Freshwater in the Bay of Plenty

Comparison against the recommended water quality guidelines

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Executive summary

The National Policy Statement (NPS-FM) for Freshwater Management (MfE, 2014, amended 2017) sets compulsory national values for freshwater to safeguard 'human health for recreation' and 'ecosystem health'. It also defines thresholds for numeric attributes, ranked into bands (A-D or E), which define water quality for a number of attributes and set 'National Bottom Lines'.

In addition, 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of freshwater values that are commonly (but not always) relevant in freshwater bodies across the region (Green and Lee, unpublished). BOPRC has also recommended an appropriate suite of initial water quality and ecology attributes and, where possible, attribute state bands to be used region-wide by BOPRC (Carter et al., 2017). These attributes will help set measurable objectives to support key values with in-stream water quality or ecology requirements, and to measure their current state. Generally, BOPRC must set freshwater objectives for all freshwater bodies at or above national bottom lines (subject to some exemptions). For all freshwater bodies that have water quality below national bottom lines, methods will be put in place to improve water quality

Monitoring data for rivers, streams and lakes in the Bay of Plenty has been compared to the attributes in the NPS-FM and Carter et al., (2017). This information will provide a baseline for discussions between BOPRC and stakeholders regarding setting freshwater objectives and appropriate limits (e.g. nutrient loads) to achieve them.

Lakes

For ecosystem health attributes in lakes, current data shows Lake Rotomahana does not meet the national bottom line for total phosphorus, and Lake Ōkaro does not meet the national bottom line for phytoplankton (chlorophyll-a). All other monitoring sites were graded either A, B or C for total nitrogen and phosphorus, ammoniacal-nitrogen, phytoplankton (chlorophyll-a) and the lake trophic level index (TLI). Two lakes are showing improving 10 year trends for total phosphorus (Rotokakahi and Rotorua) and six lakes are showing worsening trends (Ōkāreka, Ōkataina, Rotoehu, Rotomā, Rotomahana and Tarawera). Nine lakes showed improving trends for total nitrogen. Five of the twelve Te Arawa/Rotorua lakes meet or are better than the Regional Water and Land Plan TLI objective.

LakeSPI is another environmental attribute that provides an index of lake ecological health. Carter et al., (2017) recommended bands based on the % change between successive LakeSPI surveys, with a D band being where there was a > 15% reduction. Based on this method, seven of the 12 monitored lakes were in the A band for changes in the LakeSPI, showing either < 5% change, or an improvement in LakeSPI scores since the previous year's sampling. Only Lake Tikitapu showed reductions in LakeSPI scores below the bottom line, reflecting a continual decline in LakeSPI scores since 2014, due mainly to the increased depth range where the exotic plant Lagarosiphon was found. Although the Carter et al., (2017) report recommended bands based on the percent change between successive surveys, a more robust banding system is suggested, based on changes to LakeSPI scores relative to the earliest surveys. Using this method, only Lake Rotoma was always in the A band over successive surveys, while six lakes (Rerewhakaaitu, Rotoehu, Rotoiti, Rotokakahi, Tarawera and Tikitapu) were below the bottom line D band, where LakeSPI scores had declined by more than 15% since the earliest surveys. Again, these reductions were caused mostly by invasion by exotic plants such as Lagarosiphon, Egeria and Ceratophyllum.

For human health attributes in lakes, all lakes were graded 'swimmable' based on the E. coli attribute, and were in either A or B band. All sites on Lake Rotoehu, and one site on Lake Rotoiti (Okawa Bay) were ranked C over the past two assessment periods (2013-2016, 2014-2017) for planktonic cyanobacteria bio-volume. The same was true for the Lake Ōkaro site; however, this site also ranked C for the period of 2012-2015. All other monitored lake sites were graded A for cyanobacteria, across all analysis periods.

Rivers

For ecosystem health water quality attributes in rivers, all sites were better than the bottom lines for all attributes based on most recent data. All sites were graded 'A' or 'B' band for nitrate and ammoniacal-nitrogen, and four sites were graded A or B band for dissolved oxygen. One site (Rangitaiki River below Edgecumbe) was currently graded C band for dissolved oxygen. Ten sites were graded A or B band for water temperature, with four sites graded C band. Improving trends in nitrate-nitrogen were observed at two site and ammoniacal-nitrogen at five sites (Omanawa at State Highway 29, Te Mania at State Highway 2, Kaituna at Maungarangi and Waioeka at Gorge mouth, Mōtū at SH35).

Examination of ecological indices summarising invertebrate communities showed that of the 135 streams monitored, 50 were graded as being in Very Good condition and 55 in Good ecological condition, while only 13 were in Poor condition. Of those that were Poor, six were in streams draining agricultural catchments, and three in urban catchments. Trend analysis done on two of the recommended metrics (the MCI and EPT richness) found only a small number of sites displayed significant trends. Furthermore, many of these trends were the same as found previously based on data to 2015. Lack of major differences in trends with two more years of data suggests that there have been no major changes to invertebrate communities.

For human health attributes in rivers, 16 sites were graded 'swimmable' based on E. coli, and were in either A, B or C band. Six sites were graded 'not swimmable' and were graded either D or E band, being Kopurererua, Kaiate, Ngongotaha, Uretara, Utuhina, and Waiteti. The Kaituna River was graded A for planktonic cyanobacteria (the only lake-fed river monitored for this attribute).

Of the 29 rivers monitored, 19 were in the A grade for periphyton, with consistently low algal biomass. A further eight sites were in the B grade, suggesting occurrence of only short-lived blooms of relatively low biomass. Only two sites (Tuapiro at farm bridge, and Waitekohe at State Highway 2) were in the C grade, where periodic short-duration blooms occurred. No rivers displayed any prolonged benthic cyanobacterial blooms, and were always in the A grade for this attribute.

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Part 1: **Introduction**

1.1 Background

The National Policy Statement for Freshwater Management (MfE, 2014 amended 2017; NPS-FM) 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 enables land and water use while meeting water quality and quantity objectives.

Appendix 1 of the NPS-FM sets out two compulsory national values for freshwater: Ecosystem Health; and Human Health for Recreation. Human health for recreation as defined in the NPS-FM, means a healthy waterbody allows people to connect with water through a range of recreational activities. Ecosystem health is defined as a healthy ecosystem appropriate to a freshwater body type, in which ecological processes are maintained, with a range and diversity of indigenous flora and fauna, and resilience to change. For each of these values, compulsory *attributes* are specified in Appendix 2 in the NPS-FM, which are measurable characteristics of fresh water that support particular values. A number of other attributes are also indicated in the NPS-FM that should be considered as part of freshwater management for these two compulsory values. Policy CA2 of the NPS-FM also directs regional councils to identify other attributes that are appropriate for the compulsory national values, and any other national or other value applied.

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 (Green and Lee, *unpublished*). BOPRC has also recommended an appropriate suite of initial water quality and ecology attributes and, where possible, attribute state bands 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 (Carter *et al.,* 2017). The report also clarifies the frequency/duration of monitoring data required.

1.2 Purpose

The purpose of this report is to compare BOPRC's monitoring data to those attributes defined in the NPS-FM and recommended by BOPRC (Carter *et al.,* 2017). This information will be used to guide Council and communities in setting numerical objectives, and appropriate limits for freshwater.

Part 2:
Methods

2.1 Monitoring data – water quality

A range of physical, chemical and microbiological water quality parameters have been monitored at over 80 river and stream sites and in the 12 Te Arawa/Rotorua Lakes since the early 1990s as part of the Natural Environment Regional Monitoring Network (NERMN). Currently, the NERMN programme includes 55 river sites and 12 lakes. The location of these current sites is shown in Figure 1. The lowland and most downstream sites in the NERMN rivers programme is restricted to being above the brackish zone where sea water mixes with freshwater. As such, some of the lowest reaches of rivers are not included in the monitoring programme, and have been monitored and reported in a separate project (Suren and Carter, 2018). Monitoring of estuarine environments is also undertaken by BOPRC and reported separately (Park, 2016, 2015, Scholes, 2015).

Attributes monitored in rivers include the following:

- Chlorophyll-*a* – an algal pigment that gives an indication of algal biomass (productivity).
- Total nitrogen (TN) – a plant nutrient that can drive algal growth.
- Total phosphorus (TP) – along with nitrogen, this is a plant nutrient that can drive algal growth.
- Periphyton – attached (benthic) algae that live on the beds of rivers and streams.
- Nitrate – included in the NPS-FM as an attribute to manage toxicity effects on aquatic life.
- Ammonia – like nitrate, this is included in the NPS-FM as an attribute to manage toxicity effects on aquatic life.
- Dissolved oxygen – measured below point source discharges and a key attribute for the protection of aquatic life.
- Water temperature – like dissolved oxygen, this is a key attribute for the protection of aquatic life.
- Escherichia coli (*E. coli*) – an indicator of the presence of faecal contamination.
- Planktonic/benthic cyanobacteria - can produce blooms that are potentially toxic.

These water quality attributes have been compared over the required frequencies and with available data from the NERMN river and lake water quality monitoring, and in some cases from the NIWA national rivers monitoring network.

Ten year trend information is given for the attributes where this is currently available and data summaries for a number of the attributes are provided in Appendix 1. Trends reported here were consistent with the timeframe, data filtering and processing used for Land Air Water Aotearoa (LAWA) at the time of writing. Specific trend methodology can be found on LAWA and details are provided below.

"LAWA uses the 'Seasonal Kendall Trend Test'. This test compares the water quality data of each season separately (January with January, February with February, etc.) which means if any changes are detected they are not due to seasonal patterns.

The river trend analysis looks at the confidence intervals on either side of the estimated slope for each site and parameter combination. If zero is outside the 95th confidence interval range then the trend direction is determined with confidence, which means that we can be certain that water quality is showing signs of degrading or improving trends at a certain site for a certain parameter. However, if zero is within the confidence interval range, it is concluded that there are insufficient data to determine the trend direction - this is when LAWA reports an indeterminate trend. This approach is statistically powerful and used in recent national trend analysis summaries (e.g. Larned et al., 2015).

Ideally, data should be flow adjusted before trend analysis to remove any effects of variation in stream flow. However, many councils do not measure river flow at their water quality sampling sites which is why all data used for trend analysis on LAWA are not flow-adjusted. Larned et al., (2015) showed that flow adjustment makes relatively little difference to any trends identified for most sites when data is considered at a national level." LAWA, June 2018.

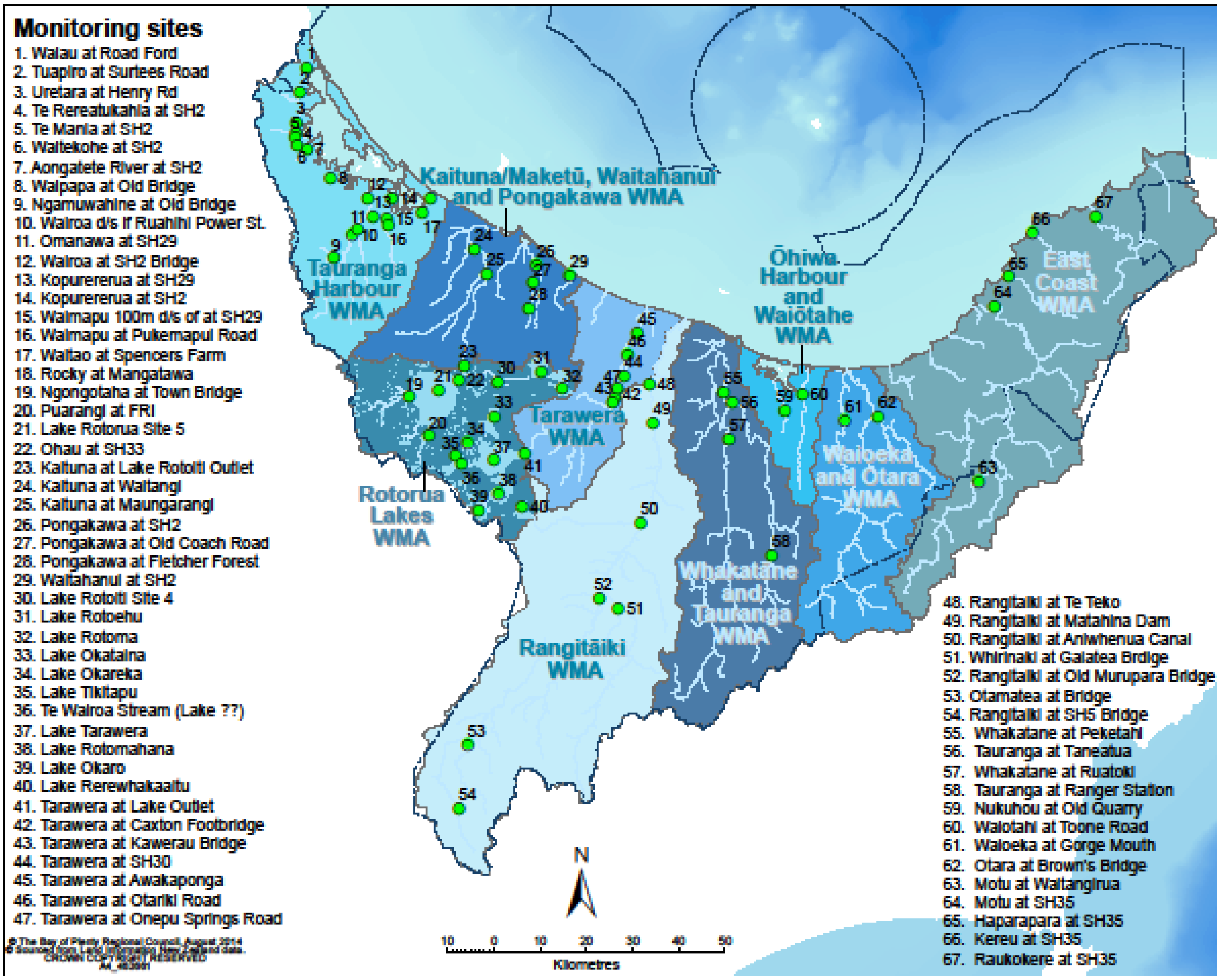

Figure 1 Natural Environment Regional Monitoring Network (NERMN) surface water quality monitoring locations in the Bay of Plenty region.

2.2 Monitoring data – ecology

Carter *et al.,* (2017) identified five relevant ecological attributes that BOPRC is currently collecting data for: invertebrates, lake macrophytes, lake cyanobacteria, benthic algal biomass (as chlorophyll-*a*), and cyanobacterial cover. The number of sampling sites for these attributes is listed in Table 1. Note that sample frequency is a reflection of the overall stability of the communities in question and how quickly they are expected to change over time. Lake cyanobacteria communities can change on a weekly (or even daily) basis, reflecting changes in wind speed and direction that can blow these buoyant communities into the shoreline. In contrast, lake macrophytes are generally slow growing, and thus only need to be sampled once every two years in order to ascertain changes in their community composition and cover.

Table 1 List of ecological attributes, the number of sites where they are collected from, and their collection frequency.

Attribute	Number of samples	Collection frequency
Freshwater invertebrates	135	Annually (summer)
Lake macrophytes	12 lakes	Bi-annually (autumn)
Lake cyanobacteria	13 sites, from 4 lakes	Weekly (November – May)
Algal biomass	29 sites	Monthly
Benthic cyanobacteria	29 sites	Monthly

2.3 Recommended attributes

There are eight recommended attributes for lakes and ten for rivers (Table 2). Detailed attribute states, including narrative and numeric states (where applicable) are provided in Tables 3-13. Where grades differed between two statistics for a given attribute (e.g. C band for annual median and D band for annual maximum), the lowest (worst) grade has been reported. For most attributes listed, the bottom of band C represents the 'bottom line' (either national or regional), and this is shown in bold in the tables.

Carter *et al.,* (2017) recommend five ecological attributes and state bands based on either those in the NPS-FM (periphyton biomass, and planktonic cyanobacteria in lakes), other current guidelines (e.g. benthic cyanobacteria), or analysis of previous historic data (lake macrophytes and invertebrate metrics). While some ecological attributes are based only on a single metric, other attributes use multi-metrics to describe current state. Thus, lake macrophytes are assessed by the LakeSPI methodology, whereas invertebrate communities are assessed by three metrics: the MCI score, EPT richness, and the BoP_IBI (see Tables 11-13).

Table 2 Attributes correlating to their value for rivers and lakes.

Ecosystem health		**Human health for recreation**	
Lakes	**Rivers**	**Lakes**	**Rivers**
Total Nitrogen (Trophic state)	Nitrate (toxicity)	Planktonic cyanobacteria bio-volume/cell count	Planktonic cyanobacteria bio-volume/cell count (lake-fed rivers only)
Total Phosphorus (Trophic state)	Ammonia (toxicity)	*E. coli* (pathogen infection risk)	*E. coli* (pathogen infection risk)
Chlorophyll-*a* (Trophic state)	Dissolved oxygen (point sources)		Benthic cyanobacteria
Ammonia (toxicity)	Temperature		
Lake TLI (Trophic state)	Macroinvertebrate communities		
LakeSPI (Trophic state)	Periphyton (Trophic state)		
	pH*		

* Not reported in this report as there was insufficient data at the time of writing.

2.3.1 Attribute tables for both rivers and lakes

Table 3 Ecosystem health (toxicity) attributes for rivers and lakes. Bold numeric attribute states identify the bottom line.

Nitrate-nitrogen	**Narrative attribute states**			
	A	B	C (**Bottom-line**)	D
	High conservation value system. Unlikely to be effects even on sensitive species.	Some growth effect on up to 5% of species.	Growth effects on up to 20% of species (mainly sensitive species such as fish). No acute effects.	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).
Numeric attribute states				
Nitrate-nitrogen (mg/L) : Annual median* (annual 95th Percentile)	≤ 1.0 (≤ 1.5)	> 1.0 & ≤ 2.4 (> 1.5 & ≤ 3.5)	> 2.4 & ≤ **6.9** (> 3.5 & ≤ **9.8**)	> 6.9 (> 9.8)
Ammonium-nitrogen	**Narrative attribute states**			
	A	B	C (**Bottom-line**)	D
	99% species protection level: No observed effect on any species tested.	95% species protection level: Starts impacting occasionally on the 5% most sensitive species.	80% species protection level: Starts impacting regularly on the 20% most sensitive species (reduced survival of most sensitive species).	Starts approaching acute impact level (i.e. risk of death) for sensitive species.
Numeric attribute states				
Ammonium-nitrogen (mg/L) : Annual median* (annual maximum*)	≤ 0.03 (≤ 0.05)	> 0.03 & ≤ 0.24 (> 0.05 & ≤ 0.40)	> 0.24 & ≤ **1.30** (> 0.40 & ≤ **2.20**)	> 1.30 (> 2.20)

*Corrected to pH 8.

Table 4 Human health attribute planktonic cyanobacterial bio-volume levels for lakes and lake fed rivers. Bold numeric attribute states identify the bottom line.

Cyanobacteria - planktonic	**Narrative attribute states**			
	A (Blue)	B (Green)	C **(Bottom-line)** (Yellow)	D (Orange/Red)
	Risk exposure from cyanobacteria is no different to that in natural conditions (from any contact with fresh water).	Low risk of health effects from exposure to cyanobacteria (from any contact with fresh water).	Moderate risk of health effects from exposure to cyanobacteria (from any contact with fresh water).	High health risks (e.g. respiratory, irritation and allergy symptoms) exist from exposure to cyanobacteria (from any contact with fresh water).
Numeric attribute states				
Numeric state 80th Percentile*	≤ 0.5 mm³/L bio-volume for the combined total of all cyanobacteria.	> 0.5 and ≤ 1.0 mm³/L bio-volume equivalent for the combined total of all cyanobacteria.	> 1.0 and ≤ **1.8 mm³/L toxic cyanobacteria bio-volume**, or > 1.0 and ≤ **10 mm³/L total cyanobacteria**.	> 1.8 mm³/L toxic cyanobacteria bio-volume, OR 10 mm³/L total cyanobacteria.

*80th Percentile must be calculated using a minimum of 12 samples collected over three years. Thirty samples collected over three years is recommended.

Table 5 Human health attribute for lakes and rivers. Bold numeric attribute states identify the bottom line.

E. coli	**Narrative attribute states**				
	A (Blue)	B (Green)	C **(Bottom-line)** (Yellow)	D (Orange)	E (Red)
	For at least half the time, estimated risk is 0.1%. Predicted risk on any day is 1%.	For at least half the time, estimated risk is 0.1%. Predicted risk on any day is 2%.	For at least half the time, estimated risk is 0.1%. Predicted risk on any day is 3%.	20-30% of time, estimated risk is > 5%. Predicted risk on any day is 3%.	More than 30% of the time, estimated risk is > 5%. Predicted risk on any day is > 7%.
Numeric attribute states					
E. coli (cfu/100 mL)					
% >540	< 5%	5 - 10%	10 - **20**%	20 - 30%	> 30%
%> 260	< 20%	20 - 30%	20 - **34**%	> 34%	> 50%
Median	≤ 130	≤ 130	≤ **130**	> 130	> 260
95th percentile	≤ 540	≤ 1,000	≤ **1,200**	> 1,200	> 1,200

2.3.2 Lake specific attribute tables

Table 6 Ecosystem health (trophic state) attributes for lakes. Bold numeric attribute states identify the bottom line. Note no bottom line defined for Lake TLI.

	Narrative attribute states			
	A	B	C **(Bottom-line)**	D
	Lake ecological communities are healthy and resilient, similar to natural reference conditions.	Lake ecological communities are slightly impacted by additional algal and/or plant growth arising from nutrient levels that are elevated above natural reference conditions.	Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrient levels that are elevated well above natural reference conditions. Reduced water clarity is likely to affect habitat available for native macrophytes.	Lake ecological communities have undergone or are at high risk of a regime shift to a persistent, degraded state (without native macrophyte/ seagrass cover), 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.
Numeric attribute states - Annual median (Annual maximum)				
Phytoplankton – chlorophyll-*a* (mg/m³)	≤ 2 (≤ 10)	> 2 & ≤ 5 (> 10 & ≤ 25)	> 5 & ≤ **12** (> 25 & ≤ **60**)	> 12 (> 60)
Total Nitrogen (mg/m³)	≤ 160* ≤ 300#	> 160 & ≤ 350* > 300 & ≤ 500#	> 350 & ≤ **750*** > 500 & ≤ **800#**	> 750* > 800#
Total Phosphorus (mg/m³)	≤ 10	> 10 & ≤ 20	> 20 & **50**	> 50
Lake TLI	≤ 3	> 3 & ≤ 4	> 4 & ≤ **5**	> 5

*Stratified lakes; # polymictic lakes.

Table 7 Ecosystem health attributes for submerged macrophytes in lakes (LakeSPI). Bold numeric attribute states identify the bottom line.

LakeSPI	Narrative attribute state			
	A	B	C **(Bottom-line)**	D
	Change to LakeSPI not indicated.	Change to LakeSPI possible.	Change to LakeSPI probable, OR introduction of new, potentially invasive species.	Change to LakeSPI indicated.
Numeric attribute state				
	0 – 5% reduction in LakeSPI OR an increase in LakeSPI.	> 5 – 10% reduction in LakeSPI.	> 10 - **15%** reduction in LakeSPI OR new incursion of a more invasive species.	> 15% reduction in LakeSPI.

2.3.3 River specific attribute tables

Table 8 Ecosystem health (trophic state) water temperature and dissolved oxygen attributes for rivers. Bold numeric attribute states identify the bottom line.

	Narrative attribute states			
	A	B	C **(Bottom-line)**	D
	No thermal/ dissolved oxygen stress on any aquatic organisms that are present at matched reference (near-pristine) sites.	Minor thermal/ dissolved oxygen stress on occasion (clear days in summer) on particularly sensitive organisms such as certain insects and fish.	Some thermal/ dissolved oxygen stress on occasion with elimination of certain sensitive insects and absence of certain sensitive fish.	Significant thermal/dissolved oxygen stress on a range of aquatic organisms. Risk of local elimination of keystone species with loss of ecological integrity.
Numeric attribute states				
Temperature (ºC) *Upland #Lowland Cox-Rutherford Index	≤ 18.0* ≤ 19.0#	≤ 20.0* ≤ 21.0#	≤ **24.0*** ≤ **25.0#**	> 24.0* > 25.0#
Dissolved oxygen (mg/L) 1 day minimum (7 day mean minimum)	≥ 7.5 (≥ 8.0)	≥ 5.0 & < 7.5 (≥ 7.0 & < 8.0)	≥ **4.0** & < 5.0 (≥ **5.0** & < 7.0)	< 4.0 (< 5.0)

Table 9 Human health attribute for benthic cyanobacterial for rivers. Bold numeric attribute states identify the bottom line.

Benthic cyanobacteria	Narrative attribute state			
	A	B	C **(Bottom-line)**	D
	Minimal risk exposure from benthic cyanobacteria for 80% of the time.	N/A	Low risk of health effects or dog deaths from exposure to benthic cyanobacteria for 80% of the time.	Potential health risks from exposure to benthic cyanobacteria, potential risk to dogs walking along river margins.
Numeric attribute state				
	Cover < 20%.		Cover 20 – **50**%.	Cover > 50%, OR max dislodging and accumulating along river's edge.

Table 10 Ecosystem health attributes for invertebrate communities in rivers, expressed as MCI scores. Bold numeric attribute states identify the bottom line.

Invertebrates	Biophysical classification	Narrative attribute state			
		A	B	C **(Bottom-line)**	D
Invertebrate communities' annual MCI scores.		MCI scores typical of healthy and resilient invertebrate communities, similar to natural reference conditions. Indicative of streams in "excellent" ecological condition.	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.	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.	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.
Numeric attribute state					
	Non-volcanic	> 120	110 – 120	**100** - 110	< 100
	Volcanic gentle	> 124	106 - 124	**88** - 106	< 88
	Volcanic steep	> 115	110 - 115	**87** - 100	< 87

Table 11 Ecosystem health attributes for invertebrate communities in rivers, expressed as the number of sensitive EPT taxa. Bold numeric attribute states identify the bottom line.

Invertebrates	Biophysical classification	Narrative attribute state			
		A	B	C **(Bottom-line)**	D
Invertebrate community's annual EPT richness.		The number of sensitive EPT taxa typical of those found in reference condition streams.	Streams showing a slight reduction in the number of sensitive EPT taxa that are typically found in similar reference condition streams.	Streams showing a moderate reduction in the number of sensitive EPT taxa that are typically found in similar reference condition streams.	Streams showing a large reduction in the number of sensitive EPT taxa that are typically found in similar reference condition streams.
Numeric attribute state					
	Non-volcanic	> 12 EPT taxa	9 - 12 EPT taxa	**6** – 9 EPT taxa	< 6 EPT taxa
	Volcanic gentle	> 11 EPT taxa	7 – 11 EPT taxa	**2** – 7 EPT taxa	< 2 EPT taxa
	Volcanic steep	> 9 EPT taxa	6 – 9 EPT taxa	**3** – 6 EPT taxa	< 3 EPT taxa

Table 12 Ecosystem health attributes for invertebrate communities in rivers, expressed as the Bay of Plenty Index of Biotic Integrity (BOP_IBI: Suren et al., 2017). Bold numeric attribute states identify the bottom line.

Invertebrates	Biophysical classification	Narrative attribute state			
		A	B	C **(Bottom-line)**	D
Invertebrate communities annual BOP_IBI.		Streams supporting a range of invertebrate species that are very similar to those found in reference condition streams.	Streams supporting a slightly reduced range of invertebrate species that would be expected in similar reference condition streams.	Streams supporting a moderately reduced range of invertebrate species that would be expected in similar reference condition streams.	Streams supporting a greatly reduced range of invertebrate species that would be expected in similar reference condition streams.
Numeric attribute state					
	Non-volcanic	> 24	16 - 24	**7** - 16	< 7
	Volcanic gentle	> 47	36 - 47	**26** - 36	< 26
	Volcanic steep	> 18	7 - 18	**3** - 7	< 3

Table 13 Ecosystem health attributes for periphyton biomass in rivers. Note the two different attribute state for streams draining catchments dominated by naturally nutrient-rich rock material (naturally productive class), and streams draining catchments dominated by low-nutrient yielding rocks (default class). Bold numeric attribute states identify the bottom line.

Periphyton	**Narrative attribute state**			
	A	B	C **(Bottom-line)**	D
	Rare blooms reflecting negligible nutrient enrichment and/or alteration of the natural flow regime or habitat.	Occasional blooms reflecting low nutrient enrichment and/or alteration of the natural flow regime or habitat.	Periodic short-duration nuisance blooms reflecting moderate nutrient enrichment and/or alteration of the natural flow regime or habitat.	Regular and/or extended-duration nuisance blooms reflecting high nutrient enrichment and/or significant alteration of the natural flow regime or habitat.
Numeric attribute state				
Exceeded no more than 8% of samples (default class).	≤ 50 mg chl-*a*/m^2	> 50 & ≤ 120 mg chl-*a*/m^2	> 120 & ≤ **200** mg chl-*a*/m^2	> 200 mg chl-*a*/m^2
Exceeded no more than 17% of samples (productive class).	≤ 50 mg chl-*a*/m^2	> 50 & ≤ 120 mg chl-*a*/m^2	> 120 & ≤ **200** mg chl-*a*/m^2	> 200 mg chl-*a*/m^2

Part 3: Lakes assessment against recommended attributes

3.1 Introduction

The Te Arawa/Rotorua Lakes are monitored for a range of water quality attributes, most notably total phosphorus (TP), total nitrogen (TN), chlorophyll-*a*, ammonia and cyanobacteria. These are used to calculate a trophic level index (TLI) for the lakes and TLI objectives are set in the Bay of Plenty Regional Natural Resources Plan (RNRP; BOPRC, 2008). Popular swimming locations are also monitored for *E. coli* during summer months as part of the summer recreational monitoring.

Results from recent monitoring are provided in the following tables and further described below.

3.2 Ecological health attributes

3.2.1 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).

The NPS-FM bottom lines associated with TN and TP concentrations in conjunction with chlorophyll-*a*, are designed to ensure that nutrient concentrations do not result in chlorophyll exceeding the bottom line in future years or push a lake to a phytoplankton-dominated state.

Lake Rotomahana is the only lake to be below the National Bottom Line (exceed band C) for TP and it has retained that grade for the past three years (Table 14). All other lake sites fall in to A, B, or C bands. Lakes Rotoiti and Tarawera have moved from B to C grade for this attribute in recent years. Two lakes are showing improving trends for TP (Rotokakahi and Rotorua) and six lakes are showing worsening trends (Ōkāreka, Ōkataina, Rotoehu, Rotomā, Rotomahana, and Tarawera). No TP trend could be determined for the remaining lakes.

Most lake sites are within A or B band, with only one site (Ōkaro) within the C band for TN (Table 15). Most lakes (nine lakes) showed improving trends for TN. No TN trends could be determined for lakes Tarawera and Tikitapu.

Table 14 Attribute state (annual median) and ten year trend for Total Phosphorus in lakes. N/A = No Data, IND = Indeterminate Trend 👎 = Ecologically meaningful degradation, 👍 = Ecologically meaningful improvement.

Total Phosphorus	2012/13	2013/14	2014/15	2015/16	2016/17	10 Yr Trend
Okareka	B	A	A	A	B	👎
Ōkaro	D	C	C	C	C	IND
Okataina	B	B	B	B	B	👎
Rerewhakaaitu	A	A	A	A	A	IND
Rotoehu	C	C	C	C	C	👎
Rotoiti	B	B	B	C	C	IND
Rotokakahi*	B	B	B	B	B	👍
Rotoma	A	A	A	A	A	👎
Rotomahana	C	C	D	D	D	👎
Rotorua	B	B	B	B	B	👍
Tarawera	B	B	C	C	C	👎
Tikitapu	A	A	A	A	A	IND

*Based on data from outlet to Te Wairoa Stream.

Table 15 Attribute state (annual median) and ten year trend for Total Nitrogen in lakes. All lakes have been compared to Seasonally Stratified attribute state bands. N/A = No Data, IND = Indeterminate Trend 👎 = Ecologically meaningful degradation, 👍 = Ecologically meaningful improvement.

Total Nitrogen	2012/13	2013/14	2014/15	2015/16	2016/17	10 Yr Trend
Okareka	B	B	B	B	B	👍
Ōkaro	D	D	C	C	C	👍
Okataina	A	A	A	A	A	👍
Rerewhakaaitu	B	B	B	B	A	👍
Rotoehu	A	A	B	B	B	👎
Rotoiti	A	A	B	B	B	👍
Rotokakahi*	B	B	B	B	B	👍
Rotoma	A	A	A	A	A	👍
Rotomahana	B	B	B	B	B	👍
Rotorua	B	A	A	B	B	👍
Tarawera	A	A	A	A	A	IND
Tikitapu	A	A	B	B	B	IND

*Based on data from outlet to Te Wairoa Stream.

3.2.2 Ammonia

Ammoniacal-nitrogen (NH_4-N) covers two forms of nitrogen: ammonia (NH_3) and ammonium (NH_4). NH_4-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 discharges (e.g. domestic, agricultural and industrial wastewater).

All lakes, except Ōkaro, were graded either A or B band for ammoniacal-nitrogen (Table 16). Lake Ōkaro has been graded C band since 2012. No trend data is available for any lakes for this attribute.

Table 16 Attribute state for Ammonia in bottom water of lakes (all data have been adjusted to pH=8).

Ammonia	2012		2013		2014		2015		2016		2017	
	Med	Max	Med	Max	Med	Max	Med	Max	Med	Max	Med	Max
Okareka	A	A	A	A	A	A	A	A	A	A	A	A
Okaro	C	C	C	C	C	C	C	C	C	C	C	C
Okataina	A	A	A	A	A	A	A	A	A	A	A	A
Rerewhakaaitu	A	A	A	A	A	A	A	A	A	A	A	A
Rotoehu	A	B	A	A	A	A	A	B	A	B	B	B
Rotoiti	A	B	A	A	A	B	A	B	A	B	A	A
Rotoma	A	A	A	A	A	A	A	A	A	A	A	A
Rotomahana	A	A	A	A	A	A	A	A	A	A	A	A
Rotorua	A	A	A	B	A	A	A	B	A	A	A	A
Tarawera	A	A	A	A	A	A	A	A	A	A	A	A
Tikitapu	A	A	A	A	A	A	A	A	A	A	A	A

3.2.3 Phytoplankton

Phytoplankton is usually made up of a wide range of microscopic algae that are found mostly in the upper, sunlit layer of lakes. As primary producer's 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.

Lake Ōkaro was the only lake below National Bottom Line (worse than band C) for chlorophyll-*a*, although this site showed an improving trend. All other lakes were graded A or B band (Table 17). Eight lakes were graded either A or B band, and two graded C. Two lakes showed improving trends for chlorophyll-*a* (Rotokakahi and Rotorua).

Table 17 Attribute state for Phytoplankton (Chlorophyll-a annual median and Maximum) in lakes. N/A = No Data, IND = Indeterminate Trend 👎 = Ecologically meaningful degradation, 👍 = Ecologically meaningful improvement.

Chlorophyll-*a*	2012/13		2013/14		2014/15		2015/16		2016/17		10 Yr Trend
	Med	Max	Med	Max	Med	Max	Med	Max	Med	Max	
Okareka	B	A	B	A	A	A	B	A	B	A	IND
Ōkaro	C	D	B	C	B	B	C	B	C	D	IND
Okataina	A	A	A	A	B	B	A	A	A	A	IND
Rerewhakaaitu	B	A	B	A	B	A	B	A	B	A	IND
Rotoehu	C	B	C	A	C	B	C	C	C	C	IND
Rotoiti	B	A	B	A	C	D	C	C	C	B	IND
Rotokakahi	B	A	B	A	B	B	B	A	B	B	👍
Rotoma	A	A	A	A	A	A	A	A	A	A	IND
Rotomahana	B	A	B	A	B	A	B	A	B	A	IND
Rotorua	C	C	C	B	C	B	C	C	C	B	👍
Tarawera	A	A	A	A	A	A	A	A	A	A	IND
Tikitapu	A	A	B	A	A	A	A	A	A	A	IND

3.2.4 Lake Trophic Level Index Classification (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.

Currently five of the twelve Te Arawa/Rotorua Lakes meet or are below the RNRP TLI objective. Lakes Rotorua, Okaro and Tikitapu have benefited from the results of restoration activities resulting in meeting community objectives for lake water quality as stated in Objective RL O1 of the RNRP. Lake Rotoehu and Lake Tarawera continue to show some declining water quality trends resulting in increasing trophic level indices.

Nine of the 12 lakes fall within either A or B band for TLI based on Carter *et al.*, 2017. Ōkaro, Rotorua and Rotoehu are graded C band.

Table 18 Three-yearly average TLI values, annual TLI and trophic status category for the Rotorua Lakes. For 2016/2017 annual average TLIs those that have met RNRP objective RL O1 TLIs are blue, others are red.

Lake	3-yearly average TLI to 2015 *TLI units*	3-yearly average TLI to 2016 *TLI units*	**3-yearly average TLI to 2017** ***TLI units***	2014/15 Annual TLI *TLI units*	2015/16 Annual TLI *TLI units*	**2016/17 Annual TLI**	Lake Type *based on Trophic Status*	*Regional Natural Resources Plan Objective* *TLI units*
Ōkaro	C	C	C	C	C	C	Eutrophic	5
Rotorua	C	C	C	C	C	C	Eutrophic	4.2
Rotoehu	C	C	C	C	C	C	Eutrophic	3.9
Rotomahana	B	B	B	B	B	B	Mesotrophic	3.9
Rotoiti	B	B	B	B	B	B	Mesotrophic	3.5
Rerewhakaaitu	B	B	B	B	B	B	Mesotrophic	3.6
Okareka	B	B	B	B	B	B	Mesotrophic	3
Tikitapu	A	A	A	A	A	A	Oligotrophic	2.7
Ōkataina	A	A	A	A	A	A	Oligotrophic	2.6
Tarawera	A	A	B	B	A	A	Oligotrophic	2.6
Rotoma	A	A	A	A	A	A	Oligotrophic	2.3
*Rotokakahi**	*B*	*B*	*B*	*B*	*B*	*B*	Mesotrophic	*3.1*

*Lake Rotokakahi results based on monitoring of Te Wairoa stream at lake outlet.

3.2.5 LakeSPI (submerged macrophytes)

NIWA has developed a LakeSPI (Submerged Plant Indicators) methodology to assess ecosystem health in lakes using aquatic macrophytes (e.g. Burton 2016). LakeSPI assessments are done in the margins of lakes, where both human interaction and ecological values are greatest. The LakeSPI methodology uses submerged macrophytes that integrate a range of environmental conditions over an extended period of time. Such conditions include sediment and nutrient loading, as well as the displacement of native vegetation by exotic or invasive plant species. LakeSPI scores range from 0 - 100% where 0% is no plants in the lake, and > 75% has excellent plant life. The higher the LakeSPI, the better the condition the lake is in. LakeSPI thus allows lake managers to assess and monitor changes in a lake over time and prioritise lake management initiatives accordingly. Decreases in a LakeSPI score could be caused by an increasing cover of invasive exotic macrophytes (and a subsequent loss of native plant cover), or a loss of submerged plants in general. The ultimate reasons behind any dramatic changes in LakeSPI score would need further examination of the raw LakeSPI data, as well as examination of other water quality data.

Carter *et al.,* (2017) developed LakeSPI bands for the rate of change to calculated LakeSPI scores. In their report, it was emphasised that the current LakeSPI bands encompass a relatively wide numerical range. This means that if an objective is set to maintain a lake in (for example) a "moderate" condition, then the overall LakeSPI score could decline quite considerably due to invasion from and exotic species, yet still be classified as "moderate". Once the lake falls into the "poor" category, it may be too late to control the invasive species as it may have spread too far. To overcome this problem, a more conservative approach was recommended to monitor attribute bands for the rate of change to calculated LakeSPI scores.

Burton (2016) developed a ranking system describing the implications of different rates of change in LakeSPI scores over time, and suggested that true declines in macrophyte community composition occurs only when LakeSPI scores decline by more than 15%. Based on this, Carter *et al.,* (2017) recommended that a bottom line for a LakeSPI score be set at the 'C' band, where new incursions of invasive weeds are reported. Small changes in LakeSPI Score (< 5% reduction between sampling occasions) were suggested as not indicating a change in LakeSPI score, whereas slightly larger reductions (> 5 - 10%) were thought to represent only a possible change in score. This approach was based on describing ecologically significant changes in lake condition over repeated surveys (i.e. to detect changes > 10%) and aligns with the NPS-FM in that councils need to "maintain or improve" ecological conditions.

LakeSPI surveys are conducted in each of the 12 Te Arawa/Rotorua lakes on a biannual basis. Thus LakeSPI scores from six lakes were compared from the 2018 and 2016 surveys, while scores from the other six lakes were compared from surveys in 2015 and 2017. Examination of the changes in LakeSPI score between these biennial samples showed that seven of the 12 monitored lakes were in the A-band, and showed either < 5% reduction in scores, or an improvement (Table 19). Only Lake Tikitapu showed a reduction in LakeSPI scores below the bottom line of 15% change, due mainly to invasion by exotic plants such as *Lagarosiphon*, *Egeria* and *Ceratophyllum*. Efforts are underway at Lake Okataina in particular to eradicate the recently discovered *Ceratophyllum dermasum*.

Table 19 Summary of LakeSPI bands between the latest LakeSPI sampling round (either 2017 or 2018) and the previous sampling round at that lake (either 2015, or 2016 respectively).

Lake	Year	Lake_SPI	% reduction	Band
Okareka	2017	50	-10.0	C
Rotoma	2017	52	-3.8	A
Rotomahana	2017	52	-3.8	A
Tikipatu	2018	32	-37.5	D
Okataina	2018	44	13.6	A
Rerewhakaaitu	2018	32	3.1	A
Rotokakahi	2018	28	-7.1	B
Rotorua	2017	26	-7.7	B
Okaro	2017	49	42.8	A
Tarawera	2018	27	7.4	A
Rotoiti	2017	19	-5.3	B
Rotoehu	2018	20	5.0	A

The relative change in LakeSPI scores between contemporary surveys and the earliest measured LakeSPI scores was also calculated, and the percentage change was allocated to the appropriate band from Carter *et al.,* (2017). In this way we assessed the degree that LakeSPI had changed from an earlier fixed time. This differs to the approach initially outlined by Carter *et al.,* (2017) that looked only at short-term changes in LakeSPI scores between consecutive samples, and is considered to be a more robust methodology to assess changes in LakeSPI score. The average time between the earliest LakeSPI data and the last survey was 33 years, ranging from 29 to 45 years.

Examination of the changes in LakeSPI scores over time showed that some lakes (Lake Rotoma) were always in the A band, while other lakes (e.g. Rerewhakaaitu, Rotokakahi and Tarawera) were mostly in the D band (Table 21). The high and stable scores for Lake Rotoma since the first surveys in 1988 reflect the relatively high values for the Native Condition Index and one of the lowest Invasive Impact Indices, despite having luxurious growths of *Lagarosiphon* (Burton 2016). Of interest is that a LakeSPI score of 69 was retrospectively calculated from this lake in 1973, which reflected the early stage of *Lagarosiphon* invasion then, and an extensive high cover of charophyte meadows (Burton 2016). By 1988 (the year of the first LakeSPI survey, and the year that future years were compared to) the Invasive Impact Index had more than doubled, and Native Condition Index decreased reflecting the spread of *Lagarosiphon* throughout the lake. This reduced the LakeSPI score to 50, putting it in the D-band relative to the earlier 1973 condition, reflecting the 38% reduction in LakeSPI score since then. However, this score has remained relatively stable since the first LakeSPI surveys in 1988, giving it an A band relative to this time. However, there is always the real risk of *Ceratophyllum* invading this lake, which would undoubtedly reduce its LakeSPI score.

Lake Rerewhakaaitu has consistently been in the D-band, reflecting the spread of invasive weeds there since 1988. An initial macrophyte survey in 1973 found none of the problematic ‘oxygen weed’ species (*Elodea, Lagarosiphon, Egeria* or *Ceratophyllum*). However, a survey in 1988 showed that *Lagarosiphon* had invaded and caused a substantial decrease in LakeSPI scores. The cover of this plant has increased over the following 20 years, further reducing LakeSPI scores. *Egeria* further impacted negatively on LakeSPI scores following its introduction and subsequent spread in the 2000’s. This plant has continued to spread throughout the lake, further reducing its LakeSPI score (Burton2016). It is this continued spread of invasive species (and the resultant continued reduction of calculated LakeSPI score) that is reflected in the sustained D band at this lake (Table 21).

Changes in LakeSPI scores were mostly in the D band at Lake Tarawera, reflecting a significant reduction in LakeSPI scores from 1988 to 2005 with the invasion of *Ceratophyllum*. This plant has continued to dominate the submerged vegetation in this lake down to a maximum depth of 13 m, and more recent change has been small since the full impact of hornwort has now taken place (Burton 2016).

Table 20 Summary table showing the number of times each of the monitored Rotorua Lakes fell into the different LakeSPI bands, calculated as the difference between LakeSPI scores on regular surveys to the earliest survey done. Blue shading (Very good) = Lakes where observed changes were always less than 5% to the earliest LakeSPI surveys (A band); Green shading (Good) = observed changes were either in the A or C band'; Yellow shading (Fair) = observed changes were in either A, B or D bands, but not dominated by D bands; Orange shading (Poor) = changes to LakeSPI score were usually in the D band.

Lake	Changes in LakeSPI score from original		
	A band	C band	D band
Ōkāreka	5	5	
Ōkaro	3	2	4
Ōkataina	1	7	3
Rerewhakaaitu	1		9
Rotoehu	2		7
Rotoiti	2		8
Rotokakahi	1		7
Rotomā	9		
Rotomahana	3	2	4
Rotorua	4	1	5
Tarawera	1		8
Tikipatu	1	1	7

Note that we have outlined two approaches at calculating the percentage change to LakeSPI scores:

- A percentage change based on differences between consecutive LakeSPI surveys (Carter *et al.,* 2017).
- A percentage change relative to the earliest LakeSPI observation (Table 20).

Both methods recognise the fact that small variations (0 – 10 units) do not necessarily reflect an actual shift in LakeSPI status, but rather more subtle changes in macrophyte cover, composition or depth as a result of natural inter-annual fluctuations in plant growth and cover. However, these two methods differ greatly in their ability to detect long-term changes in lake macrophyte cover. The disadvantage with the former method is that it will not always detect a long-term decrease in LakeSPI scores, which may have the unintended consequence of a lake's macrophyte communities degrading over time. Because of this, it is recommended that the initial banding system for LakeSPI in Carter *et al.,* (2017) be amended to measure changes in LakeSPI score relative to the earliest historic values. A hypothetical example of this situation is contained in Appendix 5. The actual calculated LakeSPI scores for each lake over time are in Appendix 6.

3.3 Human health attributes

3.3.1 *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 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.

All lakes fall within A and B band for *E. coli* and are considered suitable for primary contact recreation (including swimming) in accordance with the attribute tables set down in the NPS-FM (Table 21).

Table 21 Attribute state for E. coli in lakes, 2012 to 2017.

	2012-2017	
Suitability for Primary Contact Recreation (Appendix 2, NPS-FM)	***E. coli* state Band**	**Suitable for Primary Contact Recreation**
Lake Okareka at Steep Street Reserve	A	Yes
Lake Okaro at Boat Ramp	A	Yes
Lake Rerewhakaaitu at Homestead Arm	A	Yes
Lake Rotoiti at Gisborne Point	A	Yes
Lake Rotoiti at Hinehopu	A	Yes
Lake Rotoiti at Okawa Bay	A	Yes
Lake Rotoma at Whangaroa	A	Yes
Lake Rotorua at Hamurana	A	Yes
Lake Rotorua at Holdens Bay	A	Yes
Lake Rotorua at Ngongotaha	B	Yes
Lake Tarawera at Rangiuru Bay	A	Yes
Lake Tikitapu at Beach	A	Yes

3.3.2 Planktonic cyanobacteria

Planktonic cyanobacteria in lakes can form undesirable blooms that reduce water clarity, produce scums on the water surface, can cause undesirable odours and potentially produce toxins that can affect human and animal health. Cyanobacterial blooms were a regular occurrence in the Rotorua lakes in the early 1990's, but the magnitude and duration of these blooms has decreased dramatically. BOPRC collects weekly samples throughout the summer period, from 13 sites around the edges of Lake Rotorua, Rotoiti, Rotoehu, and Ōkaro, as well as approximately 5 – 10 ad-hoc samples from other lakes in the region (not reported here).

The actual number of samples varies based on the number of sites that have alert levels on them: more sites are monitored when blooms are occurring.

Health recommendations and warnings are based on calculations of cell bio-volume: a combination of cell counts and size. Results are compared to the planktonic cyanobacteria attribute state bands as specified in Appendix 2 of the NPS-FM for the Human Health for Recreation. The bands are also relevant for Mahinga Kai (collection only) and Ecosystem Health. The attribute is based on the 80^{th} percentile of weekly monitoring over a three year period. For this report, we provide analysis based on three periods: 2012-2015, 2013-2016, and 2014-2017 (Table 22).

Of the four lakes where cyanobacteria is monitored, Lake Rotorua was graded A in all three time periods, and Lake Rotoiti was graded A for four out of five sampling locations (Table 22). All monitored sites on Lakes Ōkaro and Lake Rotoehu were graded a 'C' for the two most recent assessment periods (2013-2016, 2014-2017), while the site at Lake Ōkaro was also ranked a 'C' for the 2012-2015 period. Okawa Bay was the only site not to be graded an 'A' over all three periods on Lake Rotoiti, and was graded a 'C' for the 2013-2016 and 2014-2017 periods. Lake Rotoehu results show a markedly different condition in the 2011-2014 periods to the more recent result. Both these lakes had multiple lake warnings to recreational water users in place due to cyanobacterial blooms over these periods.

Table 22 Attribute state for Cyanobacteria – planktonic (bio-volume, mm^3/L) in lakes and lake-fed rivers. Data is assessed against the most recent version of the National Objectives Framework (August 2017) for three rolling time periods: 2012 to 2015; 2013 to 2016; and 2014 to 2017.

Planktonic cyanobacteria bio-volume	2012-15	2013-16	2014-17
Kaituna			
Kaituna at Trout Pool	A	A	A
Ōkaro			
Lake Ōkaro	C	C	C
Rotoehu			
Lake Rotoehu at Kennedy Bay	A	C	C
Lake Rotoehu at Otautu	A	C	C
Rotoiti			
Lake Rotoiti at Hinehopu	A	A	A
Lake Rotoiti at Okawa Bay	A	C	C
Lake Rotoiti at Okere Arm	A	A	A
Lake Rotoiti at Otaramarae	A	A	A
Lake Rotoiti at Te Weta	A	A	A
Rotorua			
Lake Rotorua at Hamurana	A	A	A
Lake Rotorua at Holdens Bay	A	A	A
Lake Rotorua at Ngongotaha	A	A	A
Ohau Channel	A	A	A

Part 4:
Rivers assessment against recommended attributes

4.1 Introduction

Rivers and streams are monitored for a range of water quality attributes, including nitrate, ammonia, *E. coli*, dissolved oxygen, temperature and aquatic invertebrate communities. Results from recent monitoring are presented in the following tables and further discussed below.

4.2 Ecosystem health attributes

4.2.1 Nitrate

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_3-N) is one form of nitrogen that is highly soluble in water and is an important nutrient for plant growth. Anthropogenic sources of NO_3-N in the environment include fertilisers, leaking sewage systems, and animal wastes. At high concentrations, nitrate is also toxic to aquatic organisms and humans. NO_3-N is currently an attribute in the NPS-FM for protecting the value of Ecosystem Health (toxicity) in rivers (MfE, 2014). The NPS-FM statistics for nitrate are annual median and 95% percentile in recognition of the average long-term exposure and seasonal peak concentrations respectively (MfE, 2015).

All sites were graded A or B band for nitrate-nitrogen, and have been since 2013 (Table 23). Improving 10 year trends were observed for two sites (Waiau at Road Ford and Wairoa at State Highway 2 Bridge). For all other sites, either insufficient data were available for trend analysis or no trend was detected.

Table 23 *Attribute state for Nitrate and 10 year trends (2007-2016) in rivers and streams. N/A = No Data, IND = Indeterminate Trend 👎 = Ecologically meaningful degradation, 👍 = Ecologically meaningful improvement.*

Site by WMA	2013		2014		2015		2016		2017		10 Yr Trend
Tauranga Harbour	Med	95th	Med	95th	Med	95th	Med	95th	Med	95th	
Aongatete River at SH2	A		A		A		A	A	A	A	N/A
Kopurererua at SH2	A	A	A	A	A	A	A	A	A	A	IND
Kopurererua at SH29	B	A	A	A	A	A	A	A	A	A	IND
Ngamuwahine at Old Bridge	A		A		A		A	A	A	A	N/A
Omanawa at SH29	B	A	B	A	B	A	B	A	B	A	IND
Rocky at Mangatawa	A		A		A		A	A	A	A	N/A
Te Mania at SH2	A	A	A	A	A	A	A	A	A	A	IND
Te Rereatukahia at SH2	A		A		A		A	A	A	A	N/A
Tuapiro at Surtees Road	A		A		A		A	A	A	A	N/A
Uretara at Henry Road Ford	A		A		A		A	A	A	A	N/A
Waiau at Road Ford	A		A		A		A	A	A	A	👍
Waimapu at 100 m d/s of SH29	A	A	A	A	A	A	A	A	A	A	N/A
Waimapu at Pukemapui Road	A		A		A		A	A	A	A	N/A
Waipapa at Old Bridge	A		A		A		A	A	A	A	N/A
Wairoa at SH2 Bridge	A	A	A	A	A	A	A	A	A	A	👍
Wairoa d/s of Ruahihi	A		A		A		A	A	A	A	N/A
Waitao at Spensers farm	A	A	A	A	A	A	A	A	A	A	N/A
Waitekohe at SH2	A		A		A		A	A	A	A	N/A

Site by WMA	2013		2014		2015		2016		2017		10 Yr Trend
Kaituna, Maketu, Pongakawa	Med	95th	Med	95th	Med	95th	Med	95th	Med	95th	
Kaituna at Maungarangi	A	A	A	A	A	A	A	A	A	A	IND
Kaituna at Lake Rotoiti Outlet	A	A	A	A	A	A	A	A	A	A	N/A
Kaituna at Waitangi	A	A	A	A	A	A	A	A	A	A	N/A
Pongakawa at Old Coach	B		B		B	B	B	B	B	B	N/A
Pongakawa at SH2	B		B		B	B	B	B	B	B	N/A
Pongakawa at Forest	B		B		B	A	B	A	B	A	N/A
Waitahanui at SH2	A		A		A	A	A	A	A	A	N/A

Site by WMA	2013		2014		2015		2016		2017		*10 Yr Trend*
Rotorua Lakes	Med	95th	Med	95th	Med	95th	Med	95th	Med	95th	
Ngongotahā at Town Bridge	A	A	A	A	A	A	A	A	A	A	N/A
Ōhau at SH33	A	A	A	A	A	A	A	A	A	A	N/A
Puarenga at FRI	A	A	A	A	A	A	A	A	A	A	N/A
Tarawera at Lake Outlet	A	A	A	A	A	A	A		A	A	IND

Site by WMA	2013		2014		2015		2016		2017		*10 Yr Trend*
Tarawera	Med	95th	Med	95th	Med	95th	Med	95th	Med	95th	
Tarawera at Awakaponga	A	A	A	A	A	A	A	A	A	A	
Tarawera at Kawerau Bridge	A	A	A	A	A	A	A	A			IND
Tarawera at Caxton Footbridge			A	A	A	A	A	A	A	A	N/A
Tarawera at SH30 Bridge	A	A	A	A	A	A	A	A	A	A	N/A
Tarawera at Onepu Springs Road							A	A	A	A	N/A
Tarawera at Otakiri Road							A		A	A	N/A

Site by WMA	2013		2014		2015		2016		2017		*10 Yr Trend*
Rangitāiki	Med	95th	Med	95th	Med	95th	Med	95th	Med	95th	
Rangitaiki at Matahina Dam		A	A		A		A	A	A	A	N/A
Rangitaiki at Te Teko	A	A	A	A	A	A	A		A	A	
Rangitāiki at Old Murupara Bridge	A	A	A	A	A	A	A		B	A	N/A
Rangitaiki at Aniwhenua Canal			A		A		A		A	A	N/A
Otamatea at Bridge			B		B		B	B	B	B	N/A
Rangitāiki at SH5			A		B		B	B	B	B	N/A
Whirinaki at Galatea Bridge	A	A	A	A	A	A	A		A	A	N/A

Site by WMA	2013		2014		2015		2016		2017		*10 Yr Trend*
Whakatane and Waimana	Med	95th	Med	95th	Med	95th	Med	95th	Med	95th	
Tauranga at Taneatua					A	A	A	A	A	A	N/A
Tauranga at Ranger Station			A	A	A	A	A		A	A	N/A
Whakatāne at Rūātoki			A		A	A	A	A	A	A	N/A
Whakatāne at Pekatahi	A	A	A	A	A	A	A	A	A	A	N/A

Site by WMA	2013		2014		2015		2016		2017		*10 Yr Trend*
Ohiwa Harbour and Waiotahi	Med	95th	Med	95th	Med	95th	Med	95th	Med	95th	
Waiotahi at Toone Road			A		A	A	A	A	A	A	N/A
Nukuhou at Old Quarry	A	A	A	A	A	A	A	A	A	A	N/A

Site by WMA	2013		2014		2015		2016		2017		*10 Yr Trend*
Waioeka and Otara	Med	95th	Med	95th	Med	95th	Med	95th	Med	95th	
Otara at Brown's Bridge			A		A	A	A	A	A	A	N/A
Waioeka at Gorge Mouth	A	A	A	A	A	A	A	A	A	A	IND

Site by WMA	2013		2014		2015		2016		2017		*10 Yr Trend*
East Coast	Med	95th	Med	95th	Med	95th	Med	95th	Med	95th	
Mōtū at SH35	A	A	A	A	A	A	A		A	A	N/A
Mōtū at Waitangirua	A	A	A	A	A	A	A		A	A	N/A
Haparapara at SH35			A		A	A	A	A	A	A	N/A
Kereu at SH35			A		A	A	A	A	A	A	N/A
Raukokore at SH35			A		A	A	A	A	A	A	N/A

4.2.2 Ammoniacal-nitrogen

Ammoniacal-nitrogen (NH_4-N) covers two forms of nitrogen: ammonia (NH_3) and ammonium (NH_4). NH_4-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 discharges (e.g. domestic, agricultural and industrial wastewater).

NH_4-N is currently an attribute in the NPS-FM for protecting the value of Ecosystem Health (toxicity) in rivers and lakes (MfE, 2014). The statistics for NH_4-N are annual median and annual maximum in recognition of the average long-term exposure and seasonal peak concentrations respectively (MfE, 2015). NH_4-N concentrations need to be corrected to pH 8 and 20ºC as the toxicity of NH_4-N increases with increasing pH and temperature (Hickey, 2014).

All sites were graded A or B band for ammoniacal-nitrogen, and have been since 2013 (Table 24). Improving 10 year trends were observed for four sites (Omanawa at State Highway 29, Te Mania at State Highway 2, Kaituna at Maungarangi and Waioeka at Gorge mouth). For all other sites, either insufficient data were available for trend analysis or no trend was detected.

Table 24 Attribute state and 10 year Trend, for Ammonia in rivers and streams. N/A = No Data, IND = Indeterminate Trend 👎 = Ecologically meaningful degradation, 👍 = Ecologically meaningful improvement.

Site by WMA	**2013**		**2014**		**2015**		**2016**		***2017***		***10 Yr Trend***
Tauranga Harbour	**Med**	**Max**	**Med**	**Max**	**Med**	**Max**	**Med**	**Max**	*Med*	*Max*	
Aongatete River at SH2	A	A	A	A	A	A	A	A	A	A	N/A
Kopurererua at SH2	A	B	A	B	A	B	B	B	B	B	IND
Kopurererua at SH29	A	A	A	A	A	A	A	A	A	B	IND
Ngamuwahine at Old Bridge	A	A	A	A	A	A	A	A	A	A	N/A
Omanawa at SH29	A	A	A	A	A	A	A	A	A	A	👍
Rocky at Mangatawa	B	B	B	B	B	B	A	B	A	B	N/A
Te Mania at SH2	A	A	A	A	A	A	A	A	A	A	👍
Te Rereatukahia at SH2	A	A	A	A	A	A	A	A	A	A	N/A
Tuapiro at Surtees Road	A	A	A	A	A	A	A	A	A	A	N/A
Uretara at Henry Road Ford	A	A	A	A	A	A	A	A	A	A	N/A
Waiau at Road Ford	A	A	A	A	A	A	A	A	A	A	N/A
Waimapu at 100m d/s of SH29	A	A	A	A	A	A	A	A	A	A	N/A
Waimapu at Pukemapui Road	A	A	A	A	A	A	A	A	A	A	N/A
Waipapa at Old Bridge	A	A	A	A	A	A	A	A	A	A	N/A
Wairoa at SH2 Bridge	A	A	A	A	A	A	A	A	A	A	IND
Wairoa d/s of Ruahihi	A	A	A	A	A	A	A	A	A	A	N/A
Waitao at Spensers farm	A	A	A	A	A	A	A	A	A	A	N/A
Waitekohe at SH2	A	A	A	A	A	A	A	A	A	B	N/A

Site by WMA	**2013**		**2014**		**2015**		**2016**		**2017**		***10 Yr Trend***
Kaituna, Maketu and Pongakawa	**Med**	**Max**	**Med**	**Max**	**Med**	**Max**	**Med**	**Max**	**Med**	**Max**	
Kaituna at Maungarangi	A	A	A	A	A	A	A	A	A	A	👍
Kaituna at Lake Rotoiti Outlet	A	A	A	A	A	A	A	A	A	A	N/A
Kaituna at Waitangi	A	A	A	A	A	A	A	A	A	A	N/A
Pongakawa at Old Coach	A	A	A	A	A	A	A	A	A	A	N/A
Pongakawa at SH2	A	A	A	A	A	A	A	A	A	A	N/A
Pongakawa at Forest	A	A	A	A	A	A	A	A	A	A	N/A
Waitahanui at SH2	A	A	A	A	A	A	A	A	A	A	N/A

Site by WMA	2013		2014		2015		2016		2017		*10 Yr Trend*
Rotorua Lakes	**Med**	**Max**	**Med**	**Max**	**Med**	**Max**	**Med**	**Max**	**Med**	**Max**	
Ngongotahā at Town Bridge	A	A	A	A	A	A	A	A	A	A	N/A
Ōhau at SH33	A	A	A	A	A	A	A	B	A	B	N/A
Puarenga at FRI	A	A	B	B	B	B	B	B	B	B	N/A
Tarawera at Lake Outlet	A	A	A	A	A	A	A	A	A	A	IND

Site by WMA	2013		2014		2015		2016		2017		*10 Yr Trend*
Tarawera	**Med**	**Max**	**Med**	**Max**	**Med**	**Max**	**Med**	**Max**	**Med**	**Max**	
Tarawera at Awakaponga	A	A	A	B	A	A	A	A	A	A	IND
Tarawera at Kawerau Bridge	A	A	A	A	A	A	A	A			N/A
Tarawera at Onepu Springs Road							A	A	A	A	N/A
Tarawera at Caxton Footbridge			A	A	A	A	A	A	A	A	N/A
Tarawera at Otakiri Road							B	B	B	B	N/A
Tarawera at SH30 Bridge	B	B	A	A	B	B	B	B	B	B	N/A

Site by WMA	2013		2014		2015		2016		2017		*10 Yr Trend*
Rangitaiki	**Med**	**Max**	**Med**	**Max**	**Med**	**Max**	**Med**	**Max**	**Med**	**Max**	
Rangitaiki at Matahina Dam			A	A	A	A	A	A	A	A	N/A
Rangitaiki at Te Teko	A	A	A	A	A	A	A	A	A	A	N/A
Rangitāiki at Murupara	A	A	A	A	A	A	A	A	A	A	N/A
Rangitaiki at Aniwhenua Canal			A	A	A	A	A	A	A	A	N/A
Otamatea at Bridge			A	A	A	A	A	A	A	A	N/A
Rangitāiki at SH5			A	A	A	A	A	A	A	A	N/A
Whirinaki at Galatea Bridge	A	A	A	A	A	A	A	A	A	A	N/A

Site by WMA	2013		2014		2015		2016		2017		*10 Yr Trend*
Whakatane and Waimana	**Med**	**Max**	**Med**	**Max**	**Med**	**Max**	**Med**	**Max**	**Med**	**Max**	
Tauranga at Taneatua					A	A	A	A	A	A	N/A
Tauranga at Ranger Station			A	A	A	A	A	A	A	A	N/A
Whakatāne at Rūātoki			A	A	A	A	A	A	A	A	N/A
Whakatāne at Pekatahi	A	A	A	A	A	A	A	A	A	A	N/A

Site by WMA	2013		2014		2015		2016		2017		*10 Yr Trend*
Ohiwa Harbour and Waiotahi	**Med**	**Max**	**Med**	**Max**	**Med**	**Max**	**Med**	**Max**	**Med**	**Max**	
Waiotahi at Toone Road			A	A	A	A	A	A	A	A	N/A
Nukuhou at Old Quarry	A	B	A	A	A	A	A	B	A	B	N/A

Site by WMA	2013		2014		2015		2016		2017		*10 Yr Trend*
Waioeka and Otara	**Med**	**Max**	**Med**	**Max**	**Med**	**Max**	**Med**	**Max**	**Med**	**Max**	
Otara at Brown's Bridge			A	A	A	A	A	A	A	A	N/A
Waioeka at Gorge Mouth	A	A	A	A	A	A	A	A	A	A	👍

Site by WMA	2013		2014		2015		2016		2017		*10 Yr Trend*
East Coast	**Med**	**Max**	**Med**	**Max**	**Med**	**Max**	**Med**	**Max**	**Med**	**Max**	
Mōtū at SH35	A	A	A	A	A	A	A	A	A	A	👍
Mōtū at Waitangirua	A	A	A	A	A	A	A	A	A	A	N/A
Raukokore at SH35			A	A	A	A	A	A	A	A	N/A
Kereu at SH 35			A	A	A	A	A	A	A	A	N/A
Haparapara at SH35	A	A	A	A	A	A	A	A	A	A	N/A

4.2.3 Dissolved oxygen

Dissolved oxygen (DO) is the measure of the concentration of oxygen that is dissolved in the water and will fluctuate depending on diffusion and aeration, photosynthesis, respiration and decomposition. Oxygen is both produced and used in aquatic ecosystems and will occur on a daily cycle. The main sources of oxygen to streams are from air and aquatic plants as a product of photosynthesis, for this reason oxygen concentration will be at its highest during the day in conjunction with peak photosynthesis. Consequently, oxygen is also consumed by aquatic plants and animals as they respire and organic matter decomposes.

DO is currently an attribute contained in the NPS-FM for protecting Ecosystem Health in rivers, and is to be measured below point-source discharges. The NPS-FM numeric guidelines for DO are Daily Minimum concentration and a 7-day Mean Minimum to measure short-term and long-term impacts. Monitoring of DO is recommended during the warmest months of the year when variations are likely to be at their greatest (1 November – 30 April).

BOPRC currently monitors DO continuously over summer below five point source discharges in the region, as per the NPS-FM; one site on each of the Kaituna, and Tarawera Rivers and the Waiari Stream, and two sites on the Rangitāiki River. Four sites were graded A or B band for DO (Figure 2), and one site (Rangitaiki River below Edgecumbe) graded C band (Figure 2). At the current grade of C, reduced DO levels can cause moderate stress on aquatic organisms for several hours each day, and there is a risk of sensitive fish and macroinvertebrate species being lost (MfE, 2014).The Tarawera River has fluctuated between B and D band since 2009.

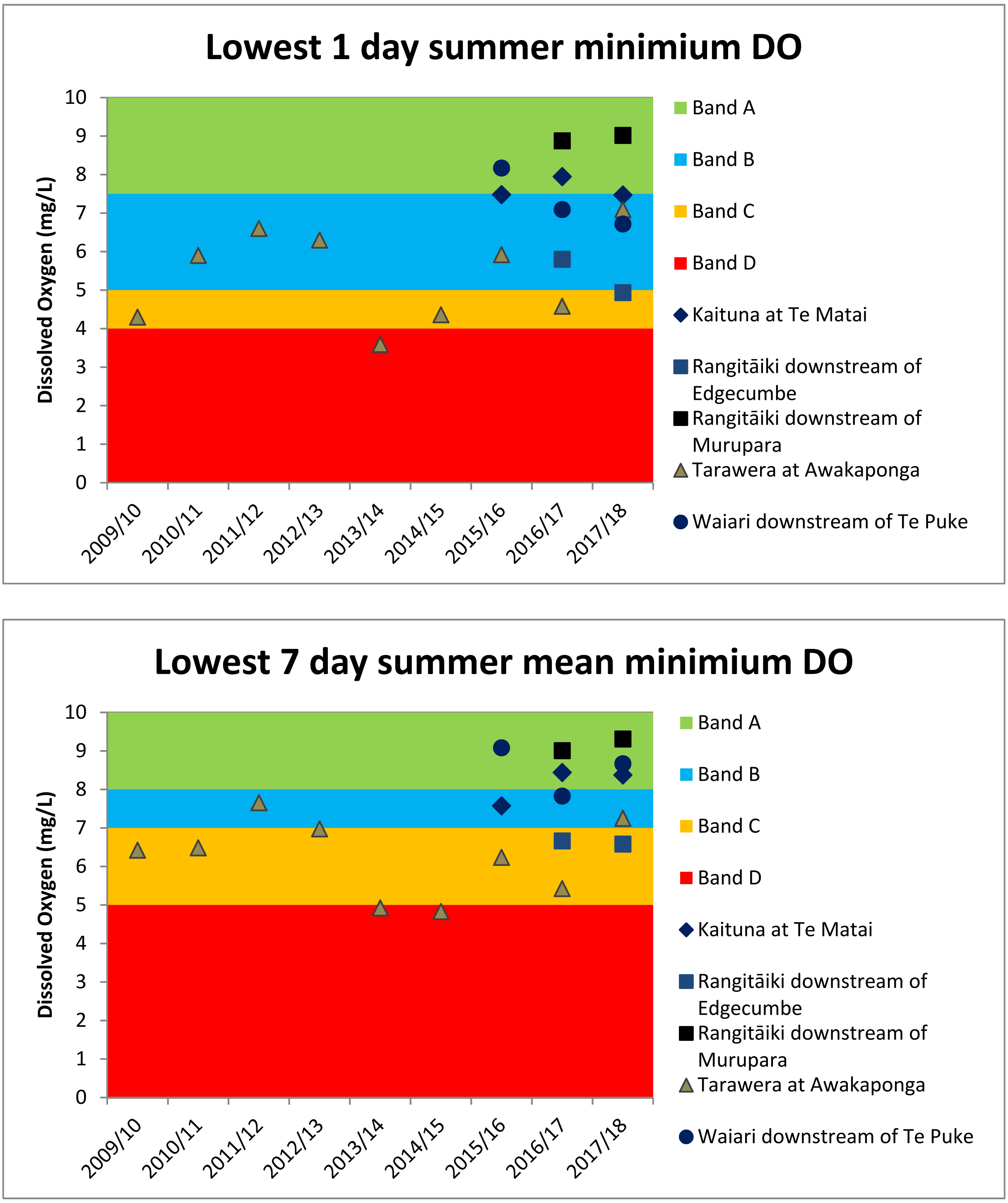

Figure 2 Attribute state for dissolved oxygen summer Daily Minimum and 7-day Mean Minimum.

4.2.4 Water temperature

Temperature influences water composition, such as DO and nitrogen, it also causes thermal stress to aquatic organisms. For this reason the recommendation by Carter *et al.,* (2017) for temperature monitoring in rivers has been adopted and is based on an increasing gradient for temperature beginning at 'A' band referring to no thermal stress to significant thermal stress at 'D' band. Management of temperature in freshwater is based on thermal requirements for all stages of life, the diel fluctuation of temperature must be considered through the mid to later summer due to the annual maxima being reached throughout these months.

BOPRC has several continuous water temperature sensors in place around the region as part of the hydrometric network monitoring river levels. These sites were not strategically selected to provide a comprehensive coverage of water temperature across the region at NERMN water quality sites, and the provision of water temperature at hydrometric sites is governed by the instrumentation installed. Given the recent recommendation from Carter *et al.,* (2017) to include water temperature, a comprehensive review of monitoring sites and locations will take place and additional sensors may need to be installed across the region.

The Cox-Rutherford-Index (CRI) defines the daily mean and maximum values. The CRI is expected to be at its highest during a clear (cloud-free) days over the midday period when solar insolation is maximal. It is acknowledged that the CRI is recommended to be based on continuous water temperature data to be done over the summer months (defined as 1 November – 30 April inclusive) and also to be calculated over the five hottest days of summer (Davies-Colley *et al.,* 2013). The CRI is calculated as:

$$CRI = (Tmax + Tmean)/2$$

The majority of sites that have been monitored for water temperature sit within the highest two bands (‘A’ and ‘B’) for this attribute (Table 25). Four sites were graded ‘C’ band for the 2017/2018 summer (Te Mania, Kaiate and Wainui Te Whara streams, and Kaituna River). Te Mania Stream has been graded C for five out of the last six years – further investigation into the causes of this and the longitudinal extent of high temperatures is required. The numerical values for each of these attributes are detailed in Appendix 1.

Table 25 Attribute state for water temperature based on the Cox Rutherford Index

		Summer					
		2012/13	**2013/14**	**2014/15**	**2015/16**	**2016/17**	**2017/18**
Site Name	**Climate Class**	Grade	Grade	Grade	Grade	Grade	Grade
Tauranga Harbour							
Kaiate at Falls Road	Eastern Dry/Lowland					B	C
Te Mania at SH2	Eastern Dry/Lowland	C	B	C	C	C	C
Wairoa above Ruahihi	Eastern Dry/Lowland	B	B	B	B	B	B
Kaituna							
Kaituna at Te Matai	Eastern Dry/Lowland		A	B	A	B	C
Mangorewa at Saunders	Maritime/Upland				A	A	A
Raparapahoe at Drop Structure	Eastern Dry/Lowland					B	B
Waitahanui at Ōtamarākau	Eastern Dry/Lowland		A	A	A	A	A
Waiari upstream of Kaituna confluence	Eastern Dry/Lowland					A	A
Tarawera							
Tarawera at Awakaponga	Eastern Dry/Lowland	B	B	C	C	B	B
Tarawera at Otartiki Road	Eastern Dry/Lowland					B	B
Rangitaiki							
Rangitāiki downstream Edgecumbe	Eastern Dry/Lowland					B	C
Rangitaiki Downstream of Murupara	Maritime/Upland					A	B
Rangitaiki at SH5	Maritime/Upland				A	A	A
Whakatāne and Tauranga							
Wainui Te Whara at Mokorua George	Eastern Dry/Lowland				C	C	B

4.2.5 Periphyton (chlorophyll-*a* biomass)

"Periphyton" is 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 an important food source for invertebrates, many of which consume this material and continually keep it at low biomass. Periphyton biomass and cover can increase dramatically when concentrations of dissolved nutrients increase, particularly during times of stable flow. The resultant periphyton blooms can have detrimental impacts on not only the ecological value of rivers but also their recreational, aesthetic and cultural values.

Periphyton biomass in streams is best measured by measuring chlorophyll-*a*, the green photosynthetic pigment that is found in all plants – including algae. Measurements of chlorophyll-*a* are included in the NPS-FM as a compulsory attribute. Samples have been collected from 29 sites throughout the region since October 2015 (Suren and Carter, 2015). These sites are considered to be more susceptible to periphyton growth than others, and are also representative of the region. Under the NPS-FM, periphyton biomass needs to be calculated from a three year mean, so the results presented here are preliminary, as monitoring has only been running for 2½ years.

Nineteen sites fell into the A band for chlorophyll-*a* biomass, while eight sites were graded in the B band. Only two sites (Tuaprio at Farm Bridge and Waitekohe at State Highway 2) fell in the C band, and no sites were graded in the D band (see Appendix 4). It is assumed unlikely that the extra monitoring time would reveal any specific issue with excessive periphyton proliferations in the streams.

4.2.6 Invertebrate communities

Freshwater invertebrates are routinely used by regional councils to monitor the state and trends of ecological health on rivers and streams. The data describing the invertebrate communities at a particular site are often simplified into metrics: specific numbers that describe parts of the invertebrate community that reflect their overall ecological integrity.

Within New Zealand, the Macroinvertebrate Community Index (MCI) is widely used as a biotic index of water quality in stony streams. MCI scores can range from 20 to 200. Scores > 120 represent streams in "Very Good" condition (the A band), while scores < 80 indicate streams in "Poor" condition (the D band). MCI scores exist for both hard-bottomed and soft-bottomed streams, which means that these different stream types can be correctly assigned to a specific stream health score.

In addition to the MCI, the number of EPT (Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies)) is another metric that is used to describe the ecological condition of a waterway. This is because many species of these insect groups become scarce at sites affected by organic enrichment (and where algal blooms are subsequently common), heavy metals, and sedimentation loads.

Carter *et al.,* (2017) recommended using both the MCI and number of EPT taxa as attributes to assess ecological conditions. They also recommended the use of a new metric, the Bay of Plenty Index of Biotic Integrity (BOP_IBI), to assess ecological conditions despite its more complex calculations. This metric was based on comparing specific components describing the invertebrate communities at sites subject to human activities to communities at appropriate reference sites under natural, or "least disturbed" conditions. The BoP_IBI has been shown to be a good tool to identify the effects of land use change on invertebrate communities (Suren *et al.,* 2017).

Carter *et al.,* (2017) also highlighted that ecological communities naturally differ between streams draining catchments dominated by volcanic or non-volcanic geology, or catchments with steep or gentle topography. They subsequently created three biophysical classes (non-volcanic; volcanic-steep, volcanic-gentle) and showed that different numerical attribute states existed for each of the biotic indices (MCI, EPT and BOP_IBI) in each of these three biophysical classes. For example, the lowest D-band MCI scores varies from 100 in non-volcanic streams to 88 and 97 in volcanic-gentle and volcanic-steep gradient streams respectively. Both these latter MCI scores are higher than the default minimum MCI score of 80 recommended under the NPS-FM.

The current state of invertebrate communities collected from 135 sites sampled in the Bay of Plenty was assessed by taking the average of the past three years data. This was done to represent the average "long-term" conditions at the sites. A three year period was chosen as some sites draining exotic plantation forest have only been sampled for this period of time, following a review of the invertebrate monitoring programme that showed that such sites were under-represented.

Examination of attribute bands for the MCI scores showed that sites were below the recommended bottom line of 80 in only 1 non-volcanic-gentle gradient stream, nine volcanic-gentle gradient streams, and three volcanic steep-gradient streams (Table 26). This finding is consistent with observations worldwide that show that stream ecological health is often lowest in urban catchments, and can be highly variable and agricultural catchments depending on local habitat conditions, farming intensity, and the degree of connectivity with upstream undisturbed catchments. Of interest was the finding that two sites draining catchments dominated by native forest were also in the D band for MCI scores (Table 27). One of these sites (BOPRC_NERM_110020) was sampled in the Tarawera River just below the lake outlet, and the low MCI scores here may simply reflect the slow flowing soft bottomed environments characteristic of this site. Of these 13 streams, three drained urban catchments, six drained agricultural catchments and two streams each drained catchments dominated by either exotic or native forest (Table 27). In contrast, the majority of streams in the steep gradient class in both volcanic and non-volcanic catchments were in the A band. The majority of streams in the volcanic gentle-gradient class were in either the B or C band.

This finding is consistent with observations worldwide that show that stream ecological health is often lowest in urban catchments, and can be highly variable and agricultural catchments depending on local habitat conditions, farming intensity, and the degree of connectivity with upstream undisturbed catchments. Of interest was the finding that two sites draining catchments dominated by native forest were also in the D band for MCI scores (Table 27). One of these sites (BOPRC_NERM_110020) was sampled in the Tarawera River just below the lake outlet, and the low MCI scores here may simply reflect the slow flowing soft bottomed environments characteristic of this site.

Table 26 Summary of the number of sites in each of the four attribute state classes as suggested by Carter et al., (2017) for the MCI score in each of the three biophysical classes.

	Geology/Slope	A	B	C	D
MCI score	Non-Volcanic/Steep	8	6	6	1
	Volcanic/Gentle	4	22	19	9
	Volcanic/Steep	30	18	9	3

Table 27 Summary of the individual sites which scored in the D band for MCI scores according to the recommended ranking system suggested by Carter et al., (2017), showing their dominant land cover class and which of the three biophysical classes they belonged to.

	Geology/Slope		
Landcover	**Volcanic/Steep**	**Volcanic/Gentle**	**Non-Volcanic**
Native	BOP_NERM_060	BOP_NERM_110020	
Exotic forest	BOP_NERM_038	BOP_NERM_118	
Agriculture	BOP_NERM_026	BOP_NERM_091 BOP_NERM_081 BOP_NERM_082 BOP_NERM_027 BOP_NERM_049	
Urban		BOP_NERM_078 BOP_NERM_079	BOP_NERM_125
(Total)	3	9	1

Examination of attribute bands for EPT richness scores showed that sites were below the recommended bottom line in only three streams: one non-volcanic-gentle gradient stream and two volcanic-gentle gradient streams (Table 28). These streams drained catchments dominated by either urban, agricultural or exotic forest. The majority of streams in non-volcanic-steep gradient and in both volcanic classes were in the A band (Table 28).

Table 28 Summary of the number of sites in each of the four attribute band classes as suggested by Carter et al., (2017) for the number of EPT taxa (i.e. richness) in each of the three biophysical classes.

	Geology/Slope	**A**	**B**	**C**	**D**
EPT richness	Non-Volcanic	19	1		1
	Volcanic/Gentle	31	12	9	2
	Volcanic/Steep	55	4	1	

Examination of attribute bands for the BOP_IBI showed that the majority of sites (23) in the volcanic gentle gradient class were below the recommended bottom line (Table 29). Of these 23 sites, 16 drained catchments dominated by agriculture, and four drained urban catchments. The majority of volcanic-steep gradient catchments were either in the A or B band (Table 29), although 5 were also in the D band. Most streams (10) in the non-volcanic steep gradient class were in the B band.

Table 29 Summary of the number of sites in each of the four attribute band classes as suggested by Carter et al., (2017) for the Bay of Plenty Index of Biotic Integrity (BOP_IBI) in each of the three biophysical classes.

	Geology/Slope	**A**	**B**	**C**	**D**
BOP_IBI	Non-Volcanic	2	10	9	
	Volcanic/Gentle	1	16	14	23
	Volcanic/Steep	24	25	6	5

Actual bands for the 135 monitored sites based on the average of monitoring data from 2014-2017 can be found in Appendix 2.

To simplify the use of three attributes that described specific aspects of the invertebrate communities at each site, each attribute band was allocated a rank, such that "A" = 1, and "D" = 4. Ranked bands for each attribute at each site were then summed, giving a theoretical range of three (all in the "A" band) to 12 (all in the "D" band). An overall stream ecological condition score was subsequently created such that:

- Very Good ecological condition = 3, 4 or 5.
- Good ecological condition = 6, 7 or 8.
- Fair ecological condition = 9 or 10.
- Poor ecological condition = 11 or 12.

Of the 135 streams monitored, 50 were in Very Good condition and 55 in Good ecological condition. A further 17 were in Fair ecological condition, and only 13 were in Poor condition. Of these 13, six were in streams draining agricultural catchments, and three in urban catchments (Table 30). Of interest was the finding that no urban streams were in the A band, highlighting the adverse effects of urban development in stream ecological condition.

Table 30 Summary results for MCI score, EPT richness, BOP_IBI and overall ecological health. (Blue = Very Good; Green = Good; Yellow = Fair; Red = Poor), using the banding system proposed by Carter et al., (2017).

Site by WMA	MCI	EPR_r	BoP_IBI	Overall Grade
East coast				
Waiiti at SH35	C	A	B	Good
Waitawake SH35 at Site 2	B	A	B	Good
Whanarua	A	A	B	Very Good
Oteakona Stream_Pine	A	A	C	Very Good
Whangaparaoa	C	A	B	Good
Raukokore	B	B	C	Fair
Motu	A	A	C	Very Good
Waiaua	C	A	B	Good
Oteakona Stream_Native	A	A	C	Very Good
Tributary into Harparapa River on SH35	B	A	C	Good
Tributary into Harparapa River_1 km u/s of SH35	A	A	C	Very Good
Waewaetukuku Stream	B	A	B	Good
Kopua Stream	A	A	B	Very Good
Nahunahu Stream	A	A	C	Very Good

Site by WMA	MCI	EPR_r	BoP_IBI	Overall Grade
Kaituna, Maketū, Pongakawa				
Domain Road, Pāpāmoa	D	D	C	Poor
Waiari Tributary at SH2	B	A	B	Good
Ohineangaanga	B	A	C	Good
Kaikokopu	C	A	D	Good
Waikoko	B	A	B	Good
Mangatoetoe	C	B	D	Fair
Waiari at Roydon Downs Road	B	A	C	Good
Pongakawa Tributary at Rotoehu Road	C	A	C	Good
Pongakawa at SH2	C	B	D	Fair
Ohaupara	B	A	B	Good
Tributary into Onaia Stream	D	D	D	Poor
Ohineangaanga at SH2	C	B	D	Fair
Raparapahoe	C	A	D	Good
Whataroa	A	A	A	Very Good
Pungarehu	A	A	C	Very Good
Tributary into Kaituna River_Maungarangi Road	A	A	B	Very Good

Site by WMA	MCI	EPR_r	BoP_IBI	Overall Grade
Ōhiwa				
Ruakaka Stream	C	A	A	Very Good
Oruamanganui Stream	C	A	C	Good
Panuiahine Stream	C	A	B	Good
Waiwhakatoitoi	C	C	D	Fair
Kutarere	B	A	B	Good
Ohiwa Tributary at Burma Road	A	A	A	Very Good
Maraetotara (Maraetotara Road)	C	A	C	Good
Maraetotara at Maraetotara/ Burma Road intersection	A	A	A	Very Good
Ohope at Ohope Hill Base	B	A	A	Very Good
Ohope Tributary at Pohutakawa Ave School	B	A	B	Good
Nukuhou	C	A	C	Good

Site by WMA	MCI	EPR_r	BoP_IBI	Overall Grade
Rangitāiki				
Pahekeheke Stream	B	A	B	Good
Ngakauroa Creek	D	C	D	Poor
Kakahotoa Stream	C	A	C	Good
Moetahanga Stream	A	A	B	Very Good
Mangaharakeke Stream	A	A	B	Very Good
Pekepeke Stream_Upper	B	A	B	Good
Flaxy Creek	B	A	B	Good
Otangimoana Stream	B	A	B	Good
Mangapapa	A	A	B	Very Good
Hikurangi at Grant Road	B	A	B	Good
Haumea	B	A	B	Good
Mangamate	A	A	A	Very Good
Whirinaki	A	A	B	Very Good

Site by WMA	MCI	EPR_r	BoP_IBI	Overall Grade
Rotorua Lakes				
Waiowhiro, Rotorua	C	B	D	Fair
Utuhina at Great West Road	B	B	D	Fair
Utuhina at Substation	B	B	D	Fair
Utuhina at Depot Street	B	A	C	Good
Puarenga	B	A	B	Good
Mangakakahi	B	A	D	Good
Waingaehe at SH30	B	B	C	Fair
Mangakino	C	A	D	Good
Ngongotaha at Paradise Valley Road	B	A	B	Good
Ngongotaha at Hamurana Road	B	A	C	Good
Waiteti	C	B	C	Fair
Te Toroa Tributary	B	B	C	Fair
Waiohewa	B	A	B	Good
Tupapakurua	C	C	C	Fair
Te Pohue	A	A	B	Very Good
Okareka Tributary	C	A	D	Good
Wairoa	D	B	D	Poor
Waiiti at SH30	B	A	B	Good

Site by WMA	MCI	EPR_r	BoP_IBI	Overall Grade
Tarawera				
Awakaponga canal at Matata Road	D	C	D	Poor
Tarawera	D	B	D	Poor
Mimiha	A	A	A	Very Good
Waikamihi	A	A	B	Very Good
Waikanapiti	A	A	A	Very Good
Mangate	A	A	B	Very Good
Buddles Creek	A	A	A	Very Good
Kaipara	A	A	B	Very Good
Awakaponga at Manawahe Road	A	A	A	Very Good
Pikowai Stream at Pikowai Road	B	A	B	Good
Mangaone	B	A	B	Good
Ruruanga at Tamarangi Drive	A	A	A	Very Good
Ruruanga at Valley Road	A	A	B	Very Good
Awatarariki	A	A	A	Very Good
Karaponga	A	A	B	Very Good

Site by WMA	MCI	EPR_r	BoP_IBI	Overall Grade
Tauranga				
Uretara at Wharawhara Road	C	B	C	Fair
Boyd	C	A	C	Good
Wainui at Tim Road	B	A	A	Very Good
Waioraka	D	C	D	Poor
Otumanga	D	C	D	Poor
Kaitemako	C	C	D	Fair
Oturu	D	D	D	Poor
Kopurererua	D	C	D	Poor
Tuapo	B	A	C	Good
Waipapa Tributary at Waipapa block Road	C	A	C	Good
Waipapa Tributary at Plummer Road	C	A	B	Good
Mangawhai	C	C	D	Fair
Te Puna Tributary	B	A	B	Good
Ohaurere	C	A	D	Good
Kaukaumoutiti Tributary	D	B	D	Poor
Piako	A	A	B	Very Good
Ngamuwahine	A	A	B	Very Good
Tahawai	C	B	B	Fair
Tuapiro at McMillan Road	C	A	C	Good

Site by WMA	MCI	EPR_r	BoP_IBI	Overall Grade
Tauranga				
Uretara at Rea Road	A	A	A	Very Good
Aongatete	A	A	B	Very Good
Waihi at Oceanview Road	D	C	D	Poor
Waiau	B	A	C	Good
Ngutaturu	C	A	B	Good
Te Mania	B	A	A	Very Good
Waitekohe at SH2 Bridge	C	A	A	Very Good
Waitao	B	A	B	Good
Tuapiro at Woodlands Road	A	A	A	Very Good
Waitekohe at Thompsons track	A	A	B	Very Good
Owairoa	A	A	A	Very Good
Te Rereatukahia at Hot Springs Road	A	A	A	Very Good
Tuapiro	A	A	A	Very Good

Site by WMA	MCI	EPR_r	BoP_IBI	Overall Grade
Waioeka-Otara				
Otara	B	A	B	Good
Waioweka	B	A	B	Good
Tributary into Taipouri Stream	A	A	A	Very Good

Site by WMA	MCI	EPR_r	BoP_IBI	Overall Grade
Whakatāne				
Wainui Te Whara at King Street	C	A	D	Good
Wainui Te Whara at Gorge Road	B	A	A	Very Good
Wainui Te Whara at upper footbridge	B	A	B	Good
Te Rahu Canal	D	B	D	Poor
Waioho	C	A	C	Good
Tauranga at Gorge	A	A	A	Very Good
Tauranga at Ogilvie Bridge	A	A	A	Very Good
Whakatane at Ruatoki	B	A	A	Very Good
Whakatane at Pekatahi	B	A	B	Good
Opurana Stream	B	A	B	Good
Paekoau Stream	B	A	A	Very Good
Owhaktoro Stream	A	A	A	Very Good
Kotorenui Stream	B	B	B	Fair

Only a limited trend analysis is reported here, as Suren *et al.,* (2017) found that invertebrate communities at the monitoring sites were generally not changing but fluctuating around a relatively stable state. Their report looked at changes to invertebrate communities from 120 sites throughout the region. Some of these sites had been sampled annually since 1991, while others were sampled annually from 2001 onwards. Some sites were also not sampled every year due to access difficulties. However, 114 sites had at least eight years of monitoring data, and so were analysed for trends. Suren *et al.,* (2017) analysed trends to seven invertebrate metrics at each site to see whether they were changing. Most sites displayed changes to only one or two metrics, and only one site (Pongakawa Tributary at Rotoehu Road) showed trends to four metrics. Lack of consistent changes to different biotic metrics describing components of the invertebrate communities implied that these communities were not changing but fluctuating instead around a stable state. This result was thought to reflect the fact that the historic landuse changes which occurred over the past 100 years would have altered the original invertebrate community composition from what would have been present to a new, stable state. Furthermore, Suren *et al.,* (2017) highlighted that land cover has not changed appreciably in the region since the stream monitoring programme began in 1991. Given this, it was not surprising that the invertebrate community composition has not changed either.

The Suren *et al.,* (2017) report only reported data to 2015. Currently, only the biological data from the 2015/2016 and 2016/2017 monitoring periods are available, as last summer's data (2017/2018) is not yet available. Given that the majority of sites analysed by the Suren *et al.,* (2017) report displayed no significant temporal differences, new trend analyses were conducted only for the MCI and EPT with this extra two years of data.

As found previously by Suren *et al.,* (2017), only a small proportion of sites analysed displayed significant trends in either MCI scores (eight sites) or EPT_r (12 sites). MCI scores showed significant trends at four sites with the latest data, whereas no trends were observed at these sites by Suren *et al.,* (2017: Table 31). One site (the Waioeka) displayed the same negative trends to MCI on both occasions. A further three sites displayed trends based on the latest data, but were not analysed previously due to lack of sufficient samples. Seven sites displayed similar trends on both occasions of EPT_r, while five sites displayed trends with the latest data only (Table 31).

Table 31 Summary results of Mann-Whitney trend analysis for MCI scores, and EPT richness, comparing the results of this analysis with data up to the 2016/2017 austral summer, with those found by Suren et al., (2017). Light blue = sites with similar results between surveys; purple = sites with different results.

Metric	**Negative trends**		**Positive trends**	
	This report	Suren *et al.,* (2017)	This report	Suren *et al.,* (2017)
MCI	Raparapahoe	Not analysed	Tuapiro at Woodlands Road	No trend detected
	Te Toroa Tributary	Not analysed		
	Ngakauroa Creek	Not analysed		
	Waioho	No trend detected		
	Tuapo	No trend detected		

Metric	Negative trends		Positive trends	
	This report	Suren *et al.*, (2017)	This report	Suren *et al.*, (2017)
	Piako	No trend detected		
	Waioweka	Waioweka		
EPT_r	Raukokore	Raukokore	Mimiha	No trend detected
	Waioweka	No trend detected	Okareka Tributary	No trend detected
			Pahekeheke Stream	Pahekeheke Stream
			Wainui Te Whara at Gorge Road	No trend detected
			Pongakawa Tributary at Rotoehu Road	Pongakawa Tributary at Rotoehu Road
			Waiwhakatoitoi	Waiwhakatoitoi
			Ohiwa Tributary at Burma Road	Ohiwa Tributary at Burma Road
			Maraetotara at Maraetotara Road	No trend detected
			Tuapiro at Woodlands Road	Tuapiro at Woodlands Road
			Waipapa Tributary at Waipapa block Road	Waipapa Tributary at Waipapa block Road

More data is currently being collected from 15 new sites in urban and forestry areas. It is however impossible to detect a trend from these new sites, as we only have two years of data. Further trend analyses will be conducted as more data becomes available over time.

4.3 Human health attributes

4.3.1 Planktonic Cyanobacteria – lake fed rivers

The Kaituna River is a lake-fed river, and as such may be subject to occasional blooms of planktonic cyanobacteria, especially if there are blooms in Lake Rotoiti (see

Table 22). Because of this, cyanobacteria is monitored at one site along the Kaituna River, and it has been graded in the A band for cyanobacteria.

4.3.2 Benthic cyanobacteria

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. Extensive mats can develop during stable flow conditions, especially in summer when water temperatures are high. Excessive cover of the streambed by cyanobacterial mats is of concern, as these mats often produce toxic substances. As the mats grow, they become thicker and thicker until parts detach from the stones' 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 frequently been recorded in some rivers throughout the country.

Benthic cyanobacteria are monitored monthly at the same 30 sites as periphyton (chlorophyll-*a)* sampling. Where cover values exceed recommended values (> 20% of the streambed), monitoring is increased to weekly. Carter *et al.,* (2017) recommended that attribute bands for benthic cyanobacteria cover are based on the 80th percentile of data collected, with a minimum of 12 samples over a three-year period, or with a more robust measure based on 30 samples collected over a three-year period. Again, because the current benthic cyanobacteria monitoring programme has not been running for the full three years, the results presented here are preliminary only.

All sites monitored were in the A band (see Appendix 4), and it is assumed unlikely that the extra monitoring time would reveal any specific issue with excessive benthic cyanobacteria in the monitored streams.

4.3.3 *E. coli*

BOPRC undertakes annual water quality surveys of popular recreational (bathing) sites and shellfish collection areas over the warmer months (October to March). These surveys assist in identifying the risk to public health from faecal contamination in these areas. This information is then used by public health and local authorities to advise the community on the suitability of water for bathing or shellfish collection. Monitored sites do not include all *Specified Rivers and Lakes* or all *Primary Contact Sites*. Note that central government modelling outputs for specified rivers and lakes is available on Ministry for the Environment (MfE's) website or by clicking here. More detailed modelling outputs will soon be available for the Kaituna Pongakawa Waitahanui, and Rangitāiki WMAs.

Sixteen sites are graded as suitable for primary contact recreation (including swimming) (A-C band for *E. coli*) and six sites are not (D or E band), being Kopurererua, Kaiate, Ngongotahā, Utuhina, Waiteti and Uretara streams. These sites have been deemed not suitable for primary contact recreation based on high *E. coli* counts across multiple numeric attribute states used to assess suitability (Table 32).

Table 32 Attribute state for E. coli in rivers.

Suitability for Primary Contact Recreation (Appendix 2, NPS-FM)	2013-2018 *E. coli* state band	2013-2018 Suitable for Primary Contact Recreation
Rotorua		
Ohau Channel	A	Yes
Puarenga at Whakarewarewa	B	Yes
Utuhina at Lake Road	D	No
Ngongotaha at Railway Bridge	D	No
Waiteti at SH36	D	No
Tauranga		
Waitangi Soda Springs*	A	Yes
Tuapiro at McMillan Road	B	Yes
Wairoa at SH2	B	Yes
Wairoa Below McLaren	C	Yes
Kopurererua at McCords*	D	No
Uretara at Henry Road Ford	D	No
Kaiate at Kaiate Falls Road	E	No
Tarawera		
Tarawera at Boyce Park	A	Yes
Rangitāiki		
Rangitaiki at Te Teko	A	Yes
Rangitaiki at Boat Ramp	A	Yes
East Coast		
Kereu at SH35	A	Yes
Kaituna		
Pongakawa at SH2	B	Yes
Waioeka and Otara		
Waioeka at Mouth of Gorge*	A	Yes
Waioeka at SH2	B	Yes
Otara at SH35	B	Yes
Whakatāne and Tauranga		
Whakatāne at Landing Road	B	Yes
Tauranga at Wardlaw Glade	B	Yes

*Only four years of data available.

Part 5: **Summary**

Monitoring data for rivers, streams and lakes in the Bay of Plenty has been compared to the recommended attributes as per the NPS-FM or Carter *et al.,* 2017. Current monitoring results show:

5.1.1 Lakes

Ecosystem health attributes

- Lake Rotomahana is the only lake to not meet the National Bottom Line (worse than band C) for TP and has retained that state for the past three years. All other lake sites fall into state bands better than the National Bottom Line (A, B, or C).
- Two lakes are showing improving trends for TP (Rotokakahi and Rotorua) and six other lakes are showing worsening trends (Ōkāreka, Ōkataina, Rotoehu, Rotomā, Rotomahana, and Tarawera). No TP trend could be determined for the remaining lakes.
- Eleven lakes were graded A or B for TN and ammonia. Only one lake (Ōkaro) was graded C. Most lakes (nine lakes) showed improving trends for TN.
- Lake Ōkaro was the only lake below the National Bottom Line (worse than band C) for chlorophyll-*a*. Eight lakes were graded either A or B band, and three graded C. Two lakes showed improving trends for chlorophyll-*a* (Rotokakahi and Rotorua).
- Currently five of the twelve Te Arawa/Rotorua Lakes meet, or are better than, their RNRP TLI objective. Lakes Rotorua, Okaro and Tikitapu have benefited from the results of restoration activities resulting in meeting community objectives for lake water quality as stated in RL O1 of the RNRP. Lake Rotoehu and Lake Tarawera continue to show some declining water quality trends resulting in increasing TLI.
- Nine of the 12 lakes fall within either A or B band for TLI recommendations based on Carter *et al.,* (2017). Ōkaro, Rotorua and Rotoehu are graded C band.
- Seven of the 12 monitored lakes were in the A band for LakeSPI, and showed either < 5% change, or an improvement in LakeSPI scores since the previous year's sampling. Lake Tikitapu showed reductions in LakeSPI scores below the bottom line, reflecting a continual decline in LakeSPI scores since 2014, due mainly to the increased depth range where the exotic plants Lagarosiphon was found.
- Using the more robust banding system based on changes to LakeSPI scores relative to the earliest surveys, Lake Rotoma was always in the A band over successive surveys, while six lakes (Rerewhakaaitu, Rotoehu, Rotoiti, Rotokakahi, Tarawera and Tikitapu) were below the bottom line D band. These lakes all showed reductions in LakeSPI scores more than 15% since the earliest surveys. Again, these reductions were caused mostly by invasion by exotic plants such as *Lagarosiphon, Egeria* and *Ceratophyllum*.
- Efforts are underway at Lake Okataina to eradicate *Ceratophyllum,* so LakeSPI scores are expected to stabilise or increase slightly there.

- One of the biggest threats to lakes is from invasive macrophytes, which have caused a great reduction in LakeSPI scores since the 1990s (which is when LakeSPI monitoring was done). Following invasion by exotic plants, LakeSPI scores generally decline to a new stable state.

Human health attributes

- Of the four lakes where planktonic cyanobacteria is monitored, Lake Rotorua was graded A at all sites, and Lake Rotoiti was graded A for four out of five sampling locations and C for the fifth location, for the 2014-2017 analysis period.
- All sites on Lakes Ōkaro and Rotoehu were ranked C for the most recent two monitoring periods (2013-2016, 2014-2017), necessitating health warnings against recreational contact.
- All lakes fall within the A or B bands for *E. coli* and are all considered suitable for primary contact recreation (including swimming) in accordance with the numeric attributes they are compared against.

5.1.2 Rivers

Ecosystem health attributes

- All sites were graded A or B band for nitrate-nitrogen, and have been since 2013. Note that the lowest reaches of rivers are not monitored in the rivers NERMN programme due to salt water influences, they have been monitored and reported separately (Suren and Carter, 2018).
- Improving trends in nitrate-nitrogen were observed for two sites (Waiau at Road Ford and Wairoa at State Highway 2 Bridge). No worsening 10 year trends were confirmed where sufficient data was available for analysis.
- All sites were graded A or B band for ammoniacal-nitrogen, and have been since 2013.
- Improving trends for ammoniacal-nitrogen were observed for four sites (Omanawa at State Highway 29, Te Mania at State Highway 2, Kaituna at Maungarangi and Waioeka at Gorge mouth). No worsening 10 year trends were confirmed.
- Four sites were graded A or B band for DO, and one site (Rangitaiki River below Edgecumbe) graded C band.
- The majority of sites that have been monitored for water temperature sit within the highest two bands (A and B) for this attribute. Four streams were graded C band for the 2016/2017 summer.
- Of the 29 rivers monitored, 19 were in the A grade for periphyton, and had consistently low chlorophyll-*a* algal biomass. A further eight sites were in the B grade, suggesting occurrence of only short-lived blooms of relatively low biomass. Only two sites (Tuapiro at farm bridge, and Waitekohe at State Highway 2) were in the C grade, where periodic short-duration blooms occurred.

- Slightly over 30% of all 135 monitored sites have MCI (macroinvertebrates) scores in either the A or B bands. A further 25% of monitored sites had MCI scores in the C band. Only 10% of sites had MCI scores low enough to be placed in the D-band. Of these 13 score less than 80. Many of these drained catchments dominated by urban or agricultural land cover.
- The majority of sites (78%) had macroinvertebrate EPT richness in the A band, while only 2% were in the D band.
- In contrast, most sites (38%) were in the B band for the macro invertebrate BOP_IBI score, while similar numbers of sites (~20%) were in the A, C or D bands.
- Differences in the number of sites in different bands for the three invertebrate attributes highlights subtle differences in what each attribute measures. An overall stream ecological condition score was created that combined each individual attribute. Of the 135 streams monitored, 50 were in *Very Good* condition and 55 in *Good* ecological condition, while only 13 were in *Poor* condition. Of these six were in streams draining agricultural catchments, and three in urban catchments.

Human health attributes

- Five sites are in 'D' band for *E. coli* (Kopurererua, Utuhina, Ngongotaha, Waiteti and Uretara streams), with one site in 'E' band (Kaiate). These sites have been deemed not suitable for primary contact recreation (including swimming) in accordance with high *E. coli* counts across multiple numeric attribute states used to assess suitability. Note that monitored sites do not include all *Specified Rivers and Lakes* or all *Primary Contact Sites*.
- None of the 29 monitored sites showed any evidence of prolonged or extensive benthic cyanobacterial blooms, and all were in the A grade.

Part 6:
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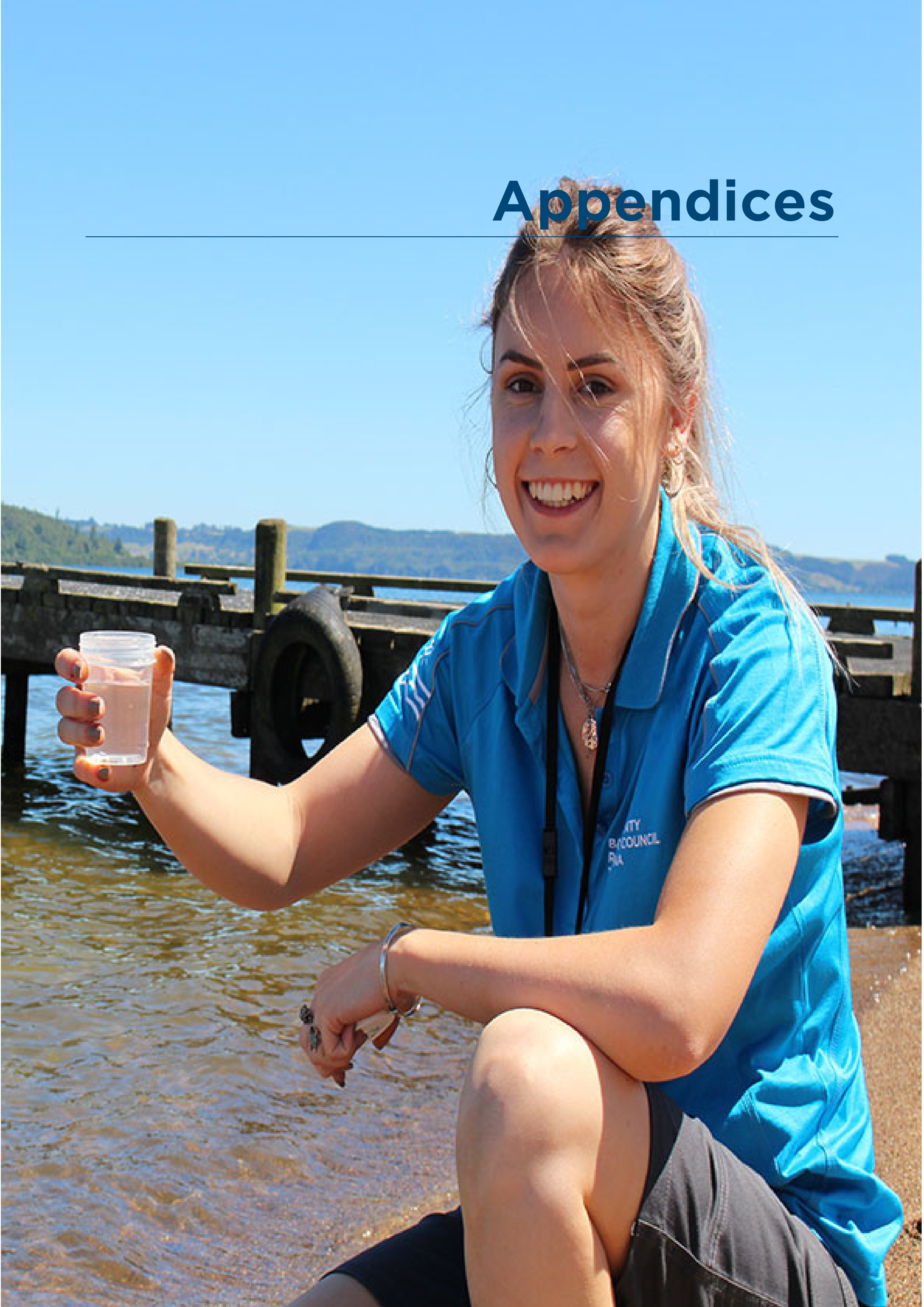
Appendices



Appendix 1

Annual data for water quality parameters

Table 1a *Annual median results for Total Phosphorus in lakes (mg/m^3). For trends: N/A = No Data, IND = Indeterminate Trend 👎 = Ecologically meaningful degradation, 👍 = Ecologically meaningful improvement.*

Total Phosphorus	2012/13	2013/14	2014/15	2015/16	2016/17	10 Yr Trend
Okareka	**10.5**	**9.5**	**9**	**9.3**	**11**	👎
Ōkaro	**71.3**	**21.3**	**26.0**	**24.0**	**34.3**	**IND**
Okataina	**11**	**10**	**11**	**13**	**12.5**	👎
Rerewhakaaitu	**9**	**9**	**9**	**8.5**	**9**	**IND**
Rotoehu	**23**	**25**	**28.5**	**31.1**	**32.5**	👎
Rotoiti	**13**	**12**	**20**	**26**	**28**	**IND**
Rotokakahi*	**16.5**	**16**	**20**	**16**	**16.5**	👍
Rotomā	**6**	**6**	**7.5**	**7**	**6.5**	👎
Rotomahana	**43.5**	**45**	**58**	**57.5**	**52**	👎
Rotorua	**17.5**	**19**	**19**	**19.5**	**16**	👍
Tarawera	**19**	**17**	**25.5**	**25**	**23.5**	👎
Tikitapu	**4**	**3.5**	**4**	**5**	**4**	**IND**

*Based on data from outlet to Te Wairoa Stream.

Table 1b *Annual median results for Total Nitrogen in lakes (mg/m^3). For trends: N/A = No Data, IND = Indeterminate Trend 👎 = Ecologically meaningful degradation, 👍 = Ecologically meaningful improvement.*

Total Nitrogen	**2012/13**	**2013/14**	**2014/14**	**2015/16**	**2016/17**	**10 Yr Trend**
Okareka	**179**	**185**	**184**	**176**	**191**	👍
Ōkaro	**921**	**854.5**	**522**	**521.5**	**610**	👍
Okataina	**85**	**85**	**95**	**87.31**	**90**	👍
Rerewhakaaitu	**365**	**339.5**	**312.5**	**306**	**300**	👍
Rotoehu	**228.5**	**221.5**	**301**	**330**	**460**	👎
Rotoiti	**152.5**	**157.5**	**185.5**	**199**	**210**	👍
Rotokakahi	**203**	**209**	**268**	**232**	**245**	👍
Rotoma	**99.5**	**104**	**103.5**	**103**	**100**	👍
Rotomahana	**183.5**	**191**	**185**	**177.5**	**190**	👍
Rotorua	**308.5**	**282.5**	**279.5**	**319.2**	**304.5**	👍
Tarawera	**86.5**	**95**	**90**	**84**	**100**	**IND**
Tikitapu	**148.5**	**157**	**172**	**180.5**	**170**	**IND**

Table 1c Annual median and maximum results for Chlorophyll-a in lakes (mg/m^3). For trends: N/A = No Data, IND = Indeterminate Trend 👎 = Ecologically meaningful degradation, 👍 = Ecologically meaningful improvement.

Chlorophyll-a	2012/13		2013/14		2014/15		2015/16		2016/17		10 Yr Trend
	Median	Max	Median	Max	Median	Max	Median	Max	Median	Max	
Okareka	3.1	6.5	2.6	6.4	1.9	7.3	2.5	3.8	4.0	8.4	IND
Ōkaro	10.4	112.0	4.1	59.3	5.0	23.4	6.8	19.1	10.7	146.0	IND
Okataina	1.5	4.7	1.3	3.3	2.1	12.7	1.7	4.3	1.9	6.9	IND
Rerewhakaaitu	3.1	5.7	2.8	6.3	2.3	5.2	3.9	8.6	3.7	7.5	IND
Rotoehu	5.4	10.2	5.1	9.8	7.9	23.7	11.0	27.5	9.1	44.2	IND
Rotoiti	5.0	8.8	4.4	9.9	5.1	117.0	5.9	38.2	5.5	16.9	IND
Rotokakahi	4.8	10	2.6	8.1	4.8	14.3	2.7	9.5	3.3	14.8	👍
Rotoma	1.2	1.8	1.1	6.7	1.3	5.3	0.9	1.6	0.9	1.3	IND
Rotomahana	3.9	7.4	2.9	5.3	4.2	8.0	4.4	8.5	3.4	7.3	IND
Rotorua	9.4	31.0	10.0	15.7	11.9	20.1	9.9	28.7	8.3	12.7	👍
Tarawera	1.5	2.5	1.7	2.8	1.8	3.9	1.5	3.8	1.5	3.3	IND
Tikitapu	1.2	8.6	2.1	3.1	1.9	4.6	2	4.6	1.2	2.9	IND

Table 1d Annual Median and Maximum Ammonia Values (g/m³), from lake samples at depth (hypolimnium) (adjusted to pH=8).

Ammonia	2012		2013		2014		2015		2016		2017	
	Med	**Max**	**Med**	**Max**	**Med**	**Max**	**Med**	**Max**	**Med**	**Max**	**Med**	**Max**
Okareka	0.002	0.003	0.001	0.005	0.004	0.03	0.003	0.014	0.002	0.007	0.002	0.004
Okaro	0.32	1.174	0.536	0.893	0.409	1.143	0.443	0.846	0.562	0.956	0.344	0.653
Okataina	0	0.003	0	0.002	0	0.002	0.001	0.006	0.001	0.003	0.001	0.001
Rerewhakaaitu	0.003	0.017	0.004	0.033	0.002	0.008	0.001	0.007	0.002	0.007	0.002	0.004
Rotoehu	0.001	0.051	0.001	0.026	0.001	0.027	0.005	0.111	0.011	0.219	0.069	0.167
Rotoiti	0.005	0.06	0.005	0.039	0.009	0.053	0.01	0.058	0.009	0.065	0.005	0.01
Rotoma	0.001	0.004	0.001	0.004	0	0.004	0.001	0.006	0.002	0.004	0.001	0.001
Rotomahana	0	0.003	0	0	0	0.01	0	0.004	0	0.005	0.001	0.001
Rotorua	0.018	0.042	0.005	0.057	0.004	0.02	0.002	0.155	0.006	0.018	0.011	0.029
Tarawera	0.001	0.002	0.001	0.001	0.001	0.003	0.001	0.002	0.001	0.004		
Tikitapu	0	0.003	0	0.002	0.001	0.007	0.001	0.003	0.001	0.005	0.001	0.002

Table 1e Attribute state for E. coli in lakes, 2012 to 2017. N/A = no data.

					2012-2017	
Suitability for Primary Contact Recreation (Appendix 2, NPS-FM)	**PercentExceed540**	**PercentExceed260**	**Median**	**Percentile95**	**Overall**	**Suitable for Primary Contact Recreation**
Lake Okareka at Steep Street Reserve	0	1	12	170	A	Yes
Lake Okaro at Boat Ramp	1	1	5	56	A	Yes
Lake Rerewhakaaitu at Homestead Arm	1	1	17	160	A	Yes
Lake Rotoiti at Gisborne Point	0	0	2	32	A	Yes
Lake Rotoiti at Hinehopu	0	0	1	41	A	Yes
Lake Rotoiti at Okawa Bay	0	0	10	89	A	Yes
Lake Rotoma at Whangaroa	1	3	4	155	A	Yes
Lake Rotorua at Hamurana	4	4	14	125	A	Yes
Lake Rotorua at Holdens Bay	0	0	9	117	A	Yes
Lake Rotorua at Ngongotaha	6	11	14	600	B	Yes
Lake Tarawera at Rangiuru Bay	0	0	1	27	A	Yes
Lake Tikitapu at Beach	0	3	6	195	A	Yes

Table 1f *Attribute state for E. coli in rivers, 2013 to 2018. N/A = no data.*

Suitability for Primary Contact Recreation (Appendix 2, NPS-FM)	PercentExceed540	PercentExceed260	Median	Percentile95	2013-2018 Overall	2013-2018 Suitable for Primary Contact Recreation
Kaiate	32	62	355	3070	E	No
Kereu	4	4	6	478	A	Yes
Kopurererua at McCords	8	29	210	1160	D	No
Whakatāne at Landing Road	7	11	97	811	B	Yes
Ngongotaha	21	49	260	2365	D	No
Ohau Channel	1	4	21	191	A	Yes
Otara at SH35	5	13	51	797.5	B	Yes
Pongakawa at SH2	5	18	93	725	B	Yes
Puarenga	6	18	125	779	B	Yes
Rangitaiki at Boat Ramp	1	10	43	456	A	Yes
Rangitaiki at Te Teko	2	7	26	383	A	Yes
Tarawera at Boyce Park	3	7	74	376	A	Yes
Tauranga at Wardlaw Glade	7	8	25	987.5	B	Yes
Tuapiro	7	12	99	795	B	Yes
Uretara	16	39	190	3060	D	No
Utuhina at Lake Road	11	34	150	965	D	No
Waioeka at Mouth of Gorge	4	9	37	497.5	A	Yes
Waioeka at SH2	9	16	75	762.5	B	Yes
Wairoa at SH2	8	15	73	866	B	Yes
Wairoa Below McLaren	10	18	47	1200	C	Yes
Waitangi Soda Springs	1	4	14	272	A	Yes
Waiteti at SH36	10	19	140	1380	D	No

Table 1g Three-yearly average TLI values, annual TLI and trophic status category for the Te Arawa/Rotorua Lakes.

Lake *Regional Water & Land Plan Objective* *TLI units*	3-yearly average TLI to 2015 *TLI units*	3-yearly average TLI to 2016 *TLI units*	**3-yearly average TLI to 2017** ***TLI units***	2014/15 Annual TLI *TLI units*	2015/16 Annual TLI *TLI units*	**2016/17 Annual TLI**	Lake Type *based on Trophic Status*	*Regional Water & Land Plan Objective* *TLI units*
Ōkaro	**4.8**	**4.6**	**4.7**	**4.6**	**4.6**	**4.9**	Eutrophic	**5**
Rotorua	**4.3**	**4.3**	**4.3**	**4.4**	**4.4**	**4.1**	Eutrophic	**4.2**
Rotoehu	**4.1**	**4.3**	**4.5**	**4.5**	**4.6**	**4.6**	Eutrophic	**3.9**
Rotomahana	**3.9**	**3.9**	**4**	**4**	**4**	**4**	Mesotrophic	**3.9**
Rotoiti	**3.5**	**3.8**	**3.8**	**3.7**	**3.8**	**3.8**	Mesotrophic	**3.5**
Rerewhakaaitu	**3.4**	**3.4**	**3.4**	**3.3**	**3.4**	**3.5**	Mesotrophic	**3.6**
Okareka	**3.2**	**3.2**	**3.3**	**3.3**	**3.2**	**3.4**	Mesotrophic	**3**
Tikitapu	**2.8**	**2.9**	**2.8**	**2.9**	**2.9**	**2.6**	Oligotrophic	**2.7**
Ōkataina	**2.8**	**2.8**	**2.8**	**2.8**	**2.8**	**2.9**	Oligotrophic	**2.6**
Tarawera	**3**	**3**	**3.1**	**3.1**	**3**	**3.1**	Oligotrophic	**2.6**
Rotoma	**2.4**	**2.4**	**2.4**	**2.5**	**2.4**	**2.3**	Oligotrophic	**2.3**
*Rotokakahi**	***3.8***	***3.8***	***3.8***	***4***	***3.7***	***3.8***	Mesotrophic	***3.1***

Table 1h   Annual Median Nitrate Values (g/m³), rivers. For trends: N/A = No Data, IND = Indeterminate Trend 👎 = Ecologically meaningful degradation, 👍 = Ecologically meaningful improvement.

Site by WMA	2013		2014		2015		2016		*2017*		*10 Yr Trend*
	Med	95th	Med	95th	Med	95th	Med	95th	Med	95th	
Tauranga Harbour											
Aongatete River at SH2	0.267		0.145		0.304		0.255	0.649	0.271	0.585	N/A
Kopurererua at SH2	0.961	1.149	0.983	1.057	0.859	1.08	0.977	1.09	0.979	1.088	IND
Kopurererua at SH29	1.005	1.057	0.99	1.095	0.986	1.051	0.996	1.084	0.996	1.059	IND
Ngamuwahine at Old Bridge	0.192		0.154		0.224		0.212	0.339	0.212	0.329	N/A
Omanawa at SH29	1.28	1.319	1.235	1.317	1.19	1.271	1.15	1.238	1.151	1.226	IND
Rocky at Mangatawa	0.612		0.408		0.679		0.675	1.288	0.675	1.188	N/A
Te Mania at SH2	0.266	0.896	0.177	0.443	0.189	0.533	0.276	0.565	0.276	0.530	IND
Te Rereatukahia at SH2	0.258		0.163		0.359		0.33	0.666	0.319	0.672	N/A
Tuapiro at Surtees Road	0.089		0.012		0.103		0.086	0.25	0.087	0.242	N/A
Uretara at Henry Road Ford	0.245		0.067		0.217		0.211	0.585	0.211	0.491	N/A
Waiau at Road Ford	0.24		0.099		0.329		0.281	0.723	0.281	0.632	👍
Waimapu at 100m d/s of SH29	0.828	0.993	0.766	1.078	0.743	0.991	0.822	1.006	0.822	0.988	N/A
Waimapu at Pukemapui Road	0.618		0.462		0.615		0.605	0.863	0.605	0.847	N/A
Waipapa at Old Bridge	0.552		0.406		0.581		0.564	0.862	0.564	0.855	N/A
Wairoa at SH2 Bridge	0.444	0.522	0.363	0.527	0.366	0.551	0.396	0.526	0.396	0.502	👍
Wairoa d/s of Ruahihi	0.31		0.351		0.33		0.308	0.428	0.309	0.421	N/A
Waitao at Spensers farm	0.367	0.583	0.369	0.758	0.271	0.708	0.431	0.695	0.431	0.673	N/A
Waitekohe at SH2	0.103		0.017		0.154		0.114	0.353	0.114	0.369	N/A
Kaituna, Maketu, Pongakawa											
Kaituna at Maungarangi	0.298	0.298	0.281	0.384	0.29	0.363	0.247	0.295	0.247	0.294	IND
Kaituna at Lake Rotoiti Outlet	0.053	0.053	0.034	0.095	0.023	0.159	0.02	0.09	0.020	0.083	N/A

Site by WMA	2013		2014		2015		2016		*2017*		*10 Yr Trend*
	Med	95th	Med	95th	Med	95th	Med	95th	Med	95th	
Kaituna at Waitangi	0.614	0.802	0.568	0.722	0.603	0.748	0.492	0.585	0.493	0.584	N/A
Pongakawa at Old Coach	1.59		1.62		1.535	1.712	1.52	1.646	1.515	1.631	N/A
Pongakawa at SH2	1.415		1.585		1.495	1.672	1.485	1.61	1.485	1.608	N/A
Pongakawa at Forest	1.56		1.41		1.34	1.465	1.3	1.413	1.300	1.380	N/A
Waitahanui at SH2	0.675		0.75		0.71	0.969	0.722	1.042	0.7225	0.8836	N/A
Rotorua Lakes											
Ngongotahā at Town Bridge	0.821	0.864	0.8	0.846	0.791	0.875	0.8	0.991	0.800	0.953	N/A
Ōhau at SH33	0.104	0.104	0.041	0.147	0.032	0.185	0.015	0.238	0.015	0.190	N/A
Puarenga at FRI	0.734	0.734	0.802	0.889	0.785	0.969	0.791	1.042	0.791	1.009	N/A
Tarawera at Lake Outlet	0.001	0.004	0.001	0.006	0.001	0.002	0.001		0.001	0.45	IND
Tarawera											
Tarawera at Awakaponga	0.404	0.439	0.341	0.377	0.377	0.421	0.394	0.437	0.422	0.468	
Tarawera at Kawerau Bridge	0.262	0.39	0.249	0.269	0.244	0.266	0.246	0.279			IND
Tarawera at Caxton Footbridge			0.253	0.27	0.245	0.267	0.246	0.28	0.246	0.279	N/A
Tarawera atSH30 Bridge	0.279	0.322	0.258	0.276	0.263	0.283	0.262	0.296	0.262	0.294	N/A
Tarawera at Onepu Springs Road							0.264	0.291	0.264	0.291	N/A
Tarawera at Otakiri Road							0.362		0.362	0.389	N/A
Rangitāiki											
Rangitaiki at Matahina Dam		0.003	0.376		0.003		0.366	0.686	0.366	0.651	N/A
Rangitaiki at Te Teko	0.405	0.517	0.235	0.428	0.368	0.535	0.368		0.708	0.894	
Rangitāiki at Old Murupara Bridge	0.994	1.102	0.711	0.935	0.798	0.95	0.75		1.162	1.298	N/A
Rangitaiki at Aniwhenua Canal			0.448		0.305		0.636		0.597	0.712	N/A
Otamatea at Bridge			2.28		2.285		2.335	2.425	2.336	2.398	N/A
Rangitāiki at SH5			0.891		1.605		1.355	2.241	1.354	2.113	N/A
Whirinaki at Galatea Bridge	0.02	0.183	0.032	0.133	0.089	0.175	0.085		0.19	0.242	N/A

Site by WMA	2013		2014		2015		2016		*2017*		*10 Yr Trend*
	Med	95th	Med	95th	Med	95th	Med	95th	Med	95th	
Whakatane and Waimana											
Tauranga at Taneatua					0.156	0.076	0.162	0.393	0.163	0.353	N/A
Tauranga at Ranger Station			0.014	0.083	0.014	0.075	0.046		0.047	0.093	N/A
Whakatāne at Rūātoki			0.058		0.064	0.114	0.044	0.132	0.044	0.119	N/A
Whakatāne at Pekatahi	0.045	0.376	0.096	0.226	0.113	0.239	0.121	0.418	0.102	0.302	N/A
Ohiwa Harbour and Waiotahi											
Waiotahi at Toone Road			0.058		0.05	0.17	0.059	0.198	0.060	0.155	N/A
Nukuhou at Old Quarry	0.259	0.737	0.295	0.846	0.291	0.873	0.563	1.199	0.563	1.056	N/A
Waioeka and Otara											
Otara at Brown's Bridge			0.052		0.055	0.179	0.071	0.224	0.071	0.180	N/A
Waioeka at Gorge Mouth	0.008	0.191	0.013	0.212	0.03	0.192	0.07	0.183	0.070	0.155	IND
East Coast											
Mōtū at SH35	0.029	0.128	0.037	0.185	0.068	0.095	0.072		0.06	0.186	N/A
Mōtū at Waitangirua	0.113	0.406	0.04	0.358	0.229	0.537	0.279		0.199	0.514	N/A
Haparapara at SH35			0.031		0.031	0.088	0.029	0.085	0.030	0.078	N/A
Kereu at SH35			0.022		0.016	0.067	0.035	0.138	0.035	0.118	
Raukokore at SH35			0.034		0.02	0.075	0.047	0.102	0.047	0.096	N/A

Table 1i *Annual Median and Maximum Ammonia Values (g/m³), rivers (adjusted to pH=8). For trends: N/A = No Data, IND = Indeterminate Trend 👎 = Ecologically meaningful degradation, 👍 = Ecologically meaningful improvement.*

Site by WMA	2013		2014		2015		2016		*2017*		*10 Yr Trend*
	Med	Max	Med	Max	Med	Max	Med	Max	Med	Max	
Tauranga Harbour											
Aongatete River at SH2	0.002	0.003	0.0011	0.0173	0.002	0.002	0.002	0.004	0.002	0.004	N/A
Kopurererua at SH2	0.018	0.084	0.018	0.063	0.022	0.075	0.047	0.167	0.047	0.167	IND
Kopurererua at SH29	0.004	0.01	0.0062	0.0134	0.005	0.014	0.014	0.05	0.014	0.050	IND
Ngamuwahine at Old Bridge	0.001	0.002	0.0011	0.0022	0.002	0.003	0.003	0.006	0.003	0.006	N/A
Omanawa at SH29	0.002	0.004	0.0025	0.0039	0.002	0.004	0.004	0.007	0.004	0.007	👍
Rocky at Mangatawa	0.058	0.085	0.0349	0.1007	0.081	0.107	0.008	0.124	0.008	0.124	N/A
Te Mania at SH2	0.006	0.04	0.0049	0.0083	0.006	0.008	0.008	0.014	0.008	0.014	👍
Te Rereatukahia at SH2	0.001	0.003	0.0013	0.0023	0.002	0.003	0.003	0.005	0.003	0.008	N/A
Tuapiro at Surtees Road	0.002	0.002	0.0015	0.023	0.002	0.004	0.002	0.013	0.002	0.013	N/A
Uretara at Henry Road Ford	0.003	0.016	0.0019	0.0041	0.002	0.002	0.002	0.005	0.002	0.005	N/A
Waiau at Road Ford	0.002	0.005	0.0034	0.0155	0.003	0.005	0.004	0.02	0.004	0.020	N/A
Waimapu at 100m d/s of SH29	0.006	0.012	0.0072	0.0187	0.007	0.01	0.009	0.025	0.009	0.025	N/A
Waimapu at Pukemapui Road	0.003	0.009	0.0063	0.0082	0.003	0.005	0.004	0.021	0.004	0.021	N/A
Waipapa at Old Bridge	0.003	0.004	0.0037	0.0043	0.003	0.005	0.005	0.007	0.005	0.049	N/A
Wairoa at SH2 Bridge	0.005	0.007	0.0035	0.0241	0.006	0.014	0.007	0.013	0.007	0.013	IND
Wairoa d/s of Ruahihi	0.004	0.005	0.0031	0.0072	0.003	0.004	0.005	0.007	0.005	0.007	N/A
Waitao at Spensers farm	0.008	0.012	0.0066	0.014	0.008	0.01	0.007	0.013	0.007	0.013	N/A
Waitekohe at SH2	0.001	0.003	0.0018	0.0132	0.002	0.003	0.002	0.004	0.003	0.126	N/A
Kaituna, Maketu and Pongakawa											
Kaituna at Maungarangi	0.002	0.004	0.0021	0.0037	0.003	0.005	0.004	0.009	0.004	0.009	👍
Kaituna at Lake Rotoiti Outlet	0.005	0.016	0.0063	0.0112	0.006	0.015	0.005	0.015	0.005	0.015	N/A
Kaituna at Waitangi	0.014	0.034	0.0122	0.0219	0.018	0.038	0.016	0.032	0.016	0.032	N/A

Site by WMA	2013		2014		2015		2016		*2017*		***10 Yr Trend***
	Med	**Max**	**Med**	**Max**	**Med**	**Max**	**Med**	**Max**	**Med**	**Max**	
Pongakawa at Old Coach	0.003	0.005	0.002	0.0046	0.003	0.012	0.004	0.006	0.004	0.006	N/A
Pongakawa at SH2	0.003	0.015	0.0028	0.0042	0.005	0.02	0.009	0.022	0.009	0.022	N/A
Pongakawa at Forest	0.001	0.003	0.0004	0.0011	0.001	0.001	0.001	0.003	0.001	0.003	N/A
Waitahanui at SH2	0.004	0.013	0.0019	0.0034	0.003	0.007	0.006	0.021	0.006	0.023	N/A
Rotorua Lakes											
Ngongotahā at Town Bridge	0.005	0.008	0.006	0.0073	0.006	0.009	0.007	0.017	0.007	0.017	N/A
Ōhau at SH33	0.006	0.039	0.0047	0.0072	0.003	0.015	0.005	0.062	0.005	0.183	N/A
Puarenga at FRI	0.026	0.034	0.0331	0.0832	0.038	0.055	0.04	0.053	0.040	0.053	N/A
Tarawera at Lake Outlet	0.001	0.007	0.001	0.0034	0.001	0.004	0.001	0.004	0.001	0.003	IND
Tarawera											
Tarawera at Awakaponga	0.021	0.028	0.0159	0.023	0.023	0.037	0.027	0.032	0.027	0.035	IND
Tarawera at Kawerau Bridge	0.002	0.004	0.0022	0.0031	0.003	0.004	0.003	0.004			N/A
Tarawera at Onepu Springs Road							0.025	0.03	0.024	0.030	N/A
Tarawera at Caxton Footbridge			0.0164	0.0201	0.016	0.02	0.016	0.019	0.016	0.019	N/A
Tarawera at Otakiri Road							0.034	0.053	0.035	0.053	N/A
Tarawera atSH30 Bridge	0.036	0.17	0.0284	0.0412	0.055	0.085	0.048	0.074	0.050	0.074	N/A
Rangitaiki											
Rangitaiki at Matahina Dam			0.004	0.0421	0.005	0.02	0.007	0.048	0.007	0.048	N/A
Rangitaiki at Te Teko	0.004	0.008	0.0048	0.0072	0.005	0.008	0.005	0.01	0.004	0.01	N/A
Rangitāiki at Murupara	0.006	0.008	0.007	0.0113	0.005	0.02	0.005	0.02	0.003	0.004	N/A
Rangitaiki at Aniwhenua Canal			0.0077	0.0107	0.008	0.049	0.01	0.013	0.010	0.013	N/A
Otamatea at Bridge			0.0027	0.0049	0.002	0.01	0.003	0.007	0.003	0.007	N/A
Rangitāiki at SH5			0.0063	0.0149	0.006	0.008	0.006	0.01	0.006	0.010	N/A
Whirinaki at Galatea Bridge	0.003	0.008	0.002	0.0048	0.003	0.006	0.002	0.004	0.002	0.005	N/A

Site by WMA	2013		2014		2015		2016		*2017*		*10 Yr Trend*
	Med	Max	Med	Max	Med	Max	Med	Max	Med	Max	
Whakatane and Waimana											
Tauranga at Taneatua					0.003	0.016	0.004	0.012	0.004	0.012	N/A
Tauranga at Ranger Station			0.0006	0.0026	0.001	0.003	0.002	0.006	0.002	0.006	N/A
Whakatāne at Rūātoki			0.0018	0.0031	0.002	0.006	0.002	0.009	0.002	0.009	N/A
Whakatāne at Pekatahi	0.002	0.007	0.0021	0.0057	0.003	0.008	0.004	0.007	0.003	0.007	N/A
Ohiwa Harbour and Waiotahi											
Waiotahi at Toone Road			0.003	0.0052	0.003	0.009	0.004	0.008	0.004	0.008	N/A
Nukuhou at Old Quarry	0.007	0.066	0.0087	0.0198	0.01	0.048	0.017	0.052	0.017	0.052	N/A
Waioeka and Otara											
Otara at Brown's Bridge			0.0012	0.0021	0.002	0.009	0.002	0.004	0.002	0.004	N/A
Waioeka at Gorge Mouth	0.001	0.003	0.0005	0.0017	0.001	0.002	0.002	0.004	0.002	0.004	👍
East Coast											
Mōtū at SH35	0.002	0.007	0.0019	0.0057	0.002	0.008	0.002	0.008	0.004	0.011	👍
Mōtū at Waitangirua	0.003	0.007	0.0053	0.0148	0.006	0.012	0.007	0.023	0.005	0.009	N/A
Raukokore at SH35			0.0009	0.0043	0.001	0.041	0.002	0.007	0.002	0.007	N/A
Kereu at SH 35			0.0007	0.0011	0.001	0.002	0.001	0.004	0.001	0.004	N/A
Haparapara at SH35	0.002	0.004	0.0005	0.0022	0.001	0.024	0.001	0.004	0.001	0.004	N/A

Table 1j Attribute state for water temperature based on the Cox Rutherford Index.

		Summer					
		2012/13	2013/14	2014/15	2015/16	2016/17	2017/18
Site Name	**Climate Class**	**CRI**	**CRI**	**CRI**	**CRI**	**CRI**	**CRI**
Tauranga Harbour							
Kaiate at Falls Road	Eastern Dry/Lowland					20.6	23.5
Te Mania at SH2	Eastern Dry/Lowland	21.1	20.8	21.5	22.3	22.9	21.8
Wairoa above Ruahihi	Eastern Dry/Lowland	20.0	19.3	19.8	20.7	19.9	20.7
Kaituna							
Kaituna at Te Matai	Eastern Dry/Lowland		18.4	19.3	17.3	20.6	21.8
Mangorewa at Saunders	Maritime/Upland				16.4	16.0	16.5
Raparapahoe at Drop Structure	Eastern Dry/Lowland					19.9	21.0
Waitahanui at Ōtamarākau	Eastern Dry/Lowland		15.6	15.8	15.8	16.4	16.4
Waiari upstream of Kaituna confluence	Eastern Dry/Lowland					17.0	17.5
Tarawera							
Tarawera at Awakaponga	Eastern Dry/Lowland	21.0	19.9	21.3	21.3	20.3	20.7
Tarawera at Otartiki Road	Eastern Dry/Lowland					20.3	20.6
Rangitaiki							
Rangitāiki downstream Edgecumbe	Eastern Dry/Lowland					20.7	21.4
Rangitaiki Downstream of Murupara	Maritime/Upland					17.3	19.7
Rangitaiki at SH5	Maritime/Upland				14.6	15.0	15.2
Whakatāne and Tauranga							
Wainui Te Whara at Mokorua George	Eastern Dry/Lowland				21.3	21.2	20.9

Appendix 2

Calculated ecological bands for invertebrate metrics based on their three year average (2014-2017)

Table 2a *Calculated ecological bands for invertebrate metrics based on their three year average (2014-2017). The table shows which Water Management Area (WMA) each site belongs to, as well as its geology/slope biophysical classification (NonVA/Stp = non-volcanic/steep grade catchments; VA/Gtl = volcanic gentle grade catchments; VA/Stp = volcanic steep grade catchments).*

WMA	Site_ID	Site Name	Geol/Slope	Landcover	MCI	EPR_r	BoP_IBI	Overall Grade
East coast	BOP_NERM_067	Waiiti at SH35	NonVA/Stp	Native	C	A	B	Good
	BOP_NERM_099	Waitawake SH35 at Site 2	NonVA/Stp	Native	B	A	B	Good
	BOP_NERM_100	Whanarua	NonVA/Stp	Native	A	A	B	Very Good
	BOP_NERM_110	Oteakona Stream_Pine	NonVA/Stp	Exotic_Forest	A	A	C	Very Good
	BOP_NERM_110001	Whangaparaoa	NonVA/Stp	Agriculture	C	A	B	Good
	BOP_NERM_110002	Raukokore	NonVA/Stp	Native	B	B	C	Fair
	BOP_NERM_110003	Motu	NonVA/Stp	Native	A	A	C	Very Good
	BOP_NERM_110004	Waiaua	NonVA/Stp	Native	C	A	B	Good
	BOP_NERM_111	Oteakona Stream_Native	NonVA/Stp	Native	A	A	C	Very Good
	BOP_NERM_113	Tributary into Harparapa River on SH35	NonVA/Stp	Exotic_Forest	B	A	C	Good
	BOP_NERM_114	Tributary into Harparapa River_1 km u/s of SH35	NonVA/Stp	Exotic_Forest	A	A	C	Very Good

WMA	Site_ID	Site Name	Geol/Slope	Landcover	MCI	EPR_r	BoP_IBI	Overall Grade
	BOP_NERM_115	Waewaetukuku Stream	NonVA/Stp	Exotic_Forest	B	A	B	Good
	BOP_NERM_116	Kopua Stream	NonVA/Stp	Exotic_Forest	A	A	B	Very Good
	BOP_NERM_117	Nahunahu Stream	NonVA/Stp	Exotic_Forest	A	A	C	Very Good
Kaituna_Maketu	BOP_NERM_125	Domain Road, Pāpāmoa	NonVA/Gtl	Urban	D	D	C	Poor
	BOP_NERM_001	Waiari Tributary at SH2	VA/Gtl	Agriculture	B	A	B	Good
	BOP_NERM_002	Ohineangaanga	VA/Gtl	Agriculture	B	A	C	Good
	BOP_NERM_003	Kaikokopu	VA/Gtl	Agriculture	C	A	D	Good
	BOP_NERM_004	Waikoko	VA/Gtl	Agriculture	B	A	B	Good
	BOP_NERM_009	Mangatoetoe	VA/Gtl	Agriculture	C	B	D	Fair
	BOP_NERM_010	Waiari at Roydon Downs Road	VA/Gtl	Agriculture	B	A	C	Good
	BOP_NERM_032	Pongakawa Tributary at Rotoehu Road	VA/Gtl	Exotic_Forest	C	A	C	Good
	BOP_NERM_033	Pongakawa at SH2	VA/Gtl	Agriculture	C	B	D	Fair
	BOP_NERM_042	Ohaupara	VA/Gtl	Native	B	A	B	Good
	BOP_NERM_118	Tributary into Onaia Stream	VA/Gtl	Exotic_Forest	D	D	D	Poor
	BOP_NERM_124	Ohineangaanga at SH2	VA/Gtl	Agriculture	C	B	D	Fair
	BOP_NERM_005	Raparapahoe	VA/Stp	Agriculture	C	A	D	Good
	BOP_NERM_006	Whataroa	VA/Stp	Native	A	A	A	Very Good
	BOP_NERM_031	Pungarehu	VA/Stp	Exotic_Forest	A	A	C	Very Good
	BOP_NERM_119	Tributary into Kaituna River_Maungarangi Road	VA/Stp	Exotic_Forest	A	A	B	Very Good
Ohiwa	BOP_NERM_107	Ruakaka Stream	NonVA/Stp	Exotic_Forest	C	A	A	Very Good
	BOP_NERM_108	Oruamanganui Stream	NonVA/Stp	Exotic_Forest	C	A	C	Good
	BOP_NERM_109	Panuiahine Stream	NonVA/Stp	Exotic_Forest	C	A	B	Good
	BOP_NERM_068	Waiwhakatoitoi	VA/Gtl	Agriculture	C	C	D	Fair
	BOP_NERM_069	Kutarere	VA/Stp	Agriculture	B	A	B	Good

WMA	Site_ID	Site Name	Geol/Slope	Landcover	MCI	EPR_r	BoP_IBI	Overall Grade
	BOP_NERM_072	Ohiwa Tributary at Burma Road	VA/Stp	Exotic_Forest	A	A	A	Very Good
	BOP_NERM_073	Maraetotara (Maraetotara Road)	VA/Stp	Agriculture	C	A	C	Good
	BOP_NERM_096	Maraetotara at Maraetotara/ Burma Road intersection	VA/Stp	Native	A	A	A	Very Good
	BOP_NERM_097	Ohope at Ohope Hill Base	VA/Stp	Native	B	A	A	Very Good
	BOP_NERM_098	Ohope Tributary at Pohutakawa Ave School	VA/Stp	Native	B	A	B	Good
	BOP_NERM_110007	Nukuhou	VA/Stp	Agriculture	C	A	C	Good
Rangitaiki	BOP_NERM_019	Pahekeheke Stream	VA/Gtl	Exotic_Forest	B	A	B	Good
	BOP_NERM_049	Ngakauroa Creek	VA/Gtl	Agriculture	D	C	D	Poor
	BOP_NERM_101	Kakahotoa Stream	VA/Gtl	Exotic_Forest	C	A	C	Good
	BOP_NERM_102	Moetahanga Stream	VA/Gtl	Exotic_Forest	A	A	B	Very Good
	BOP_NERM_103	Mangaharakeke Stream	VA/Gtl	Agriculture	A	A	B	Very Good
	BOP_NERM_104	Pekepeke Stream_Upper	VA/Gtl	Exotic_Forest	B	A	B	Good
	BOP_NERM_105	Flaxy Creek	VA/Gtl	Exotic_Forest	B	A	B	Good
	BOP_NERM_106	Otangimoana Stream	VA/Gtl	Agriculture	B	A	B	Good
	BOP_NERM_021	Mangapapa	VA/Stp	Exotic_Forest	A	A	B	Very Good
	BOP_NERM_039	Hikurangi at Grant Road	VA/Stp	Agriculture	B	A	B	Good
	BOP_NERM_040	Haumea	VA/Stp	Agriculture	B	A	B	Good
	BOP_NERM_041	Mangamate	VA/Stp	Native	A	A	A	Very Good
	BOP_NERM_110014	Whirinaki	VA/Stp	Native	A	A	B	Very Good
Rotorua Lakes	BOP_NERM_126	Waiowhiro, Rotorua	VA/Gtl	Urban	C	B	D	Fair
	BOP_NERM_127	Utuhina at Great West Road	VA/Gtl	Native	B	B	D	Fair
	BOP_NERM_128	Utuhina at Substation	VA/Gtl	Agriculture	B	B	D	Fair

WMA	Site_ID	Site Name	Geol/Slope	Landcover	MCI	EPR_r	BoP_IBI	Overall Grade
	BOP_NERM_129	Utuhina at Depot Street	VA/Gtl	Urban	B	A	C	Good
	BOP_NERM_013	Puarenga	VA/Gtl	Agriculture	B	A	B	Good
	BOP_NERM_014	Mangakakahi	VA/Gtl	Agriculture	B	A	D	Good
	BOP_NERM_016	Waingaehe at SH30	VA/Gtl	Agriculture	B	B	C	Fair
	BOP_NERM_020	Mangakino	VA/Gtl	Agriculture	C	A	D	Good
	BOP_NERM_035	Ngongotaha at Paradise Valley Road	VA/Gtl	Agriculture	B	A	B	Good
	BOP_NERM_036	Ngongotaha at Hamurana Road	VA/Gtl	Agriculture	B	A	C	Good
	BOP_NERM_037	Waiteti	VA/Gtl	Agriculture	C	B	C	Fair
	BOP_NERM_046	Te Toroa Tributary	VA/Gtl	Agriculture	B	B	C	Fair
	BOP_NERM_047	Waiohewa	VA/Gtl	Agriculture	B	A	B	Good
	BOP_NERM_071	Tupapakurua	VA/Gtl	Agriculture	C	C	C	Fair
	BOP_NERM_012	Te Pohue	VA/Stp	Agriculture	A	A	B	Very Good
	BOP_NERM_015	Okareka Tributary	VA/Stp	Agriculture	C	A	D	Good
	BOP_NERM_038	Wairoa	VA/Stp	Exotic_Forest	D	B	D	Poor
	BOP_NERM_048	Waiiti at SH30	VA/Stp	Native	B	A	B	Good
Tarawera	BOP_NERM_027	Awakaponga canal at Matata Road	VA/Gtl	Agriculture	D	C	D	Poor
	BOP_NERM_110020	Tarawera	VA/Gtl	Native	D	B	D	Poor
	BOP_NERM_007	Mimiha	VA/Stp	Agriculture	A	A	A	Very Good
	BOP_NERM_008	Waikamihi	VA/Stp	Agriculture	A	A	B	Very Good
	BOP_NERM_011	Waikanapiti	VA/Stp	Native	A	A	A	Very Good
	BOP_NERM_022	Mangate	VA/Stp	Exotic_Forest	A	A	B	Very Good
	BOP_NERM_023	Buddles Creek	VA/Stp	Native	A	A	A	Very Good
	BOP_NERM_024	Kaipara	VA/Stp	Native	A	A	B	Very Good

WMA	Site_ID	Site Name	Geol/Slope	Landcover	MCI	EPR_r	BoP_IBI	Overall Grade
	BOP_NERM_028	Awakaponga at Manawahe Road	VA/Stp	Agriculture	A	A	A	Very Good
	BOP_NERM_029	Pikowai Stream at Pikowai Road	VA/Stp	Agriculture	B	A	B	Good
	BOP_NERM_043	Mangaone	VA/Stp	Native	B	A	B	Good
	BOP_NERM_044	Ruruanga at Tamarangi Drive	VA/Stp	Native	A	A	A	Very Good
	BOP_NERM_045	Ruruanga at Valley Road	VA/Stp	Native	A	A	B	Very Good
	BOP_NERM_050	Awatarariki	VA/Stp	Native	A	A	A	Very Good
	BOP_NERM_054	Karaponga	VA/Stp	Agriculture	A	A	B	Very Good
Tauranga	BOP_NERM_057	Uretara at Wharawhara Road	VA/Gtl	Agriculture	C	B	C	Fair
	BOP_NERM_062	Boyd	VA/Gtl	Agriculture	C	A	C	Good
	BOP_NERM_077	Wainui at Tim Road	VA/Gtl	Native	B	A	A	Very Good
	BOP_NERM_078	Waioraka	VA/Gtl	Urban	D	C	D	Poor
	BOP_NERM_079	Otumanga	VA/Gtl	Urban	D	C	D	Poor
	BOP_NERM_080	Kaitemako	VA/Gtl	Agriculture	C	C	D	Fair
	BOP_NERM_081	Oturu	VA/Gtl	Agriculture	D	D	D	Poor
	BOP_NERM_082	Kopurererua	VA/Gtl	Agriculture	D	C	D	Poor
	BOP_NERM_085	Tuapo	VA/Gtl	Agriculture	B	A	C	Good
	BOP_NERM_086	Waipapa Tributary at Waipapa block Road	VA/Gtl	Agriculture	C	A	C	Good
	BOP_NERM_087	Waipapa Tributary at Plummer Road	VA/Gtl	Agriculture	C	A	B	Good
	BOP_NERM_088	Mangawhai	VA/Gtl	Agriculture	C	C	D	Fair
	BOP_NERM_089	Te Puna Tributary	VA/Gtl	Agriculture	B	A	B	Good
	BOP_NERM_090	Ohaurere	VA/Gtl	Agriculture	C	A	D	Good
	BOP_NERM_091	Kaukaumoutiti Tributary	VA/Gtl	Agriculture	D	B	D	Poor

WMA	Site_ID	Site Name	Geol/Slope	Landcover	MCI	EPR_r	BoP_IBI	Overall Grade
	BOP_NERM_092	Piako	VA/Gtl	Native	A	A	B	Very Good
	BOP_NERM_110035	Ngamuwahine	VA/Gtl	Native	A	A	B	Very Good
	BOP_NERM_055	Tahawai	VA/Stp	Agriculture	C	B	B	Fair
	BOP_NERM_056	Tuapiro at McMillan Road	VA/Stp	Native	C	A	C	Good
	BOP_NERM_058	Uretara at Rea Road	VA/Stp	Native	A	A	A	Very Good
	BOP_NERM_059	Aongatete	VA/Stp	Native	A	A	B	Very Good
	BOP_NERM_060	Waihi at Oceanview Road	VA/Stp	Native	D	C	D	Poor
	BOP_NERM_061	Waiau	VA/Stp	Agriculture	B	A	C	Good
	BOP_NERM_063	Ngutaturu	VA/Stp	Agriculture	C	A	B	Good
	BOP_NERM_064	Te Mania	VA/Stp	Agriculture	B	A	A	Very Good
	BOP_NERM_065	Waitekohe at SH2 Bridge	VA/Stp	Native	C	A	A	Very Good
	BOP_NERM_075	Waitao	VA/Stp	Agriculture	B	A	B	Good
	BOP_NERM_083	Tuapiro at Woodlands Road	VA/Stp	Native	A	A	A	Very Good
	BOP_NERM_093	Waitekohe at Thompsons Track	VA/Stp	Native	A	A	B	Very Good
	BOP_NERM_094	Owairoa	VA/Stp	Native	A	A	A	Very Good
	BOP_NERM_095	Te Rereatukahia at Hot Springs Road	VA/Stp	Native	A	A	A	Very Good
	BOP_NERM_710015	Tuapiro	VA/Stp	Native	A	A	A	Very Good
Waioeka-Otara	BOP_NERM_110005	Otara	NonVA/Stp	Native	B	A	B	Good
	BOP_NERM_110006	Waioweka	NonVA/Stp	Native	B	A	B	Good
	BOP_NERM_112	Tributary into Taipouri Stream	NonVA/Stp	Exotic_Forest	A	A	A	Very Good
Whakatane	BOP_NERM_025.2	Wainui Te Whara at King Street	VA/Gtl	Urban	C	A	D	Good
	BOP_NERM_025	Wainui Te Whara at Gorge Road	VA/Stp	Native	B	A	A	Very Good

WMA	Site_ID	Site Name	Geol/Slope	Landcover	MCI	EPR_r	BoP_IBI	Overall Grade
	BOP_NERM_025.1	Wainui Te Whara at upper footbridge	VA/Stp	Native	B	A	B	Good
	BOP_NERM_026	Te Rahu Canal	VA/Stp	Agriculture	D	B	D	Poor
	BOP_NERM_051	Waioho	VA/Stp	Native	C	A	C	Good
	BOP_NERM_110008	Tauranga at Gorge	VA/Stp	Native	A	A	A	Very Good
	BOP_NERM_110009	Tauranga at Ogilvie Bridge	VA/Stp	Native	A	A	A	Very Good
	BOP_NERM_110010	Whakatane at Ruatoki	VA/Stp	Native	B	A	A	Very Good
	BOP_NERM_110011	Whakatane at Pekatahi	VA/Stp	Native	B	A	B	Good
	BOP_NERM_120	Opurana Stream	VA/Stp	Exotic_Forest	B	A	B	Good
	BOP_NERM_121	Paekoau Stream	VA/Stp	Exotic_Forest	B	A	A	Very Good
	BOP_NERM_122	Owhaktoro Stream	VA/Stp	Native	A	A	A	Very Good
	BOP_NERM_123	Kotorenui Stream	VA/Stp	Exotic_Forest	B	B	B	Fair

Appendix 3

Calculated LakeSPI scores in the 12 Te Arawa/Rotorua Lakes (1980s to 2018)

Table 3a Calculated LakeSPI scores in 12 Rotorua Lakes (1980s to 2018), showing their calculated bands based on the % change between successive surveys and the earliest LakeSPI score.

Lake	Year	LakeSPI score	% Reduction	Band
Okareka	1980	40	0.0	A
	1988	44	10.0	A
	2001	41	2.5	A
	2003	34	-15.0	C
	2006	34	-15.0	C
	2009	34	-15.0	C
	2011	35	-12.5	C
	2013	36	-10.0	C
	2015	55	37.5	A
	2017	50	25	A
Okaro	1982	31	0.0	A
	1989	22	-29.0	D
	2003	19	-38.7	D
	2006	19	-38.7	D
	2009	21	-32.3	D
	2011	27	-12.9	C
	2013	35	12.9	A
	2015	28	-9.7	C
	2017	49	58.1	A
Okataina	1981	51	0.0	A
	1988	47	-7.8	C
	2001	43	-15.7	D
	2005	44	-13.7	C
	2008	48	-5.9	C
	2009	45	-11.8	C
	2010	44	-13.7	C

Lake	Year	LakeSPI score	% Reduction	Band
	2012	44	-13.7	C
	2014	40	-21.6	D
	2016	38	-25.5	D
	2018	44	-13.7	C
Rerewhakaaitu	1973	55	0.0	A
	1988	41	-25.5	D
	2001	35	-36.4	D
	2005	38	-30.9	D
	2008	41	-25.5	D
	2010	34	-38.2	D
	2012	36	-34.5	D
	2014	40	-27.3	D
	2016	31	-43.6	D
	2018	32	-41.8	D
Rotoehu	1988	30	0.0	A
	2003	34	13.3	A
	2006	23	-23.3	D
	2008	19	-36.7	D
	2010	16	-46.7	D
	2012	18	-40.0	D
	2014	18	-40.0	D
	2016	19	-36.7	D
	2018	20	-33.3	D
Rotoiti	1981	26	0.0	A
	1988	26	0.0	A
	2001	20	-23.1	D
	2003	18	-30.8	D
	2006	18	-30.8	D
	2009	21	-19.2	D
	2011	20	-23.1	D
	2013	21	-19.2	D
	2015	20	-23.1	D
	2017	19	-36.7	D
Rotokakahi	1988	52	0.0	A
	2005	32	-38.5	D
	2008	31	-40.4	D
	2010	28	-46.2	D
	2012	31	-40.4	D

Lake	Year	LakeSPI score	% Reduction	Band
	2014	26	-50.0	D
	2016	30	-42.3	D
	2018	28	-46.2	D
Rotoma	1988	50	0.0	A
	2001	49	-2.0	A
	2005	51	2.0	A
	2008	48	-4.0	A
	2009	48	-4.0	A
	2011	51	2.0	A
	2013	55	10.0	A
	2015	54	8.0	A
	2017	52	4.0	A
	1988	72	0.0	A
Rotomahana	2002	74	2.8	A
	2005	69	-4.2	A
	2008	66	-8.3	C
	2009	63	-12.5	C
	2011	52	-27.8	D
	2013	42	-41.7	D
	2015	54	-25.0	D
	2017	62	-16.2	D
Rotorua	1982	27	0.0	A
	1988	18	-33.3	D
	2001	22	-18.5	D
	2003	22	-18.5	D
	2006	22	-18.5	D
	2009	27	0.0	A
	2011	20	-25.9	D
	2013	23	-14.8	C
	2015	28	3.7	A
	2017	36	33.3	A
Tarawera	1988	54	0.0	A
	1994	41	-24.1	D
	2005	28	-48.1	D
	2008	22	-59.3	D
	2010	25	-53.7	D
	2012	24	-55.6	D
	2014	25	-53.7	D

Lake	Year	LakeSPI score	% Reduction	Band
	2016	25	-53.7	D
	2018	27	-50.0	D
Tikipatu	1988	63	0.0	A
	2001	57	-9.5	C
	2005	48	-23.8	D
	2008	32	-49.2	D
	2010	34	-46.0	D
	2012	41	-34.9	D
	2014	45	-28.6	D
	2016	44	-30.2	D
	2018	32	-49.2	D

Appendix 4

Results of periphyton monitoring, showing bands for both chlorophyll a and cover of benthic cyanobacteria

Table 4a Results of periphyton monitoring, showing bands for both chlorophyll a and cover of benthic cyanobacteria.

Name	Class	Chlorophyll-*a* biomass (mg/cm²)			Benthic cyanobacterial cover (%)		
		Percentile92	Number of samples	Attribute Band	80thPercentile	Number of samples	Attribute Band
Aongatete at Lockington Road Quarry	Default	63.5105	23	B	0.45	28	A
Atuarere at Waiotahe Valley Road	Default	100.6734	21	B	0	24	A
Horomanga at Galatea Road	Default	91.10764	13	B	0	25	A
Horomanga u/s Troutbeck Road	Default	21.22951	12	A	0	24	A
Manganuku u/s SH2	Default	5.578972	11	A	0	24	A
Mangaonuku at Takaputahi	Default	18.667	18	A	0	26	A
Mangapae at Ruatahuna Road	Default	31.51082	18	A	0.55	23	A
Mimiha at Ruatahuna Road	Default	17.77022	18	A	0	24	A
Ngamuwahine at Reserve	Default	80.55363	17	B	8.6	27	A
Ohutu at Troutbeck Road	Default	35.2107	10	A	0	23	A
Omaukora at Wairata	Default	22.48566	13	A	0	24	A
Oruamanganui at Waiotahe Valley Road	Default	62.66637	23	B	0	26	A
Otangimoana at Forestry Road	Default	15.22675	8	A	0	20	A

Name	Class	Chlorophyll-*a* biomass (mg/cm^2)			Benthic cyanobacterial cover (%)		
		Percentile92	Number of samples	Attribute Band	80thPercentile	Number of samples	Attribute Band
Otangimoana at Matea Road	Default	60.57121	16	B	0	26	A
Owhakatoro at Owhakatoro	Default	47.55788	13	A	0	22	A
Raroa at Raroa Road	Default	25.7798	14	A	0	25	A
Tauranga at Wardlaw Glade	Default	78.9101	11	B	0	24	A
Te Rereatukahia at SH2	Default	93.83622	22	B	9.55	28	A
Tuapiro at Farm Bridge	Default	126.7484	23	C	0	27	A
Tutaetoko at Tutaetoko Road	Default	10.58553	13	A	0	22	A
Waiaua d/s Oiratiti	Default	34.04851	16	A	0	26	A
Waihua at Galatea Road	Default	25.69183	16	A	0	28	A
Waikokopu at Galatea Road	Default	36.99272	18	A	0	26	A
Waiotahe at 1100 Waiotahe Valley Road	Default	14.60509	14	A	0	25	A
Waiotahe d/s Kahunui Village Trust	Default	7.194969	17	A	0	25	A
Waitekohe at SH2	Default	123.1118	26	C	13.85	28	A
Waitukuaruhe at Ngaupokotangata confluence	Default	12.81586	20	A	0	25	A
Whakatane at Pekatahi Bridge	Default	38.83315	8	A	0	24	A
Whirinaki u/s Waiparera confluence	Default	19.75931	14	A	0	23	A

Appendix 5

Example of LakeSPI attribute banding

Consider a hypothetical situation where a LakeSPI score declines by five units every two years, due to a variety of stressors on the macrophyte communities. Using the percentage change relative to the previous survey, this hypothetical lake would only score a D band in the last survey in 2017 (Table 5a). The gradual decline prior to this would not necessarily result in any interventions by Council, as the lake would be in the B or C band until the most recent 2017 survey. By this time, it may be too late to undertake any realistic intervention to improve LakeSPI scores. If, however, the LakeSPI scores were always compared to the earliest scores, then clearly the LakeSPI score would have reduced to an unacceptable state by the 2005 survey (Table 5a). At this time, BOPRC would likely be expected to implement actions to address the further decline of LakeSPI score.

Table 5a Hypothetical changes in LakeSPI scores over an 18 year period showing the differences in banding based on whether the percent change is simply between consecutive surveys (%change), or based on a percentage change to the earliest survey (% change from earliest). Shading as per Table 21.

Year	LakeSPI	% change	% change band	% change from earliest	% change earliest band
1999	70				
2001	65	7.1	B	7.1	B
2003	60	7.7	B	14.3	C
2005	55	8.3	B	21.4	D
2007	50	9.1	B	28.6	D
2009	45	10.0	B	35.7	D
2011	40	11.1	C	42.9	D
2013	35	12.5	C	50.0	D
2015	30	14.3	C	57.1	D
2017	25	16.7	D	64.3	D