zealand. As with NO<sub>3</sub>-N, values ranged from life supporting capacity or ecosystem health through to trout spawning, and some councils listed more than nine values for this attribute. As such, there is a large range of numeric thresholds in the table below.

Table 23 Examples of NH<sub>4</sub>-N attribute and numeric thresholds/guidelines from some other councils.

Attribute	Numeric Threshold/Guideline	Water body	Council
<b>Ammonia NH<sub>4</sub>N (pH = 8, T = 20°C)</b>	< 0.32 mg/L at all times	Rivers	Recommended to Marlborough District Council (Clapcott and Hay, 2014)
<b>Ammoniacal-N</b>	Overall range < 0.320 - 0.400 g/m <sup>3</sup> *	Rivers	Horizons Regional Council, (2014)
<b>Ammoniacal-N</b>	Overall range for maximum 1.7 - 2.1 g/m <sup>3</sup> *	Rivers	
<b>Ammoniacal-N</b>	< 0.4 g/m <sup>3</sup> when pH > 8.5	Lakes	
<b>Ammoniacal-N</b>	Overall range 0.01 - 0.1 mg/L* <sup>∞</sup>	Rivers	Otago Regional Council (2016)
<b>Ammoniacal-N</b>	Overall range 0.01 - 0.1 mg/L* <sup>#</sup>	Lakes	
<b>Ammoniacal-N (Annual Median)</b>	Short-term target range: 0.002 - 0.291 mg/L* 80-year target range: 0.002 - .024 mg/L*	Rivers	Waikato Regional Council (2016)
<b>Ammoniacal-N (Annual maximum)</b>	Short-term target range: 0.003 - 0.419 mg/L <sup>@</sup> 80-year target range: 0.003 - 0.40 mg/L	Rivers	
<b>Ammoniacal-N (Annual Median)</b>	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	Rivers	Gisborne District Council (2015)

Attribute	Numeric Threshold/Guideline	Water body	Council
<b>Ammoniacal-N Annual 95<sup>th</sup> percentile)</b>	Band A: ≤ 0.05 mg/L Band B: > 0.05 ≤ 0.4 mg/L Band C: > 0.4 ≤ 2.20 mg/L Band D: > 2,20 mg/L	Rivers	
<b>Ammoniacal-N (Annual Median)</b>	Overall range 0.03 - 0.24 mg/L* <sup>^</sup>	Rivers	Northland Regional Council (2016)
<b>Ammoniacal-N (Annual maximum)</b>	Overall range 0.05 - 0.4 mg/L* <sup>^</sup>	Rivers	
<b>Ammoniacal-N (Annual Median)</b>	< 0.03 - 0.5 mg/L <sup>^</sup>	Lakes	
<b>Ammoniacal-N (Annual maximum)</b>	< 0.03 - 0.5 mg/L <sup>^</sup>	Lakes	
<b>Ammoniacal-N (Annual Median)</b>	Overall range 0.012 - 0.099 mg/L* <sup>^</sup>	Coastal waters	
<b>Ammoniacal-N (max average)</b>	Overall range 0.32 - 0.9 mg/L* <sup>^</sup>	Rivers	Recommended to Greater Wellington Regional Council (Ausseil 2013b)
<b>Ammoniacal-N (maximum)</b>	Overall range 4.3 - 7.5 mg/L* <sup>^</sup>	Rivers	

\* Target/standard varies for different zones/units/water bodies/classifications.

∞ achieved when 80% of samples collected when river flow ≤ median over a rolling 5-year period meet limit.

# achieved when 80% of samples collected over a rolling 5-year period meet limit.

<sup>^</sup> at pH 8 and temperature 20°C.

NH<sub>4</sub>-N is currently an attribute in the NPS-FM for protecting the value of Ecosystem Health (toxicity) in rivers and lakes (MfE, 2014). The numeric attribute state bands for NH<sub>4</sub>-N are based on the 'no observed effect concentration' (NOEC) and 'threshold effect concentration' (TEC) values for 19 species, which includes fish, invertebrate and bivalve species listed in Appendix 3 (Hickey, 2014). The statistics for NH<sub>4</sub>-N are Annual Median and Annual Maximum in recognition of the average long-term exposure and seasonal peak concentrations respectively (MfE, 2015). NH<sub>4</sub>-N concentrations need to be corrected to pH 8 and 20°C as the toxicity of NH<sub>4</sub>-N increases with increasing pH and temperature (Hickey, 2014). There is existing recommended methodology to correct NH<sub>4</sub>-N concentrations to pH 8, but currently no recommendation for compensating for temperature (Hickey, 2014, MfE 2015).

NH<sub>4</sub>-N is not considered key attribute for lakes, as other attributes, such as TN and TP, are better indicators of lake nutrient enrichment (see section 5.4.5).

Recommendation: Use the NH<sub>4</sub>-N attribute as specified Appendix II of the NPS-FM for the protection of Ecosystem Health (toxicity), Significant Indigenous Species and Habitat, Mahinga Kai (collection only) and Fishing values in rivers and lakes.

#### 5.4.4 Dissolved Reactive Phosphorus (DRP) and Dissolved Inorganic Nitrate (DIN)

Like nitrogen, phosphorus occurs naturally in the environment and is an essential plant nutrient. Anthropogenic sources of phosphorus and nitrogen include fertiliser, and agricultural, urban and industrial discharges. Phosphorus (as phosphate) enters waterways attached to soil particles that are transported from the land, usually via runoff. As the sediments remain in waterways, the phosphate dissolves and becomes DRP which feeds plant and algal growth. DIN is the combined total of NH<sub>4</sub>-N, NO<sub>3</sub> and NO<sub>2</sub>, all of which feed plant and algal growth.

Table 24 summarises how the DIN and DRP attributes have been used by some other councils around New Zealand.

Table 24 Examples of DIN and DRP attributes and numeric thresholds/guidelines from some other councils.

Attribute	Numeric Threshold/Guideline	Water body	Council
<b>Dissolved reactive phosphorus</b>	<0.015 mg/L < median flow	Rivers	Recommended to Marlborough District Council (Clapcott and Hay, 2014)
<b>Dissolved inorganic nitrogen</b>	< 0.444 mg/L < median flow	Rivers	
<b>DIN</b>	Overall annual average range 0.07-0.444 g/m <sup>3</sup> *	Rivers	Horizons Regional Council, (2014)
<b>DRP (annual average concentration)</b>	Overall range 0.006-0.015 g/m <sup>3</sup> when river flow ≤ 20 <sup>th</sup> ile*	Rivers	
<b>DRP</b>	Overall range 0.005-0.026 mg/L*∞	Rivers	Otago Regional Council (2016)
<b>DRP</b>	Annual median (g/m <sup>3</sup> ) Band A: ≤ 0.09 Band B: > 0.09 and ≤ 0.01 Band C: >0.01 and ≤ 0.03 Band D: >0.03	Rivers	Gisborne District Council (2015)
<b>DRP (annual median)</b>	0.008-0.092 mg/L*	Coastal waters	Northland Regional Council (2016)

\* Target/standard varies for different zones/units/water bodies/classifications.

∞ achieved when 80% of samples collected when river flow ≤ median over a rolling 5-year period meet limit.

The 'Clean Water 2017' consultation document proposed that in-stream DRP and DIN concentrations be determined for the control of periphyton in rivers, with consideration of the sensitivity of downstream receiving environments (MfE, 2017), although no specific numeric limits are provided. The nutrient guidelines from Biggs (2000) and ANZECC (2000) could be considered conservative for moderately degraded river systems. BOPRC initiated a region-wide periphyton monitoring programme in October 2015 in response to a lack of information about periphyton in the region (Suren et al., 2016, Suren and Carter, 2016). This periphyton monitoring programme will assist with: determining the current-state of periphyton biomass in the region; developing models to explain the interaction between periphyton, nutrients (such as nitrate) and flow; and developing nutrient limits to reduce problematic periphyton growth (Suren and Carter, 2016). Additionally, research is planned to estimate appropriate loads of nutrients draining into the estuaries to achieve outcomes indicated by the estuary trophic level index (Robertson et al., 2016a and 2016b). It is envisaged that bands and limits for DRP and DIN would be proposed to provide for ecosystem health by controlling problematic periphyton growth (where applicable) or detrimental impacts of elevated nutrients on sensitive receiving environments. Data from these research projects is not yet available.

DIN and DRP are important attributes for ecosystem health of both freshwater and coastal water. They are currently monitored by BOPRC and should be part of a comprehensive water quality framework. However, it is recommended that Council awaits the results of the estuary trophic level index and periphyton research, before considering how thresholds/bands could be developed.

DIN and DRP are not considered key attributes for lakes, as other attributes, such as TN and TP, are better indicators of lake nutrient enrichment (see section 5.4.5).

Recommendation: Recognise DIN and DRP as important attributes for ecosystem health in freshwater and marine water and prioritise investigation into the development of attribute state bands in line with results from regional and national research.



### 5.4.5 Total Nitrogen (TN) and Total Phosphorus (TP)

TN and TP are the sums of all the different forms of nitrogen and phosphorus respectively. TN and TP are considered key indicators of lake water enrichment, for which indices have been developed defining the relationship between nutrient levels and productivity (chlorophyll) (Vant, 1987). Table 25 summarises how the TN and TP attributes have been used by some other councils around New Zealand.

Table 25 Examples of TN and TP attributes and numeric thresholds/guidelines from some other councils.

Attribute	Numeric Threshold/Guideline	Water body	Council
<b>TN (average annual concentration)</b>	Overall range 0.337 - 0.490 g/m <sup>3*</sup>	Lakes	Horizons Regional Council, (2014)
<b>TP (average annual concentration)</b>	Overall range 0.02 - 0.03 g/m <sup>3*</sup>	Lakes	
<b>TN</b>	Overall range 0.1 - 0.55 mg/L*	Lakes	Otago Regional Council (2016)
<b>TP</b>	Overall range 0.005 - 0.033 mg/L*	Lakes	
<b>TN (annual median)</b>	Short-term target range: 562 - 631 mg/m <sup>3*</sup> 80-year target range: 350 mg/m <sup>3*</sup>	Rivers	Waikato Regional Council (2016)
<b>TP (annual median)</b>	Short-term target range: 43-50 mg/m <sup>3*</sup> 80-year target range: 10 - 20 mg/m <sup>3*</sup>	Rivers	
<b>TN (annual median)</b>	80-year target range: 750 - 800 mg/m <sup>3*</sup>	Lakes	
<b>TP (annual median)</b>	80-year target: 50 mg/m <sup>3</sup>	Lakes	
<b>TN (annual median)</b>	Overall range 160 - 800 mg/m <sup>3*</sup>	Lakes	Northland Regional Council (2016)
<b>TP (annual median)</b>	Overall range ≤ 10 ≤ 20 mg/m <sup>3*</sup>	Lakes	
<b>TN (annual median)</b>	Overall range 0.120 - 0.300 mg/L*	Coastal waters	
<b>TP (annual median)</b>	Overall range 0.015 - 0.009 mg/L*	Coastal waters	

\* Target/standard varies for different zones/units/water bodies/classifications.

# achieved when 80% of samples collected over a rolling 5-year period meet limit.

Both TN and TP are currently attributes contained within Appendix II of the NPS-FM for protecting the value of Ecosystem Health (trophic state) in lakes (MfE, 2014). The NPS-FM bottom lines associated with TN and TP concentrations in conjunction with chlorophyll-a, are designed to ensure that nutrient thresholds are not exceeded that may result in chlorophyll exceeding the bottom line in future years and pushing a lake to a phytoplankton-dominated state (Howard-Williams and Hamilton, 2013).

TN and TP may not yet be considered as key attributes for rivers, partly because other nutrient species (e.g. NO<sub>3</sub>-N and NH<sub>4</sub>-N) are better indicators of river nutrient enrichment and potential risks to ecosystem health, and because it is the dissolved components of nitrogen and phosphorus that influence ecological health in rivers.

Recommendation: Use the TN and TP attributes as specified in Appendix II of the NPS-FM for the protection of Ecosystem Health (Trophic State), Significant Indigenous Species and Habitat, Mahinga Kai (collection only) and Fishing in lakes.

#### 5.4.6 Lake Trophic Level Index (TLI)

Lake water quality is often expressed in terms of trophic state, which refers to the production of algae (phytoplankton), epiphytes and macrophytes in a lake. The lake Trophic Level Index (Lake TLI) comprises four key attributes: TN, TP, chlorophyll-*a* and Secchi depth (Burns, 2000) and gives an indication of how healthy a lake is.

The TLI has been one of the most robust and effective limit setting measures in the Bay of Plenty driving nationally and regionally funded programmes to reach objectives set for lakes. BOPRC has TLI targets for the Rotorua Te Arawa lakes in the Regional Water and Land Plan (RWLP; BOPRC, 2008) and Table 26 summarises how the TLI attribute has been used by some councils around New Zealand.

Table 26 TLI attribute and numeric thresholds/targets from some other councils.

Attribute	Numeric Threshold/Guideline	Water body	Council
Lake TLI	Overall range 2.6-5.0*	Lakes	BOPRC (2008)
Lake TLI	Overall range 2.0-6.0*	Lakes	Environment Canterbury (2017)

\* Target/standard varies for different zones/units/water bodies/classifications.

In 2012 a science panel convened by the Ministry for the Environment also developed a framework for lakes into five different classes and within each class four bands describe their water quality status, ranging from excellent to unacceptable (Verberg, 2012). Classes were essentially the same for total nitrogen, total phosphorus, and chlorophyll-*a*, the only distinction being between polymictic and stratified lakes. Other classes were separated by optical properties being affected by algae, sediment, and dissolved organic matter. Rotorua-Te Arawa lakes fell into the clear water class and therefore can be considered in one group.

Three of the four attributes that form the TLI, namely TN, TP, and chlorophyll-*a*, are - defined in Appendix II of the NPS-FM. These closely align to the Burns (2000) classification system for lakes. A TLI attribute for ecosystem health can be formulated from the three current parameters in the NPS-FM of total nitrogen, total phosphorus, and chlorophyll-*a*. However, as this differs from the Burns TLI classification (Burns, 2000) which has been used to set TLI objectives in the RWLP, it is advised that the TLI is calculated as per the Burns (2000) protocol. Table 27 shows how a banding structure might look based on the Burns TLI classification (Burns, 2000), and is recommended for the protection of Ecosystem Health in lakes. Full classification table as per the Burns TLI classification system is given in Appendix 1.



Table 27 Proposed trophic level index bands for lakes.

Value			
Freshwater Body Type			
Attribute			
Attribute Unit TLI			
Attribute State	Narrative Attribute State		
	Trophic Level Index	Lake Classification	
A	≤ 3	<b>Oligotrophic</b>	Lake ecological communities are healthy and resilient, similar to natural reference conditions.
B	> 3 and ≤ 4	Mesotrophic	Lake ecological communities are slightly impacted by additional algal and plant growth arising from nutrients levels that are elevated above natural reference conditions.
C	> 4 and ≤ 5	<b>Eutrophic-</b>	Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrients levels that are elevated well above natural reference conditions.
D	>5	Supertrophic	Lake ecological communities are at high risk of a regime shift to a persistent, degraded state, due to impacts of elevated nutrients leading to excessive algal and/or plant growth, as well as from losing oxygen in bottom waters of deep lakes.

Recommendation: Use the lake trophic level index attribute and state bands as specified in Table 27 for the protection of Ecosystem Health (Trophic State), Significant Indigenous Species and Habitat, Mahinga Kai (collection only) and Fishing in lakes. It is envisioned that TLI objectives set for new lakes would be investigated based on the framework in Table 27, but for the Rotorua-Te Arawa Lakes existing TLI objectives would be retained.

#### 5.4.7 Other toxicants (metals and pesticides)

Toxicant is a term used for chemical contaminants that have potential to exert toxic effects at concentrations that might be found in the environment. There is a large range of toxicants that are potentially discharged into the environment, examples include: heavy metals such as copper, zinc, cadmium, arsenic; pesticides and herbicides; hydrocarbons; polychlorinated biphenyls (PCBs); and volatile organic compounds (VOC).

Some toxicants occur naturally in the environment, such as NO<sub>3</sub> and NH<sub>4</sub> already discussed above and also heavy metals associated with geothermal discharges. Others might be associated with a range of activities where monitoring is targeted specifically to an activity and toxicant(s) of interest.

ANZECC (2000) guidelines have been developed to assist in protecting ambient waters from sustained exposure to toxicants, that is, chronic toxicity. Trigger levels have been defined for three categories of ecosystem type: slightly to moderately disturbed; highly disturbed; and high conservation/ecological values. Trigger levels are set using a statistical distribution method for four different protection levels based on multiple species toxicity tests: 99%; 95%, 90% and 80%. Triggers can also be influenced by physico-chemical conditions and the ANZECC guidelines note where this may be the case. Table 28 summarises how toxicants attributes have been used by some other councils around New Zealand.

Table 28 Examples of toxicant attributes and numeric thresholds/guidelines from some other councils.

Attribute	Numeric Threshold/Guideline	Water body	Council
Toxicants (protection level)	Overall range 95-99%~	Rivers	Recommended to Marlborough District Council (Clapcott and Hay, 2014)
Toxicants (protection level)	Overall range 95-99%*	Rivers	Horizons Regional Council, (2014)
Toxicants (protection level)	Overall range 95-99%*	Rivers	Recommended to Greater Wellington Regional Council (Ausseil 2013b)

\* Target/standard varies for different zones/units/water bodies/classifications.  
 ~ different thresholds apply for different values.

A 95% species protection level is recommended for slightly to moderately disturbed ecosystems and is the approach employed by many other councils throughout New Zealand. For some environmental values it may not be feasible to protect water to the same level, and a case by case approach may be warranted in line with objectives. Discharges from point sources will require site specific criteria based on an assessment of toxicity, in line with the criteria set for the receiving environment. Note that the sediment quality targets set in the ANZECC guidelines could also be considered from for some toxicants.

Table 29 sets out a possible framework for toxicant guidelines for the protection of freshwater ecosystem values. Future work may include evolving standards for individual toxicants that have been identified as a potential problem and using local reference data and ANZECC risk based frameworks to provide a more definitive risk gradient. As with other attributes, a banding model could use the ANZECC framework to apply a desired state of ecological outcome over toxicant thresholds (Figure 4).

As the environmental risk from toxicants is often associated with point source discharges, or controlled as an infrastructure based activity where multiple contaminants might be found (i.e. stormwater discharges), the status quo planning approach could be maintained, which is to address toxicant impacts on a case by case basis through discharge consenting.

The options considered are: a) to not set any toxicants as attributes under the NPS-FM but to deal with them under the discharge consenting framework; or b) to use trigger values as indicated in Table 29 and Figure 4 as water quality targets. Protection levels would depend on background concentrations, consultation with the community on ecosystem management goals and FMUs. Targets set at a 99-95% species protection level based on toxicity thresholds could be applicable to high value ecosystems or to have no change in biodiversity, but modified and impacted urban streams could require a less stringent target. Note that the sediment quality targets set in the ANZECC guidelines could also be considered from for some toxicants.

Table 29 Proposed protection levels for aquatic species from toxicants at different states of ecological intactness.

Toxicants	Ecological State (relates to FMU)	Level of protection for % species (based on ANZECC, 2000)
	Natural state	99%
Slightly to moderately disturbed	90% to 99%	
Highly disturbed	80% to 95%	

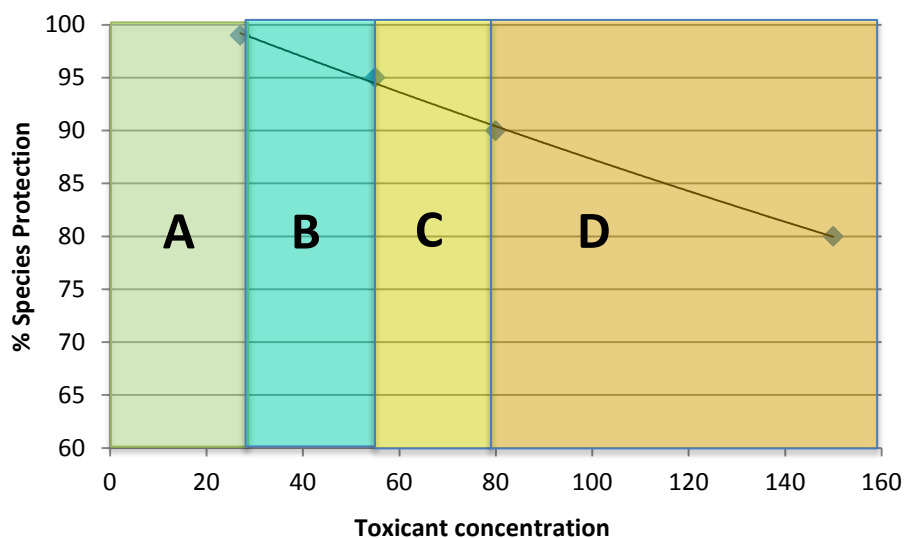


Figure 4 Example of a banding framework that could be used for an individual toxicant based upon ANZECC guidelines.

## 5.5 Microbiological attributes

### 5.5.1 Escherichia coli (E.coli)

If human or animal faecal matter finds its way into waters of recreational value, there is a risk that water users will be exposed to a diverse range of pathogenic (disease causing) micro-organisms. The impacts of pathogenic micro-organisms on human health are commonly manifested as gastro-enteritis, but other common illnesses include respiratory problems and skin rashes. Serious illness can also be attributed to infection from pathogens contained in waters, for example, hepatitis A, giardiasis, cryptosporidiosis, campylobacteriosis and salmonellosis (MfE/MoH, 2003).

Indicator micro-organisms are used to assess recreational water quality. The bacteriological indicators chosen are associated with the gut of warm blooded animals and are common in faecal matter. In freshwaters, the indicator bacteria recommended in the New Zealand Microbiological Water Quality Guidelines (see Appendix 1) is *E.coli*. Research that relates illness to indicator bacterial levels has been used to develop guideline levels which are based on the tolerable risk to healthy people.

Table 30 summarises how the *E.coli* attribute has been used by some other councils around New Zealand. Note that different Councils have identified a range of values which their attributes relate to, some of which are similar between Councils and some are regionally specific. Because of the differences in value definitions between councils, the values have not been included below and readers wanting this information are directed to the relevant Council's documents.

*E.coli* is currently an attribute in the NPS-FM, and the statistics for *E.coli* are Annual Median (for secondary contact e.g. wading/boating) and 95%ile for primary contact (e.g. swimming). At the time of writing, proposed amendments to the NPS-FM were open for public submission, and there remained significant uncertainty around final content. Consequently, for the purpose of this report, comparisons of the *E.coli* attribute in particular have been made against to the operative NPS-FM (2014). Note that subsequent reports will incorporate any amendments to the NPS-FM.

Table 30 Examples of *E.coli* attribute and numeric thresholds/guidelines from some other councils.

Attribute	Numeric Threshold/Guideline	Water body	Council
<b><i>E.coli</i> (mean) Primary contact</b>	< 126/100 mL river flows < median Nov-Apr	Rivers	Recommended to Marlborough District Council (Clapcott and Hay, 2014)
<b><i>E.coli</i> (max.) Primary contact</b>	< 260/100 mL river flows < median Nov-Apr	Rivers	
<b><i>E.coli</i> (mean) Secondary contact</b>	< 260/100 mL river flows < median Nov-Apr	Rivers	
<b><i>E.coli</i> (max.) Secondary contact</b>	< 550/100 mL river flows < median Nov-Apr	Rivers	
<b><i>E.coli</i></b>	260/100 mL when river flows < median during bathing season 550/100 mL rest of the time when river flow < 20 <sup>th</sup> percentile	Rivers	Horizons Regional Council (2014)
<b><i>E.coli</i></b>	260/100 mL (1 Nov - 30 Apr) 550/100 mL (1 May - 31 Oct)	Lakes	
<b><i>E.coli</i></b>	Overall range 50-260/100 mL * <sup>∞</sup>	Rivers	Otago Regional Council (2016)
<b><i>E.coli</i></b>	Overall range 10 - 126/100 mL * <sup>#</sup>	Lakes	
<b><i>E.coli</i> (Annual 95<sup>th</sup> percentile)</b>	Short-term target range: 15 - 6224 n/100 mL * 80-year target range: 540 n/100 mL *	Rivers	Waikato Regional Council (2016)
<b><i>E.coli</i> (Annual 95<sup>th</sup> percentile)</b>	80-year target range: 540 n/100 mL	Lakes	
<b><i>E.coli</i> (Annual median)</b>	Band A: ≤ 260/100 mL Band B: >260 ≤ 540/ 100 mL Band C: >550 ≤ 1,000/ 100 mL Band D: >1,000/100 mL	Rivers	Gisborne District Council (2015)
<b><i>E.coli</i> (95<sup>th</sup> percentile)</b>	Band A: ≤ 260/100 mL Band B > 260 ≤ 540/ 100 mL	Rivers	
<b><i>E.coli</i> (Annual median)</b>	≤ 260/100 mL	Rivers and Lakes	Northland Regional Council (2016)
<b><i>E.coli</i> (95<sup>th</sup> percentile)</b>	>260 ≤ 540/100 mL	Lakes	

Attribute	Numeric Threshold/Guideline	Water body	Council
<b><i>E.coli</i> (single sample)</b>	260/100 mL river flows < median in bathing season 550/100 mL river flows > median and < 3 x median during bathing season 550/100 mL at river flows < 3 x median outside bathing season	Rivers	Recommended to Greater Wellington Regional Council (Ausseil 2013a)

\* Target/standard varies for different zones/units/water bodies/classifications.

∞ achieved when 80% of samples collected when river flow ≤ median over a rolling 5-year period meet limit.

# achieved when 80% of samples collected over a rolling 5-year period meet limit.

*E.coli* is routinely measured monthly at BOPRCs Natural Environment Regional Monitoring Network (NERMN) river water quality sites. In addition, *E.coli* is measured seasonally at popular swimming sites over summer as part of the NERMN Recreational Surveillance programme.

Recommendation: Use the *E.coli* attribute as specified in Appendix II of the NPS-FM for the protection of Human Health for Recreation and Mahinga Kai (collection only) in both rivers and lakes.

### 5.5.2 Enterococci

Just as *E. coli* is the recommended indicator bacteria for freshwaters, enterococci is the recommended indicator bacteria in marine waters (MfE/MoH, 2003). Many of our rivers and streams drain into estuaries at the bottom of their catchments. In considering appropriate attributes for freshwater, due consideration has been given to the impacts on receiving environments (e.g. estuaries). Enterococci is currently measured in estuaries and marine waters across the Bay of Plenty (along with many other water quality parameters; Scholes, 2015, Scholes et al., 2016), and this information will be important when considering the impacts our freshwaters are having on our estuarine ecosystems.

Northland Regional Council proposed water quality limits for enterococci in coastal waters (Table 31) in its new Draft Regional Plan (NRC, 2016).

Table 31 Examples of enterococci attribute and numeric thresholds/guidelines from some other councils.

Attribute	Numeric Threshold/Guideline	Water body	Council
<b>Enterococci (95<sup>th</sup> percentile)</b>	Overall range 40 - 200/100 mL*	Coastal waters	Northland Regional Council (2016)

\* Target/standard varies for different zones/units/water bodies/classifications.

Enterococci ranked highly in the attribute evaluation because it is a widely used indicator of faecal contamination, is regularly monitored in marine/estuarine water bodies, and has existing guidelines. Enterococci is the preferred indicator bacteria for marine waters, and as such it should continue to be monitored in estuarine and coastal environments and compared to the Microbial Water Quality Guidelines as is current practice. No further recommendations are made for enterococci here as it is an indicator bacteria for marine waters. *E. coli* is the equivalent indicator bacteria for freshwater, and recommendations for *E. coli* have been made in Section 5.5.1.

### 5.5.3 Faecal coliforms

Like *E.coli* and enterococci, faecal coliforms are microbiological indicators of faecal contamination. Faecal coliforms indicate the presence of pathogenic bacteria, protozoa and viruses and have a stronger correlation with health risks associated with eating shellfish than enterococci (MfE/MoH, 2003), making them a useful indicator for shellfish health. Research that relates illness to indicator bacterial levels has been used to develop guideline levels which are based on the tolerable risk to healthy people. Table 32 summarises how the faecal coliform attribute has been used by some other councils around New Zealand.

Table 32 Examples of faecal coliform attribute and numeric thresholds/guidelines from some other councils.

Attribute	Numeric Threshold/Guideline	Water body	Council
Faecal coliforms (median)	14 MPN	Coastal waters	Northland Regional Council (2016)
Faecal coliforms (90 <sup>th</sup> percentile)	43 MPN	Coastal waters	

The bacterial standard used for stock drinking water is 100 faecal coliforms/100 ml (median value, ANZECC 2000, BOPRC, 2008). The levels of faecal coliforms in water closely match that of *E.coli* as these are part of the group of faecal coliforms. Faecal coliform thresholds are also stated in the Microbial Water Quality Guidelines for waters above shellfish gathering areas (see Appendix 1). Faecal coliforms are not considered a key attribute for rivers or lakes as other microbiological attributes (i.e. *E.coli*) are considered more appropriate.

## 5.6 Recommendations

The recommendations for physical, chemical and microbiological attributes for rivers are provided in two categories: recommended attributes with state bands, and recommended attributes without state bands. This recognises the importance of particular attributes to ecosystem health in both rivers and marine water, and the challenges around defining attribute state bands at this time for those attributes.

Table 1 lists the recommended physical, chemical and microbiological attributes and corresponding state bands for rivers, and Table 2 lists the recommended physical, chemical and microbiological attributes without state bands. This distinction only applies to river attributes as all of the recommended lake attributes have corresponding state bands (Table 4).

### 5.6.1 Other monitoring recommendations

In compiling this report, the authors noted many attributes that would benefit from additional research or investigation, and made many recommendations that were out of scope for this report. This section provides a summary of these key monitoring recommendations and is intended to inform decisions around BOPRCs monitoring programmes and further recommendations around attributes in future.

- Continue to monitor enterococci in estuarine and coastal environments and compare to the Microbial Water Quality Guidelines as is current practice.
- Review recommendations from national research into the sediment attribute once available and determine relevant sediment-related attributes for the Bay of Plenty.
- Continue with periphyton monitoring programme and planned research into estuary health and propose recommendations for thresholds/bands for dissolved inorganic nitrogen and dissolved reactive phosphorus once sufficient data from these research programmes is available. Note this should include consideration of the assimilative capacity of sensitive receiving environments.

- Investigate options for continuous dissolved oxygen, pH and temperature monitoring to allow reporting against these attributes. Note that a risk assessment could be undertaken to determine rivers at high-risk for DO, thermal or pH stress in order to prioritise where any new sensors should be located. This makes best use of resources by prioritising to high-risk areas.
- Investigate establishing a monitoring programme for deposited sediment in the Bay of Plenty as per the protocols developed by Clapcott et al., (2011). This monitoring programme should include adequate 'reference' sites in both hard and soft-bottomed streams, and include analysis of particle size distribution. It should also complement other sediment monitoring in the region and align with current research direction (e.g. Hicks et al., 2016).



# Part 6:

# Ecological attributes and bands

## 6.1 Introduction

Many ecological parameters could be used as attributes in rivers and lakes. These attributes, and the measures used to describe them, are described below. Monitoring ecological parameters is often seen as a more robust direct measure of environmental condition than monitoring water quality or hydrological parameters, as most ecological parameters integrate the antecedent environmental conditions prior to sampling. This contrasts with measures of water quality and flow which can change hourly, daily or weekly. For example, assessing contaminant loads in urban streams is notoriously difficult, and dependent on many factors such as rainfall intensity and duration, time since the last rainfall event, and traffic volume. Such variability makes it hard to properly assess the degree to which stormwater contamination may be affecting ecological values. However, by sampling the invertebrate communities, we can see if pollution sensitive taxa are absent from streams subject to stormwater inputs. Thus, the presence of a particular ecological parameter (for example macrophytes, or the presence of sensitive insects such as stoneflies) at a particular site suggests that environmental conditions prior to the time of sampling had been suitable for that particular organism to exist. Consequently, measuring ecological parameters requires a less frequent sampling protocol than occurs for parameters such as water quality and hydrology. For example, sampling invertebrate communities on an annual basis is generally regarded as a suitable timeframe by which to be able to assess the overall ecosystem health of rivers and streams.

Ecological parameters can be used to set both freshwater objectives as well as to help set numerical limits of a particular attribute. In deciding whether an ecological attribute could be an objective-setting, or limit-setting attribute, it is useful to recognise the fact that attributes high up on the trophic level (such as invertebrates or fish) are influenced by many more factors than factors lower down on the trophic level, such as algae. This means it may be more difficult to justify a particular numerical limit for attributes such as invertebrates or fish, as their relationships with environmental drivers is often complex and not well-known. In contrast, attributes such as periphyton are often controlled by fewer environmental drivers (e.g. nutrients, flow and light), and so it may be more realistic to set numerical limits on the desired quantity of periphyton in a river. This however should not detract from the fact that all ecological attributes – regardless of their trophic level – represent good descriptors of environmental state, and as such are useful to determine the extent to which the desired environmental outcome has been achieved. Setting objectives based on ecosystem attributes is therefore a way to evaluate the extent to which the values identified in section 3.1 are provided for.

In this section, a number of potential ecological attributes are discussed, as well as providing information as to what other regional councils throughout the country are doing. All attributes are presented in their trophic order, from primary producers (algae) up to secondary consumers (fish). Part of this work also involved examining reports and documents from other regional councils that outlined what attributes they had chosen. Whilst this review is not meant to be exhaustive, it highlights some of the major attributes and suggested limits that some other councils throughout the country have used.

Furthermore, this section describes the merit of six specific ecological attributes (benthic algae, lake phytoplankton, cyanobacteria, macrophytes, invertebrates and fish) for use as objective-setting attributes, or justifying their use as limit-setting attributes. It also covers assessments of stream habitat quality as an additional attribute, as stream habitat can often have dramatic effects on both water quality (e.g. temperature and dissolved oxygen) and ecological communities.



## 6.2 Attribute evaluation

As with the physical, chemical and microbiological attributes, all the ecological attributes were assessed against the evaluation criteria developed in Section 4.3, and the results are shown in the tables below.

Each ecological attribute was relevant for a different number of values (Table 33), with macrophytes being relevant for 17 values, and phytoplankton only for 7. This information was used to assign each ecological attribute a specific score as part of the multi-criteria evaluation.

*Table 33 List of different ecological attributes showing which ones support different values in the draft regional freshwater values set. Values shaded yellow represent cultural values which are outside the scope of this report. N=not a direct measure of value, Y= a direct measure of value, L=linked to value but not a direct measure.*

Draft regional freshwater values set Value	Benthic Periphyton	Phytoplankton	Cyanobacteria - benthic	Cyanobacteria - planktonic	Macrophytes	Invertebrates	Fish	Habitat
Te Hauora o te Wai/The health and mauri of water								
Ecosystem health	Y	Y	Y	Y	Y	Y	Y	Y
Significant indigenous species and habitat	N		N	N	N	Y	Y	Y
Te Hauora o te Tangata/the health and mauri of the people								
Occasional immersion/secondary contact recreation	Y		N	Y	Y	N	N	L
Frequent immersion/primary contact recreation	Y	Y	Y	Y	Y	N	N	L
Te Hauora o te Taiao/the health and mauri of the environment								
Natural form and character	Y	Y	Y	Y	Y	N	N	L
Mahinga kai/food gathering, places of food								
Mahinga kai – Kai is safe to harvest and eat <sup>1</sup>	N	N	Y	Y	Y	Y	Y	N
Mahinga kai – Kei te ora te mauri (the mauri of the place is intact) <sup>2</sup>								
Fishing	L	N	L	L	L	N	Y	Y
Game birds	N	N	N	L	Y	N	N	Y
Wai Māori/municipal waters and domestic water supply								
Municipal and domestic water supply	N	N	Y	Y	L	N	L	L
Treated wastewater discharge	Y	Y	Y	Y	Y	Y	Y	N
Urban stormwater drainage and assimilation	Y	N	Y	N	Y	Y	Y	Y
He ara haere/navigation								
Transport and Tauranga waka	L	N	N	N	Y	N	N	Y
Mahi māra/cultivation								
Irrigation and food production cultivation	N	N	Y	Y	Y	Y	Y	N
Animal drinking water	N	N	Y	Y	Y	N	N	N

Draft regional freshwater values set Value	Benthic Periphyton	Phytoplankton	Cyanobacteria - benthic	Cyanobacteria - planktonic	Macrophytes	Invertebrates	Fish	Habitat
Āu Putea/economic or commercial development								
Commercial and industrial use	Y	Y	Y	Y	Y	Y	Y	Y
Hydro-electric power generation	Y	Y	Y	Y	Y	Y	Y	Y
Flood water conveyance								
Flood protection and control	N	N	N	N	Y	N	Y	Y
Wai Tapu/sacred Waters								
Wai tapu								
Korero tuturu/sites or areas of cultural and historical significance								
Sites of cultural significance								
Cultural heritage and connection								
Rawa Tuturu/customary resources								
Rawa Tuturu								
Influence on other freshwater bodies								
Base flow/quantity	Y	N	Y	Y	Y	Y	Y	Y
Water quality	Y	N	Y	Y	Y	Y	Y	N
Moana/influence on sensitive coastal waters and receiving environments								
Influence on sensitive coastal waters and receiving environments	Y	N	Y	Y	Y	Y	Y	N
Influences on/by geothermal heat								
Influenced by geothermal water	L	N	L	N	N	L	L	N
Total number of direct values	11	6	14	14	17	11	13	10
Scoring of values	2	1	2	2	3	2	2	1

- 1 Relevance of attributes for Mahinga Kai – kai safe to eat and harvest are based on cyanobacteria potentially affecting some invertebrates (e.g. kakahi) or fish, and of macrophytes (water cress) invertebrates (kakahi, koura) or fish (tuna, inanga) being safe in terms of bacterial or heavy metal contamination.
- 2 Attributes related to iwi cultural values (shaded yellow) have not been considered in this report which is focussed on western science attributes. These important values will be dealt with in other reports.

Table 34 Results of the ranking process of individual ecological attributes showing the scores assigned for each of the 7 different criteria. The total value of each attribute was determined by the sum of these ranks.

Waterway type	Attribute	Measured parameter	Values	Responds	Ease	Cost	Mandate	Indices	Defensible	Sum
Rivers	Fish	Fish_IBI	2	1	2	2	1	2	2	12
	Invertebrates	Biotic indices (MCI/QMCI, EPT etc.)	2	1	3	2	3	3	3	17
	Macrophytes	% submerged and/or emergent cover	3	2	3	3	3	2	2	18
	Benthic Periphyton	PeriWCC, PeriMat	2	3	2	2	3	3	3	18
		Chlorophyll-a biomass (Biggs 2000 guidelines)	2	3	2	2	3	3	3	18
	Cyanobacteria-benthic	% cover (MfE/MoH guidelines)	2	2	3	3	3	3	3	19
	Cyanobacteria-planktonic	Biovolume (Lake-fed rivers only)	2	3	3	2	3	3	3	19
	Habitat	Rapid Habitat Assessment Protocols (Clapcott, 2015)	1	2	2	2	2	2	2	13
Lakes	Fish	Fish_IBI	2	1	2	2	1	2	2	12
	Invertebrates	Biotic indices (MCI/QMCI, EPT etc.)	2	1	3	2	3	3	3	17
	Macrophytes	Lake SPI	3	2	3	2	2	3	3	18
	Phytoplankton	Chlorophyll-a (mg/m3: to calculate TLI)	1	3	2	2	3	3	3	17
	Cyanobacteria-planktonic	Biovolume	1	3	2	2	3	3	3	17

This ranking process showed that for rivers, benthic and planktonic cyanobacteria had the highest attribute score (19), followed by macrophytes, and periphyton (both cover and *chlorophyll-a*). Attributes describing invertebrates had intermediate score weightings (17), while habitat and fish have the lowest score weightings. Similar results were found for lake attributes, with the macrophytes, *chlorophyll-a* and planktonic cyanobacteria having the highest score weightings, and fish and invertebrates the lowest (Table 34).

Note that these rankings are based purely on assessment of each attribute according to the multi-criteria evaluation as presented in section 4.3. The importance of some attributes, such as habitat, may change as more work is done on investigating linkages between habitat quality and ecosystem health. This means that some features of habitat such as the nature and degree of riparian protection, or percentage of riparian area supporting vegetation that shades the stream may be important in affecting ecological values in a stream which Council has the mandate to manage via statutory or non-statutory methods. These habitat features would also be easy to measure, and respond to factors that Council has a mandate to control.

Following this scoring process, relevant attributes were selected for use in the Bay of Plenty as potential as objective-setting or limit-setting attributes. Appendix II of the NPS-FM (2014) already contains some bands for the attributes periphyton and phytoplankton. Other attributes such as cyanobacteria cover were not identified in the NPS-FM, but bands exist in other documents (e.g. Wood et al 2009), or have been used in other regions. When this occurred, these published bands were recommended for use in the Bay of Plenty.

Although there are four recognised “water quality” classes for the Macroinvertebrate Community Index (MCI: e.g. Stark 1985; Stark and Maxted 2007), these have been shown not to discriminate between streams flowing through different land use classes in each of the biophysical classifications (Suren et al, 2017). Because of this, bands for biotic metrics such as the MCI were developed specifically for the region. Note it is extremely difficult to produce clearly defined numerical bands for many attributes without due regard to what **particular value** is the focus for a management objective.

### 6.2.1 Benthic periphyton

“Periphyton” is the term used to describe the slime that grows attached to rocks, stumps, and other stable substrates in rivers and streams. It is composed mostly of algae, although it can also contain fungi and bacteria. It is a natural component of rivers, and provides an important food source for invertebrates. Periphyton can also be an important indicator of changes of water quality because increases in the concentrations of dissolved nutrients may lead to excessive cover and biomass of periphyton (i.e. a bloom or proliferation). Periphyton blooms have detrimental impacts on not only the ecological value of rivers but also their recreational, aesthetic and cultural values (Biggs, 2000).

Assessments of periphyton biomass in streams can be made either by measuring chlorophyll-a (the photosynthetic pigment that is found in all plants – including algae), or by a visual assessments of percentage cover of different periphyton groups. In both cases, a river is divided into four transects, and visual observations are made of algal communities at five locations across each transect.

Chlorophyll-a is often used as a measure of the productivity of a water body and gives an indication of the trophic state of the water body. MfE (2015) highlight that increasing nutrients can cause water bodies to become eutrophic, which are often associated with poor ecological health due to blooms of plants or algae, large fluctuations in DO, pH, smothering of habitat and potential alteration of ecological communities.

Environment Canterbury has recognised 10 different River Management Units throughout the Canterbury region, emphasising that key physical and ecological processes in these rivers reflect whether a river’s main headwaters originate at high altitudes in the Southern Alps, in the foothills or as springs in low relief areas. These features enable a river classification system that reflects a logical grouping according to biophysical characteristics, values and vulnerabilities (Hayward et al., 2009). Within these management units, specific outcomes for chlorophyll biomass and percentage cover by different algal groups of the stream bed have been developed (Table 35).

Table 35 Periphyton attributes and outcomes for chlorophyll-a biomass and percent stream cover in the different river management units in Canterbury.

River management unit	trophic status objective	Chlorophyll-a (mg/m <sup>3</sup> )	Percent cover of stream bed
Alpine – Upland	Oligotrophic	50	10
Alpine – lower	Mesotrophic	120	20
Lake fed	Mesotrophic	200	30
Hill fed – Upland	Oligotrophic	50	10
Hill fed – lower	Mesotrophic	200	30
Banks Peninsula	Mesotrophic	120	20
Spring fed Upland	Oligotrophic	50	10
Spring fed – lower basins	Mesotrophic	200	30
Spring fed - plains	Mesotrophic	200	30
Spring fed plains - (urban)	Mesotrophic	200	30

Greater Wellington Regional Council developed periphyton guidelines in relation to water managed for contact recreation (CR), amenity (A) and stock drinking water (SW) management purposes (Ausseil, 2013a). For waters with a CR or A management purpose, they suggested an upper periphyton cover of 30% cover of filamentous algae greater than 2 cm long, or 60% cover of cyanobacterial mats greater than 3 mm thick.

Horizons Regional Council has identified 23 different values for waterways in their region, which were assigned to one of four groups (Horizons Regional Council, 2014). For example, the "ecosystem values" group includes five individual values recognising intrinsic value of freshwater for the living communities and natural processes they sustain, while the recreational and cultural values group includes nine individual values associated with the spiritual and cultural values and recreational use of water bodies. Two of the 23 values are particularly relevant for this report: Life Supporting Capacity (LSC) and Trout Fishery (TF:(Ausseil and Clark, 2007)). For the LSC value, the management goal is: "*the water body supports healthy aquatic life/ecosystems*" (Ausseil and Clark, 2007). This value specifically recognises the water quality requirements of native aquatic ecosystems, including, but not restricted to, fish and aquatic macroinvertebrates.

Horizons have used the New Zealand Periphyton Guidelines (Biggs 2000) to help define two levels of protection based on the physical conditions and inherent values of waterways in their region. Ten such waterway categories were defined, including eight riverine freshwater categories, one for freshwater lakes and one for coastal marine waters (Ausseil and Clark, 2007: see Table 36). Periphyton biomass standards were subsequently assigned to these different riverine freshwater categories.

Table 36 Periphyton chlorophyll-a biomass and percent stream cover in the eight different Water Management Zone Classes in the Manawatu.

Life supporting class category	Water Management Zone Class	Recommended periphyton biomass standard ( <i>chlorophyll-a</i> mg/m <sup>2</sup> )
<b>UHS</b>	Upland hard sedimentary	50
<b>UVA</b>	Upland volcanic acid	50
<b>UVM</b>	Upland volcanic mixed	120
<b>ULi</b>	Upland limestone	120
<b>HM</b>	Hill mixed	120
<b>HSS</b>	Hill soft sedimentary	200
<b>LM</b>	Lowland mixed	200
<b>LS</b>	Lowland sand	200

Northland Regional Council identified three river water quality management units (lowland, hill country and outstanding rivers: Northland Regional Council, 2016). They have yet to determine biomass levels for chlorophyll in either lowland or hill-country rivers, but have set an upper limit of less than 50 mg/m<sup>2</sup> chlorophyll-a in outstanding rivers with hard substrates.

Waikato Regional Council does not apply the periphyton Attribute as per NPS-FM, because of limited relevance in most streams and rivers in the Waikato-Waipā Catchment, which are dominated by highly mobile soft substrates and as such unlikely to support significant algal biomass. Not all sites within the Waikato region are like this, and periphyton cover in various gravel bed streams has been monitored annually in these streams (Collier and Hamer, 2010). They found that the vast majority of samples had periphyton cover less than 20%, indicative of high quality, and no evidence of periphyton proliferations. Because of this, Waikato Regional Council has concluded that periphyton is only of limited relevance as a measure of ecosystem health in their region, and it has not been included as an attribute (Scarsbrook, 2016; Snelder et al., 2013).

Measurements of algal biomass (as *chlorophyll-a*) are included in the NPS-FM as a compulsory attribute. In response to this, Suren and Carter (2015) developed a periphyton monitoring protocol for the Bay of Plenty region, and samples had been collected from 30 sites since October 2015. Under the NPS-FM, periphyton biomass needs to be calculated from a three year mean, so monitoring will continue until this time is reached. All data will then be analysed to determine the strength of relationships between periphyton biomass and driving variables such as nutrients, temperature and flow.

Recommendation: It is recommended that the periphyton attribute (as measured by chlorophyll-a biomass per unit area) as specified in Appendix II of the NPS-FM be used in rivers for the protection of Ecosystem Health, Significant Indigenous Species and Habitat, Mahinga Kai (collection only), Fishing and Human Health for Recreation .

### 6.2.2 Lake phytoplankton

In contrast to rivers and streams, where algae most commonly grow on the streambed and other structures, algae in lakes is dominated by phytoplankton. Phytoplankton is usually made up of a wide range of microscopic algae that are found mostly in the upper, sunlit layer of lakes. These algae include a wide range of different groups such as diatoms, cyanobacteria, desmids and dinoflagellates, although many other groups of algae are also represented. These small algae are consumed by zooplankton such as rotifers, copepods and waterfleas such as *Daphnia*, which in turn are consumed by fish.

As primary producers phytoplankton rely on nutrients for their growth and development, and in lakes where nutrients are high, phytoplankton blooms are common. Phytoplankton blooms can lower water clarity, and this can then lead to the loss of submerged plants. This loss of submerged plants will then have other negative impacts on the invertebrates and fish that utilise them as habitat. Furthermore, blooms of short-lived phytoplankton can often result in lake waters becoming deoxygenated in their bottom waters as dead cells settle to the lakebed. Here, bacterial decomposition will reduce the oxygen concentration of the water, especially in stratified lakes where oxygen rich water does not mix with oxygen depleted water. Under such anoxic conditions, phosphorus is also released from sediments, and when the lake becomes mixed again, this is released back into the water column, further adding to the nutrient loads in the lake.

The sudden disappearance of submerged macrophytes and dominance of phytoplankton in lakes is called “lake flipping”. This has happened in a number of iconic lakes in the country, including Te Waihora/Lake Ellesmere in Canterbury. This lake was originally macrophyte dominated, but the combination of increased nutrients, plus a high suspended sediment load from wave action (exacerbated by the Waihine Storm in 1969) resulted in the loss of macrophytes, and a lake that is now dominated by phytoplankton productivity.

The simplest measure for assessing the amount of phytoplankton in a lake is by measuring the amount of *chlorophyll-a* in a water sample: the more phytoplankton there is, the higher the chlorophyll content. Another way of assessing phytoplankton communities is based on the microscopic examination of water samples to identify and count the different types of phytoplankton in a sample. This, however, relies on a high degree of taxonomic expertise, needs specialised equipment (e.g. inverted microscopes), and is a costly and time-consuming process. Measurements of chlorophyll-*a* in contrast are quicker and simpler to do, and provide valuable information as to a lakes trophic state. Moreover, chlorophyll-*a* is one of the components of the TLI (see Section 5.4.6).

Measurements of lake phytoplankton, in terms of biomass of chlorophyll-*a*, are included in the NPS-FM as a compulsory attribute. Within the Bay of Plenty, monthly measures of *chlorophyll-a* are collected from the 12 Te Arawa/Rotorua lakes as part of the long-term TLI monitoring programme run by the Council. As such, the chlorophyll-*a* bands are not used directly by Council, but instead make up a component of the TLI.

Recommendation: use the phytoplankton attributes (as measured by chlorophyll-*a* biomass per unit area) as specified in the Appendix II of the NPS-FM for lakes, for the protection of Ecosystem Health, Mahinga Kai (collection only), Fishing and Human Health for Recreation, but incorporate this into calculating the Lake TLI value on a monthly basis (see Section 5.4.6). The proposed TLI bands (Burns 2000) have the same range of chlorophyll-*a* values as the NPS-FM bands for the annual median. The advantage of using the Burns (2000) TLI bands is that it is fully compatible with the current TLI objectives that have been set for many of the Te Arawa Rotorua lakes.

### 6.2.3 Cyanobacteria – benthic

Cyanobacteria are also commonly referred to as blue-green algae, but in fact are bacteria. Their common colour (blue-green, or cyan) gives them their name. Cyanobacteria are one of the oldest forms of life, and were responsible for the release of huge quantities of oxygen into the atmosphere during the Pre-Cambrium period, some 3.5 million years ago. Many cyanobacteria have the ability to fix their own nitrogen from the atmosphere so they can flourish in low nitrogen environments. They also have the ability to store phosphorus in excess of their immediate needs. There are two broad groups of cyanobacteria relevant to limit setting in freshwaters: benthic (that grow on large stable stones in stream beds), and planktonic (that occur in the water column of lakes, and are found in lake-fed rivers).

Benthic, mat-forming cyanobacteria are widespread in rivers and streams throughout the country and are found in a wide range of water-quality conditions, from low nutrient (oligotrophic) to highly enriched (eutrophic) waters (Biggs 2000). The most common mat-forming benthic cyanobacteria genus is *Phormidium*, which often appears as a black-brown leathery mat that grows on stable surfaces such as cobbles and boulders in rivers (Biggs and Kilroy, 2000). During stable flow conditions, and especially in summer when water temperatures are high, *Phormidium* can form extensive mat-like growths over the streambed. Although other types of algae such as diatoms and filamentous green algae can also proliferate during times of stable flow and warm temperature, *Phormidium* mats can often out-compete these other algae (Suren et al., 2003).



Excessive algal growth in rivers over summer can have large detrimental effects on a stream's ecological, aesthetic, and recreational values (Biggs, 1985; Biggs and Price, 1987; Suren and Riis, 2010). However, *Phormidium* blooms have the additional problem that, unlike other algae, they can often produce toxic substances. As *Phormidium* mats grow and age, they become thicker and thicker until parts of the mat die or weaken, and detach from the surface. This detached material often accumulates along river edges, where it poses risks to humans and, in particular, dogs, which seem attracted to the rather "musty" smell of the drying material. Dog deaths have now frequently been recorded in some rivers throughout the country (Wood et al., 2009).

Environment Canterbury (Hayward et al., 2009) has a narrative statement applicable to all river management units that "*toxin producing cyanobacteria shall not render the river unsuitable for recreation or animal drinking water*". It is assumed that they are using the current Ministry of Health Cyanobacterial Guidelines for this. Environment Canterbury has also set numeric outcomes for benthic cyanobacteria mats in its operative Land and Water Regional Plan (Table 37).

Table 37 Numeric outcomes for the % cover of cyanobacterial mats in the different river management units in Canterbury.

River management unit	Trophic status objective	Cyanobacterial mat cover (%)
Alpine – upland	Oligotrophic	20
Alpine – lower	Mesotrophic	30
Lake-fed	Mesotrophic	50
Hill-fed – upland	Oligotrophic	20
Hill-fed – lower	Mesotrophic	50
Banks Peninsula	Mesotrophic	30
Spring-fed upland	Oligotrophic	20
Spring-fed – lower basins	Mesotrophic	50
Spring-fed – plains	Mesotrophic	50
Spring-fed plains - (urban)	Mesotrophic	50

This attribute had the equal highest ranking as part of our attribute scoring process (Table Table 34). The high ranking for this attribute reflected its high scores for criteria such as ease and cost of measurement, existence of clear and defensible indices, and being clearly defensible and transparent: there are clear health implications in waterways with a high cover of benthic cyanobacteria.

As part of the current monthly periphyton monitoring (Suren and Carter, 2016), assessments of benthic cyanobacteria cover are made using the standard MfE protocols (Wood et al., 2009). It is recommended that this monitoring be continued, and that current Wood et al., (2009) bands already identified be used to determine potential health risks to recreational users. It is also important to realise that benthic cyanobacteria are normally restricted to large stable cobbles and boulders, and are generally absent from unstable, pumice bed streams. This attribute would therefore mostly be used in streams dominated by large substrates. This would restrict benthic cyanobacteria mainly to the non-volcanic steep gradient stream biophysical class, although they may occur to a lesser extent in volcanic steep gradient streams.

Although the Wood et al (2009) guidelines do not specify an exceedance frequency, it is suggested that an exceedance frequency be incorporated into any bands that are developed for benthic cyanobacteria. This is somewhat complicated by the fact that the frequency of sampling for benthic cyanobacteria will change depending on the alert level at a particular river. It will also vary greatly depending on the frequency, magnitude and duration of flood events, as benthic cyanobacteria will normally only occur during periods of low, stable flow. This means that it may be difficult or impossible to implement a regular monthly sampling protocol for benthic cyanobacteria.



Instead, it is recommended that a more pragmatic approach be taken whereby bands are based on the 80<sup>th</sup> percentile of data collected. As with the NPS-FM attribute for planktonic cyanobacteria, it is recommended that the 80<sup>th</sup> percentile is calculated with a minimum of 12 samples over a three-year period, however a more robust measure would be based on 30 samples collected over a three-year period.

Recommendation: Use the benthic cyanobacteria attribute as specified in Table 38 for the protection of Ecosystem Health, Significant Indigenous Species and Habitat, Mahinga Kai (collection only), Fishing and Human Health for Recreation in Rivers.

Table 38 Suggested bands for benthic cyanobacterial monitoring.

Attribute		Benthic cyanobacteria	
<b>Attribute unit</b>	Percentage cover of the stream bed, based on sample protocols as outlined by Woods et al., (2009)		
<b>Attribute state</b>	Numeric attribute state		Narrative attribute state.
	80 <sup>th</sup> percentile*		
<b>A</b>	Cover < 20%.	Minimal risk exposure from benthic cyanobacteria for 80% of the time.	
<b>B</b>	N/A		
<b>C</b>	Cover 20 – 50%	Low risk of health effects or dog deaths from exposure to benthic cyanobacteria for 80% of the time.	
<b>D (regional bottom line)</b>	Cover > 50%, OR max dislodging and accumulating along river's edge	Potential health risks from exposure to benthic cyanobacteria, potential risk to dogs walking along river margins.	

\*The 80<sup>th</sup> percentile is calculated from either a minimum of 12 samples over a three-year period, or more preferably from 30 samples over three years, concentrating mainly on times during heightened cyanobacteria risk.

#### 6.2.4 Cyanobacteria – planktonic

Planktonic cyanobacteria are of concern as their presence in lakes can lead to blooms that produce a number of undesirable effects, including green colouration of the water, reduced clarity, algal scums on the water surface, undesirable odours and potentially production of toxins that can affect human and animal health. They also have the ability to alter their buoyancy to take advantage of the environmental conditions. This means they are often found floating on the surface of the lakes and can form bright green blooms that are blown on the wind or moved by currents into the shore and lake bays. Planktonic cyanobacteria can also form problems in lake-fed rivers, as blooms can travel down the river from the lake outlet.

As with benthic cyanobacteria, certain planktonic cyanobacteria can also produce toxins. These are a threat to humans and animals when consumed in drinking water or by contact during recreational activities. Cyanotoxins produce symptoms such as nausea, diarrhoea, gastroenteritis and can cause liver damage.

Cyanobacterial blooms have become a regular occurrence in the Rotorua lakes since the early 1990's. Since then, monitoring of cyanobacterial concentrations has been undertaken by BOPRC in conjunction with the Bay of Plenty District Health Board. BOPRC collects weekly samples throughout the summer period, from approximately 15 sites around the edges of Lake Rotorua, Rotoiti, Rotoehu and 5 – 10 samples from other lakes in the region. Health recommendations and warnings have traditionally been based on counts of the number of cyanobacterial cells/mL. However, in recent years very small planktonic species of cyanobacteria (usually termed picoplankton) have become increasingly prevalent, artificially increasing the counts of cells/mL. These high cell counts have often resulted in the unnecessary issuing of health warnings.

To circumvent this problem, biovolume ( $\text{mm}^3/\text{L}$ ) is used instead, which considers the variability in size of different cyanobacterial species, and is therefore a better indicator of potential health risks. Additionally, toxin concentration per cell is more closely related to cyanobacterial biovolume than concentration.

Northland Regional Council uses the NPS-FM attribute bands for setting limits on planktonic cyanobacteria. They have also produced two lake management units: shallow lakes and deep lakes (Table 39), which differ in their desired freshwater objectives. Thus, shallow lakes have a biovolume objective equivalent to the NPS-FM 'C' band, while deep lakes have a biovolume objective of the NPS-FM 'A' band. Waikato Regional Council has also used the NPS-FM planktonic cyanobacterial guidelines.

Table 39 Cyanobacterial attributes and suggested freshwater objectives for lakes in the Northland region.

Attribute	Unit	Compliance metric	Shallow lakes management unit	Deep lakes management unit
<b>Cyanobacteria - Planktonic</b>	$\text{mm}^3/\text{L}$ OR cells/mL	80 <sup>th</sup> percentile	> 0.5 and < 1.8 $\text{mm}^3/\text{L}$ biovolume equivalent of potentially toxic cyanobacteria OR > 0.5 and < 10 $\text{mm}^3/\text{L}$ of total cyanobacteria.	< 0.5 $\text{mm}^3/\text{L}$ biovolume equivalent of a combined total of all cyanobacteria OR < 500 cells/mL of total cyanobacteria.

Planktonic cyanobacteria are already included in the NPS-FM as a compulsory attribute.

Recommendation: Use the planktonic cyanobacteria attribute as specified in Appendix II of the NPS-FM for the protection of Ecosystem Health, Mahinga Kai (collection only) and Human Health for Recreation in lakes.

### 6.2.5 Macrophytes

In addition to algae, aquatic macrophytes are the other major plant of waterways. The term "macrophyte" literally means "large plant", and these are easily observed with the naked eye. Aquatic macrophytes include both bryophytes (mosses and liverworts), aquatic ferns (such as the free floating *Azolla*, and other plants such as *Lemna*), and flowering plants which are either submerged (e.g. *Elodea*, or "oxygen weed"), floating (e.g. water-lily), or emergent (e.g. wetland plants such as *Typha*). Each of these plants has very distinctive morphologies, habitats, and reproductive life cycles (Table 40).

Aquatic bryophytes are usually restricted to small headwater streams on large stable substrates (Suren, 1996). They are often lost from streams subject to high sediment loads, or high algal blooms that occur with the removal of riparian canopy shade, and nutrient enrichment leading to algal blooms. These plants represent important habitats for invertebrates and algae (Suren, 1991, 1992), especially in flood prone headwater streams. The value of these plants as attributes would be fairly limited, and restricted mostly to values concerning maintenance of indigenous biodiversity. As such, they were not considered further.

Aquatic ferns can often form nuisance growths in slow flowing environments such as ponds, lakes or backwaters in rivers, where they can cover the entire surface of aquatic environments. Under such conditions, they could potentially reduce many values such as aesthetics, recreation, and ecology. They thus may serve as an objective-setting attribute where some form of maximum cover band could be expressed. The difficulty with this however is that aquatic ferns can spread by a wide range of vectors including waterfowl, making it rather impractical to set meaningful freshwater objectives. Aquatic ferns were thus not considered further.

Aquatic flowering plants, including submerged, emergent and floating forms are arguably the most important macrophytes in streams. They are found mainly in lowland unshaded streams where substrates are generally fine, and which are subject to less than six bed moving floods per year. Streams which flood more than this generally do not support aquatic macrophyte growth.

Aquatic macrophytes play important roles in soft bottomed streams where they often represent the dominant stable habitat. They also can represent beneficial habitats in lakes. They represent a major source of primary production, and provide important habitats for both fish and invertebrates in rivers (e.g. Collier, 2004) and lakes (e.g. de Winton and Schwarz, 2004; Weatherhead, 2001). Many exotic macrophytes have been introduced to New Zealand and these have had major impacts on both river and lake ecosystems throughout the country. These plants have spread throughout the country, and often out-compete native species which are generally of low stature, less competitive, and easily excluded from their shallow habitats. Major invasive plants in the Bay of Plenty include *Lagarosiphon*, *Elodea*, *Egeria*, and *Ceratophyllum*, which often cover and choke lowland waterways, wetlands and drains, and displace native plants. These plants have a large range of negative effects on many values including:

- Ecological Health - by smothering habitats, and causing increased sedimentation amongst macrophyte beds.
- Water quality - by causing large daily variations in both oxygen and pH, and by trapping large accumulations of sediment and decaying organic matter.
- Drainage: by blocking up channels, therefore reducing the water flow.
- Recreation: by making it difficult to wade, swim, boat or fish.

Aesthetic: blocking up water bodies, accumulations of dead plants floating on the surface.

Table 40 Description of the common macrophytes found in waterways.

Dominant plant group	Morphology	Habitat	Reproductive life cycle	Ecological notes
<b>Bryophytes</b>	Mostly small (< 20 mm). Consist either of plate like leaves (thallus), or simple single celled leaves growing from stems. Plants either prostrate forming “wefts” over boulders, or erect forming cushions or turfs. Attached to rocks by stolons.	Restricted to large stable substrates that rarely move (“Rolling Stones gather no moss”). More common in smaller headwater streams. More common in shaded streams	Reproduced by spores, or more usually by fragmentation.	Important habitat for invertebrates and algae, especially in flood prone steep streams. Obtain nutrients from the water column.
<b>Aquatic ferns</b>	Range of size: Small (1-5 mm) such as Lemna, or larger (15-25 mm) such as Azolla.	Restricted to slow flowing environment such as ponds, sheltered embayments and lakes, or backwaters of rivers.	Mostly by vegetative propagation.	Can form extensive mats over ponds, or in slow flowing drains which may reduce habitat qualities for invertebrate, fish and bird life. Obtain nutrients from the water column.
<b>Submerged and emergent flowering plants</b>	Variable size and shape, but mostly more than 50 mm. Consist of leaves arranged up a stem, and rooted.	Dominant in slow flowing environments such as ponds or lakes, and in large slow flowing streams with fine substrate. In lakes, are restricted to shallow areas that receive enough light.	Either by vegetative propagation of fragments, or by seed dispersal from flowers.	Important habitats for invertebrates and fish. Excess growths have major adverse effects on ecological values, as well as drainage, recreation and aesthetics. Invasive macrophytes are especially common in many lowland streams, and lakes. Obtain nutrients mainly from sediments.
<b>Floating plants</b>	Variable size and shape. Often consist of large, usually flat and circular leaves floating on the surface, attached to longer stems.	Dominant in slow flowing environments such as ponds or lakes, and in large slow flowing streams with fine substrate.	Either by vegetative propagation of fragments, or by seed dispersal from flowers.	Important habitats for invertebrates and fish. As with ferns, excess growth can have major adverse effects on ecological values, by covering extensive areas of open water. Obtain nutrients mainly from sediments.

de Winton and Schwarz (2004) proposed a model showing how the benefits of aquatic macrophytes can vary greatly according to biomass. Although this model was developed for lakes, it is also applicable to streams and rivers. This model shows that macrophytes at low biomass have little ecological benefits, and can risk becoming lost from lakes and rivers due to physical forces such as waves and currents acting directly on the plants (Figure 5). Within the lake context, maintenance of aquatic macrophytes at such low biomass may be unsustainable unless suitable restoration activities are implemented. In contrast, macrophytes can greatly affect values at high biomass levels. In lakes, excessive macrophyte growth can result in a loss of biodiversity and natural character, while in rivers, excess macrophytes can completely block channels and reduce instream habitat. Under such situations, control measures are recommended.

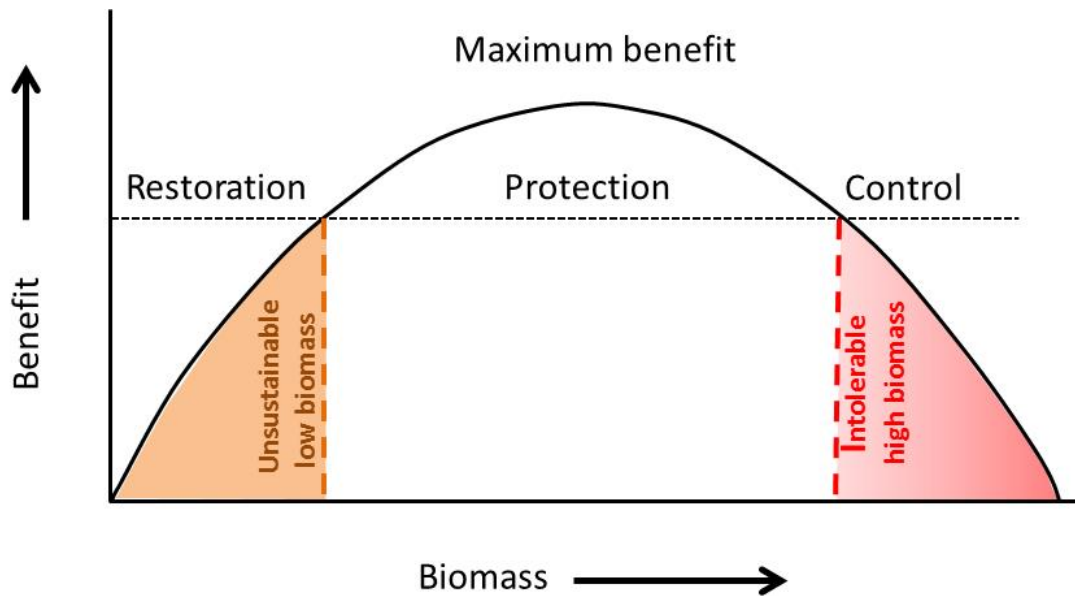


Figure 5 *Conceptual model of relationships between macrophyte biomass and the benefits they confer on values such as ecology and recreation. Note how different management actions and responses differ across the gradient of plant biomass. (Modified from de Winton and Schwarz 2004).*

In recognition of this model, some form of macrophyte cover, or of the dominance of exotic versus native plants could be used as an attribute to assess instream values such as ecosystem health. Because macrophyte cover responds to only a few key parameters (mainly nutrients, light (mostly in lakes) and flow (in rivers)) these plants could be used as a limit-setting attribute where a desired numeric objective for maximum cover is developed.

### 6.2.6 River macrophytes

Few councils monitor macrophyte cover in rivers and streams throughout their regions. One exception to this is Environment Canterbury, who have assessed macrophyte cover at five points across several transects of representative river reaches (Hayward et al., 2009). They assessed macrophyte cover based on either visual assessments of the aerial extent of growth is (e.g. percentage cover of the substrate), or the percentage of the river which is covered. Environment Canterbury set management objectives for macrophytes only for spring fed rivers in upland areas, lower basin areas and the Canterbury plains (Table 41) as these streams were considered the only ones where they could become problematic. Furthermore, they emphasised that the majority of nuisance macrophytes are caused by introduced species. An annual maximum of 50% cover of total macrophytes was considered appropriate for streams in the spring fed planes, there is an annual maximum of 30% of total macrophytes cover was considered appropriate for streams in upland or lower basin areas. In contrast, a much higher cover of 60% was deemed acceptable for spring-fed streams in urban areas of Christchurch (Table 41)

Environment Canterbury also emphasised that emergent macrophytes were also problematic, especially as they can completely obstruct natural flows, raise water levels, and form very high biomass which can lead to decreased oxygen levels (Hayward et al., 2009). They therefore considered that an annual maximum of 30% cover of emergent macrophytes was desirable for protecting spring fed streams of the lower basins and plains, whereas an annual maximum of 20% cover of emergent macrophytes was set as the outcome for upland spring fed streams (Table 41).

*Table 41 Summary of maximum cover of emergent, or total macrophytes in different River Management Units as identified by Environment Canterbury.*

River management unit	Total macrophytes [maximum cover of riverbed] (%)	Emergent macrophytes [maximum cover of the riverbed] (%)
Spring fed – upland	30	20
Spring fed – lower basins	30	30
Spring fed – plains	50	30
Spring fed – plains (urban)	60	30

Greater Wellington Regional Council also adopted a 30% annual maximum cover of emergent macrophytes and 50% annual maximum cover of total macrophytes as interim limits in rivers and streams managed for contact recreation and amenity purposes (Ausseil, 2011). It is emphasised that although these limits could be applied across a broad range of stream types, they were particularly relevant to spring fed and soft bottomed streams. However, no specific limits relating to macrophyte cover were recommended for water that is managed for stock drinking.

River macrophytes also had the equal highest ranking from the attribute scoring process (Table 34). In recognition of this, it is recommended that some form of macrophyte cover, or assessment of the dominance of exotic versus native plants could be used as an attribute to assess instream values such as ecosystem health. In the absence of any detailed information about the extent of macrophyte growths in rivers and streams throughout the Bay of Plenty, it is recommended that the provisional guidelines of Matheson et al (2012) be used as potential bands throughout the region.

Recommendation: Use the river macrophytes attribute as specified in (Table 42) for the protection of Ecosystem Health, Significant Indigenous Species and Habitat, Mahinga Kai (collection only), Fishing and Human Health for Recreation in Rivers.

*Table 42 Suggested bands for macrophyte monitoring.*

Attribute	Channel cross-sectional area or volume OR channel water surface area	
Attribute unit	% cover of channel	
Attribute State	Numeric attribute state	Narrative attribute state.
A	<50%	Aquatic plants will have little adverse effects on recreational, drainage, aesthetic or ecological values.
D (Regional bottom line)*	>50%	Aquatic plants likely to have significant adverse effects to one or more values for recreation, drainage, aesthetics or ecology.

\*Note that the regional bottom line for macrophyte cover would not be applicable to any waterways classified as a drain.



## 6.2.7 Lake macrophytes

NIWA has developed a Lake SPI (Submerged Plant Indicators) methodology to assess ecosystem health in lakes using aquatic macrophytes. The Lake SPI methodology is designed to complement traditional water quality monitoring such as the TLI (refer Appendix 4) by providing ecological information about lake health in terms of macrophyte communities. Moreover, Lake SPI assessments are done in the margins of lakes, where both human interaction and ecological values are greatest (Clayton and Edwards, 2006b). The Lake SPI methodology uses submerged macrophytes that are thought to integrate a range of environmental conditions over an extended period of time. Such conditions would include sediment and nutrient loading, as well as the displacement of native vegetation by exotic or invasive plant species.

There are three components of Lake SPI:

- Native condition index, which captures the native character of the vegetation,
- Invasive impact index, which captures the invasive character of vegetation in the lake based on the degree of impact by invasive weeds.
- Lake SPI index, a synthesis of components from both the native condition and invasive impact condition. The higher the score, the better the condition.

Lake SPI thus allows lake managers to assess and report on the status of lakes at an individual, regional or national level; monitor changes in a lake or group of lakes over time and prioritise lake management initiatives accordingly (e.g. protection, monitoring, weed surveillance). Lake SPI is recommended by the Ministry for the Environment as one of the few indicators for State of the Environment (SOE) reporting. Given that a Lake SPI score is influenced by three major drivers (nutrients, sediments, and invasive species), it may be possible to use it to express a freshwater objective and to justify the setting of limits, particularly if management actions can be initiated to minimise adverse effects of these drivers. Indeed, Environment Canterbury has used Lake SPI to describe lake outcomes in its operative Land and Water Regional Plan. Thus, large high-country lakes have a freshwater outcome of an “Excellent” Lake SPI score, while small to medium-size high-country lakes and artificial lakes on rivers have a freshwater outcome of a “High” Lake SPI score. Coastal lakes have a desired outcome of only a “Moderate” Lake SPI score.

The current Lake SPI methodology can be used to provide bands (or bottom lines) for desired macrophyte communities in individual lakes. In theory, the five Lake Condition categories developed by Burton (2016) could be used as attributes, as they provide a defensible description of the status of a lake’s macrophyte community. A potential problem with this approach lies in the fact that numeric values of the Lake SPI index are relatively large within a particular band. For example, consider a situation where an objective was set to maintain a certain lake (e.g. Lake Okataina) in a “Moderate” condition. Burton (2016) showed that this lake had an overall “Moderate” Lake SPI condition score (38), but that this was at risk of declining further if hornwort spread further throughout the lake. Further spread of this plant would result in calculated Lake SPI scores declining as the invasive impact index increased. However, this lake could decline a further 18 points to 20 (i.e. exhibit a 47% reduction in score from its current state) and still be regarded as in “Moderate” condition. Thus, even though this lake was still being maintained in “Moderate” condition, the extent of hornwort spread may become too large to practically deal with. An unintended consequence of this objective would therefore be having the lake decline to a “Poor” category, as it would not be realistic to control hornwort once it had spread throughout the lake.

Another, more conservative approach would be to set attribute bands for the rate of change to calculated Lake SPI scores. This approach is based on the scale of probabilities developed by Burton (2016) to describe ecologically significant changes in lake condition over repeated surveys (Table 43). Note that adopting this approach is likely to be more conservative than setting attribute bands based on the four Lake SPI classes described by Burton (2016), as the rate of changes are much smaller than could occur within a single Lake SPI class, as outlined above. Furthermore, although the NPS-FM is clear that councils need to “maintain or improve” ecological conditions, natural temporal changes to Lake SPI scores may cause fluctuations of +/- 10 of a lakes long term score without any reduction to ecological health. This reflects that fact that a decline in Lake SPI score of, say 10 units, may not necessarily reflect an ecological decline. According to Burton (2016), it is only when Lake SPI scores are declining by more than 15 units can we be confident that a true decline in the macrophyte community composition in a lake is occurring. Ideally the bottom line for a Lake SPI score could be set at the ‘C’ band, where new incursions of invasive weeds are reported. However, it is acknowledged that in some instances this may be problematic, especially if any new incursion is well-contained and not spreading.

We feel a more pragmatic approach is to set a bottom line such that Lake SPI scores do not decline by more than 15, above which a change in lake condition is indeed probable. In this way we can still maintain lake health while accepting that minor (and controlled) incursions of invasive macrophytes are acceptable, as long as overall Lake SPI scores do not decline by > 15.

Recommendation: Lake SPI monitoring continues in the Te Arawa/Rotorua lakes and that the proposed bands for changes to Lake SPI scores be chosen as management objectives for individual lakes. In this way it does not matter what the current Lake SPI score is for a particular lake, as this score will not be allowed to significantly decline. Ideally, management objectives for all lakes would be as per the 'A' band, although it is acknowledged that some lakes where there are incursions of invasive plants such as hornwort may be managed to a lower objective band, reflecting the practical difficulties of controlling these invasive plants once established. Use the Lake SPI attribute as per Table 43 for the protection of Ecosystem Health, Significant Indigenous Species and Habitat, Mahinga Kai (collection only), Fishing and Human Health for Recreation in lakes.

Table 43 Summary of guidelines for assessing the significance of change in Lake SPI scores over time.

Attribute		Changes to Lake SPI scores	
<b>Attribute unit</b>	Changes to calculated Lake SPI scores based on annual or biannual sampling.		
<b>Attribute state</b>	Numeric attribute state.		Narrative attribute state.
<b>A</b>	0 – 5 reduction in Lake SPI score OR an increase in Lake SPI score.		Change to Lake SPI not indicated.
<b>B</b>	>5 – 10 reduction in Lake SPI score.		Change to Lake SPI possible.
<b>C</b>	>10 - 15 reduction in Lake SPI score OR New incursion of a more invasive species.		Change to Lake SPI probable, OR introduction of new, potentially invasive species.
<b>D (Regional bottom line)</b>	>15 reduction in Lake SPI score.		Change to Lake SPI indicated.

### 6.2.8 Invertebrate attributes

Within New Zealand, the Macroinvertebrate Community Index (MCI) is widely used as a biotic index of water quality in stony streams (Stark, 1985, 1993). MCI scores can range from 20 to 200. Scores > 120 represent streams in "excellent" condition, while scores < 80 indicate highly degraded streams (Table 44). The MCI score relies on the presence or absence of invertebrates in a stream and so provides only a relatively coarse indication of stream health. It is not particularly sensitive to changes in the relative abundance of different taxa, which is arguably one of the first signs that a particular environment is under stress. Because of this, the quantitative variant of the MCI (i.e. the QMCI) is also used to describe the health of a particular waterway. This score simply takes the relative abundance of each taxa into consideration. Calculated QMCI scores range from 1 to 10. Streams with scores > 6 represent streams in excellent condition, and streams with scores < 4 represent highly degraded streams (Table 44). A third variant, the Semi-Quantitative MCI (SQMCI) is also used by some councils to describe the invertebrate communities. This score uses invertebrate abundance bands (i.e. rare, occasional, common, abundant) as opposed to actual counts or percentage data. Four discrete quality classes have been identified for the MCI/QMCI and SQMCI (Table 44).

All three indices were initially developed for stony bottomed streams, and this did not work well in soft bottomed streams. For example, MCI scores from soft-bottomed streams flowing in undisturbed native forest would have scores indicative of "degraded" conditions, even though the stream could be regarded as being in "excellent" condition for that type of stream. In response to this, Stark and Maxted (2007) developed soft-bottomed versions of these metrics (MCI\_sb and QMCI\_sb). These are calculated in the same way as the hard bottomed metrics, and have the same scoring bands. Use of the MCI-sb thus enables even soft-bottomed streams to score as "excellent", when previously they may not have if the original hard-bottomed MCI score had been used.



Table 44 Summary and interpretation of the Stark and Maxted (2007) water quality classes is based on the MCI, SQMCI and QMCI, for both hard and soft bottomed (sb) streams.

Stark and Maxted (2007) quality class	Stark (1985) descriptions	MCI and MCI-sb	SQMCI and QMCI and SQMCI-sb / QMCI-sb
<b>Excellent</b>	Clean water.	≥ 119	> 5.99
<b>Good</b>	Doubtful quality or possible mild pollution.	111 – 119	5.00 – 5.99
<b>Fair</b>	Probably moderate pollution.	80 – 99	4.00 – 4.44
<b>Poor</b>	Probably severe pollution.	< 80	< 4.00

The number or percentage of EPT (Ephemeroptera (mayflies), Plecoptera (stoneflies), Trichoptera (caddisflies)) is another metric that is commonly calculated by ecologists to describe the ecological condition of a waterway. Many species of these insect groups show reductions in density at sites affected by organic enrichment (and where algal blooms are subsequently common), heavy metals, and sedimentation loads. An exception to this is for the two Hydroptilid (or “purse-case”) caddisflies *Oxyethira* and *Paroxyethira*. These are common in streams dominated by high algal biomass, and are generally regarded as highly tolerant of organic enrichment. As such, the number and percentage of EPT is often calculated without these animals (commonly referred to as EPT\* and % EPT\*). Unlike the MCI and QMCI, no discrete bands representing different ecological condition classes have yet been developed for the EPT metrics.

Although clearly defined biological indices such as the MCI/QMCI, and EPT or %EPT currently exist that summarise a waterway’s ecological condition, considerable debate exists about which index should be used as ecological attributes (Ausseil and Clark 2007). For example, some researchers suggest that the %EPT taxa is superior to the MCI (Biggs 2000), as this index correlates best with observed organic and sediment enrichment. However, acceptable bands for %EPT cannot easily be defined (Ausseil and Clark 2007). Other researchers recommend using the MCI, especially in relation to the protection of values such as trout fishery (Hay et al., 2006) and life supporting capacity. Still, other researchers recommend using the QMCI (Ausseil and Clark 2007), as this index seems to best correlate with water quality and habitat degradation in the Horizons region.

In contrast to single indices such as the MCI, QMCI and EPT, multimetric indices utilise several metrics to evaluate stream health. They thus represent different aspects of the invertebrate community, and are thus arguably a better way to assess stream health than single metrics. Multimetrics also compare the value of a particular metric at a test site to that at appropriate reference sites, and in doing so can minimise the effects of natural variations as a result of annual climatic variability. In response to potential uncertainties of using metrics such as the MCI and EPT as measures of stream health, and of relying on pre-defined bands to allocate stream health classes, Suren et al. (2017) developed a multimetric index, called the Bay of Plenty Index of Biotic Integrity (BoP\_IBI). This was developed on the basis of the biophysical classification (see section 2.2), and was based on comparing observed values of a wide range of calculated biotic metrics that summarised the invertebrate composition (e.g. richness, MCI, EPT, % worms, % snails etc.) at test sites to those at appropriate reference sites under natural, or “least disturbed” conditions. The BoP\_IBI was based on a combination of different individual metrics within each biophysical class. Four numerical bands of the BoP\_IBI were created, based on the percentile distribution of individual metrics in the relevant reference stream class.

Examination of the number of sites assigned to one of four stream health classes showed significant differences between streams when assessed using the MCI, QMCI, or the BoP\_IBI. The MCI in particular underestimated the number of streams in either the Fair or Poor condition classes when compared to the QMCI or BoP\_IBI. The BoP\_IBI also displayed the strongest responses to land-use gradients in each stream class, whereas other metrics could not discriminate as well. As such, the BoP\_IBI appears to be an ideal candidate for use in future analysis of state and trends of stream health throughout the Bay of Plenty. Although this metric may be slightly more difficult to explain, it appears to have greater ability to respond in a predictable manner to stressors associated with land use change or land use practices.

A number of challenges exist with selecting an appropriate invertebrate metric to serve as an attribute. The advantages and disadvantages of different metrics are highlighted in Table 45. It is suggested that metrics such as the MCI/QMCI, EPT, or even multi-metrics such as the BOP\_IBI could be potentially useful as attributes to describe what the current state is, and to monitor tracking towards (or maintaining) that state.

The main issue with using either single or multimetric biological indices to summarise invertebrate communities as attributes concerns the great range of stressors that can drive these (Clapcott et al., 2014; Collier et al., 2014). Although most biotic indices decline with increasing land use intensity, this often reflects multiple stressors including changes to water quality, flow regimes, and instream habitat conditions. Increasing land use intensity also changes the structure and type of the riparian vegetation, and this may have large effects on the suitability of riparian vegetation for adult insects. If there is no suitable vegetation for adult insects to utilise for food, shelter or egg laying, then these insects will soon be lost from a stream irrespective of the instream conditions. Although all these changes will result in a decline in the value of a particular metric, this cause for this decline cannot be determined. As such, invertebrate metrics are best used to set specific freshwater objectives to ensure that specific objectives are met.

Table 45 List of different invertebrate metrics that could be suitable as ecosystem health attributes, showing pros and cons of each metric, and its suitability as a potential attribute.

Invertebrate metric	Pros	Cons	Comments on use as an attribute
<b>MCI</b>	<ul style="list-style-type: none"> <li>Widely used and simple to calculate.</li> <li>Predictive models have been developed.</li> <li>Based on published research, and four water quality classes have been identified.</li> <li>Have now been developed for both hard and soft bottomed streams.</li> </ul>	<ul style="list-style-type: none"> <li>Current MCI lacks tolerance values for many taxa (but see Greenwood, 2015).</li> <li>Regarded as only a coarse measure of ecosystem health, relying only on presence absence. Environmental degradation would not be detected until local species extinction occurs.</li> <li>Response to a wide range of stressors, but doesn't respond to all stressors.</li> </ul>	<ul style="list-style-type: none"> <li>Ideal for assessment of state.</li> <li>Difficult to identify specific drivers of degradation, so cannot be used as a limit-setting attribute.</li> <li>Could be used as an objective-setting attribute.</li> </ul>
<b>EPT-r and %EPT-r</b>	<ul style="list-style-type: none"> <li>Widely used and simple to calculate.</li> <li>Predictive models have been developed.</li> </ul>	<ul style="list-style-type: none"> <li>Regarded as only a coarse measure of ecosystem health, relying only on presence absence. Environmental degradation would not be detected until total loss of individual EPT taxa occur.</li> <li>Response to a wide range of stressors, but doesn't respond to all stressors.</li> <li>No current bands exist (although LAWA webpage has provided tentative bands).</li> <li>May not work well in all stream types, as EPT are generally naturally uncommon in soft bottomed streams.</li> </ul>	<ul style="list-style-type: none"> <li>Ideal for assessment of state.</li> <li>Difficult to identify specific drivers of degradation, so cannot be used as a limit-setting attribute.</li> <li>May need regional ground truthing as not all streams naturally support high EPT numbers.</li> <li>Could be used as an objective-setting attribute.</li> </ul>

Invertebrate metric	Pros	Cons	Comments on use as an attribute
<b>QMCI</b>	<ul style="list-style-type: none"> <li>Widely used and simple to calculate.</li> <li>Based on published research, and four water quality classes have been identified.</li> <li>Have been developed for both hard and soft bottomed streams.</li> <li>Could be regarded as providing a more conservative measure of ecosystem health as it considers changes to relative abundance.</li> </ul>	<ul style="list-style-type: none"> <li>Current QMCI lacks tolerance values for many taxa (but see Greenwood, 2015).</li> <li>Changes in relative abundance caused by occasional unpredictable stressors such as algal proliferations may complicate interpretation.</li> <li>Response to a wide range of stressors, but doesn't respond to all stressors.</li> <li>Difficult to implement management actions to achieve a required standard.</li> </ul>	<ul style="list-style-type: none"> <li>Ideal for assessment of state.</li> <li>Difficult to identify specific drivers of degradation, so cannot be used as a limit-setting attribute.</li> <li>Could be used as an objective-setting attribute.</li> </ul>
<b>%EPT_n</b>	<ul style="list-style-type: none"> <li>Simple to calculate.</li> <li>Could be regarded as providing a more conservative measure of ecosystem health as it considers changes to relative abundance.</li> </ul>	<ul style="list-style-type: none"> <li>Responds to a wide range of stressors, but doesn't respond to all stressors.</li> <li>May not work well in all stream types, as EPT are generally naturally uncommon in soft bottomed streams.</li> </ul>	<ul style="list-style-type: none"> <li>Ideal for assessment of state.</li> <li>Difficult to identify specific drivers of degradation, so cannot be used as a limit-setting attribute may need regional ground truthing as not all streams naturally support high EPT.</li> <li>Could be used as an objective-setting attribute.</li> </ul>
<b>Richness</b>	<ul style="list-style-type: none"> <li>Simple to calculate.</li> </ul>	<ul style="list-style-type: none"> <li>Taxon richness is often not associated with environmental degradation.</li> <li>May get increasing trends in richness as identification and sample processing techniques improve.</li> </ul>	<ul style="list-style-type: none"> <li>Not recommended.</li> </ul>

Invertebrate metric	Pros	Cons	Comments on use as an attribute
<b>BoP_IBI (multimetric approach)</b>	<ul style="list-style-type: none"> <li>• Can be developed specifically for regions and the taxa encountered there.</li> <li>• Can be developed to respond to specific environmental gradients as part of the metric identification process.</li> <li>• Appeared to work "better" than traditional metrics.</li> <li>• Incorporates a reference condition comparison, therefore automatically correcting itself for climatic influences.</li> </ul>	<ul style="list-style-type: none"> <li>• Complicated to calculate.</li> <li>• Currently not based on any publishable research.</li> <li>• Applicable to only specific regions for where the metric has been developed.</li> <li>• Lacks ability to be used at a national level (unless national multimetric models are developed).</li> </ul>	<ul style="list-style-type: none"> <li>• Arguably a better approach to assess ecological state.</li> <li>• Difficult to identify specific drivers of degradation, so cannot be used as a limit-setting attribute.</li> <li>• Are based on regional comparisons between reference and test sites, unlikely to be useful at a national perspective.</li> <li>• Could be used as an objective-setting attribute.</li> </ul>
<b>Individual stressor metrics (e.g. LIFENZ, AMDI)</b>	<ul style="list-style-type: none"> <li>• Developed specifically for individual stressors.</li> <li>• Changes to metrics score can lead to specific management actions as the stressor has been identified.</li> </ul>	<ul style="list-style-type: none"> <li>• Only relevant for particular stressors.</li> <li>• Will need the development of multiple individual metrics based on multiple stressors affecting ecological integrity.</li> </ul>	<ul style="list-style-type: none"> <li>• Ideal for assessment of pressures.</li> <li>• Purpose-built to identify specific drivers of degradation, so can be used to set meaningful limits on resource use.</li> </ul>
<b>Observed/expected predictive models</b>	<ul style="list-style-type: none"> <li>• Can be developed specifically for regions and the taxa encountered there.</li> <li>• Models developed based on inherent environmental factors unlikely to change as a result of human activity.</li> <li>• Are successfully used overseas (e.g. North America, United Kingdom).</li> </ul>	<ul style="list-style-type: none"> <li>• Complicated to calculate.</li> <li>• Lacks ability to be used at a national level (unless national multimetric models are developed).</li> <li>• Models may need to be recalibrated (see Scarsbrook, 2016), potentially adding to further costs.</li> </ul>	<ul style="list-style-type: none"> <li>• Potentially a better approach to assess ecological state.</li> <li>• Difficult to identify specific drivers of degradation, so cannot be used as a limit-setting attribute.</li> <li>• Could be used as an objective-setting attribute.</li> </ul>

In a review of the influence of land-use change on stream ecosystems, Allan (2007) highlighted six principal mechanisms by which land uses influence stream ecosystems (Table 46). Although all of these mechanisms can act singularly or in combination in streams, experimental work by Piggott et al., (2012) in a third order stream in Otago highlighted that sediment affected 93% of all biological response of variables (generally in a negative manner), whereas nutrient enrichment and temperature affected only 59% of biological response variables. This suggests that, at least in these Otago streams, major ecosystem stressors could be represented by sediments, followed by nutrients and temperature. This means that stressor-specific indices could be developed as attributes to set freshwater objectives that are more clearly linked to particular stressors. If monitoring shows that these stressor-specific indices have fallen below a defined numerical objective, then it suggests that the specific stressor has exceeded some threshold to cause a change to the invertebrate community. Such a scenario could therefore evoke immediate management actions. A range of individual stressors exist, including:

- excess plant growth,
- nutrients,
- fine sediment,
- temperature,
- dissolved oxygen,
- pH, and
- metals.

*Table 46 Summary of the dominant environmental factors thought to affect stream ecosystems as a result of land-use change, and the mechanism of environmental effect.*

<b>Environmental factor</b>	<b>Mechanism of effect</b>
<b>Sedimentation</b>	Increases turbidity, scouring and abrasion. Reduces periphyton quantity and food value. Reduces habitat availability. Potential direct physiological effects.
<b>Nutrient enrichment</b>	Increases algal and macrophyte productivity. Increases organic matter decomposition rates, leading to reduced dissolved oxygen.
<b>Contaminant pollution</b>	Increases heavy metals, pesticides and herbicides. Alters invertebrate community composition through differential mortality of species.
<b>Hydrological alteration</b>	Increases frequency, timing and magnitude of high and low flow events. Contributes to altered channel dynamics including increased bank erosion. Changes soil run-off properties leading to higher peak flows, and lower base flows.
<b>Riparian clearing/canopy opening</b>	Reduces shading, increasing temperatures, and plant growth. Changes to bank stability. Changes to inputs of leaf litter and wood, altering stream energy dynamics.
<b>Loss of habitat</b>	Reduces habitat for feeding, attachments, and cover. Loss of sediment and organic matter storage.

Some work has already been initiated on stressor-specific indices in New Zealand, including an acid mine drainage index (Gray and Harding, 2012), an index of stream-bed stability (Schwendel et al., 2011), and an index to show the degree of hydrological change in a river (Greenwood et al., 2016). Development of other stressor specific indices that respond to fine sediment or temperature may also be relatively simple. For example, Relyea et al. (2012) developed a Fine Sediment Biotic Index (FSBI) as a regional, stressor-specific biomonitoring index to assess fine sediment (< 2 mm) impacts on invertebrate communities in north-western US streams. Similar work could be done in New Zealand, especially given the extensive literature documenting the effects of fine sediment on invertebrate communities (Ryan, 1991; Suren and Jowett, 2001; Suren et al., 2005). The upper thermal tolerances of many New Zealand invertebrate are also relatively well known (Quinn et al., 1994), and water temperature has been shown to have a large effect on invertebrate communities in both perennial (Quinn et al., 2009) and ephemeral (Storey and Quinn, 2013) streams.

However, part of developing any stressor-specific metric would also include the need to understand the influence of natural variability to metrics caused by attributes such as geology, flow regime, and climate. This would inevitably involve some form of classification, so decisions need to be made as to what classification should be used (e.g. River Environment Classification (REC) Snelder and Biggs 2002, or FENZ). A reference site approach is also important with this approach, although a "reference condition" need not be pristine, but could instead represent the best attainable condition, or least disturbed condition sites in a region.

Although the above features limit our ability to use invertebrate metrics as limit setting attributes (with the exception of stressor-specific attributes), they are extremely useful as objective-setting attributes. Thus, if a particular band for a waterway is not met, or if trend analysis shows that the ecological condition of a waterway is declining, then this should lead to an appropriate response in terms of further investigations to explain this reduction in stream health.

#### **Invertebrate attributes used by some other councils**

The inability to clearly define the triggers for observed reductions in invertebrate metrics is one reason why some councils (e.g. Waikato) do not recommend the use of invertebrate metrics as attributes (Scarsbrook, 2016). A similar recommendation was made by Northland Regional Council, despite having created regional specific MCI, SQMCI and QMCI bands (Stark, 2014). In our opinion, this is a rather overly restrictive approach, and ignores the fact that invertebrate metrics can be very powerful monitoring attributes, which can be used to set clearly articulated freshwater objectives, despite the fact that a broad range of statutory and non-statutory actions may be required to help achieve the objective. Horizons Regional Council has identified 44 water management zones and 117 sub-zones across throughout Region (Ausseil and Clark, 2007). These zones are typically catchment, or part-catchment based and encompass the waterways within the zones, and the surrounding land area. Horizons then gave minimum acceptable values of QMCI for waterways in each of their management zones (Table 47)

in order to protect the Life Supporting Capacity of streams in each class. Horizons have also identified limits for biological indicators for streams based on the trout fishery value. Horizons recognises three levels of protection for trout fisheries:

- TF1 - outstanding trout fishery value, recommended standards aim to protect optimum in or near optimum conditions for trout.
- TF2 - regionally significant trout fishery - recommended standards aim to protect as much as practicable, conditions deemed "good to excellent" for trout.
- TF3 - other trout fisheries value - recommended standards aim is to maintain "tolerable to good" conditions for trout.

*Table 47 Recommended QMCI standards in the different Water Management Zone Classes in the Manawatu based on different LSC classes.*

Life Supporting Class category	Water Management Zone Class	Recommended QMCI standard
<b>UHS</b>	Upland hard sedimentary	6
<b>UVA</b>	Upland volcanic acid	6
<b>UVM</b>	Upland volcanic mixed	5
<b>ULi</b>	Upland limestone	5
<b>HM</b>	Hill mixed	5
<b>HSS</b>	Hill soft sedimentary	5
<b>LM</b>	Lowland mixed	5
<b>LS</b>	Lowland sand	5

Based on work done by the Cawthron Institute (Hay et al 2006), an MCI score of 120 is the minimum and to maintain TF1 and TF2 standards. Horizons thus set a QMCI score for these rivers at 6. For TF3 waters, the minimum MCI score of 100 was recommended (Hayes et al 2006), which corresponds to a QMCI score of 5.

Environment Canterbury has also set minimum QMCI scores for waterways in their 10 River Management Units (Table 48), in recognition that ecological communities will naturally differ between these management units (Hayward et al., 2009).

*Table 48 QMCI scores in Environment Canterbury's LWRP for waterways in the 10 different management units.*

River management unit	Trophic status objective	QMCI [minimum score]
<b>Alpine – upland</b>	Oligotrophic	5 – 6
<b>Alpine – lower</b>	Mesotrophic	5 – 6
<b>Lake-fed</b>	Mesotrophic	6
<b>Hill-fed – upland</b>	Oligotrophic	5 – 6
<b>Hill-fed – lower</b>	Mesotrophic	5 – 6
<b>Banks Peninsula</b>	Mesotrophic	4 – 5
<b>Spring-fed upland</b>	Oligotrophic	6
<b>Spring-fed – lower basins</b>	Mesotrophic	5
<b>Spring-fed - plains</b>	Mesotrophic	4.5 – 5
<b>Spring-fed plains - (urban)</b>	Mesotrophic	3.5

#### **Development of state bands for invertebrate attributes**

Ideally, any ecological attributes need to respond to specific drivers, so that subsequent management actions can be identified to meet a desired attribute state. This will allow us to set clear limits on the extent of resource use to enable a given freshwater object be met. However, we also recognise that objective-setting attributes are an important part of the NPS-FM process, as they allow councils to assess whether ecological conditions in waterways are changing. As such, they are vital in quantifying aspects of the compulsory NPS-FM value of maintain or improve “Ecosystem Health”.



Suren et al., (2017) recommended that future biological monitoring in the Bay of Plenty should use the invertebrates measures EPT\_r, the MCI, and the BoP\_IBI. They also emphasised that ecological communities will naturally differ between the three biophysical classes. These recommendations were used as a basis for developing invertebrate attributes and numerical bands. The following steps were used in this process.

Invertebrate indices were examined to determine whether they differed between the different biophysical classes. If these indices were the same between classes, then there would be no point in producing different bands for each biophysical class. ANOVA showed significant differences between biophysical classes for EPT\_r, MCI and the BoP\_IBI. Volcanic gentle gradient streams generally have lower EPT richness and MCI scores, and higher BoP\_IBI scores than either non-volcanic steep or volcanic steep streams (Figure 6). Although it may have been tempting to have just used two classes based on catchment gradient for this analysis (i.e. steep and gentle gradient), work by Snelder et al. (2016) demonstrated significant differences in water quality parameters between the three biophysical classes. For example, non-volcanic steep streams had much lower nutrient levels than either the volcanic steep or volcanic gentle gradient streams. Because of potential linkages between water quality and ecological condition, it was therefore decided to develop invertebrate attributes for each of the three biophysical classes.

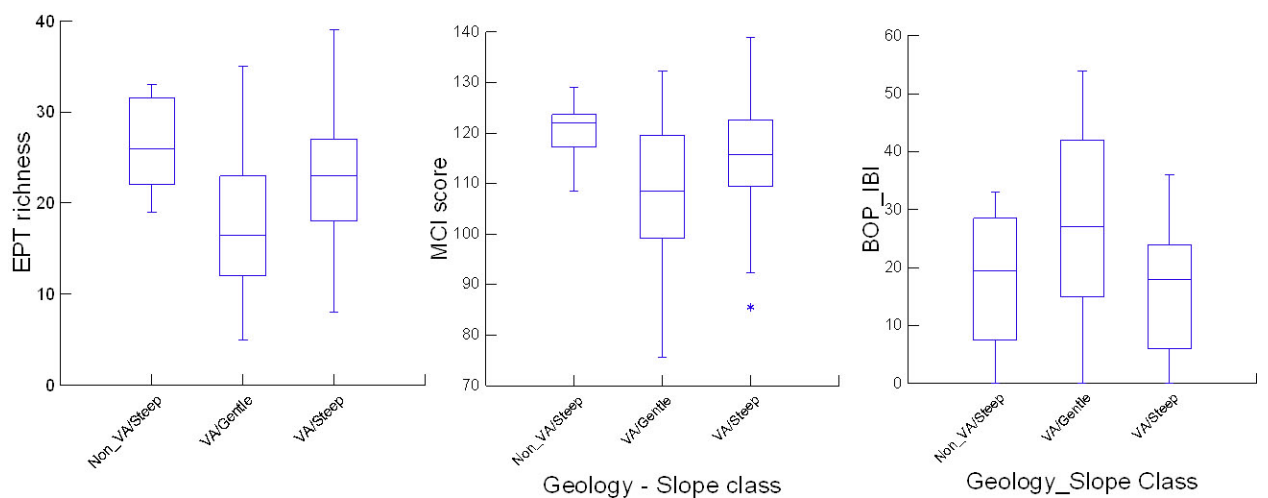


Figure 6 Box plots of the three invertebrate indices suggested for use as attributes, showing how they differed between the three biophysical classes.

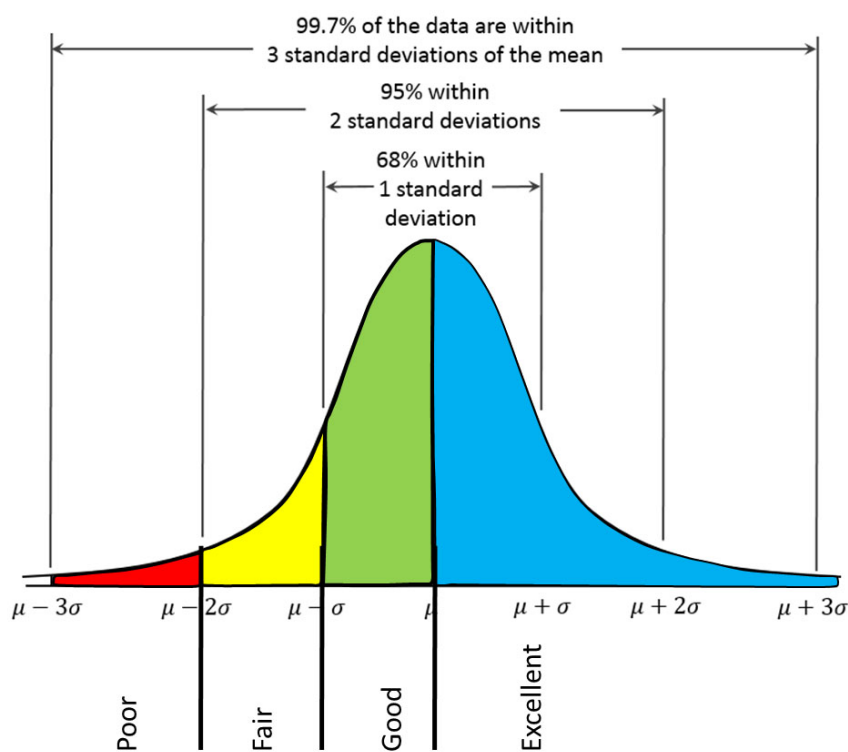
Each invertebrate metric was then examined to see whether it differed between reference and test sites in each of the biophysical classes. Statistical T-tests showed that in both non-volcanic gentle and volcanic steep biophysical classes, all three invertebrate metrics were higher in reference sites than test sites. All three metrics were however similar in both reference and test sites in streams belonging to the non-volcanic steep biophysical class.

Given the fact that most attributes differed between reference and test streams, it was decided to develop numerical thresholds for each attribute band based on statistical summaries of the average conditions in reference sites, including deviations from this average as outlined below. Thus, if the value of a specific attribute at a site was greater than the average reference site condition, then that site was regarded as in “Excellent” condition. Deviations to the average condition were then expressed as the average condition minus 1 standard deviation, or the average condition minus 2 standard deviations. These deviations were based on the fact that 68% of a population fall within one standard deviation of the average, and 95% of the population within two standard deviations (Figure 7). Because we were interested only in values less than the average reference site condition, we were effectively banding the test population so that they were equivalent to the lower 34%, or 47.5% of the reference population. This gave us four ecological condition bands (Table 49). Values of each attribute band were therefore calculated based on statistical summaries of reference site conditions. The resultant values were subsequently used as thresholds to describe numerical bands for the MCI, EPT richness, and BoP\_IBI (Table 49, Table 50, Table 51).

Examination of the bands for the MCI score in each of the biophysical classes showed interesting comparisons to the published quality classes of Stark and Maxted (2007). For the non-volcanic streams, suggested MCI values describing the B, C and D bands were generally much higher than the published bands (Figure 8). Thus, the bottom line limit 'D' band for streams in this class was in fact equivalent to streams in "Fair" ecological condition using the Stark and Maxted (2007) quality class. Streams in both the volcanic steep and volcanic gentle gradient classes however had a banding system much closer to the published quality classes of Stark and Maxted (Figure 8), although streams in the volcanic gentle biophysical class had slightly higher MCI scores for each band than the published scores (Figure 8).

The fact that the suggested MCI bands developed for streams in each of the three biophysical classes generally mirrored the values published by Stark and Maxted (2007) gave us some confidence that the approach used here was robust. It was also felt more appropriate to use a banding system developed for the Bay of Plenty based on data from the state of environment monitoring programme in the region, rather than from data obtained from other regions.

Recommendation: Use the invertebrate attributes as specified in Table 49, Table 50 and Table 51 for the protection of Ecosystem Health in rivers.



Quality classes with respect to reference site condition

Figure 7 Theoretical distribution of standard deviations around the mean (μ) showing the proportion of a population that is found within + 1 standard deviation, (68%), or 2 standard deviations (95%).

Table 49

*Suggested bands for metrics summarising the invertebrate communities as expressed by the MCI score in each of the three geology slope biophysical classes.*

Attribute				Invertebrate communities, assessed by MCI scores		
Attribute unit	MCI scores, based on comparisons to comparable reference streams in each biophysical class.					
Biophysical class	Attribute state	Numeric attribute state	Narrative attribute state.			
<b>Non-Volcanic</b>	A	>120	MCI scores typical of healthy and resilient invertebrate communities, similar to natural reference conditions. Indicative of streams in “excellent” ecological condition.			
	B	110 - 120	MCI scores show slight reductions, suggesting loss of some potentially sensitive taxa from what would be expected in a similar reference condition stream. Indicative of streams in “Good” ecological condition.			
	C	100 - 110	MCI scores show moderate impacts, with a more noticeable reduction in the majority of sensitive taxa from what would be expected in a similar reference condition stream. Indicative of streams in “Fair” ecological condition.			
	D (Regional bottom line)	<100	Reduction in MCI scores show large detrimental impacts, with a loss of all sensitive taxa from what would be expected in a similar reference condition stream. Indicative of streams in “Poor” ecological condition.			
<b>Volcanic_Gentle</b>	A	>124	MCI scores typical of healthy and resilient invertebrate communities, similar to natural reference conditions. Indicative of streams in “excellent” ecological condition.			
	B	106 – 124	MCI scores show slight reductions, suggesting loss of some potentially sensitive taxa from what would be expected in a similar reference condition stream. Indicative of streams in “Good” ecological condition.			
	C	88 – 106	MCI scores show moderate impacts, with a more noticeable reduction in the majority of sensitive taxa from what would be expected in a similar reference condition stream. Indicative of streams in “Fair” ecological condition.			
	D (Regional bottom line)	<88	Reduction in MCI scores show large detrimental impacts, with a loss of all sensitive taxa from what would be expected in a similar reference condition stream. Indicative of streams in “Poor” ecological condition.			
<b>Volcanic Steep</b>	A	>115	MCI scores typical of healthy and resilient invertebrate communities, similar to natural reference conditions. Indicative of streams in “excellent” ecological condition.			
	B	100 – 115	MCI scores show slight reductions, suggesting loss of some potentially sensitive taxa from what would be expected in a similar reference condition stream. Indicative of streams in “Good” ecological condition.			
	C	87 – 100	MCI scores show moderate impacts, with a more noticeable reduction in the majority of sensitive taxa from what would be expected in a similar reference condition stream. Indicative of streams in “Fair” ecological condition.			

Attribute				Invertebrate communities, assessed by MCI scores		
	D (Regional bottom line)	<87		Reduction in MCI scores show large detrimental impacts, with a loss of all sensitive taxa from what would be expected in a similar reference condition stream. Indicative of streams in “Poor” ecological condition.		

Table 50 Suggested bands for metrics summarising the invertebrate communities as expressed by EPT richness in each of the three geology slope biophysical classes.

Attribute				Invertebrate communities, assessed by EPT-richness		
<b>Attribute unit</b>	EPT richness, based on comparisons to comparable reference streams in each biophysical class.					
<b>Biophysical class</b>	Attribute state	Numeric attribute state	Narrative attribute state.			
<b>Non-Volcanic</b>	A	>12 EPT taxa	The number of sensitive EPT taxa typical of those found in reference condition streams.			
	B	9 - 12 EPT taxa	Streams showing a slight reduction in the number of sensitive EPT taxa that are typically found in similar reference condition streams.			
	C	6 – 9 EPT taxa	Streams showing a moderate reduction in the number of sensitive EPT taxa that are typically found in similar reference condition streams.			
	D (Regional bottom line)	<6 EPT taxa	Streams showing a large reduction in the number of sensitive EPT taxa that are typically found in similar reference condition streams.			
<b>Volcanic_Gentle</b>	A	>11 EPT taxa	The number of sensitive EPT taxa typical of those found in reference condition streams.			
	B	7 – 11 EPT taxa	Streams showing a slight reduction in the number of sensitive EPT taxa that are typically found in similar reference condition streams.			
	C	2 – 7 EPT taxa	Streams showing a moderate reduction in the number of sensitive EPT taxa that are typically found in similar reference condition streams.			
	D (Regional bottom line)	< 2 EPT taxa	Streams showing a large reduction in the number of sensitive EPT taxa that are typically found in similar reference condition streams.			
<b>Volcanic Steep</b>	A	>9 EPT taxa	The number of sensitive EPT taxa typical of those found in reference condition streams.			
	B	6 – 9 EPT taxa	Streams showing a slight reduction in the number of sensitive EPT taxa that are typically found in similar reference condition streams.			
	C	3 – 6 EPT taxa	Streams showing a moderate reduction in the number of sensitive EPT taxa that are typically found in similar reference condition streams.			
	D (Regional bottom line)	<3 EPT taxa	Streams showing a large reduction in the number of sensitive EPT taxa that are typically found in similar reference condition streams.			

Table 51

*Suggested bands for metrics summarising the invertebrate communities as expressed by BoP\_IBI scores in each of the three geology slope biophysical classes.*

Attribute				Invertebrate communities, assessed by the BoP_IBI		
Attribute unit	Calculated BoP_IBI scores, based on comparisons of individual invertebrate indices between reference and test streams.					
Biophysical class	Attribute state	Numeric attribute state	Narrative attribute state.			
<b>Non-Volcanic</b>	A	>24	Streams supporting a range of invertebrate species that are very similar to those found in reference condition streams.			
	B	16 - 24	Streams supporting a slightly reduced range of invertebrate species that would be expected in similar reference condition streams.			
	C	7 – 16	Streams supporting a moderately reduced range of invertebrate species that would be expected in similar reference condition streams.			
	D (Regional bottom line)	<7	Streams supporting a greatly reduced range of invertebrate species that would be expected in similar reference condition streams.			
<b>Volcanic_Gentle</b>	A	>47	Streams supporting a range of invertebrate species that are very similar to those found in reference condition streams.			
	B	36 - 47	Streams supporting a slightly reduced range of invertebrate species that would be expected in similar reference condition streams.			
	C	26 - 36	Streams supporting a moderately reduced range of invertebrate species that would be expected in similar reference condition streams.			
	D (Regional bottom line)	<26	Streams supporting a greatly reduced range of invertebrate species that would be expected in similar reference condition streams.			
<b>Volcanic Steep</b>	A	>18	Streams supporting a range of invertebrate species that are very similar to those found in reference condition streams.			
	B	7 - 18	Streams supporting a slightly reduced range of invertebrate species that would be expected in similar reference condition streams.			
	C	3 - 7	Streams supporting a moderately reduced range of invertebrate species that would be expected in similar reference condition streams.			
	D (Regional bottom line)	<3	Streams supporting a greatly reduced range of invertebrate species that would be expected in similar reference condition streams.			

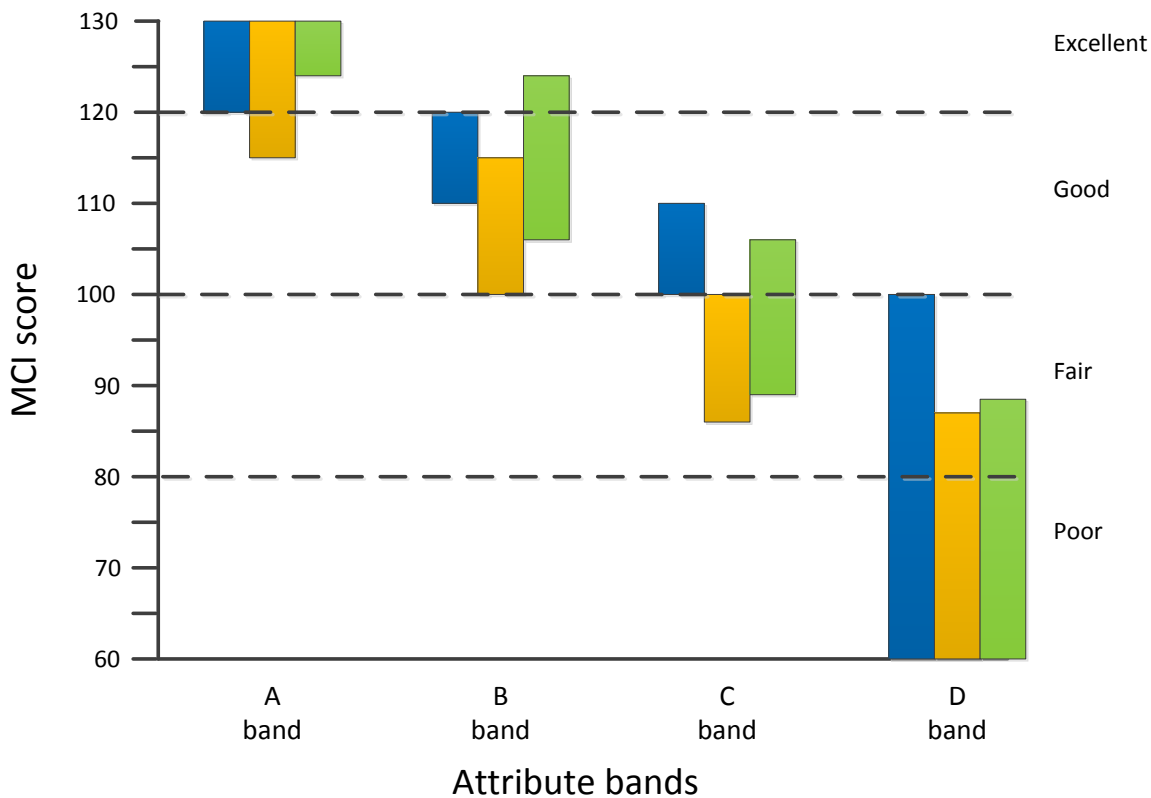


Figure 8 Comparison of bands (A – D) for MCI scores as calculated for streams belonging to either the non-volcanic (blue bars), volcanic steep (yellow bars), or volcanic gentle gradient streams (green bars). Also shown are the four quality classes of Stark and Maxted (2007), showing boundaries between the different classes (dashed lines).

### 6.2.9 Fish attributes

One of the most important ecological values of rivers and streams for most people would undoubtedly be fish. For centuries, freshwater fish have sustained iwi, who have developed a very close relationship with the natural life cycle of many of New Zealand's native freshwater species to ensure they could harvest what was once a bountiful supply (McDowall, 2011). With the arrival of European settlers, introduced fish such as salmon and trout were liberated throughout the country, and these have now formed the basis of a hugely important recreational resource throughout the country (McDowall, 1990). Unfortunately, other introduced fish such as mosquito fish, goldfish, and carp have also been introduced throughout the country, and these have often had dramatic negative effects on native fish communities and habitat conditions.

Despite their importance, many fish (both native and introduced) are being adversely affected by human activities throughout New Zealand. In particular activities associated with agricultural development such as removal of riparian vegetation, channel straightening and ongoing drain maintenance, water abstraction and inputs of nutrients and sediments are having demonstrable negative effects on fish communities throughout the country. Furthermore, large hydroelectric dams, and many other obstacles to fish passage such as perched culverts, have affected the ability of native fish to successfully complete their life cycle as they have blocked free access to and from the sea. Finally, many native New Zealand fish have been displaced by the larger and more aggressive introduced trout and salmon. Other pest species such as mosquito fish can also displace native fish due to their aggressive behaviour, and other fish such as tench, catfish and carp can dramatically degrade aquatic habitats through their foraging behaviour as they up root aquatic plants.

Monitoring fish communities in streams is one way of determining the overall health of a waterway. There is a strong influence of distance to sea and altitude on fish distributions, with more fish species at lowland sites close to the coast, and fewer species in higher elevation sites inland. However other factors such as habitat or water quality may also affect fish distributions at a site, as does the presence of any downstream barriers to migration.

No councils appear to have used fish as numeric attributes. However, the values of fish have commonly been identified as important, either as trout, native fish, or as native fish spawning, and have been incorporated into many narrative regional plan objectives. These values are then generally protected by ensuring other parameters to protect other aspects of stream ecosystems are met. For example, Horizons Regional Council have identified water quality parameters (e.g. pH, dissolved oxygen, temperature, clarity and nutrients), and the biological parameters (e.g. QMCI and periphyton biomass) as important for maintaining the specific value for a healthy trout fishery or trout spawning areas (Ausseil and Clark, 2007).

Although the Joy and Death (2004) metric could be used as an attribute throughout the region, Suren (2016) developed a Fish\_IBI specifically for the Bay of Plenty region using the same methods of Joy (2007), and calculated the following banding system (Table 52).

*Table 52 Calculated Fish IBI scores and integrity classes for the Bay of Plenty, based on percentile distributions of the calculated Fish IBI score.*

BoP Fish IBI score	Integrity class	Attributes
46 – 60	Excellent	Equivalent to the best situations without human disturbance; all species expected in the stream given its location are present. Site is above the 75 <sup>th</sup> percentile of streams.
36 – 45	Good	Site is above the 50 <sup>th</sup> percentile of streams, but species richness and habitat or migratory access reduced. Shows some signs of stress.
24 – 35	Moderate	Site is above the 25 <sup>th</sup> percentile. Species richness is reduced. Habitat and/or access is impaired.
6 – 23	Poor	Site is impacted or migratory access almost non-existent.
0	No fish	Site is grossly impacted or access the system.

Development of this Fish IBI for the Bay of Plenty is seen as an important step in using fish as indicators of overall stream health throughout the region.

The five narrative class bands used to describe a stream’s fish integrity are likely to represent a very useful tool to policy and planning in terms of setting objectives of various waterways based on these clearly defined attribute bands. These narrative bands can also be used as part of consent or compliance conditions to ensure that, for example, the Fish IBI shall not be reduced, or only be reduced by a certain percentage, by a specific activity. This provides a potentially useful numeric descriptor of the desired environmental state for fish communities at a site. Prior to the development of the Fish IBI, such numeric descriptors did not exist.

A Fish IBI has also been developed for the Waikato Region (e.g. David et al 2016). Calculated Fish IBI scores were shown to be considerably higher in reference streams than non-reference streams in the Waikato, and scores also did not vary greatly between sites sampled over time. These findings suggest that the Fish IBI may be useful metric by which to describe fish communities in a stream, and it may be possible to develop numeric bands for the Fish IBI. Unfortunately, at present BoPRC does not monitor fish communities as part of its on-going National Environment Resources Monitoring programme. Furthermore, no nationally recognised protocols exist for SoE fish monitoring that describe aspects such as site selection and frequency of sampling, despite the recent development of national methods for fish monitoring (Joy et al 2013). Work is currently underway within Regional; Councils to develop national SoE protocols for fish sampling, and when completed, we are likely to commence an ongoing monitoring programme in the Bay of Plenty.



Until an agreed national protocol for monitoring fish communities for SoE purposes has been developed, including site selection, the Fish IBI cannot be used for objective setting. Once national protocols are done, acceptable numerical bands need to be set for the Fish IBI within the Bay of Plenty. These bands would represent an objective-setting attribute for fish.

### 6.2.10 Habitat attributes

Stream habitat conditions are a vital, but often overlooked, component that can affect values such as ecosystem health. Stream habitat represents the living space for all aquatic plants and animals, and consists of the water and physical, chemical and biological environment, both instream and along the immediate streamside (or riparian) margin of streams (Harding et al., 2009). Instream habitat includes a wide range of different potential attributes, including the:

- nature of the stream bed (e.g. mud, cobbles or boulders),
- type, and diversity of different flow types (e.g. riffles, runs or pools),
- presence of fine sediment,
- degree of bank erosion and undercut banks,
- amount of overhanging vegetation along a stream that provides shade or habitat for fish to spawn amongst, and for use by adult insects,
- debris for instream habitat and food for invertebrates.

Many of these parameters are relatively easy to measure (Harding et al 2009), and can be quantified with some accuracy. They also can have dramatic effects on instream communities. For example, small-scale fluctuations in water velocity and depth can have profound effects on stream ecology (Jowett and Richardson, 1990; Pridmore and Roper, 1985), and substrate size has been demonstrated as fundamentally important in influencing invertebrate and plant communities within stream reaches (e.g. (Biggs et al., 2001; Minshall, 1984).

The importance of instream habitat in structuring ecosystem health (and in particular those fish and invertebrate communities) cannot be underestimated. However, the use of factors describing instream habitat conditions as potential attributes is currently uncertain, as work has not yet established the relative importance of different instream habitat factors in structuring invertebrate or fish communities. Work is currently underway to further investigate the relationships between instream habitat conditions and invertebrate communities, and it is hoped that this will highlight some useful information as to which local instream habitat variables affect ecosystem health.

If this analysis identifies particular in stream habitat factors as structuring invertebrate communities, it should be possible to identify bands for different attributes that may respond to different classes of ecosystem health. For example, it may be that streams which lack overhead shade, or which lack an extensive riparian buffer may have lower ecosystem health than well shaded and protected streams. One approach to developing bands would be to then examine the average shade or riparian buffer size in reference streams, and develop a banding system based on deviation from this mean.

Although our attribute scoring system ranked instream habitat as relatively low, it must be remembered that this same scoring system also ranked chlorophyll biomass as relatively low. This is despite the fact that assessments of chlorophyll biomass are a compulsory attribute under the NPS-FM. This, however, does not imply that habitat is not an important component in streams – more likely the low score simply reflects a lack of relevant analyses that illustrate the importance of specific habitat factors.

Recommendation: Defer any further discussion of habitat factors as potential attributes pending analyses of relationships between instream habitat conditions and invertebrate and/or fish communities.



## 6.3 Recommendations

Based on the attribute evaluation process above, we identified a number of recommended ecological attributes and bands for rivers and lakes respectively (Table 3 and Table 4). Some of these attributes, such as metrics describing invertebrate communities, or the fish IBI (once a regular fish monitoring programme commences) would be useful as objective-setting attributes, as they can usefully describe the state of stream health that we may be interested in achieving. Other attributes such as benthic or phytoplanktonic cyanobacteria could be used as limit-setting attributes, in a similar way as the NPS-FM compulsory attribute of periphyton biomass, where clearly defined bands have been set to maintain specific ecological conditions.

### 6.3.1 Other monitoring recommendations

As with the physical, chemical and biological attributes, some ecological attributes would benefit from additional research or investigation, and a summary of these key monitoring recommendations is provided below

- Unfortunately, there is presently insufficient information on macrophyte communities in the region to set more than general macrophyte cover bands based on recommendations of Matheson et al., (2012). It is recommended that a survey of rivers and streams throughout the region is undertaken to determine the spatial extent of macrophyte cover, and to help validate the proposed bands.
- Although the importance of fish as attributes are not disputed, more work is required to help determine a potential banding system for the fish\_IBI for it to be used as an objective-setting attribute. Once national protocols for fish SoE monitoring have been developed, it may take some time to develop numeric bands for the Fish IBI until the magnitude of natural temporal variation is assessed.

Finally, no attributes or bands currently exist for features describing instream habitat. Work is currently underway examining the effect of different components of instream habitat in explaining stream ecosystem health. Should this work show that some components of instream habitat are important in influencing instream health, then these components could be included as further attributes to be measured in future.

# Part 7:

## Further considerations

There are a number of other factors that the authors considered important in the process of setting objectives/limits/targets that were outside the scope of this report. Some of the relevant other considerations are briefly summarised here.

### 7.1 Receiving environments

Rivers and streams usually discharge into lakes, estuaries or harbours, or to the open coast. These receiving environments represent the ultimate destination for contaminants that are transported via rivers and streams. They often act like sinks, and contaminants can build up in them over time, often with ecological consequences.

Although the NPS-FM is focussed on freshwater quality, Policies A1 (a) (iii), B1(c) and C2 (b) require Council to have regard to the connections between freshwater bodies and coastal water during freshwater quality and quantity objective setting, and in the integrated management of the effects of use and development of land<sup>9</sup>. When considering limit setting objectives and limit setting for rivers, it is imperative that the cumulative impacts on the receiving environment are actively considered and accommodated. This needs to be a core focus for freshwater objective setting for contaminants that will impact on sensitive receiving environments (like DIN and DRP), and has been recognised by recommending these attributes without attribute state bands at this time.

### 7.2 Drains

There is a large drainage network throughout the region, a large component of which is maintained and operated by Council, e.g. throughout the Kaituna and Rangitāiki Plains. This network consists of a number of highly modified natural watercourses, as well as artificial drains cut in the past as part of agricultural development of this area. Many of these drains are often below the water level of the river they discharge into, and so are actively pumped into these rivers during times when water levels are high.

Land drainage canals specified under Schedule 3 of the Regional Water and Land Plan are defined as water bodies and are therefore will be the subject of freshwater objective under the NPS-FM. Other drainage channels and farm drains are defined as artificial water courses, not rivers or water bodies, and consequently freshwater objectives will not be set for these under the NPS-FM. Discharges of contaminants from farm drains must be managed via discharge rules and contaminant generation may also potentially be managed by land use rules, limits and/or other methods in order to contributing to meeting fresh water and coastal receiving environment objectives of the water bodies they discharge in to.

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<sup>9</sup>The New Zealand Coastal Policy Statement 2010 also requires integrated management and consideration of catchment and land use causes of effects on coastal environments (e.g. Objective 1 and policies 4, 22 and 23).

# Part 8:

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# Appendices

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# Appendix 1:

## Summary of relevant existing water quality guidelines and standards

### A1. Resource Management Act (RMA)

Schedule 3 of the Resource Management Act 1991 (RMA) sets out 11 water quality classes and lists water quality standards for each class. The water quality classes and standards are summarised in Table 53.

Table 53 Water quality classes and standards as per Schedule 3 of RMA (1991).

Water Quality Class	Water Quality Standards
<b>Aquatic ecosystem (AE)</b>	<ul style="list-style-type: none"> <li>Natural temperature not changed by &gt; 3°C.</li> <li>Any pH change, increase in deposited matter on the bed of the water body or discharge of contaminant if they have an adverse effect on aquatic life.</li> <li>DO &gt; 80% of saturation.</li> <li>No undesirable biological results as a result of any discharge of contaminant into water.</li> </ul>
<b>Fishery (F)</b>	<ul style="list-style-type: none"> <li>Natural temperature not changed by &gt; 3°C and not exceed 25°C.</li> <li>DO &gt;80% of saturation.</li> <li>Fish not rendered unsuitable for human consumption by the presence of contaminants.</li> </ul>
<b>Fish Spawning (FS)</b>	<ul style="list-style-type: none"> <li>Natural temperature not changed by &gt; 3°C.</li> <li>Temperature shall not adversely affect spawning of specified fish during spawning season.</li> <li>DO &gt;80% saturation.</li> <li>No undesirable biological results as a result of any discharge of contaminant into water.</li> </ul>
<b>Shellfish Gathering (SG)</b>	<ul style="list-style-type: none"> <li>Natural temperature not changed by &gt; 3°C.</li> <li>DO &gt;80% of saturation.</li> <li>Aquatic organisms not rendered unsuitable for human consumption by the presence of contaminants.</li> </ul>
<b>Contact Recreation (CR)</b>	<ul style="list-style-type: none"> <li>Visual clarity not be so low as to be unsuitable for bathing.</li> <li>Water not rendered unsuitable for bathing by the presence of contaminants.</li> <li>No undesirable biological results as a result of any discharge of contaminant into water.</li> </ul>

Water Quality Class	Water Quality Standards
<b>Water Supply (WS)</b>	<ul style="list-style-type: none"> <li>• pH of surface water between 6.0 - 9.0.</li> <li>• DO in surface water &gt;5 g/m<sup>3</sup>.</li> <li>• Water not rendered unsuitable for treatment for human consumption by the presence of contaminants.</li> <li>• Water not tainted or contaminated to render it unpalatable or unsuitable for consumption by humans after treatment, or unsuitable for irrigation.</li> <li>• No undesirable biological results as a result of any discharge of contaminant into water.</li> </ul>
<b>Irrigation (I)</b>	<ul style="list-style-type: none"> <li>• Water not tainted or contaminated to render it unsuitable for irrigation or crops.</li> <li>• No undesirable biological results as a result of any discharge of contaminant into water.</li> </ul>
<b>Industrial abstraction</b>	<ul style="list-style-type: none"> <li>• Quality of water not altered for characteristics that have direct bearing on the suitability for the specified industrial abstraction.</li> <li>• No undesirable biological results as a result of any discharge of contaminant into water.</li> </ul>
<b>Natural State (NS)</b>	<ul style="list-style-type: none"> <li>• Natural quality of water shall not be altered.</li> </ul>
<b>Cultural (C)</b>	<ul style="list-style-type: none"> <li>• Quality of water not altered for characteristics that have direct bearing on the specified cultural or spiritual values.</li> </ul>

Additionally, Section 70 (1) contains water quality standards in relation to rules in regional plans for permitted discharges to water or land. Specifically, any rule must not result in the following effects after reasonable mixing:

- Conspicuous oil or grease films, scums or foams, or floatable or suspended material,
- Conspicuous change in the colour or visual clarity,
- Emission of objectionable odour,
- Rendering freshwater unsuitable for consumption by farm animals, and
- Any significant adverse effects on aquatic life.

## A2. National Policy Statement for Freshwater Management

The NPS-FM (2014) has a National Objectives Framework (NOF) which sets thresholds for numeric attributes, ranked into four bands (A-D), defining water quality for “human” and “ecosystem” health (Table 54) Ministry for the Environment, 2014). In March 2017, the Ministry for Environment released a consultation document proposing changes to the NPS-FM. The most significant change in the proposed amendments relevant to attributes is the new proposed table for *E.coli*. At the time of writing, the proposed changes were open for public submission, and there remained significant uncertainty around differing numeric statistics in the proposed amendments and on the Ministry’s website. Subsequently, for the purpose of this attribute report, comparisons of the *E. coli* attribute in particular have been made against the operative NPS-FM (2014). Note that subsequent attribute reports will incorporate any changes made to the NPS-FM and NOF.

Table 54

Water quality attributes from the National Objective Framework – values and related attributes for lakes and rivers (summarised from MfE, 2014). Green shaded cells apply to rivers, orange shaded cells apply to rivers and lakes, blue shaded cells apply to lakes. 7-d mean min = the average of all daily minimum values over a 7 day period. 1-d min = the lowest daily value. Med = annual median, 95<sup>th</sup> = annual 95<sup>th</sup> percentile, Max = annual maximum.

Value	Band	Attributes								
		DO (mg/L)		Nitrate (mg/L)		Ammonia (mg/L)		TN (mg/L)		TP (mg/L)
		7-d mean min	1-d min	Med	95 <sup>th</sup>	Med	Max	Med#	Med^	Med
Ecosystem health	A	≥8	≥7.5	≤1	≤1.5	≤0.03	≤0.05	≤160	≤300	≤10
	B	≥7 <8	≥5 <7.5	>1 ≤2.4	>1.5 ≤3.5	>0.03 ≤0.24	>0.05 ≤0.40	>160 ≤350	>300 ≤500	>10 ≤20
	C	≥5 <7	≥4 <5	>2.4 ≤6.9	>3.5 ≤9.8	>0.24 ≤1.30	>0.40 ≤2.20	>350 ≤750	>500 ≤800	>20 ≤50
	D	<5	<4	>6.9	>9.8	>1.3	>2.20	>750	>900	>50
Human health for recreation										
						<i>E. coli</i> (cells/100mL)				
						Med	95 <sup>th</sup>			
		A				≤260	≤260			
		B				>260 ≤540	>260 ≤540			
C				>540 ≤1000	N/A					
D				>1000	N/A					

\* Below point source discharges from 1 November to 30 April.

# seasonally stratified and brackish.

^ Polymictic.

### A3. Regional Water and Land Plan

The operative Bay of Plenty Regional Water and Land Plan (RWLP) is the document where policies and rules relating to the use of fresh water are given statutory effect. Activities that involve the abstraction of water or the discharge of contaminants to water require resource consent, unless a rule in a regional plan (or a national environmental standard/regulation) permits such activities. The abstraction of water for domestic and stock drinking is expressly permitted under section 14 of the RMA and there are a number of other provisions in the Act that relate specifically to water.

Prior to the Resource Legislation Amendment Act (2017), under Section 69 of the RMA regional councils were able to set rules for water bodies based on the 'Water quality classes' given in Schedule 3 of the Act (which under the Resource Legislation Amendment Act no longer applies to freshwater). These water quality classifications were widely used in regional council policies and plans, and these will be reviewed and amended as necessary in line with the Resource Legislation Amendment Act. Where a council considers that these classes are not adequate or appropriate, new classes and standards may be stated in a regional plan. This is the approach that BOPRC has taken in developing its own water quality classifications in the RWLP and the Regional Plan for the Tarawera River Catchment.

The water quality classification standards and criteria for rivers and streams in the Bay of Plenty are given in the Regional Water and Land Plan and the Regional Plan for the Tarawera River Catchment (Table 55 and Table 56). Each classification is based on standard physical and chemical water quality parameters (e.g. pH, dissolved oxygen), macro-nutrients (nitrogen and phosphorus) and indicator bacteria (*E.coli* and faecal coliforms).

Under the RWLP, river and stream systems are assigned to a particular classification (or classifications) depending on their predominant use or value. For example, streams and rivers classified under 'Natural State' have a level of protection such that no discharge is allowed to "alter the natural quality of the water" while others allow slightly lower standards for some parameters (e.g. 'Contact Recreation' has a lower standard for water clarity).

It is important to note that different classifications can apply to different reaches of the same waterway; for example the upper reaches of the Whakatāne River are classified as 'Aquatic Ecosystem' while the lower reaches have a less stringent classification, 'Water Supply'.

Table 55 Water quality standards and criteria as per the Regional Water and Land Plan (Schedule 9).

<b>Quality Standard</b>	<b>Natural State (NS)</b>	<b>Aquatic Ecosystem (AE)</b>	<b>Contact Recreation (CR)</b>	<b>Water Supply (WS)</b>	<b>Modified with Ecological values (MWEV)</b>	<b>Regional Baseline (RB)</b>
<i>Temperature, pH, SS</i>	No increase in Temperature or SS. No change in pH	Natural temperature shall not change by < 3°C		6.0 > pH < 9.0	Temperature < 18 °C	Natural temperature shall not change by < 3°C
<i>Bacterial quality</i>	<i>E.coli</i> < 126 cfu/100 ml	<i>E.coli</i> < 126 cfu/100 ml	<i>E.coli</i> < 126 cfu/100 ml	<i>E.coli</i> < 126 cfu/100 ml		<i>E.coli</i> < 410 cfu/100 ml
<i>Undesirable biological growths</i>		Shall not increase	Shall not increase	Shall not increase	Shall not increase	Shall not increase
<i>Water clarity</i>	0% decrease	<10% decrease	> 1.6 black disk	<20% decrease	<20% decrease	<20% decrease
<i>Dissolved oxygen</i>	No decrease	DO > 80%		DO > 5g/m <sup>3</sup>	not be lowered	DO > 80%
<i>Farm animal consumption*</i>	Median FC < 100 cfu/ 100 ml	Median FC < 100 cfu/ 100 ml	Median FC < 100 cfu/ 100 ml	Median FC < 100 cfu/ 100 ml	Median FC < 100 cfu/ 100 ml	Median FC < 100 cfu/ 100 ml
<i>Aquatic life</i>	ANZECC (2000)	ANZECC (2000)	ANZECC (2000)	ANZECC (2000)	ANZECC (2000)	ANZECC (2000)

\* FC = faecal coliforms, SS = suspended solids; see Regional Water and Land Plan: Schedule 9 for detail.



Table 56

Water quality standards and criteria as per the Regional Plan for the Tarawera River Catchment (Rules in Chapter 15: Surface Water Quality).

Quality Standard	Fish spawning – Upper Tarawera (FSUT)	Fish purposes – Lower Tarawera (FPLT)
Dissolved oxygen	DO > 80%	DO > 4.5 g/m <sup>3</sup> (7 & 30 day limits also)
Water clarity/colour	Black disk - 0% decrease	Colour - 0.8 abs at 440 nm/cm
Temperature	Temperature < 25 °C	Temperature < 25 °C
pH	pH , > 6.5, < 8.5	pH , > 6.5, < 8.5
Undesirable biological growths	Periphyton < 40% bed cover, &/or 100 mg chl-a/m <sup>2</sup>	Periphyton < 40% bed cover, &/or 100 mg chl-a/m <sup>2</sup>
Farm animal consumption		Median FC < 100 cfu/100 ml

## A4. Microbial Water Quality Guidelines

The Microbiological Water Quality Guidelines (MfE/MoH 2003) provide the framework for assessing the health risk associated with faecal contamination of water for recreational purposes. There are two tiers to the guidelines. The first tier is used to compare weekly monitoring results with the microbiological guidelines over a bathing season, providing water managers with a tool for assessing more immediate health risk to the public. The second tier is a site grading providing an analysis of the suitability for recreation over time, using a combination of information from microbiological bathing survey results and catchment characteristics.

A three-tiered management framework has been adopted to help signal when recreational waters are potentially at risk to users. The system uses the colours green (safe mode, 'surveillance'), orange (cautionary mode, 'alert') and red (unsafe mode, 'action') to denote the level of risk to users. The indicator bacteria levels and recommended management responses to these different modes are listed in Table 57. This framework is used to assess health risk of recreational waters weekly as individual sample results are obtained.

Table 57

Surveillance, alert and action levels for fresh and marine waters (MfE/MoH, 2003).

Mode	Guideline - freshwaters ( <i>E.coli</i> count in colony forming units per 100 mL)	Recommended management response
Green/Surveillance	Single sample ≤ 260	Routine monitoring.
Orange/Alert	Single sample > 260 and ≤ 550	Increased monitoring, identify possible sources.
Red/Action	Single sample > 550	Public warnings, increased monitoring, source investigation.

Mode	Guideline - marine (Enterococci count in colony forming units per 100 mL)	Recommended management response
Green/Surveillance	Single sample ≤ 140	Routine monitoring.
Orange/Alert	Single sample > 140 and ≤ 280	Increased monitoring, identify possible sources.
Red/Action	Two consecutive single samples > 280	Public warnings, increased monitoring, source investigation.

The microbial water quality guidelines outline a process to grade the suitability of marine and fresh waters for recreational use. A 'Suitability for Recreation Grade' (SFRG) is generated through a combination of qualitative assessment of susceptibility of recreational sites to faecal contamination and by direct measurement of appropriate bacteriological indicators at the site. In contrast to the SFRG, the alert and action levels described above provide a real time indication of the changing risk over a bathing season. The SFRG describes the risk of faecal contamination at a given site over several bathing seasons.

There are currently guideline values for shellfish in regards to the level of bacterial contamination that is deemed acceptable for human consumption. The guidelines for water quality above shellfish gathering areas for safe shellfish consumption are:

- The median FC content should not exceed a Most Probable Number (MPN) of 14/100 mL.
- No more than 10% of samples should exceed a MPN of 43/100 mL.

## A5. Drinking water standards for New Zealand

The Drinking Water Standards for New Zealand (DWSNZ) 2005 (revised in 2008) provide the maximum allowable concentrations of potentially harmful contaminants that may be present in treated drinking water (MoH, 2008). The DWSNZ are based on many principles, one of which is to define the maximum acceptable values (MAVs) concentrations of contaminants related to human health in water that would not pose significant risk to the health of someone who consumes 2 L of that water each day over their lifetime (usually taken as 70 years). Table 58 provides a summary of the MAVs for contaminants considered relevant for this project.

Table 58 Maximum acceptable values for microbial and chemical parameters (adapted from MoH, 2008).

Parameter	MAV
<b><i>E.coli</i></b>	< 1/100 mL
<b>Arsenic</b>	0.01 mg/L
<b>Cadmium</b>	0.004 mg/L
<b>Copper</b>	2 mg/L
<b>Lead</b>	0.01 mg/L
<b>Nitrate (short-term)*</b>	50 mg/L NOTE: this equates to a nitrate-nitrogen concentration of ~11.3 mg/L
<b>Nitrite (short term)*</b>	3 mg/L NOTE: this equates to a nitrite-nitrogen concentration of ~0.91 mg/L
<b>Nitrite (long-term)*</b>	0.2 mg/L NOTE: this equates to a nitrite-nitrogen concentration of ~ 0.061 mg/L

\*The sum of the ratio of concentrations of nitrate and nitrite to each of their MAVs must not exceed one.

The DWSNZ also provide guidelines for aesthetic parameters, recognising that the public generally assess the quality of water by aesthetic observations (MoH, 2008). The guideline values are not part of the drinking water standards, however the National Environmental Standard for Sources of Drinking Water (see Section A6) include reference to these aesthetic guidelines and as such RMA practices are required to include these. Table 59 provides a summary of the guideline values for aesthetic parameters considered relevant for this project.

Table 59 Guideline values for aesthetic parameters (adapted from MoH, 2008).

Parameter	Guideline Value
<b>Ammonia</b>	1.5 mg/L (odour threshold in alkaline conditions) NOTE: this equates to a ammoniacal-nitrogen concentration of ~ 1.16 mg/L
<b>Colour</b>	10 TCU
<b>pH</b>	7.0-8.5
<b>Total dissolved solids</b>	1,000 mg/L NOTE: this equates to an electrical conductivity of ~1,493 $\mu$ S/cm
<b>Turbidity</b>	1.5 NTU

For a full list of the parameters and corresponding MAVs, refer to <https://www.health.govt.nz/system/files/documents/publications/drinking-water-standards-2008-jun14.pdf>.

## A6. NES for drinking water

The National Environmental Standards for Sources of Human Drinking Water (NESDW) Regulations (2007) were made under the RMA (1991) for the purpose of reducing risk of contamination of drinking water sources. The NESDW requires regional councils to consider effects of activities on drinking water sources when reviewing plan rules or granting any water or discharge permits. The NESDW does not contain specific water quality standards, instead referring specifically to the MAVs and Guideline Values contained in the DWSNZ (refer Section A5).

## A7. Animal Products (Dairy) Approved Criteria for Farm Dairies

The DPC2 Animal Products (Dairy) Approved Criteria for Farm Dairies (NZFSA, 2008) contains water quality criteria for water that may come into contact with raw milk intended for manufacturing dairy products. This includes during milking and cleaning the milking plant.

Table 60 Water Quality Standards for water that comes into contact with raw milk (NZFSA, 2008).

Parameter	Criteria
<b>E.coli</b>	Absent in 100 mL of water
<b>Turbidity</b>	$\leq 5$ NTU
<b>Clarity</b>	As a surrogate for turbidity and only where clarity is correlated to APHA measurement of turbidity.

## A8. MfE Water Quality Guidelines No. 2 (1994)

These guidelines were developed to assist users and water managers in the application of statutory standards relating to water quality. A move away from managing based on suspended solids and turbidity is recommended in favour of optical techniques. As colour and clarity can be explained in terms of the light-adsorbing and scattering properties of water, these inherent optical properties can be added together to determine the reduction in strength (attenuation) of a light beam passing through water. These are discussed in more detail in sections below.

As people can detect changes in visual clarity, aesthetic characteristics in terms of water clarity are important. However, waters vary widely optically due to a range of physical influences such as geology and biology. The guidelines work on the assumption that protecting visual clarity will protect other optical values and avoid regulatory and monitoring complexity.

## A9. ANZECC

The ANZECC 2000 Guidelines provide guidance on fresh and marine water quality management criteria in both New Zealand and Australia. Basic sediment quality information is also included.

The guidelines are designed to help water managers assess whether the water quality of a water resource is good enough for it to be used for humans, food production, or aquatic ecosystems (i.e. differing environmental values).

Application of the guidelines is described as follows: *for some environmental values the guideline number provided may be an adequate guide to quality (e.g. for recreation or drinking). For other specific environmental values the guideline can be just a starting point to trigger an investigation to develop more appropriate guidelines based on the type of water resource and inherent differences in water quality across regions. For water whose environmental value is aquatic ecosystem protection, for example, the investigation should aim to develop and adapt these guidelines to suit the local area or region. This document incorporates protocols and quite detailed advice to assist users in tailoring the water quality guidelines to local conditions. Invariably, the process of refining these guidelines — ‘trigger values’ — to local conditions will result in numbers for toxicants at least, that are less conservative and hence less constraining on surrounding activities.*

The guidelines do have defined trigger values for physical and chemical stressors and toxicants for the protection of aquatic ecosystems (Table 61). The guidelines recommend to follow the order: “use of biological effects data, then local reference data, and finally (least preferred) the tables of default values provided in the Guidelines”.

*Table 61 Default trigger values for physical and chemical stressors in New Zealand for slightly disturbed ecosystems. Trigger values are used to assess risk of adverse effects due to nutrients, biodegradable organic matter and pH in various ecosystem types. Chl a = chlorophyll-a, TP = total phosphorus, FRP = filterable reactive phosphate,<sup>d</sup> TN = total nitrogen, NO<sub>x</sub> = oxides of nitrogen, NH<sub>4</sub><sup>+</sup> = ammoniacal nitrogen, DO = dissolved oxygen. Sourced from ANZECC (2000)*

Ecosystem type	Chl a	TP	FRP	TN	NO <sub>x</sub>	NH <sub>4</sub> <sup>+</sup>	DO <sup>e</sup> (% saturation)		pH <sup>e</sup>	
							Lower limit	Upper limit	Lower limit	Upper limit
	(µg L <sup>-1</sup> )	(µg P L <sup>-1</sup> )	(µg P L <sup>-1</sup> )	(µg N L <sup>-1</sup> )	(µg N L <sup>-1</sup> )	(µg N L <sup>-1</sup> )				
Upland river	na <sup>a</sup>	26 <sup>b</sup>	9 <sup>b</sup>	295 <sup>b</sup>	167 <sup>b</sup>	10 <sup>b</sup>	99	103	7.3	8.0
Lowland river	no data	33 <sup>c</sup>	10 <sup>c</sup>	614 <sup>c</sup>	444 <sup>c</sup>	21 <sup>c</sup>	98	105	7.2	7.8

na = not applicable.

a = monitoring of periphyton and not phytoplankton biomass is recommended in upland rivers — values for periphyton biomass (mg Chl a m<sup>-2</sup>) to be developed. New Zealand is currently making routine observations of periphyton cover.

b = values for glacial and lake-fed sites in upland rivers are lower.

c = values are lower for Haast River which receives waters from alpine regions.

d = commonly referred to as dissolved reactive phosphorus in New Zealand.

e = DO and pH percentiles may not be very useful as trigger values because of diurnal and seasonal variation — values listed are for daytime sampling.

For stock drinking water, key relevant attributes the guidelines propose are:

- a median value for faecal coliforms of 100/100 mL,
- nitrate concentration < 400 mg/L (which equates to ~90.3 mg/L of nitrate-nitrogen),
- nitrite concentration < 30 mg/L (which equates to ~9.12 mg/L of nitrite-nitrogen),
- pesticides and organic contaminants – as per drinking water standards since no specific stock thresholds had been developed.

Guidelines are also provided for tolerances of livestock to total dissolved solids (salinity) and heavy metals (Table 63). Total dissolved solids (TDS) is a measure of all inorganic salts dissolved in water and is a guide to water quality (Table 62). For convenience, TDS is often estimated from electrical conductivity (EC). An approximate conversion of EC to TDS is:

- $EC \text{ (dS/m)} \times 670 = TDS \text{ (mg/L)}$ , or
- $EC \text{ (}\mu\text{S/cm)} \times 0.67 = TDS \text{ (mg/L)}$ .

Table 62 Tolerances of livestock to total dissolved solids (salinity) in drinking water (ANZECC 2000).

Livestock	Total dissolved solids (mg/L)		
	No adverse effects on animals expected.	Animals may have initial reluctance to drink or there may be some scouring, but stock should adapt without loss of production.	Loss of production and a decline in animal condition and health would be expected. Stock may tolerate these levels for short periods if introduced gradually
<b>Beef cattle</b>	0–4,000	4,000–5,000	5,000–10,000
<b>Dairy cattle</b>	0–2,500	2,500–4,000	4,000–7,000
<b>Sheep</b>	0–5,000	5,000–10,000	10,000–13,000 <sup>b</sup>
<b>Horses</b>	0–4,000	4,000–6,000	6,000–7,000
<b>Pigs</b>	0–4,000	4,000–6,000	6,000–8,000
<b>Poultry</b>	0–2,000	2,000–3,000	3,000–4,000

a From ANZECC (1992), adapted to incorporate more recent information.

b Sheep on lush green feed may tolerate up to 13,000 mg/L TDS without loss of condition or production.

Table 63 Recommended water quality trigger values (low risk) for heavy metals and metalloids in livestock drinking water a (ANZECC, 2000).

Metal or metalloid	Trigger value (low risk) a, b (mg/L)
<b>Aluminium</b>	5
<b>Arsenic</b>	0.5 up to 5 <sup>c</sup>
<b>Beryllium</b>	ND
<b>Boron</b>	5
<b>Cadmium</b>	0.01
<b>Chromium</b>	1
<b>Cobalt</b>	1
<b>Copper</b>	0.4 (sheep) 1 (cattle) 5 (pigs) 5 (poultry)
<b>Fluoride</b>	2
<b>Iron</b>	not sufficiently toxic
<b>Lead</b>	0.1
<b>Manganese</b>	not sufficiently toxic
<b>Mercury</b>	0.002

Metal or metalloid	Trigger value (low risk) a, b (mg/L)
<b>Molybdenum</b>	0.15
<b>Nickel</b>	1
<b>Selenium</b>	0.02
<b>Uranium</b>	0.2
<b>Vanadium</b>	ND
<b>Zinc</b>	20

The ANZECC guidelines also include a section with recommendations for aquaculture and human consumption of aquatic foods, which refers directly to the Food Standards Code for Australia and New Zealand (see Section A10).

## A10. Australia New Zealand Food Standards Code

Schedule 19 of the Food Standards Code (Australia New Zealand Food Standards Code, 2016) provides maximum levels of contaminants and natural toxicants for food and Schedule 27 provides the microbiological limits for food. In New Zealand, the provisions of the code that apply are adopted under, or incorporated in the Food Act 2014. Note these are limits in the food itself, rather than water quality in source waters. There are no known guidelines providing quantitative limits for source water quality and linking to organism contaminant levels (e.g. flesh). *Note that for mean levels of mercury in fish, crustacea and molluscs, see section S19-7 in the Food Standards Code.* Some potentially relevant contaminants and maximum levels from Schedule 19 (of the Food Standards Code) are shown in Table 64, and microbiological contaminants from Schedule 27 are shown in Table 65. For a comprehensive list of the contaminants, readers are directed to the Food Standards Code.

*Table 64 Maximum levels of metal contaminants for food (in mg/kg unless otherwise specified). From Schedule 19 of Food Standards Australia New Zealand (2016).*

Contaminant	Food	Maximum level
Arsenic (inorganic)	Crustacea	2
	Fish	2
	Molluscs	1
	Seaweed	1
Cadmium	Chocolate and cocoa products	0.5
	Kidney of cattle, sheep and pig	2.5
	Leafy vegetables (as specified in Schedule 22)	0.1
	Liver of cattle, sheep and pig	1.25
	Meat of cattle, sheep and pig (excluding offal)	0.05
	Molluscs (excluding dredge/bluff oysters and queen scallops)	2
	Root and tuber vegetables (as specified in Schedule 22)	0.1
Lead	Brassicas	0.3
	Edible offal of cattle, sheep, pig and poultry	0.5
	Fish	0.5
	Fruit	0.1
	Meat of cattle, sheep, pig and poultry (excluding offal)	0.1
	Molluscs	2

Contaminant	Food	Maximum level
	Vegetables (except brassicas)	0.1
Mercury	Fish, crustacea, molluscs	see s19-7
Neurotoxic shellfish poisons	Bivalve molluscs	200 MU/kg
Paralytic shellfish poisons (Saxitoxin equivalent)	Bivalve molluscs	0.8

*Table 65 Microbiological limits in food. From Schedule 27 of Food Standards Australia New Zealand (2016). Unacceptable microbiological levels are when a food listed has the number of sample units specified in column 2 (n) tested and the number of sample units in column 3 (c) are above the limit in column 4 (m) OR any of the sample units tested are above the limit specified in column 5 (M).*

Column 1	Column 2 (n)	Column 3 (c)	Column 4 (m)	Column 5 (M)
<b>All cheese</b>				
<i>Escherichia coli</i>	5	1	10 <sup>2</sup> /g	10 <sup>2</sup> /g
<b>Raw milk cheese</b>				
<i>Campylobacter</i>	5	0	not detected in 25 mL	
Coliforms	5	1	10 <sup>2</sup> /mL	10 <sup>3</sup> /mL
<i>Escherichia coli</i>	5	1	3/mL	9/mL
<i>Salmonella</i>	5	0	not detected in 25 mL	
SPC*	5	1	2.5 x 10 <sup>4</sup> /mL	2.5 x 10 <sup>5</sup> /mL
<b>All comminuted fermented meat which has not been cooked during the production process</b>				
<i>Escherichia coli</i>	5	1	3.6/g	9.2/g
<b>Cooked crustacea</b>				
SPC*	5	2	10 <sup>5</sup> /g	10 <sup>6</sup> /g
<b>Raw crustacea</b>				
<i>Salmonella</i>	5	0	not detected in 25 g	
SPC	5	2	5 x 10 <sup>5</sup> /g	5 x 10 <sup>6</sup> /g
Bivalve molluscs, other than scallops				
<i>Escherichia coli</i>	5	1	2.3/g	7/g
<b>Mineral water</b>				
<i>Escherichia coli</i>	5	0	not detected in 100 mL	
<b>Packaged water</b>				
<i>Escherichia coli</i>	5	0	not detected in 100 mL	
<b>Packaged ice</b>				
<i>Escherichia coli</i>	5	0	not detected in 100 mL	

\*means a standard plate count at 30°C with an incubation time of 72 hours.



## A11. Periphyton Guidelines for New Zealand

The periphyton guidelines of Biggs (2000) give some indication of the potential for periphyton growths to occur in relation to in-stream nutrient concentrations. Details about periphyton specifically are provided in Section 6.2.1.

The following nutrient threshold concentrations are recommended in the guidelines for the control of periphyton growth: 0.295 g/m<sup>3</sup> for dissolved inorganic nitrogen (DIN) and 0.026 g/m<sup>3</sup> for dissolved reactive phosphorus (DRP). These guidelines relate to a 20-day mean accrual of nutrient based on the time taken for periphyton to accrue nutrients before scour or loss due to high flow events (Biggs, 2000).

## A12. Deposited Sediment guidelines

Clapcott et al., (2011) developed protocols and guidelines to assess the effects of deposited sediment on in-stream values. The protocols and guidelines apply to sediments deposited on the streambed that are > 2 mm in diameter. The methodology for assessing deposited sediment was designed to apply to a broad range of conditions and rivers, and yet still be sensitive enough to be able to detect changes. The guidelines focus on 'hard-bottomed' streams (dominated by coarse gravel or larger substrate) in low to median flows. The guidelines are linked to in-stream values and are shown in Table 66.

Table 66 Deposited sediment guidelines (from Clapcott et al., 2011).

Value	Sediment measure	Sediment value	Method	Supporting info	Application
<b>Biodiversity</b>	Sediment cover (%)	<20% OR within 10% cover of reference	Bankside visual estimate OR In-stream visual estimate	Photo Photo	SoE reporting Assessment of effects
	Substrate size (%)	<20% cover or within 10% cover of reference	Wolman pebble count		SoE reporting or assessment of effects
	Suspendible sediment	<450 g/m <sup>2</sup>	Quorer		SoE reporting or assessment of effects
<b>Salmonid spawning habitat</b>	Sediment cover (%)	<20% OR within 10% cover of reference	Bankside visual estimate OR In-stream visual estimate	Photo Photo	SoE reporting Assessment of effects
	Substrate Size (%)	<20% cover	Wolman pebble count		SoE reporting or assessment of effects
<b>Amenity</b>	Sediment cover (%)	<25%	Bankside visual estimate OR In-stream visual estimate	Photo Photo	SoE reporting Assessment of effects
	Suspendible sediment	<3	Shuffle index	Photo	SoE reporting

## A13. Lake Trophic Level Index (Lake TLI)

The lake Trophic Level Index (TLI) integrates four key measures of lake trophic state - total nitrogen, total phosphorus, chlorophyll-a and secchi depth. The overall TLI score for a lake is the average of individual TLI scores for each variable. The overall score is categorised into seven trophic states, indicative of accelerated eutrophication as evidenced by more nutrients, more algal productivity and reduced water clarity. Trophic state categories and values of key variables defining the boundaries are shown in Table 67.

Table 67 Definition of Trophic Levels based on water quality measures (source Burns et al., 2000).

Trophic State	TLI Score	Chl a (mg/m <sup>3</sup> )	Secchi depth (m)	TP (mg/m <sup>3</sup> )	TN (mg/m <sup>3</sup> )
<b>Ultra-microtrophic</b>	<1	< 0.33	> 25	< 1.8	< 34
<b>Microtrophic</b>	1 - 2	0.33 – 0.82	15 - 25	1.8 – 4.1	34 - 73
<b>Oligotrophic</b>	2 - 3	0.82 - 2.0	15 - 7.0	4.1 – 9.0	73 - 157
<b>Mesotrophic</b>	3 - 4	2.0 - 5.0	7.0 - 2.8	9.0 - 20	157 - 337
<b>Eutrophic</b>	4 - 5	5.0 - 12	2.8 - 1.1	20 – 43	337 - 725
<b>Supertrophic</b>	5 - 6	12-31	1.1 - 0.4	43-96	725 - 1558
<b>Hypertrophic</b>	>6	>31	<0.4	>96	>1558

Some of the trophic state bands for chlorophyll-a align with the phytoplankton attribute state bands in the NPS-FM. For example, the ultra-microtrophic, microtrophic and oligotrophic chlorophyll-a ranges in Table 67 above, all equate to Band 'A' in the NPSFW (annual median  $\leq 2$  mg/m<sup>3</sup>), the mesotrophic chlorophyll-a range above equates to Band 'B' in the NPSFW, the eutrophic range equates to Band 'C' and the National Bottom Line (annual median 12mg/m<sup>3</sup>), and the supertrophic and hypertrophic ranges equate to Band 'D'.

# Appendix 2:

## Species used to derive nitrate toxicity guidelines

Table A1 Summary of species used to derive chronic nitrate toxicity guidelines. Shaded boxes indicate species resident in New Zealand (from Hickey, 2013).

Group	Common name	Scientific Name
Fish	Lake trout	<i>Salvelinus namaycush</i>
Fish	Chinok salmon	<i>Oncorhynchus tshawytscha</i>
Fish	Lahontan cutthroat trout	<i>Salmo clarki</i>
Fish	Coho salmon	<i>Oncorhynchus kisutch</i>
Fish	Lake whitefish	<i>Coregonus clupeaformis</i>
Amphibian	American Toad	<i>Bufo americanus</i>
Fish	Inanga	<i>Galaxias maculatus</i>
Amphibian	Pacific treefrog	<i>Pseudacris regilla</i>
Invertebrate	Freshwater crayfish	<i>Astacus astacus</i>
Invertebrate	Water flea	<i>Ceriodaphnia dubia</i>
Invertebrate	Mayfly	<i>Deleatidium sp.</i>
Invertebrate	Florida apple snail	<i>Pomacea paludosa</i>
Fish	Rainbow trout	<i>Oncorhynchus mykiss</i>
Invertebrate	Freshwater prawn	<i>Macrobrachium rosenbergii</i>
Amphibian	African clawed frog	<i>Xenopus laevis</i>
Invertebrate	Midge	<i>Chironomus dilutes</i>
Invertebrate	Crustacean	<i>Hyalella azteca</i>
Fish	Fathead minnows	<i>Pimephales promelas</i>
Amphibian	Red-eared frog	<i>Rana aurora</i>
Algae	Green algae	<i>Pseudokirchneriella subcapitata</i>
Fish	Topeka shiner	<i>Notropis topeka</i>
Invertebrate	Water flea	<i>Daphnia magna</i>

# Appendix 3:

## Species used to derive ammonia toxicity guidelines

Table A2 Summary of species used to derive chronic nitrate toxicity guidelines. Shaded boxes indicate species resident in New Zealand (from Hickey, 2014).

Group	Common name	Scientific Name
Invertebrate	Water flea	<i>Ceriodaphnia acanthine</i>
Fish	Cutthroat trout	<i>Oncorhynchus clarki</i>
Invertebrate	Water Flea	<i>Daphnia magna</i>
Invertebrate	Water flea	<i>Ceriodaphnia dubia</i>
Fish	Fathead minnow	<i>Pimephales promelas</i>
Fish	Rainbow trout	<i>Oncorhynchus mykiss</i>
Invertebrate	Mussel glochidia (NZ)	<i>Echridella menziesii</i>
Fish	Green sunfish	<i>Lepomis cyanellus</i>
Fish	White sucker	<i>Catostomus commersoni</i>
Fish	Smallmouth bass	<i>Micropterus dolomieu</i>
Invertebrate	Mayfly (NZ)	<i>Coloburiscus humeralis</i>
Fish	Sockeye salmon	<i>Oncorhynchus nerka</i>
Fish	Channel catfish	<i>Ictalurus punctatus</i>
Invertebrate	Long fingernail clam	<i>Sphaerium transversum</i>
Invertebrate	Mayfly (NZ)	<i>Delatidium</i> sp.
Fish	Bluegill	<i>Lepomis macrochirus</i>
Invertebrate	Wavy-rayed lampmussel	<i>Lampsilis fasciola</i>
Invertebrate	Fingernail clam (NZ)	<i>Sphaerium novaezelandaise</i>
Invertebrate	Fatmucket mussel	<i>Lampsilis siliquoidea</i>
Invertebrate	Rainbow mussel	<i>Villosa iris</i>

# Appendix 4:

## Summary of relevant existing national guidelines for ecological attributes

### National Policy Statement for Freshwater Management

Periphyton and phytoplankton are two of seven attributes included in the NPS-FM to ensure the maintenance of healthy freshwater ecosystems in rivers and lakes respectively (MfE, 2014) Appendix II of the NPS-FM proposes four bands (A to D) for periphyton biomass in rivers, measured as *chlorophyll-a*. The D band ( $> 200 \text{ mg/m}^2$ ) represents conditions that fail to meet the National "bottom line". Biomass exceeding this level is generally associated with invertebrate communities dominated by taxa such as snails, worms and midges, which are characteristic of degraded ecosystems (e.g., Biggs 2000). The A band for maximum chlorophyll biomass is less than  $50 \text{ mg/m}^2$ . Periphyton biomass within this band is expected to be associated with invertebrate taxa such as mayflies, caddis flies and stoneflies, which are found only in areas of high water quality and good habitat conditions (Biggs 2000).

The NPS-FM statistic for periphyton biomass in rivers (measured by chlorophyll-a concentration per square meter) is expressed as a percentage of exceedance of specified biomass. There are two classes of rivers identified:

- 1 'Productive class' which recognises that some environmental conditions (namely climate and geology) can result in natural conditions that are more favourable to periphyton growth. These are defined using the REC (Snelder and Biggs, 2002) as 'Dry' Climate categories and soft-sedimentary, volcanic acidic or volcanic basis geology categories, and
- 2 'Default class' which is all other streams not defined in the productive class.

The NPS-FM attribute allows for exceedance of 8% for the default class, and 17% for the productive class, and this is based on monthly monitoring for a minimum of three years.

The NPS-FM also has attribute bands for phytoplankton, to protect either ecosystem health, or human health for recreation Table 68. High levels of phytoplankton in lakes usually occur as a result of increased nutrients accumulating in lake water. These algal blooms, which are often dominated by blue green algae, can have dramatic effects on lake ecosystems (Rowe, 2004), and in extreme cases can result in the lake "flipping". When this occurs, lakes become highly turbid and dominated by phytoplankton productivity (tending towards the D band), whilst submerged macrophytes usually disappear. In contrast, lakes in the A band are usually oligotrophic, have clear waters, and are often dominated by submerged aquatic macrophytes in their littoral (shallow) zones. The NPS-FM attribute for phytoplankton has set bands based on the annual median value (presumably based on monthly sampling), as well as the annual maximum value. These maximum values are most likely to occur in summer or early autumn when temperatures are warm, and where deoxygenation events may occur in the deep part of the lakes, which can then release phosphorus. This phosphorus release can often lead to phytoplankton blooms.

The NPS-FM also has attributes for planktonic cyanobacteria to maintain human health for recreation Table 68. The four NPS-FM bands are based on the fact that some cyanobacteria contain toxic compounds that have a number of health implications for recreational users. The National bottom line (D band) is reached when there are potential health risks from cyanobacterial blooms. Unlike the phytoplankton biomass to protect ecosystem health, the NPS-FM cyanobacterial attribute is based on the 80th percentile of a number of samples collected over time. This is a much more conservative standard than the annual median value (i.e. 50<sup>th</sup> percentile) for phytoplankton, and most likely reflects the human

health implications of cyanobacterial blooms. The NPS-FM stipulates that the 80<sup>th</sup> percentile is calculated on a minimum of 12 samples collected over three years, and recommends analysis of 30 samples collected over a three-year period.

*Table 68 Ecological attributes from the National Objective Framework – values and related attributes for lakes and rivers (summarised from (MfE, 2014). Green shaded cells apply to rivers, orange shaded cells apply to lakes and lake-fed rivers, blue shaded cells apply to lakes. Med = annual median, 80<sup>th</sup> %ile = 80<sup>th</sup> percentile, Max = annual maximum.*

Value	Band	Attributes			
		River Periphyton biomass (mg chl-a /m <sup>2</sup> )		Lake Phytoplankton (mg chl-a /m <sup>3</sup> )	
		≤ 8% exceedance*	≤ 18% exceedance^	Med	Max
Ecosystem health	A	≤50	≤50	≤2	≤10
	B	>50 ≤120	>50 ≤120	>2 ≤5	>10 ≤25
	C	>120 ≤200	>120 ≤200	>5 ≤12	>25 ≤60
	D	>200	>200	>12	>60
				Lake and lake fed rivers Planktonic cyanobacteria biovolume (mm <sup>3</sup> /L) OR cell count (cells/mL)	
				80 <sup>th</sup> %percentile	
Human health for recreation	A			≤0.5mm <sup>3</sup> /L OR ≤500 cells/mL	
	B			N/A	
	C			>0.5 ≤1.8 mm <sup>3</sup> /L PT OR >0.5 ≤10 mm <sup>3</sup> /L ALL	
	D			>1.8 5mm <sup>3</sup> /L PT OR >10 mm <sup>3</sup> /L ALL	

\*'Default class' which is all other streams not defined in the productive class.

^ 'Productive class' which recognises that some environmental conditions (namely climate and geology) can result in natural conditions that are more favourable to periphyton growth. These are defined using the REC (Snelder and Biggs, 2002) as 'Dry' Climate categories and soft-sedimentary, volcanic acidic or volcanic basis geology categories.

# minimum of 12 samples over 3 years; 30 samples over 3 years recommended.

## Periphyton guidelines for New Zealand

Periphyton biomass can influence many instream values, such as recreation, aesthetics, and ecology. In recognition of this, interim guidelines for periphyton cover and biomass for the maintenance of aesthetics, benthic biodiversity, and trout habitat and angling values (Table 69) have been produced by the Ministry for the Environment (Biggs, 2000). The guidelines were specified as either estimates of percentage cover of the stream bed by periphyton mats (comprising diatoms/cyanobacteria) or filamentous algae, or measures of *chlorophyll-a* (the photosynthetic pigments that is found in all algae and used as a surrogate for periphyton biomass), determined from quantitative samples collected from the stream substrates. For example, maintenance of aesthetics and recreation would be achieved in rivers having less than 60% cover of diatom films greater than 0.3 cm thick, or less than 30% cover of filamentous algae (greater than 2 cm long). Benthic biodiversity would also be maintained if a maximum of *chlorophyll-a* biomass of < 50 mg m<sup>-2</sup> is maintained (Biggs, 2000).

Table 69 Provisional biomass and cover guidelines for periphyton growing in gravel/cobble bed streams for three main in stream values

In stream value/variable	Diatoms/cyanobacteria	Filamentous algae
<b>Aesthetics/recreation (1 November – 30 April)</b>		
Maximum cover of visible bed	60% > 0.3 c, thick	30% > 2 cm long
Maximum AFDM (g/m <sup>2</sup> )	N/A	35
Maximum <i>chlorophyll-a</i> (mg/m <sup>2</sup> )	N/A	120
<b>Benthic biodiversity</b>		
Mean monthly <i>chlorophyll-a</i> (mg/m <sup>2</sup> )	15	15
Maximum <i>chlorophyll-a</i> (mg/m <sup>2</sup> )	50	50
<b>Trout habitat and angling</b>		
Maximum cover of holes stream bed	N/A	30% > 2 cm long
Maximum AFDM (g/m <sup>2</sup> )	35	35
Maximum <i>chlorophyll-a</i> (mg/m <sup>2</sup> )	200	120

More recently, in a review of the Biggs (2000) guidelines, Matheson et al., (2012) highlighted a number of limitations with these. One was that the MfE guidelines provided separate thresholds for mat forming algae (such as the diatoms and cyanobacteria) and filamentous algae. However, it is possible for combined cover by both types of periphyton to be high, while cover by each type is below the MfE threshold. For example, 30% cover of diatom/cyanobacterial mats combined with 25% cover of filamentous algae (each of which meets the respective guideline) is likely to constitute an unacceptable condition which would negatively impact in stream values. To solve this anomaly, Matheson et al. (2012) recommended the use of a periphyton weighted composite cover (PeriWCC) such that:

- PeriWCC = % filamentous cover + (% mat cover/2).

Matheson et al. (2012) also suggested four bands for PeriWCC such that <20% = “excellent”; 20 – 39% = “good”; 40 – 55% = “fair”; >55% = “poor”. They showed that invertebrate metrics such as the MCI, QMCI and percentage of EPT responded in a relatively consistent manner to increases in PeriWCC, and suggested that these four bands could form the basis of provisional general periphyton cover thresholds to protect benthic biodiversity.

A second limitation of the MfE periphyton guidelines is the fact that the relationships presented in these guidelines linking periphyton biomass, nutrient concentrations, and biomass accrual time were derived using data primarily from gravel-bed rivers. These empirically derived relationships did not consider other important regulators of periphyton growth, such as light availability or substrate stability (Biggs, 2000). Matheson et al. (2012) highlight the fact that this limitation makes it difficult to apply the model to rivers other than open gravel-bed rivers. Consequently, they suggest that the nutrient thresholds in the periphyton guidelines represent worst-case scenarios, and are applicable to streams where periphyton growth will be optimal. Such streams would be typified as having no shade, high water clarity, gravel-cobble substrates, and long periods of low stable flow.



## Benthic cyanobacteria guidelines

The Ministry of Health has developed a methodology for monitoring benthic cyanobacteria in rivers (Wood et al., 2009) that involves assessing cyanobacteria cover at five points across each of four transects in a selected river. Given the close links between a river's flow regime and algal cover, they also suggest monitoring on a fortnightly basis when no flushing flows have occurred in the past few weeks (a flushing flow is defined as one which is 3 times the median flow, and which usually results in a decrease of algal biomass (Clausen and Biggs, 1997)). The average percentage cover of cyanobacteria is then calculated, as is the average percentage cover per site. Three alert thresholds have been identified (Table 70), based on this cover (Wood et al., 2009). There are also different monitoring requirements that vary subject to the specific alert level encountered, with fortnightly monitoring at low levels of cyanobacterial cover, increasing to weekly sampling at higher levels of cover. This reflects the increased need for monitoring as the amount of cyanobacteria cover in a river increases.

*Table 70 Alert – level framework for benthic cyanobacteria (when using biovolume not cells/mL), New Zealand Guidelines for Cyanobacteria in Recreational Fresh Waters (Wood et al 2009).*

Alert level	Description	Action
<b>Green</b>	Cover < 20%.	Surveillance mode. Fortnightly monitoring.
<b>Amber</b>	Cover 20 – 50%	Alert mode. Switch to weekly sampling. Notify Crown public health. Potentially test match for toxins.
<b>Red</b>	Cover > 50%, OR max dislodging and accumulating along river's edge	Action mode. As per alert mode, plus installation of public warnings.

## Planktonic cyanobacteria guidelines

As with benthic cyanobacteria, the Ministry of health has developed a three-year staged alert level framework (Table 71) for monitoring plankton cyanobacteria in recreational freshwaters (Wood et al., 2009). This alert level is based on calculation of cell biovolumes. As with benthic cyanobacteria, there are different monitoring requirements that vary subject to the specific alert level encountered. This reflects the increased need for monitoring as the amount of planktonic cyanobacteria increases.

*Table 71 Alert – level framework for planktonic cyanobacteria (when using biovolume not cells/mL), New Zealand Guidelines for Cyanobacteria in Recreational Fresh Waters (Wood et al 2009).*

Alert level	Actions
<p><b>Surveillance (green mode)</b></p> <p><b>Situation 1:</b> The cell concentration of total cyanobacteria does not exceed 500 cells/mL.<sup>a</sup></p> <p><b>Situation 2:</b> The biovolume equivalent for the combined total of all cyanobacteria does not exceed 0.5 mm<sup>3</sup>/L.</p>	<ul style="list-style-type: none"> <li>Undertake weekly or fortnightly visual inspection<sup>b</sup> and sampling of water bodies where cyanobacteria are known to proliferate between spring and autumn.</li> </ul>
<p><b>Alert (amber mode)</b></p> <p><b>Situation 1:</b> Biovolume equivalent of 0.5 to &lt; 1.8 mm<sup>3</sup>/L of potentially toxic cyanobacteria (see Tables 1 and 2), or</p> <p><b>Situation 2<sup>c</sup>:</b> 0.5 to &lt; 10 mm<sup>3</sup>/L total biovolume of all cyanobacterial material.</p>	<ul style="list-style-type: none"> <li>Increase sampling frequency to at least weekly<sup>d</sup></li> <li>Notify the public health unit.</li> <li>Multiple sites should be inspected and sampled.</li> </ul>

Alert level	Actions
<p><b>Action (red mode):</b>  <b>Situation 1:</b> <math>\geq 12 \mu\text{g/L}</math> total microcystins; or biovolume equivalent of <math>\geq 1.8 \text{ mm}^3/\text{L}</math> of potentially toxic cyanobacteria (see Tables 1 and 2), or  <b>Situation 2<sup>c</sup>:</b> <math>\geq 10 \text{ mm}^3/\text{L}</math> total biovolume of all cyanobacterial material, or  <b>Situation 3<sup>e</sup>:</b> cyanobacterial scums consistently present.</p>	<ul style="list-style-type: none"> <li>• Continue monitoring as for alert (amber mode).<sup>d</sup></li> <li>• If potentially toxic taxa are present (see Table 1), then consider testing samples for cyanotoxins.<sup>f</sup></li> <li>• Notify the public of a potential risk to health.</li> </ul>

- (a) A cell count threshold is included at this level because many samples may contain very low concentrations of cyanobacteria and it is not necessary to convert these to a biovolume estimate.
- (b) In high concentrations planktonic cyanobacteria are often visible as buoyant green globules, which can accumulate along shorelines, forming thick scums (see Appendix 3). In these instances, visual inspections of water bodies can provide some distribution data. However, not all species form visible blooms or scums; for example, dense concentrations of *Cylindrospermopsis raciborskii* and *Aphanizomenon issatschenkoi* are not visible to the naked eye (see Appendix 3).
- (c) This applies where high cell densities or scums of 'non-toxicogenic' cyanobacteria taxa are present (i.e. where the cyanobacterial population has been tested and shown not to contain known toxins).
- (d) Bloom characteristics are known to change rapidly in some water bodies, hence the recommended weekly sampling regime. However, there may be circumstances (e.g. if good historical data/knowledge is available) when bloom conditions are sufficiently predictable that longer interval sampling is satisfactory.
- (e) This refers to the situation where scums occur at the recreation site for more than several days in a row.
- (f) Cyanotoxin testing is useful to: provide further confidence on potential health risks when a health alert is being considered; enable the use of the action level  $10 \text{ mm}^3/\text{L}$  biovolume threshold (i.e. show that no toxins are present; and show that residual cyanotoxins are not present when a bloom subsides).

## River macrophyte framework

To date, no national guidelines exist for riverine macrophytes as attributes. However, Matheson et al. (2012) have developed a decision-making/risk assessment framework to allow regional councils to define appropriate in stream plant abundances and defensible nutrient concentrations for a broad range of river types and hydrological regimes. This framework relied on analysis of existing databases, and production of Bayesian belief network models to predict the probability of nuisance macrophytes growth in rivers and streams.

Matheson et al (2012) suggested that macrophyte abundance in rivers and streams should be quantified as a proportion of channel cross-sectional area or volume (CAV), and water surface area (SA), as these were deemed to be the best indicators of a nuisance effect. They suggested two provisional guidelines for macrophyte abundance:

- $\leq 50\%$  of macrophytes channel cross-sectional area or volume (CAV) to protect Instream ecological conditions, flow conveyance and recreational values.
- $<50\%$  macrophytes channel water surface area (SA) to protect instream aesthetic and recreational values.

## Lake Submerged Plant Indicators (Lake SPI)

The Lake SPI (Submerged Plant Indicators) methodology developed by NIWA is designed to complement traditional water quality monitoring such as the TLI (refer Section 5.4.6). It does this by providing ecological information about lake health in terms of macrophyte communities, whereas the TLI is focused primarily on water quality parameters. Moreover, Lake SPI assessments are done in the margins of lakes, where both human interaction and ecological values are greatest (Clayton and Edwards, 2006b). The Lake SPI methodology uses submerged macrophytes that are thought to integrate a range of environmental conditions over an extended period of time. Such conditions would include sediment and nutrient loading, as well as the displacement of native vegetation by exotic, or invasive plant species.

There are three components of Lake SPI:

- Native condition index, which captures the native character of the vegetation,
- Invasive impact index, which captures the invasive character of vegetation in the lake based on the degree of impact by invasive weeds,
- Lake SPI index, a synthesis of components from both the native condition and invasive impact condition. The higher the score, the better the condition.

Lake SPI methodology uses submerged macrophytes to allow managers to monitor and report on the status of lakes at an individual, regional or national level. Burton (2016) has suggested five lake condition categories based on the Lake SPI index (Table 72).

Table 72 Summary of the five lake condition categories according to the Lake SPI score.

Lake SPI index score	Lake condition category
>75%	Excellent
>50 – 75%	High
>20 – 50%	Moderate
>0-20%	Poor
0%	Non-vegetated

Burton (2016) also highlighted that changes to Lake SPI indices can provide an indication of current stability and lake condition and direction of change. Based on this, she recommended a scale of probabilities that describes ecologically significant changes and lake condition using averaged Lake SPI indices over repeated surveys (Table 73).

Table 73 Summary of guidelines for assessing the significance of change in Lake SPI scores over time.

Observation	Scale of certainty	
<b>New incursion of a more invasive weed</b>	Yes	Change predicted
<b>No new incursion</b>	0 – 5% change in Lake SPI	Change not indicated
	>5 – 10% change in Lake SPI	Change possible
	>10 - 15% change in Lake SPI	Change probable
	>15% change in Lake SPI	Change indicated

## Invertebrate guidelines

There has been almost universal uptake of indices such as the MCI and QMCI throughout the country, and this has somewhat been assisted by the existence of the four clearly defined water quality bands based on these biotic scores (Stark 1985; Stark and Maxted 2007). However, no invertebrate metrics have currently been recommended as attributes under the NPS-FM, because of the difficulty in identifying specific causes of decline for this attribute. However, MfE (2017) recently suggested making monitoring macroinvertebrates a compulsory part of a regional council's assessment of ecosystem health.

Despite the lack of national guidelines in the NPS-FM for invertebrate metrics, the MCI, taxonomic richness, and percentage of EPT form core reporting metrics of ecological condition for the LAWA webpage ([www.lawa.org.nz](http://www.lawa.org.nz)). Taxonomic richness refers to the number of different types of invertebrates (or taxa) identified at a site, and is based on the assumption that richness is reduced in sites heavily impacted by organic enrichment. The LAWA webpage has suggested bands (Table 71) for the % of EPT taxa, coded to one of the four water quality classes of Stark and Maxted (2007). Although it may be tempting to use these values as attribute bands for the Bay of Plenty, examination of invertebrate data collected from the Natural Environmental Reporting Monitoring Network SoE programme throughout the region suggests that these suggested numeric bands may not be relevant (Suren et al 2017).

For example, EPT taxa are often naturally uncommon in the soft-bottomed, pumice dominated streams that are common in Western parts of the region. This means that even streams flowing through undisturbed native bush generally have a low percentage of EPT. This low percentage would result in these streams scoring a low quality class under the current LAWA bands than they would if regionally specific bands were created. This can be shown in Figure 9, where just under 60% of monitored streams in the Bay of Plenty would be scored as only in "Fair" condition when assessed according to the LAWA bands for % EPT taxa. This is in sharp contrast to the number of stream sasses as being in "Fair" condition using the other metrics examined (Figure 9).

*Table 74 Values of the MCI/QMCI and percentage of EPT taxa richness for the four water quality classes as shown on the LAWA webpage*

Quality class	Description	MCI score	QMCI/SQMCI score	%EPT Taxa
<b>Excellent</b>	Clean water.	>119	>5.99	>70
<b>Good</b>	Doubtful quality or possible mild pollution.	100-119	5.00-5.99	51-70
<b>Fair</b>	Probable moderate pollution.	80-99	4.00-4.99	25-50
<b>Poor</b>	Probable severe pollution.	<80	<4.00	<25

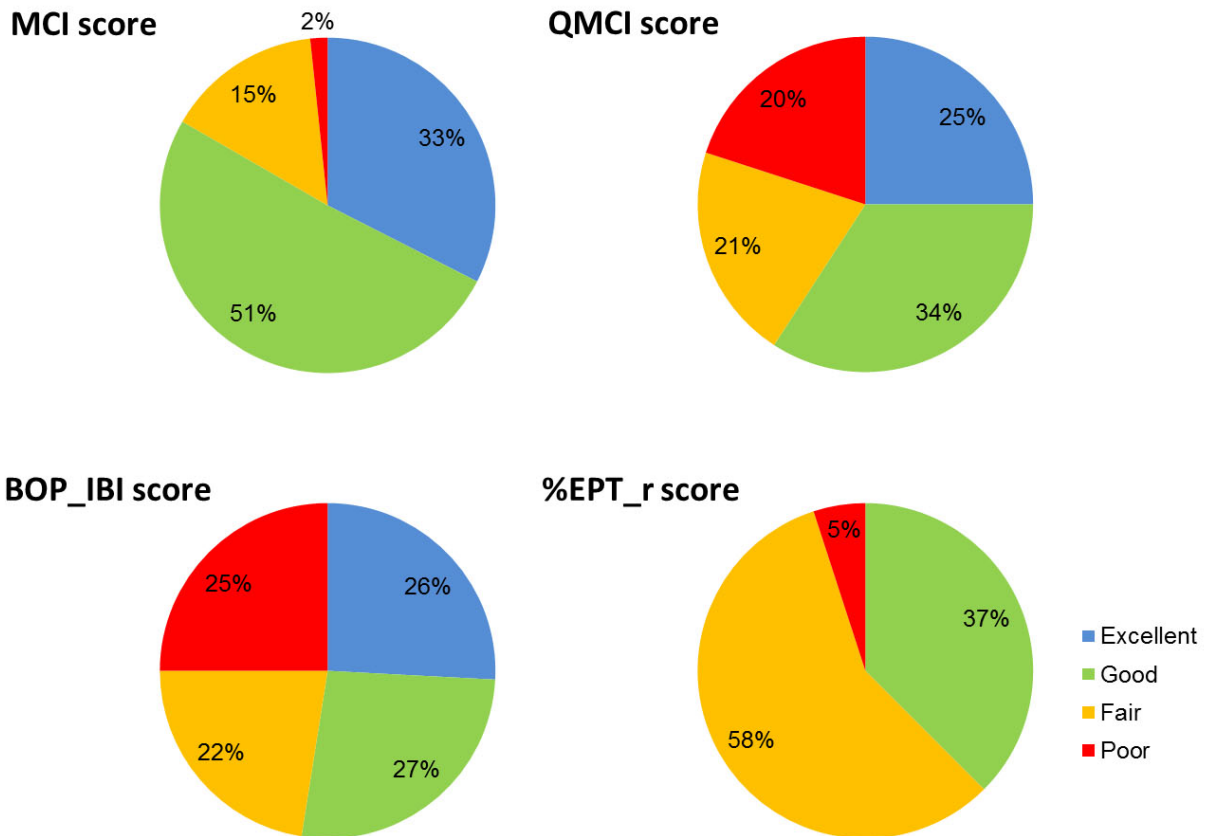


Figure 9 Pie charts showing the percentage of invertebrate monitoring sites that belonged to one of four water quality classes when assessed using the MCI, QMCI, BOP\_IBI and percentage of EPT richness. Note the marked difference in water quality classification for the sites, including the fact that no sites scored excellent in the Bay of Plenty in terms of percentage of EPT richness.

## Fish biotic index

Joy and Death (2004) developed a biotic index to assess the integrity of fish communities in New Zealand. This index was a modification of an earlier index of biotic integrity developed for fish communities in the USA (Karr et al., 1986). This metric was based on six aspects of the fish community that were thought to respond to different pressures associated with human activities:

- native species,
- riffle dwelling species,
- benthic pool species,
- pelagic pool species,
- intolerant species,
- proportion of native species.

Because elevation and distance to the sea has such a large effect on fish communities, the six metrics are assessed on the basis of both elevation and distance to sea using quantile regression analysis. For example, if the number of species for each individual metric at a specific site of a known altitude was less than the number observed under the 33% quantile regression line, then that site would score a 1. If the number of species was between the 33% and 66% line, the site would score a 3, and if the number of species was above the 66% line, then the site would score a 5. Site scores would range from 0 (no fish present) to 60 (sites with more species than predicted by the 66% quantile regression line).

## Habitat assessments

Although standardised protocols for the assessment of physical habitat exist (Harding et al 2009), these protocols do not provide a consistent scoring system to rank sites based on habitat quality. Clapcott (2015) recently developed a national rapid habitat assessment (RHA) protocol to assess habitat quality in rivers and streams. A draft protocol containing nine parameters was trialled at 560 sites throughout New Zealand. The resultant habitat scores were strongly related to catchment scale measures of native vegetation cover, impervious cover, and land use intensification. Following analysis of this data, Clapcott recommended a national RHA that assessed 10 individual habitat parameters along a river reach. Each of these parameters was assigned a score of one to 10, with the subsequent habitat quality score (HQS) being based on the sum of these parameters. The total HQS maximum score was 100, although this score could be scaled to a reference score to provide a percentage HQS for reporting.

Although this RHA provides nationally consistent protocols to assess habitat quality, no councils appear to be using this method yet in terms of attribute setting.

Table 75 Rapid habitat assessment methodology showing the 10 parameters and their scoring bands

Habitat parameter	Condition category										Score	
1. Deposited sediment	The percentage of the stream bed covered by fine sediment.											
	0	5	40	15	20	30	40	50	60	≥ 75		
<b>Score</b>	10	9	8	7	6	5	4	3	2	1		
2. Invertebrate habitat diversity	The number of different substrate types such as boulders, cobbles, gravel, sand, wood, leaves, root mats, macrophytes, periphyton. Presence of interstitial space scores higher.											
	≥ 5	5	5	4	4	3	3	2	2	1		
<b>Score</b>	10	9	8	7	6	5	4	3	2	1		
3. Invertebrate habitat abundance	The percentage of substrate favourable for EPT colonisation, for examples flowing water over gravel – cobbles clear of filamentous algae/macrophytes.											
	95	75	70	60	50	40	30	25	15	5		
<b>Score</b>	10	9	8	7	6	5	4	3	2	1		
4. Fish cover diversity	The number of different substrate types such as woody debris, root mats, undercut banks, overhanging/encroaching vegetation, macrophytes, boulders, cobbles. Presence of substrates providing spatial complexity score higher.											
	≥ 5	5	5	4	4	3	3	2	2	1		
<b>Score</b>	10	9	8	7	6	5	4	3	2	1		
5. Fish cover abundance	The percentage of fish cover available.											
	95	75	60	50	40	30	20	10	5	0		
<b>Score</b>	10	9	8	7	6	5	4	3	2	1		
6. Hydraulic heterogeneity	The number of hydraulic components such as pool, riffle, fast run, slow run, rapid, cascade/waterfall, turbulence, backwater. Presence of deep pools score higher.											
	≥ 5	5	4	4	3	3	2	2	2	1		
<b>Score</b>	10	9	8	7	6	5	4	3	2	1		
7. Bank erosion	The percentage of the stream bank recently/actively eroding due to scouring at the waterline, slumping of the bank, or stock pugging.											
	Left bank	0	≤ 5	5	15	25	35	50	65	75	> 75	
	Right bank	0	≤ 5	5	15	25	35	50	65	75	> 75	

Habitat parameter	Condition category										Score
<b>Score</b>	10	9	8	7	6	5	4	3	2	1	
8. Bank vegetation left bank and right bank	The maturity, diversity and naturalness of bank vegetation.										
	Mature native trees with diverse and intact understory.	Regenerating native or faxes/sedges/tussock > dense exotic.			Mature shrubs, sparse tree cover > Young exotic, long grass.			Heavily grazed or mown grass > bear/impervious ground.			
<b>Score</b>	10	9	8	7	6	5	4	3	2	1	
9. Riparian width	The width (m) of the riparian buffer constrained by vegetation, fence or other structure(s).										
Left bank	> 30	15	10	7	5	4	3	2	1	0	
Right bank	> 30	15	10	7	5	4	3	2	1	0	
<b>Score</b>	10	9	8	7	6	5	4	3	2	1	
10. Riparian shade	The percentage of shading of the stream bed throughout the day due to vegetation, banks or other structure(s).										
	≥ 90	80	70	60	50	40	25	15	10	≤ 5	
<b>Score</b>	10	9	8	7	6	5	4	3	2	1	
<b>TOTAL</b>	(Sum of parameters 1 – 10).										