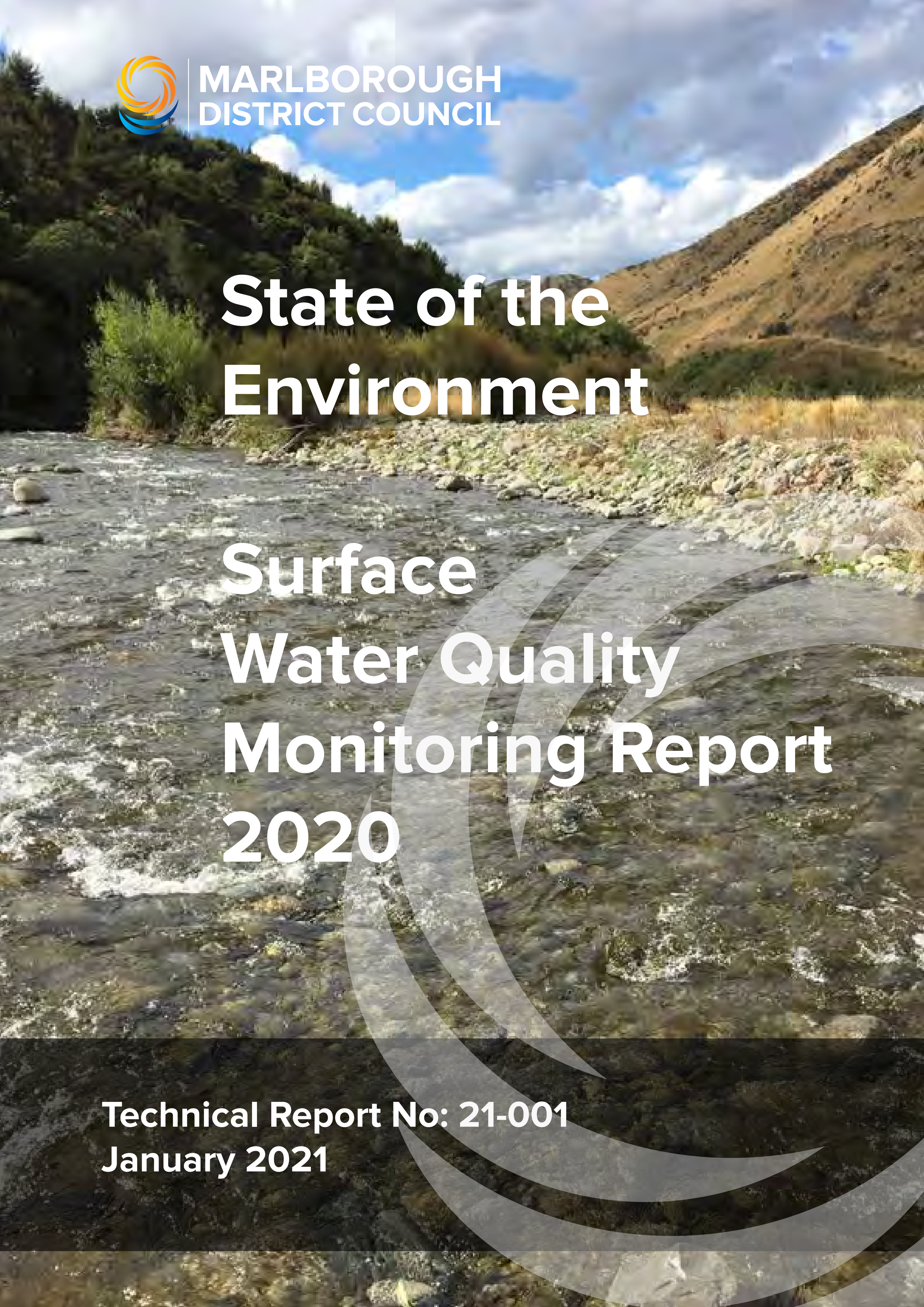

MARLBOROUGH
DISTRICT COUNCIL

State of the Environment

Surface Water Quality Monitoring Report 2020

Technical Report No: 21-001
January 2021

State of the Environment Surface Water Quality Monitoring Report, 2020

MDC Technical Report No: 21-001

ISSN 1179 819X (Online)
ISBN 978-1-927159-94-1(Online)

File Reference/Record No: E375-001-001-03/2114130

January 2021

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Executive Summary

This report is one of a series of annual reports on the state of the environment of the Marlborough District. The focus of this report is the state of surface water quality in the region's rivers and streams.

Monthly measurements of chemical and physical parameters at 35 sites across Marlborough are summarised using the CCME Water Quality Index. The Index combines data of the last three years (2017-2019) and allows categorisation of water quality into five classes. The classes 'excellent', 'good' and 'fair' represent acceptable water quality, while 'marginal' and 'poor' water quality needs to be improved, where possible.

Calculation of the WQI is based on the setting of guidelines values for each of the parameters included. Continued revision of the NPS-FM has produced a wealth of scientific literature that provides New Zealand specific limits for many parameters. It was therefore necessary to review the current WQI guidelines to align them with the NPS-FM and the new information available. The new guidelines for the calculation of the WQI are a mixture of attribute limits in the NPS-FM and proposed limits for attributes that were developed, but have not (yet) been implemented in the NPS-FM.

Turbidity has had a disproportionate effect on the previous WQI, resulting in rivers with good or fair ecological health to be classed as poor (ie; Awatere River). To ensure that the WQI is more representative of overall water quality and ecological health a "cube-root transformation" is applied to turbidity data. Similarly, spikes in E. coli data are reduced with the same data transformation.

Figure 1 shows the WQI for the 35 monthly monitoring sites and the parameters causing degradation of water quality at the individual sites.

The majority of sites have good or fair water quality. 14 sites are in the marginal category, indicating unacceptable water quality in these waterways. Sites in the marginal category generally show the greatest number of parameters. In Doctors Creek, as many as seven parameters exceed guideline values. Apart from the mid Awatere, all rivers in the marginal category are listed in the Marlborough Environment Plan as degraded or at risk from degradation.

Council has been successful in securing central government funding for a number of projects that aim to improve water quality in these waterways. These projects include the Taylor River Improvement Project (TRIP) and Catchment Care Programme. The Te Hoiere Project also aims to improve water quality and ecological health in a number of these waterways.

Some of the main causes of degraded water quality are livestock access to waterways and erosion, but also include leaching of nitrogen from land uses such as cattle pasture, cropping and potentially during the establishment of new vineyards.

In urban areas, contamination with sewage due to damaged infrastructure is one of the main causes of degradation; however, sewage contamination is also present in some (semi-) rural areas.

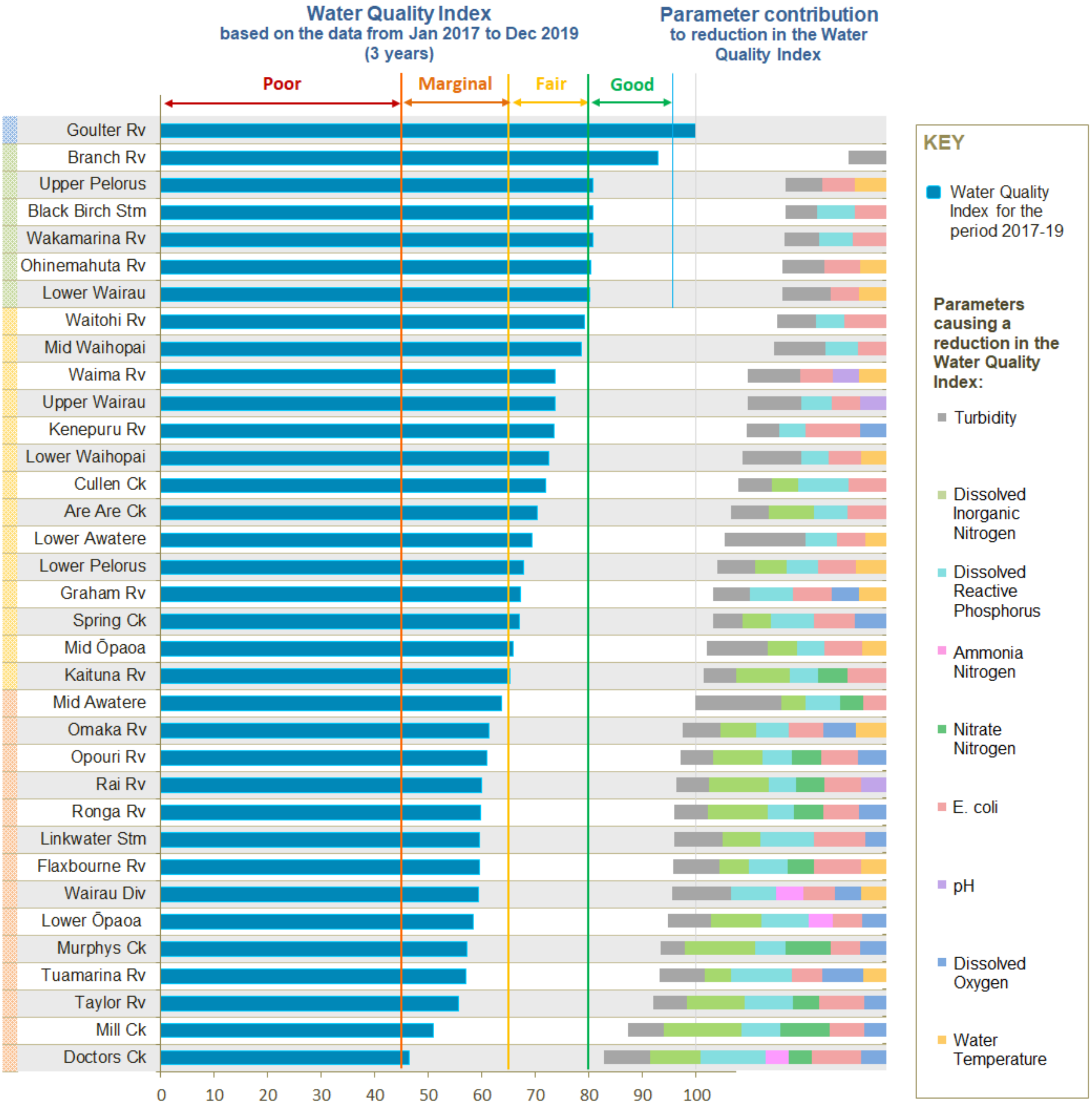


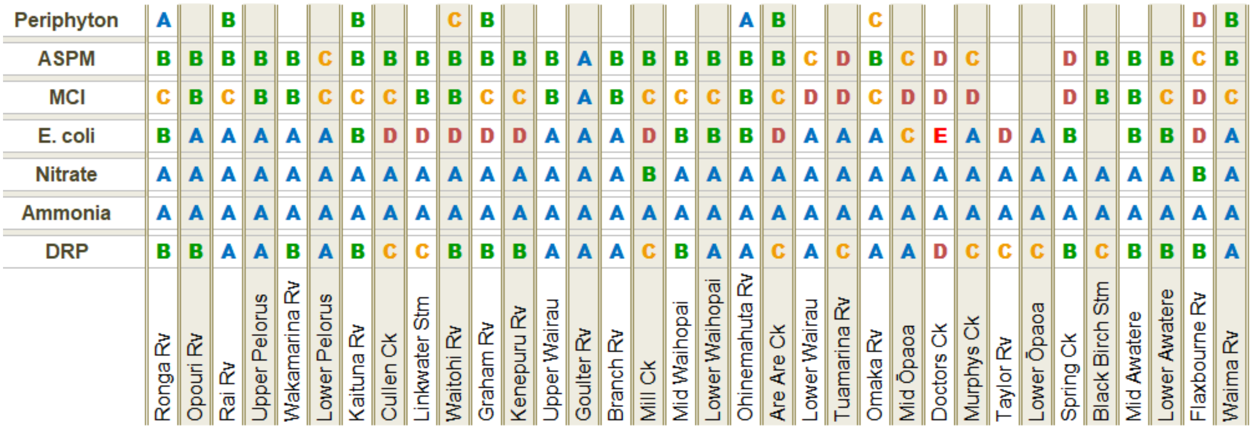
Figure 1: Water Quality Index for the SoE sites for the period 2017-2019 (dark blue bars on the left side of the graph). Also shown are the parameters that cause a reduction in the Water Quality Index (right side of the graph).

In addition to the monthly monitoring of chemical and physical parameters, annual sampling of Macroinvertebrates is carried out at 50 sites across the region. Macroinvertebrates are a good indicator for the ecological health of rivers and streams.

At sites that are also part of the monthly monitoring programme, the new Water Quality Index was generally in good agreement with the results of the Macroinvertebrate monitoring.

In recent years, water quality has become a more prominent focus of central government policies, with a new National Policy Statement for Freshwater Management (NPS-FM) and new National Environmental Standards released in 2020.

Of the 12 river specific attributes in the 2020 NPS-FM, seven are currently monitored as part of the Freshwater SoE programme. To align the programme with the requirements of the NPS-FM, a review of the programme was carried out in 2020. The review is informing the current establishment of a revised monitoring programme. The final form of the programme is influenced by choices yet to be made in regard to implementation of the many new requirements in the NPS-FM.



	Ronga Rv	Opouri Rv	Rai Rv	Upper Pelorus	Wakamarina Rv	Lower Pelorus	Kaituna Rv	Cullen Ck	Linkwater Stm	Waitohi Rv	Graham Rv	Kenepuru Rv	Upper Wairau	Goulter Rv	Branch Rv	Mill Ck	Mid Waihopai
Periphyton	A		B				B			C	B						
ASPM	B	B	B	B	B	C	B	B	B	B	B	B	B	A	B	B	B
MCI	C	B	C	B	B	C	C	C	B	B	C	C	B	A	B	C	C
E. coli	B	A	A	A	A	A	B	D	D	D	D	D	A	A	A	D	B
Nitrate	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	B	A
Ammonia	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
DRP	B	B	A	A	B	A	B	C	C	B	B	B	A	A	A	C	B

	Lower Waihopai	Ohinemahuta Rv	Are Are Ck	Lower Wairau	Tuamarina Rv	Omaka Rv	Mid Ōpaoa	Doctors Ck	Murphys Ck	Taylor Rv	Lower Ōpaoa	Spring Ck	Black Birch Stm	Mid Awatere	Lower Awatere	Flaxbourne Rv	Waima Rv
Periphyton		A	B			C										D	B
ASPM	B	B	B	C	D	B	C	D	C			D	B	B	B	C	B
MCI	C	B	C	D	D	C	D	D	D			D	B	B	C	D	C
E. coli	B	B	D	A	A	A	C	E	A	D	A	B		B	B	D	A
Nitrate	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	B	A
Ammonia	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
DRP	A	A	C	A	C	A	A	D	C	C	C	B	C	B	B	B	A

Figure 2: Attribute states for SoE monitoring sites based on NPS-FM limits.

Figure 2 shows the NPS-FM states for attributes currently monitored. Almost all monitoring sites are in the A-band for the Nitrate and Ammonia Nitrogen attributes. For the other attributes, states range from A to D/E. Overall, Doctors Creek and the Flaxbourne River have the poorest attribute states, but there are also a number of rivers with NPS-FM states in the A or B-band for all parameters monitored.

Trend analysis was carried out over 5 year (2015-2019) and 10 year (2010-2019) periods. The results showed decreasing Nitrate concentrations for some rivers in the lower Wairau Plain and the Kaituna River, but increasing Nitrate levels for some of the dairy catchments. The most notable changes in E. coli concentrations were increases for Linkwater Stream, Are Are Creek and the Taylor River and decreasing E. coli levels in Cullen Creek. There were very few significant changes in Dissolved Reactive Phosphorus concentrations, with the exception of decreases in the Tuamarina River and Black Birch Stream. The greatest changes for turbidity were improvements in the Upper Wairau River and the Awatere River.

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1. Introduction

1.1. Purpose

Healthy rivers and streams are key to a thriving region. Apart from providing ecosystem functions, rivers supply water for agricultural uses, viticulture and industry. For most people however, the main connection to waterways is through recreational uses, such as swimming, fishing and boating.

The Marlborough District Council monitors surface water quality in the streams and rivers of the region as part of its obligations under the Resource Management Act (RMA 1991). The monitored waterways cover a broad range of catchment types and land uses, from pristine native bush catchments to predominantly urbanised catchments. The monitoring is usually carried out as close to the bottom of each catchment as possible to allow the assessment of cumulative effects of human activities on our surface water resources.

The main purpose of this report is to present information on river water quality for a non-technical audience. The intended outcome is the inclusion of a wide range of interested parties into the discussions around surface water quality and the effectiveness of policies and rules.

The report provides information on the current state of water quality based on physical, chemical and ecological parameters. It explores the reasons for the observed states and discusses changes observed over the years.

The 2020 National Policy Statement for Freshwater Management includes limits for a number of parameters for the assessment of river health. Councils are required to report on the state of waterbodies based on these limits on an annual basis. This report fulfils parts of this requirement.

1.2. The Region

The three largest rivers in the Marlborough region are the Te Hoiere/Pelorus River in the North-West, the Wairau River, and the Awatere River in the South. The Wairau River has the largest catchment spanning the region from the mountains of the St Arnaud Ranges in the West to the Pacific Ocean in the East and cumulatively the largest flow of all the rivers in Marlborough.

The Marlborough region is located on the eastern side of the South Island and as a consequence, large parts of the region are in the rain shadow of the Southern Alps. This results in a striking variation in rainfall across the region (Figure 3). The greatest amount of rainfall (more than 2 meters a year) falls in the Te Hoiere/Pelorus catchment and around the upper reaches of the Waihopai River. The opposite extreme can be found in some areas along the East coast and in the lower river flats of the Awatere River catchment. The total annual rainfall in these parts of the region is less than 600 mm, making the East Coast catchments some of the driest places in New Zealand. Consequently, although the Awatere River catchment is approximately twice the size of the Te Hoiere/Pelorus catchment, the mean flow in the Awatere River is considerable less than the flow in the Te Hoiere/Pelorus River. During late summer the eastern parts of some of the rivers in the South dry up completely.

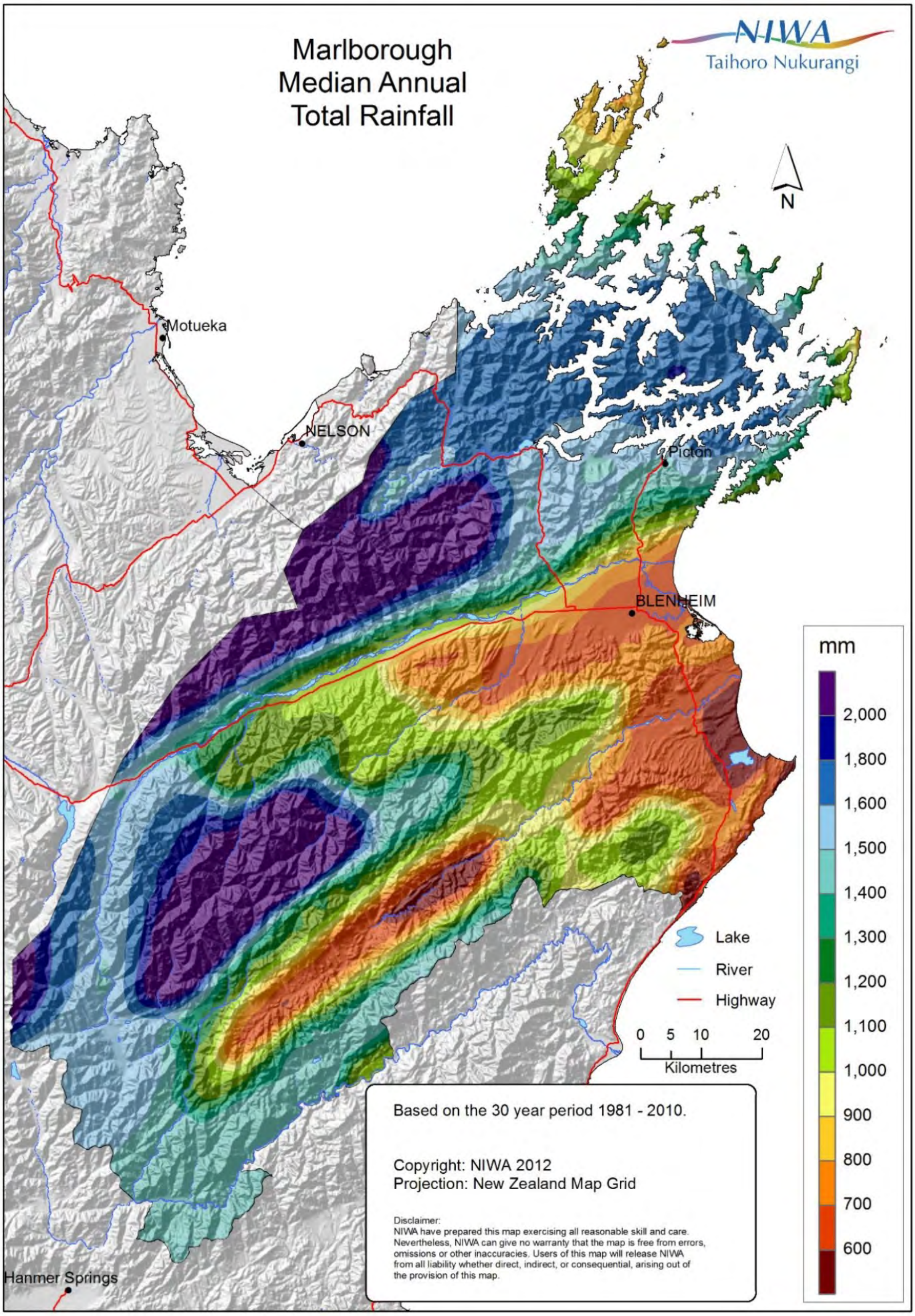

Figure 3: Median Annual Total Rainfall in Marlborough [39].

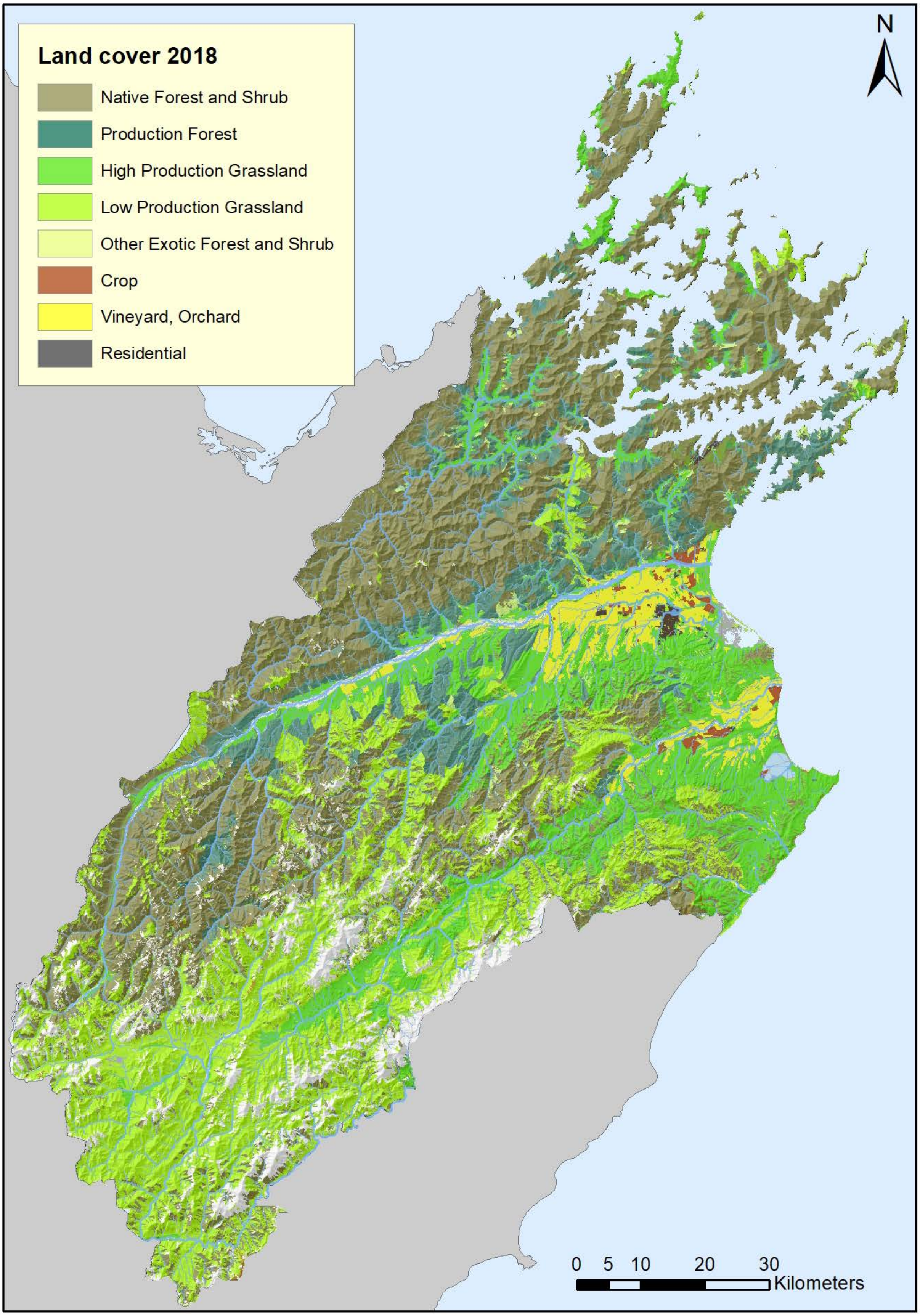

Figure 4: Land cover in Marlborough as of 2018 based on LCDb5.

In the past rivers and streams with poor water quality were often associated with sources of contamination that came directly from point source discharges such as pipes discharging effluent or industrial waste into water ways. In recent decades many improvements have been made in reducing the number and impact of such point sources. Diffuse sources such as run-off from land and activities related to productive land use have now become the main source of contaminants that impact water quality in most streams and rivers. Nevertheless, a few point sources from stormwater systems still remain, mainly in and around residential areas.

Alteration of the natural land cover is one of the most important factors influencing water quality. Prior to human settlement in New Zealand the majority of the country was covered in forests. Since the arrival of humans there has been a systematic clearance of these forests and as a result the majority of our waterways are no longer pristine. The map in Figure 4 shows the land cover for the Marlborough region. Much of the North and West remains in native vegetation, particularly at higher altitude. Native forest, shrub and tussock still cover over 40% of the region. However, most of the river flats have been cleared of native vegetation and are now used agriculturally. Nearly 30% of the region has been converted to pasture. The majority is used to graze sheep and beef. A number of dairy farms are also operating, especially in the flats of the Rai and Te Hoiere/Pelorus River, but also in the Tuamarina, Kaituna and Linkwater areas. Production forest is mainly comprised of *Pinus radiate*. It covers the lower hills of Wairau River tributaries and the Rai/TeHoiere area as well as parts of the Marlborough Sounds.

Marlborough is most renowned for its viticulture. The majority of vineyards can be found on the Wairau Plain and the lower Awatere River, but vineyard development has moved further up river valleys and into other areas of the region.

2. Methodology

2.1. Sampling and sample analysis

Monthly water quality samples and field measurements are taken at 35 sites across the region. One of these sites is part of the national monitoring network and the water quality samples are collected and analysed by NIWA. NIWA kindly provides sampling data for this site via their internet portal. At the remaining 34 sites, water samples are collected by Marlborough District Council staff and sent to an independent, accredited laboratory for analysis. Water temperature and dissolved oxygen are measured in the field using YSI handheld meters.

Sampling is carried out independent of weather conditions during roughly the same week each month.

At 50 sites, Macroinvertebrates are sampled annually during the summer months. Sampling is carried out during baseflow conditions using the Kicknet method (C1 [37]). Samples are taken from riffles where possible and analysed by Stark Environmental Ltd using coded abundance (P1).

Figure 5 shows the location of the monthly and annual monitoring sites.

2.2. Water Quality Index (WQI)

The field measurements and laboratory analysis results from three consecutive years (2017 to 2019 inclusive) are used to calculate a Water Quality Index for each site.

The Marlborough District Council uses the CCME Water Quality Index (WQI) for the reporting of surface water quality. Based on guideline values the WQI combines a wide array of data and information into a single figure allowing an easy comparison of the water quality in different streams and rivers. The guidelines were carefully chosen when the Index was first introduced in 2013 using the information available at the time. Since then a greater focus on water quality, particularly by central government has led to substantial scientific work, which resulted in the development of national, New Zealand specific limits for a large number of parameters. Many of these limits are now part of the latest National Policy Statement for Freshwater Management (NPS-FM). These developments meant that it was necessary to review the current guidelines for the Water Quality Index to align them with the NPS-FM and the new information available.

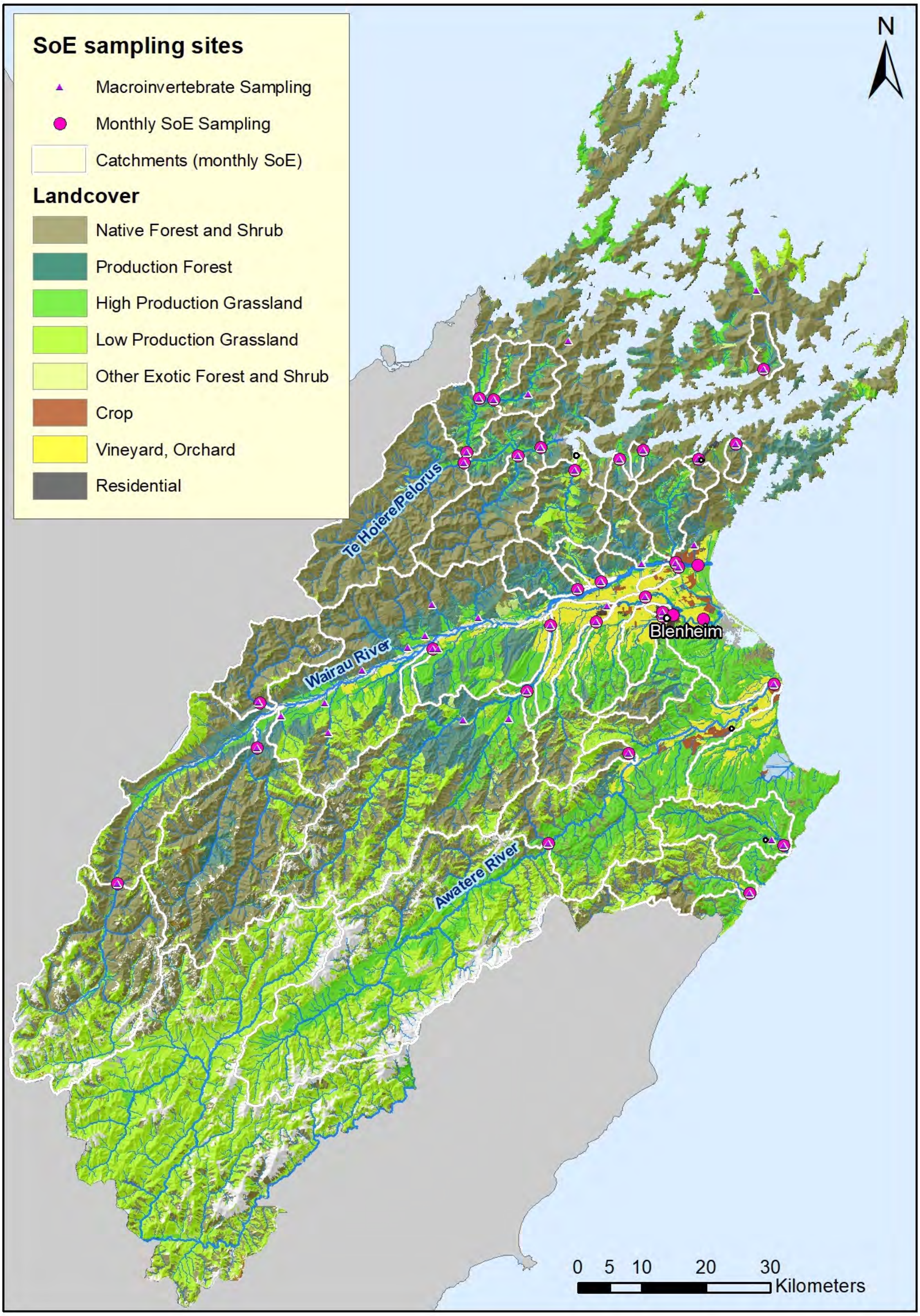

Figure 5: Location of annual Macroinvertebrate sites and monthly sampling sites for physical/chemical parameters. Also shown are the associated catchments of the monthly monitoring sites and Landuse as of 2018.

The new WQI guidelines are a mixture of attribute limits in the NPS-FM and proposed limits for attributes that were developed, but have not (yet) been implemented in the NPS-FM. In the NPS-FM, attribute states are often calculated using limits for at least two different statistics, a Maximum or 95th percentile and the Median. The majority of guidelines for the Water Quality Index are limits for Medians. This may seem counter-intuitive for the use in an index that is based on exceedances of guidelines for individual measurements. However, limits for Maxima or 95th percentiles are higher than those for Medians. Therefore using Median concentrations as guidelines highlighting arising issues before measured values exceed maximum allowable levels. The calculation of the Index accounts for the magnitude and frequency of guideline exceedances. This means occasional minor exceedances of guideline levels will still present as acceptable water quality.

The monitoring network has been established with a focus on resource management. Sampling sites are generally located at the bottom of catchments. This is the point where surface water (and groundwater) from the whole catchment is flowing out. This means that the state as well as changes of water quality at this site are an indication of conditions in the catchment as a whole. However, this means that monitoring site are usually in lowland areas and a certain degree of water quality deterioration will occur naturally [38]. It would also be unreasonable to expect water quality to be pristine. Guideline values are therefore mainly based on B-Band limits. This is most fitting for the type of sites monitored and represents river health that is still well above the nation bottom lines. Exceptions are Nitrate and Ammonia toxicity guidelines, which represent comparatively high limits. For these parameter, the A-band limits were chosen. These are also the basis for Objectives in the Marlborough Environment Plan. Total Ammoniacal Nitrogen data is adjusted based on pH and water temperatures in accordance with the NPS-FM requirements.

Choosing a guideline value for turbidity was less straight forward. The Draft NPS-FM [30] included limits for turbidity, but in the final version of the NPS-FM [31], these limits had been replaced by limits for clarity. Both, turbidity and clarity are indirect measures of sediment in the water column. Turbidity was chosen for the SoE monitoring programme in this region as it provides many advantages, including its suitability for continuous monitoring. The NPS-FM does however, allow the conversion of clarity limits into turbidity limits once site-specific correlations have been established. Unfortunately, clarity has not been routinely monitored in the past and therefore this conversion is only available for a very small number of sites. However, analysis of the data available showed that the converted limits are very close to the turbidity limits in the Draft NPS-FM.

For Sediment related attributes, such as clarity, rivers are divided into different classes based on the NIWA River Environment Classification (REC) system. The NPS-FM has separate limits for the different river classes. The majority of sites in Marlborough belong to Class 3, with some sites in Class 1. The limits for Class 3 are more stringent than the limits for Class 1. The guideline for the calculation of the Water Quality Index was subsequently based on the turbidity B-band limit for the Class 3 equivalent[1] in the Draft NPS-FM.

Table 1 lists the new guidelines for the Water Quality Index, their origin and the guidelines used in previous reports.

In the previous WQI, turbidity had a dominating influence on the Index for some of the sites. For example, the Awatere River was generally classed as poor due to high turbidity levels. However, Macroinvertebrate monitoring and occasional fish monitoring showed that this classification is not representative of the ecological health of the river. Additionally, during flood flows, turbidity level can be several magnitudes above the guideline value. These events are important to record as they provide an insight into sediment transported into receiving environments downstream, such as Estuaries. However, these data spikes have a disproportionate effect on the Water Quality Index. To reduce their effect, the cube root transformation is applied to turbidity data. This ensures that Water Quality Indices are more representative of overall water quality.

Similar to turbidity, E. coli levels also spike during flood flows. Therefore, the same transformation is applied to E. coli concentration data.

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[1] The Draft NPS-FM uses different river classes.

Parameter	Guideline Value	Source	Previous Guideline Value
Water Temperature	21.0 °C	Davies-Colley R et al. (2013) [8]; B-band	21.5 °C
Dissolved Oxygen	8 mg/L	Davies-Colley R et al. (2013) [8]; B-band; 7-day mean	70 %
pH	Lower: 6.5 Upper: 8.5	Davies-Colley R et al. (2013) [8]; B-band	Lower: 6.7 Upper: 7.8
Nitrate Nitrogen	1.0 mg/L	NPS-FM (2020) [31], A-band; Median	2.4 mg/L
Ammonia Nitrogen	0.03 mg/L	NPS-FM (2020) [31], A-band; Median	winter: 0.76 mg/L summer: 0.2 mg/L
Dissolved Inorganic Nitrogen	0.50 mg/L	Draft NPS-FM (2019) [30]; B-band; Median	0.165 mg/L
Dissolved Reactive Phosphorus	0.010 mg/L	NPS-FM (2020) [31], A-band; Median	0.015 mg/L
E. coli concentration	130 E.coli/100mL	NPS-FM (2020) [31], A-C-band; Median	550 E.coli/100mL
Turbidity	1.3 NTU	Draft NPS-FM (2019) [30]; B-band; Median for predominant Class (3)	5.6 NTU

Table 1: The parameters used for the calculation of the Water Quality Index.

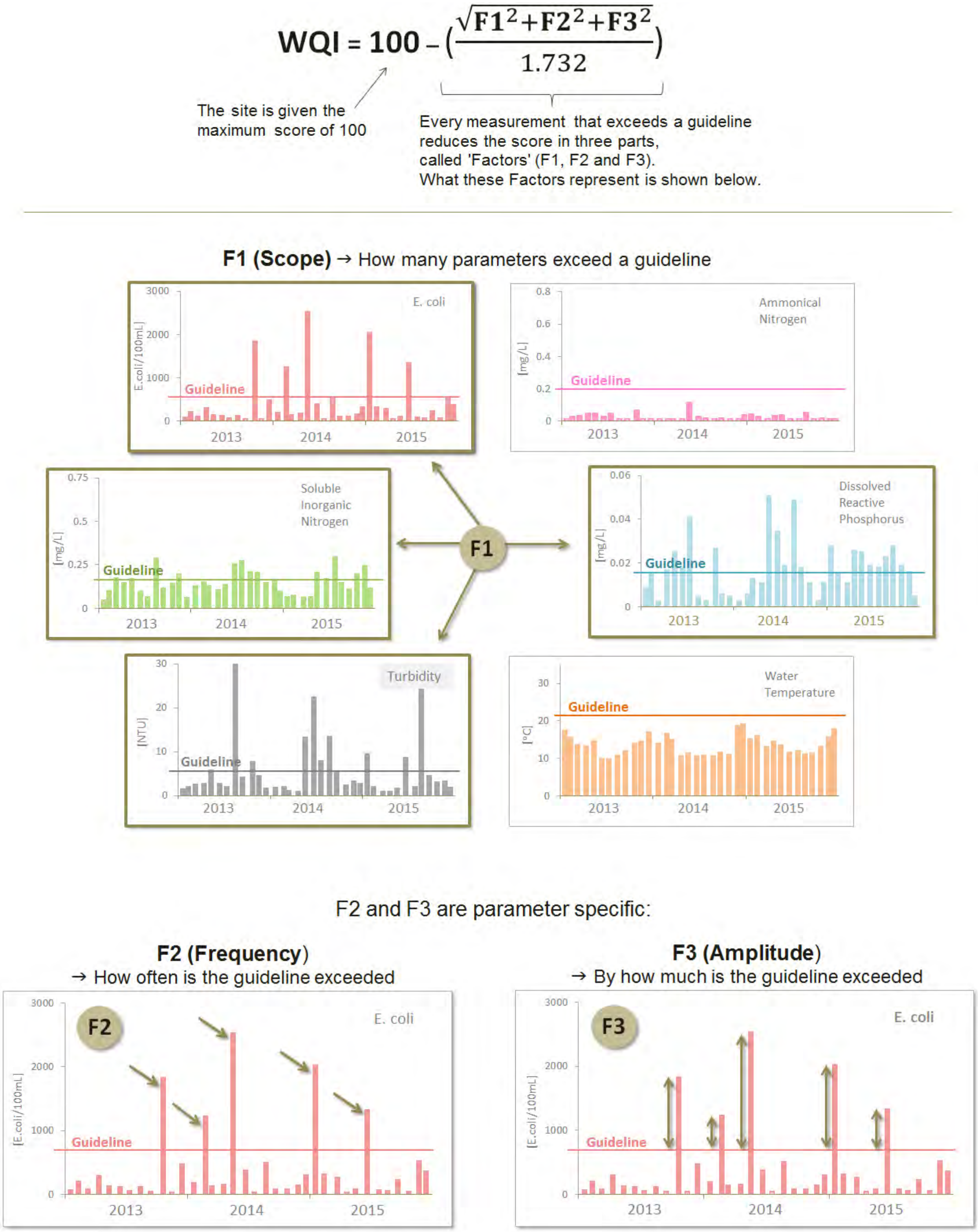
The most meaningful results are obtained when at least 30 data points are used for the calculation of the Water Quality Index [8, 12]. The Marlborough District Council undertakes monthly sampling of water quality, so, to obtain a sufficient number of data points, data from three consecutive years is combined.

The actual calculation of the Index is done in three parts, which are referred to as ‘factors’ (see Figure 6).The first factor, F1 (Scope), is calculated based on the number of guidelines that are exceeded. F2 (Frequency), the second factor, is calculated from the number of samples that exceed a guideline and the third and final factor, F3 (Amplitude), is based on the magnitude by which guidelines are exceeded.

Once calculated, the Water Quality Index produces a number between 0 and 100, with higher indices representing better water quality. Based on the index, water quality of a river or stream can then be categorised into one of five quality classes (Table 2, [1]). The classes ‘Excellent’, ‘Good’ and ‘Fair’ represent acceptable water quality, while waterways classed as ‘Marginal’ or ‘Poor’ need to be improved if possible.

Quality Class	Water Quality Index	Description
Excellent	95 -100	Conditions **very close to** natural or pristine level
Good	80-94	Conditions **rarely** depart from natural or desirable level
Fair	65 -79	Conditions **sometimes** depart from natural or desirable level
Marginal	45 - 64	Conditions **often** depart from natural or desirable level
Poor	0 - 44	Conditions **usually** depart from natural or desirable level

Table 2: Quality classes for the Water Quality Index and the associated meaning.



$$\text{WQI} = 100 - \left(\frac{\sqrt{F1^2+F2^2+F3^2}}{1.732}\right)$$

The site is given the maximum score of 100

Every measurement that exceeds a guideline reduces the score in three parts, called 'Factors' (F1, F2 and F3). What these Factors represent is shown below.

Figure 6: Principals calculation of the Water Quality Index.

A detailed description of the calculation is given in Appendix 7.1.

2.3. Trend Analysis

There are many different techniques for the assessment of trends, but non-parametric tests are most suitable for water quality data because no specific distribution of the data is assumed. Due to the common occurrence of values below the detection limit, water quality data tend to be skewed to varying extent [17], making the fitting of a distribution curve difficult. Additionally the seasonality of some of the parameters has to be taken into account. A common test used is the Seasonal Mann-Kendell test. This test produces two main results: the magnitude of the trend (presented as ‘annual change’ in this report) and a P-value, which represents the probability that the trend occurred by chance. P-values of 0.05 (5%) or less are usually indicative of statistically significant trends. Data from at least five years of monthly sampling (60+ data points) is required to produce statistically meaningful results [36] and the number of ‘seasons’ should be set to 12 (one for each month) [1]. For many parameters, increased flow is associated with either dilution or increased values due to run-off from land. Therefore, water quality data is generally flow adjusted where possible[2]. LOWESS (30% span) flow adjustment was used with flow data from the actual sampling site or from nearby flow recorders. For some sites, the data from the closest flow recorder did not allow sufficient correlations with spot flow measurements at the site. Here the flow was estimated using flow data from several neighbouring catchments. The flow data itself was tested for trends to ensure that no artificial trends were introduced by the flow adjustment.

Both, flow-adjusted and un-adjusted trends were calculated using the Time Trends software by NIWA. If the flow-adjustment was explaining less than 5% of the variation in the data, the un-adjusted trend was used.

Trends were calculated over a period of 5 years (2015-2019) and 10 years (2010-2019) for Nitrate Nitrogen, pH, E. coli concentrations and turbidity. Spot measurements of water temperature and dissolved oxygen were not analysed for trends. The values of these parameters change significantly over the course of the day. Although measurements are mostly taken at roughly the same time of the day, there have been changes in the sampling regime over the years, which would result in misleading trend results.

In 2011 the Marlborough District Council changed laboratory service providers. As a result the method for the analysis of Dissolved Reactive Phosphorus concentrations changed, causing a noticeable step-change in the results for a number of sites. Unfortunately, no duplicate samples were sent to both laboratories to allow adjustment of the earlier results. Since the step change will influence the results of the 10-year trend analysis, Dissolved Reactive Phosphorus concentrations were only assessed over a period of 5-years.

The change in laboratory also caused differences in detection limits for some of the parameters. When this was the case, the higher detection limit was set as the standard. To avoid ties[3], which can affect the trend analysis, values below detection limit were assigned small random values using the Excel Rand() function. Due to the high number of ties in the pH data, additional decimal points were added using the same Excel function, ensuring that the actual result values were not changed. All additions of random values were checked for trends to avoid the introduction of artificial trends.

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[2] Note that trends shown on the national LAWA website (www.lawa.org.nz) are not flow adjusted and therefore some results on the website differ from those presented in this report. It is recommended to flow adjust data for trend analysis [2, 3]. LAWA also present trend with lower P-values. The trends in this report are equivalent to “very likely” trends on the LAWA website.

[3] Ties are results with the same value.

2.4. National Policy Statement (NPS-FM)

A new National Policy Statement for Freshwater Management (NPS-FM) came into force on 3 September 2020. It includes a number of policies and objectives for the management of rivers, lakes and wetlands. For the reporting on river water quality, the most important part of the NPS-FM are so-called ‘attributes’. These are parameters for the assessment of ecosystem health and recreational values. The NPS-FM provides limits for 22 attributes, which define bands ranging from A to D/E. The A-band represents healthy ecosystems, while attribute states in the D and E-bands are referred to as “below the national bottom line”. Unless caused by natural sources, attributes states below the national bottom line are consider unacceptable.

The majority of attributes has limits for more than one statistic, which vary from attribute to attribute. The most common statistics are Medians, 95th Percentiles and Minima or Maxima. Attributes also vary in the number of data points and the time periods over which the attribute state is determined.

Thirteen of the 22 attributes are measures for the health of rivers and streams. Apart from four of these attributes, these measures are already included in the current State of the Environment (SoE) monitoring programme.

Eight of the attributes exclusively apply to the monitoring of lakes. Marlborough only has a few, comparatively small lakes, but there is very little information available about their health. Currently, lakes are not monitored as part of the SoE programme, but will need to be included in the future.

	Table	Attribute	Rivers	Lakes	Currently monitored
Appendix 2A	1	Phytoplankton		x	No
	2	Periphyton	x		Yes
	3	Total Nitrogen		x	No
	4	Total Phosphorus		x	No
	5	Ammonia	x	x	Yes
	6	Nitrate	x		Yes
	7	Dissolved Oxygen below point sources	x		Consents
	8	Suspended fine sediment	x		As Turbidity
	9	E. coli	x	x	Yes
	10	Cyanobacteria		x	No
Appendix 2B	11	Submerged native plants		x	No
	12	Submerged invasive plants		x	No
	13	Fish	x		No
	14	Macroinvertebrates (MCI)	x		Partially
	15	Macroinvertebrates (ASPM)	x		Partially
	16	Deposited fine sediment	x		No
	17	Dissolved Oxygen (continuous)	x		No
	18	Lake-bottom dissolved oxygen		x	No
	19	Mid-hypolimnetic dissolved oxygen		x	No
	20	Dissolved Reactive Phosphorus	x		Yes
	21	Ecosystem metabolism	x		No
	22	E. coli swimming sites	x	x	Yes

Table 3: The 22 attributes for which the 2020 NPS-FM provides limits. Also shown is the type of waterbody they apply to and whether they are currently monitored as part of the SoE monitoring programme.

3. Parameter Results

The following sections present the results for individual parameters that are monitored as part of the State of the Environment (SoE) programme. The results are presented using simplified Box and Whiskers plots, which are ideal for displaying the distribution of data for several sites in one graph. Figure 7 illustrates how Box and Whiskers Plots are created and shows examples for some of the most common data distributions.

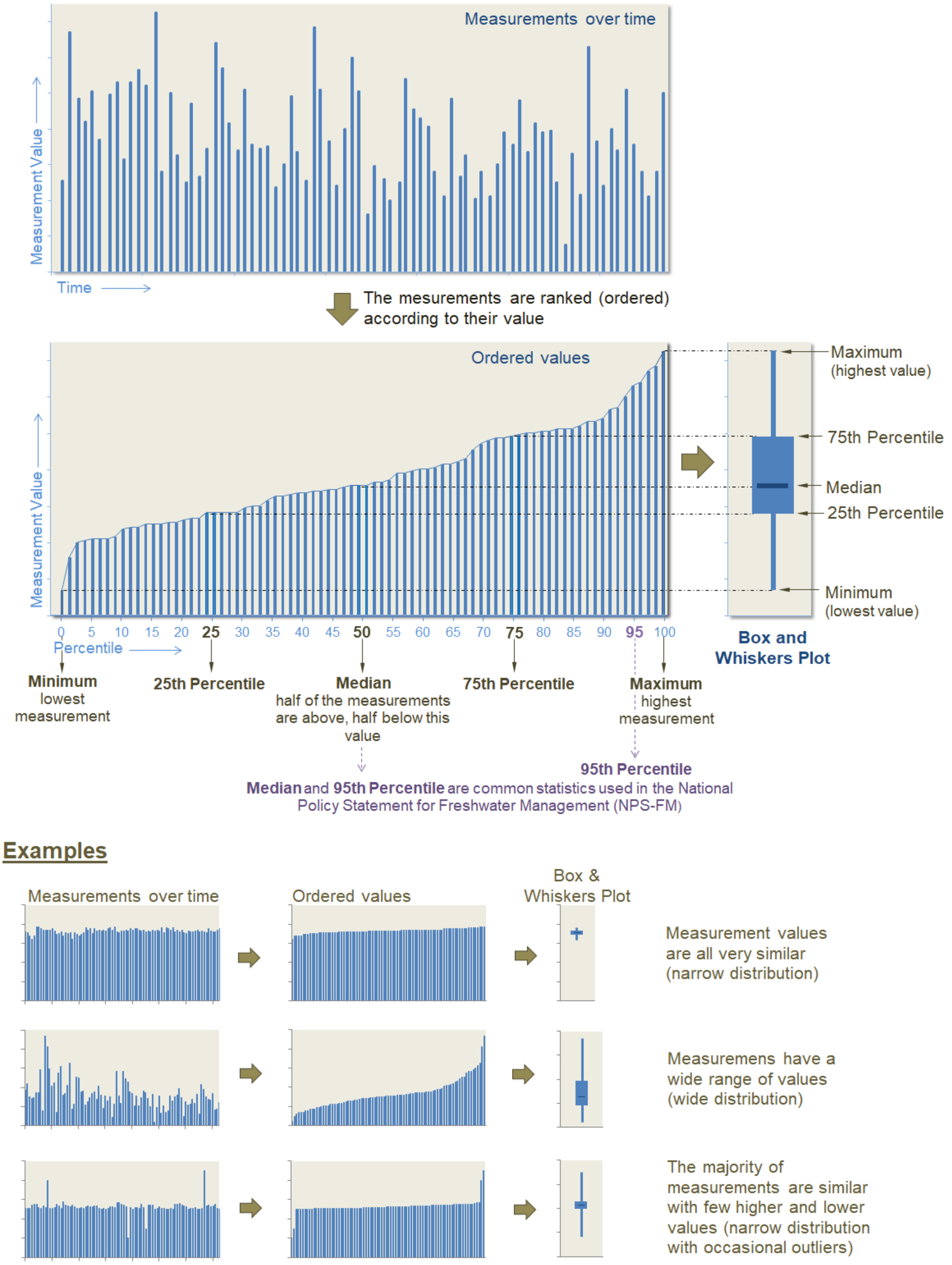

Figure 7: Creation of Box and Whiskers Plots and examples of different data distributions.

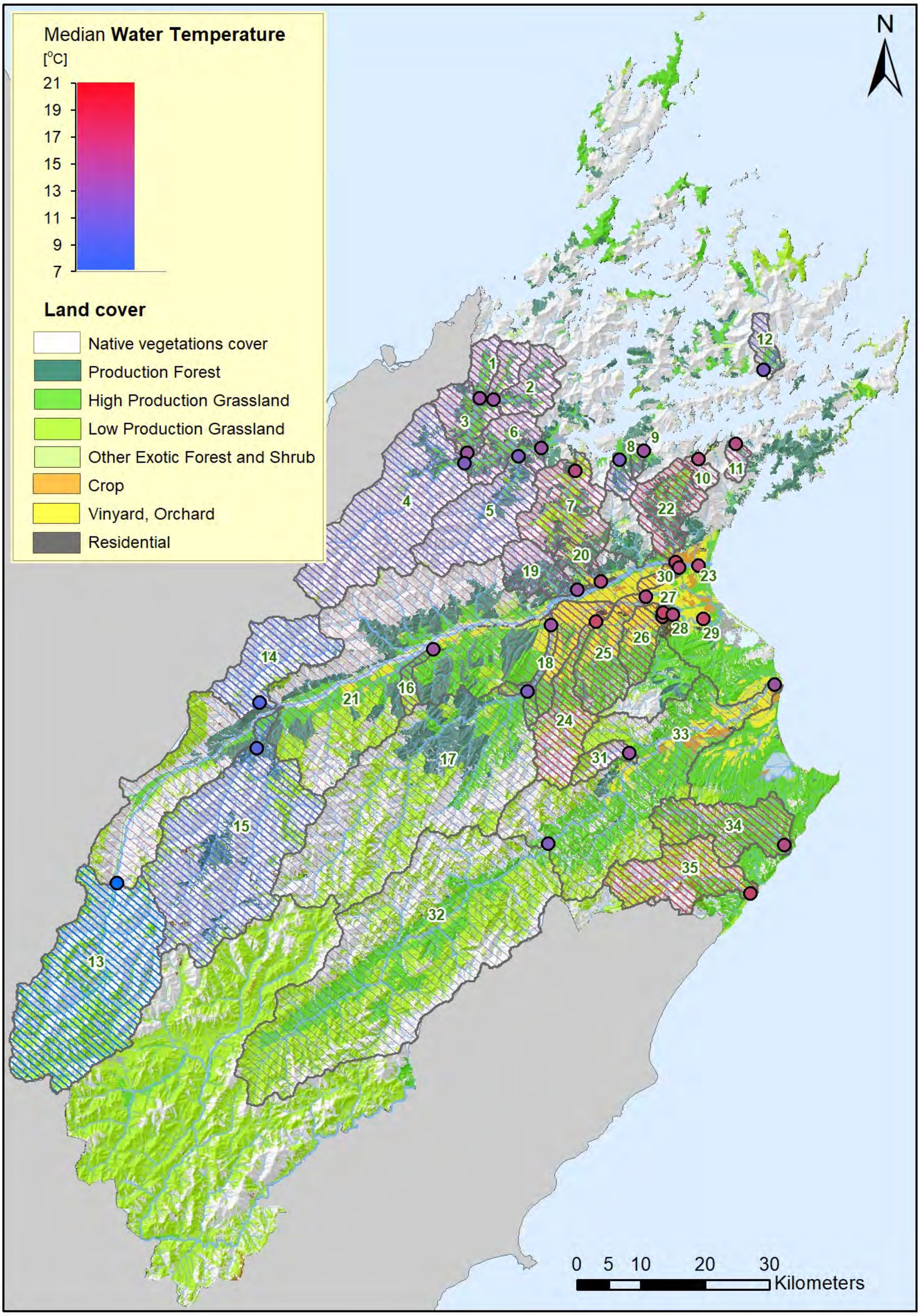

Figure 8: Water Temperature at the SoE monitoring sites. Shown is the Median over three years (2017-2019). The shaded areas show the associated catchments areas. The numbers relate to the graph on the next page. Lighter shading indicates areas where monitoring is less representative. Unshaded areas are currently not monitored. Also shown is the Landcover in 2018 (LCDb5).

3.1. Water Temperature

Water temperature changes over the course of the day. Stream water is cooler during the night and warms up during the day. The highest values are usually reached just after midday. Aquatic organisms become stressed when temperatures become too high and sensitive species may die. High water temperatures also reduce the amount of oxygen that can be dissolved in water.

Measurements of water temperature are taken during monthly site visits. These spot measurements are likely to capture only some of the temperature maxima. However, they can still provide an indication of potential issues.

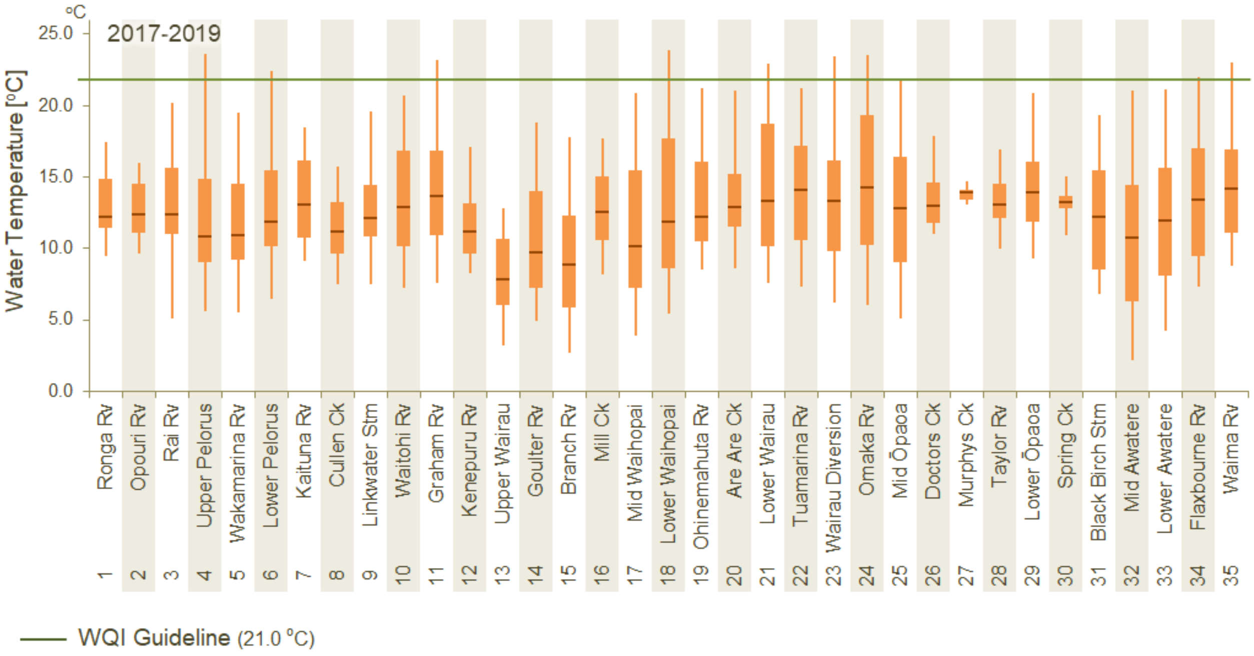

Figure 9: Box and Whiskers Plot of Water Temperatures at SoE sites, 2017 – 2019.

The highest water temperatures are usually observed in the lower parts of the catchments. Streams and rivers are generally wider in the lower reaches, which means that direct sunlight can reach the water more easily. Tall riparian vegetation such as trees and bushes can shade waterways, keeping water temperatures low. However, as rivers gain more flow they become so wide that even mature forest cannot sufficiently shade the whole river. Measurements in the Goulter River and Black Birch Stream show this. The catchment of both rivers is almost completely covered in mature, native vegetation.

Water depth also influences water temperature. Shallow, unshaded streams heat up more quickly. This means that wide, braided rivers, such as the Wairau, Waihopai and Awatere River can be expected to have some of the highest water temperatures in the region. These rivers also show the greatest variability in measurement values.

Rainfall during the warmer months will lower water temperatures. Therefore, streams and rivers in the dryer parts of the region will generally have higher water temperatures. A lack of shading riparian vegetation in large areas of the catchment will exacerbate this. An example for this is the Omaka River.

Compared to stream water, the temperature of groundwater is comparatively more stable. This is the reason that spring-fed streams, such as Murphys Creek and Spring Creek have lower, less variable water temperatures.

Overall, Guideline exceedances were only observed occasionally during the summer months. However, as these are spot measurements, it is difficult to assess how long aquatic animals have to endure high water temperatures. In the long-term, continuous monitoring would provide information that is more reliable. Sites with spot measurements near or above the guideline should be prioritised for this monitoring.

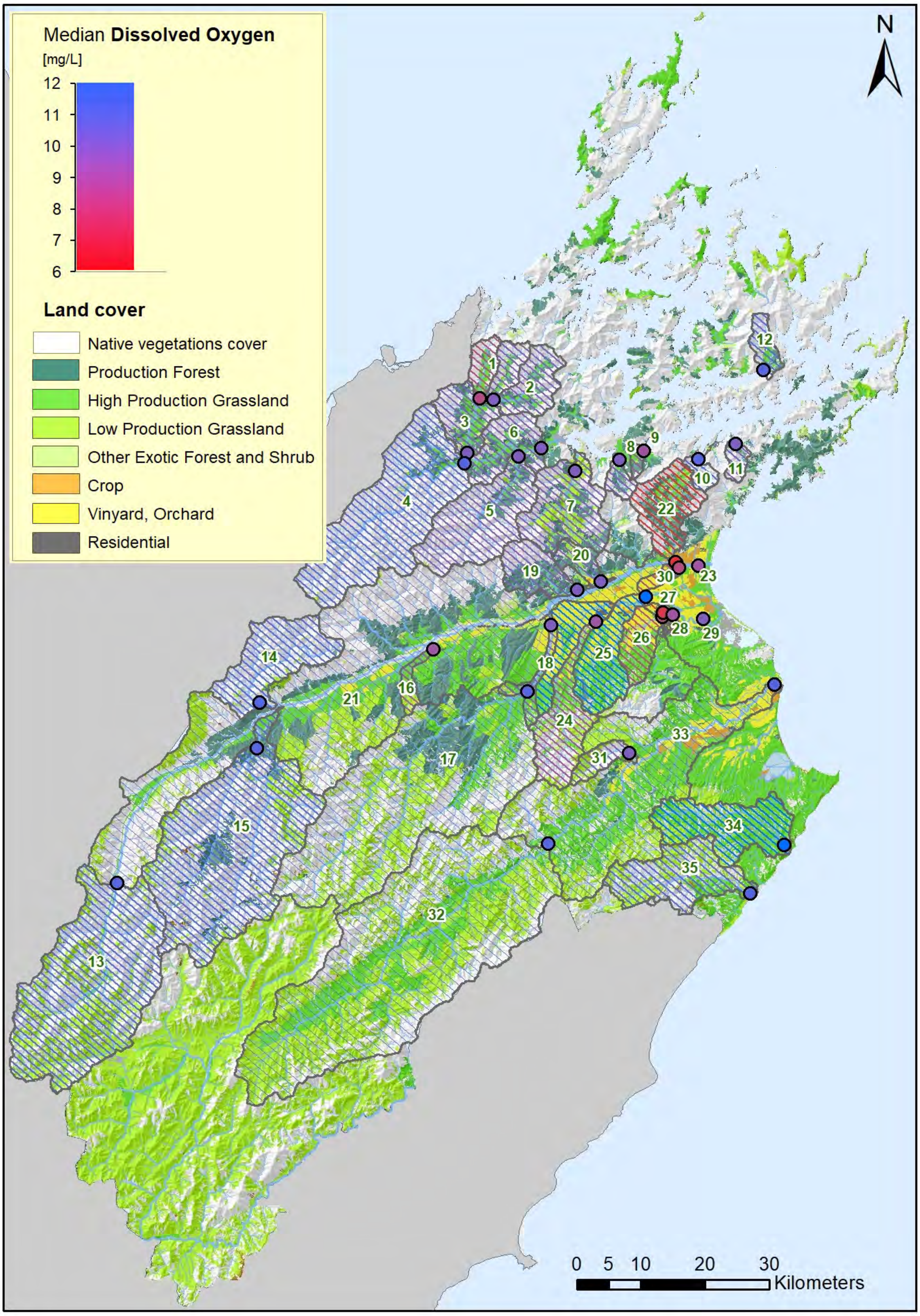

Figure 10: Dissolved Oxygen concentration at the SoE monitoring sites. Shown is the Median over three years (2017-2019). The shaded areas show the associated catchments areas. The numbers relate to the graph on the next page. Lighter shading indicates areas where monitoring is less representative. Unshaded areas are currently not monitored. Also shown is the Landcover in 2018 (LCDb5).

3.2. Dissolved Oxygen

Aquatic plants and animal requires oxygen to survive. The amount of oxygen needed varies between the different species, but fish and macroinvertebrates are generally the most sensitive to low oxygen levels.

Similar to water temperature, dissolved oxygen levels change during the day. During daylight hours aquatic plants release oxygen into the water as a result of photosynthesis. This ceases when the sun goes down and oxygen levels decrease due to respiration by animals, plants and the activity of microorganism. The lowest concentrations are usually observed just before sunrise. A dense cover of algae or other aquatic vegetation can significantly lower oxygen concentrations, as the plants also become oxygen users. Organic material, such as faecal matter, also reduces oxygen levels. This is caused by an increase in bacterial activity. The bacteria use up oxygen during the break down of organic material.

Dissolved oxygen is measured during monthly sampling. Subsequently, measurements are taken during the day when oxygen levels are higher. This means that guideline exceedances are an indication of potentially significantly lower oxygen levels at night.

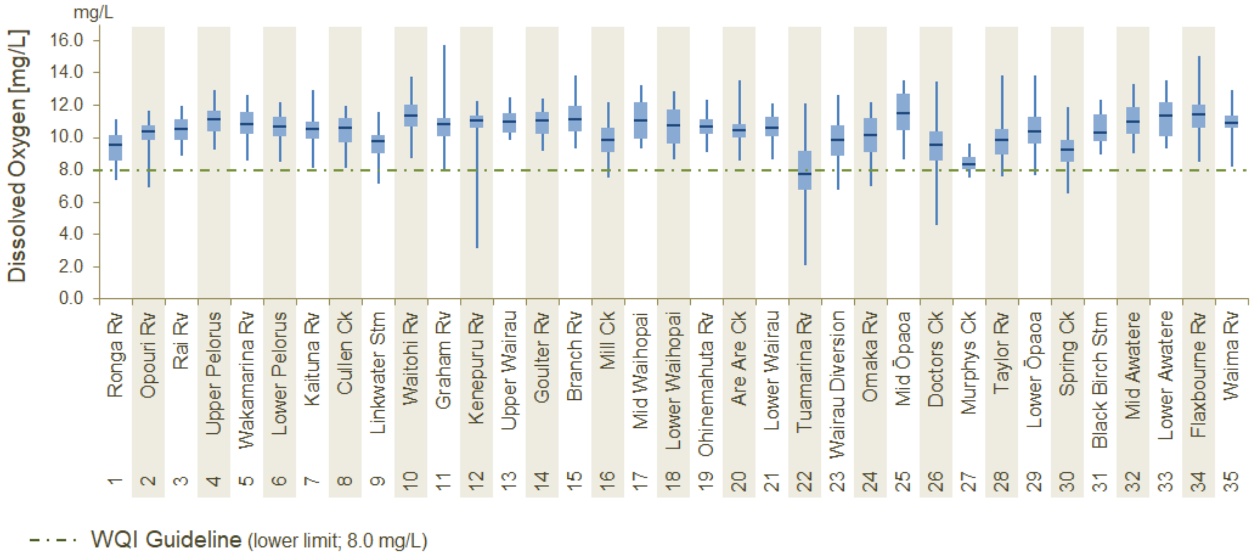

Figure 11: Box and Whiskers Plot of Dissolved Oxygen concentrations at SoE sites, 2017 – 2019.

The lowest dissolved oxygen was measured in the Tuamarina River. This monitoring site is located downstream of the largest remaining wetland on the Wairau Plain, the Para Swamp. Temporary continuous monitoring upstream and downstream of the wetland, has shown that oxygen levels upstream are consistently suitable for aquatic life. However, downstream of the wetland, oxygen concentrations reach levels as low as 1.5 mg/L [22].

Streams that receive most of their flow from groundwater can also be comparatively low in oxygen. An example is Murphys Creek with relatively stable oxygen concentrations. Doctors Creek also has large groundwater inflows in the lower reaches. However, dissolved oxygen levels are more variable than those observed in Murphys Creek, which is an indication of other influencing factor, such as faecal contamination and aquatic plant growth. This is also the case for Spring Creek, but to a lesser degree.

Oxygen is also exchanged with the atmosphere, but this process is comparatively slow. In areas of a stream where the water surface is broken by turbulences, such as in riffles, the surface area is increased and oxygen exchange is improved. However, when water levels drop during dry spells, sections of a stream might only flow underground, reducing the input of oxygen from the atmosphere. In this situation, organic material introduced by livestock and other sources has a greater effect on oxygen levels. This can be observed in the Kenepuru River, which has occasionally very low oxygen concentrations during the summer months. Livestock access is also the likely cause for sporadic lower Oxygen levels in the Ronga and Rai Rivers. However, rural residential areas are a potential additional source of organic pollution in those waterways.

The highest oxygen concentrations were observed in the Graham River and Flaxbourne River. The bed of both waterways is often covered in thick stands of filamentous algae.

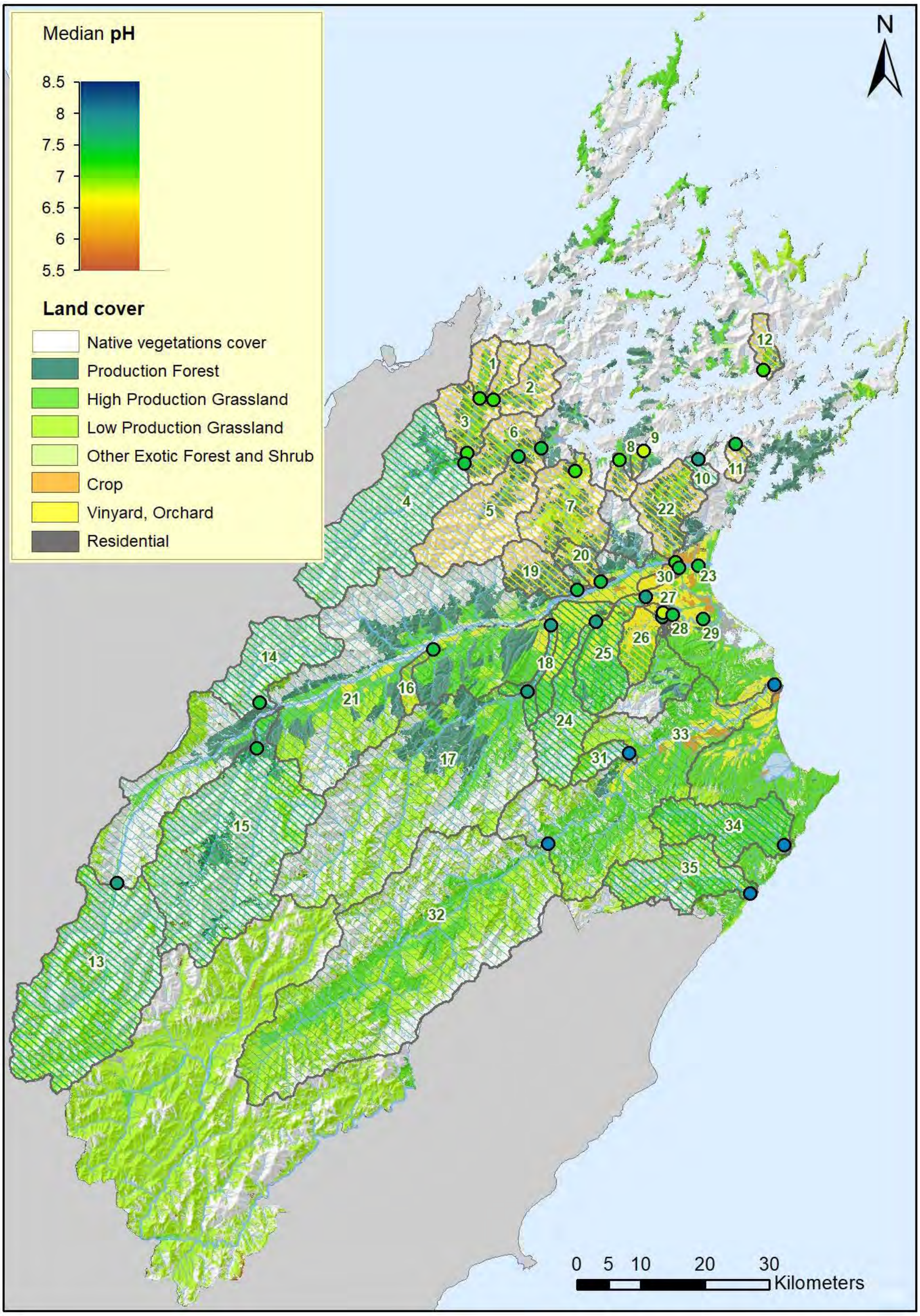

Figure 12: pH at the SoE monitoring sites. Shown is the Median over three years (2017-2019). The shaded areas show the associated catchments and numbers relate to the graph on the next page. Also shown is the Landcover in 2018.

3.3. pH

PH is a measure for the acidity or alkalinity of the water. Values range between 0 (strong acid) and 14 (strong alkaline). A value of 7.0 is referred to as a neutral pH. Generally, rivers and streams are slightly alkaline with pH values around 7.5. This is caused by the natural buffering effect of bicarbonate.

Aquatic organisms have an optimal pH range that varies between different species. Generally, eggs and young animals are more sensitive to low pH values. However, indirect effects of pH often have a greater impact on the aquatic ecosystem than the pH itself [8]. For example, at high pH values, the toxic form of Ammoniacal Nitrogen is more prevalent and low pH values increase the toxicity of heavy metals.

The majority of the rivers in the region have a pH in the optimal range for aquatic organisms. There have been very few guideline exceedances in recent years (Figure 13).

Photosynthetic activity by aquatic plants increases the pH of the water, resulting in daily variations similar to those in dissolved oxygen with a maximum around mid-afternoon. The highest pH levels are usually observed during dry spells in summer. Warmer water temperatures and longer days favour the growth of aquatic plants. Occasional high pH levels in the Waitohi, Wairau and many other rivers coincide with thick algae cover.

The presence of limestone causes naturally higher pH values in rivers and stream in the southern part of the region. The pH is highest in the Waima River, furthest to the South.

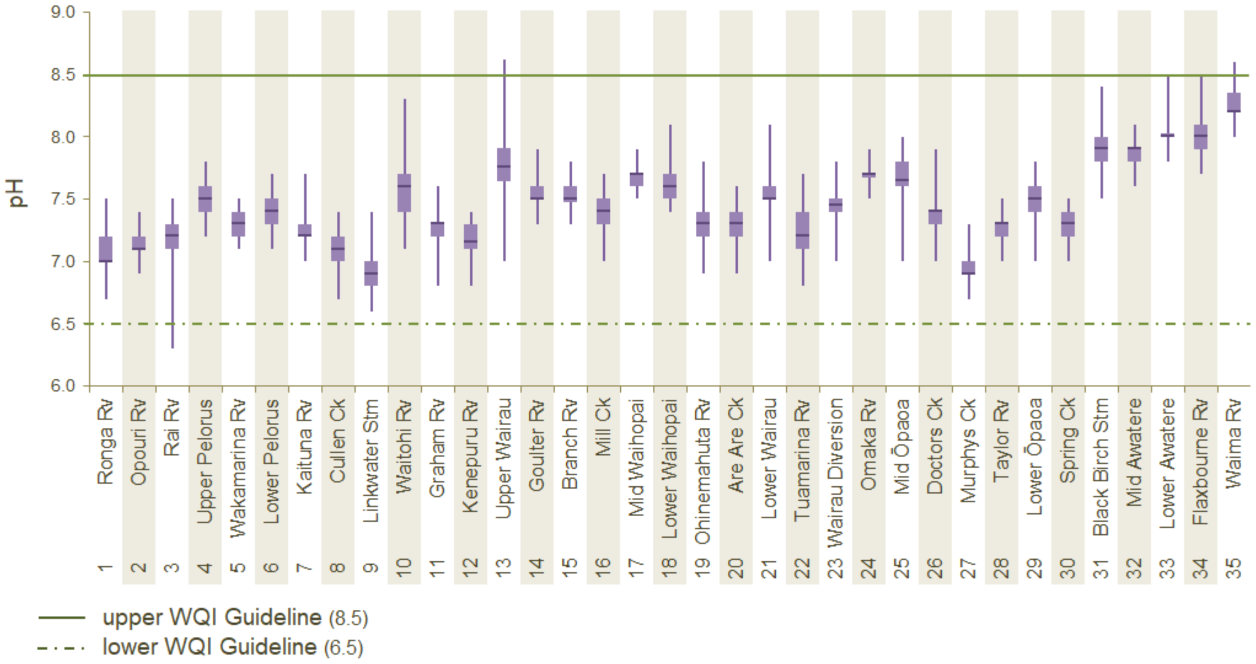

Figure 13: Box and Whiskers Plot of pH values at SoE sites, 2017 – 2019.

Discharges of organic material, such as faecal material and Ammonia can lower the pH. The lowest pH value was observed in the Rai River during rainfall and was likely caused by animal faeces that were washed into the river via surface run-off. It was the only exceedance of the lower guideline.

The upper Wairau River has the largest range of pH values. This site is monitored by NIWA, which means that we do not have field observations that might aid in the identification of the causes. High variability presents greater stress to aquatic organism than more stable pH values at the margins of the optimal range.

Trend analysis shows changes in pH for a number of sites (Figure 14). Most noticeable is an increase of the pH in Black Birch Stream. The water from this stream is the source for the Seddon drinking water supply. To protect water quality, agricultural and residential development in this catchment are restricted and subsequently more than 90% of the catchment remains in native vegetation. The change in pH is therefore likely a natural occurrence. It is thought to be caused by exposure of limestone rich sediment as a result of earthquakes in the area.

Similarly, increasing trends for the Flaxbourne River and Waima River are most likely due to slips following the relatively recent Kaikoura earthquake.

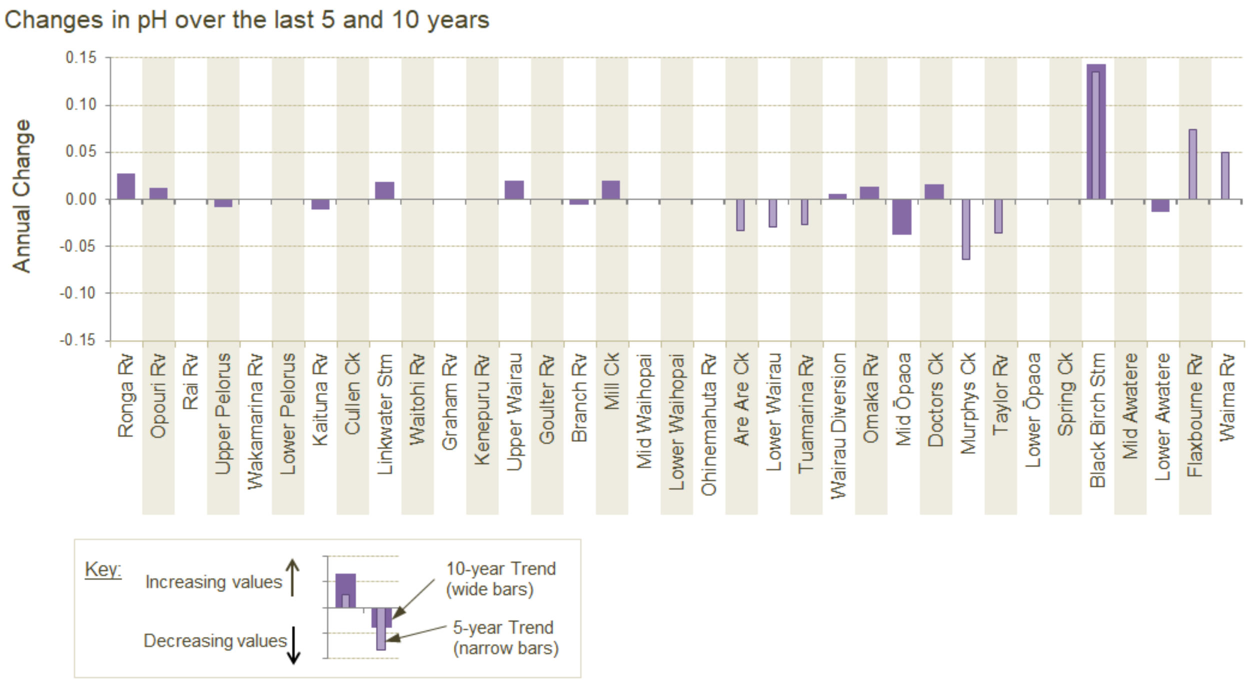

Figure 14: Changes in pH at the SoE sites over the last five (2015-2019) and ten years (2009-2019).

Small increases in pH over the last 10 years are observed in some dairy catchments, such as the Ronga River, Rai River and Linkwater Stream. Here, compulsory fencing of streams has reduced direct input of faecal material from dairy cattle into waterways.

The amount of organic (faecal) material directly discharged into Doctors Creek and Mill Creek has also been reduced. Although in these catchments, the reason is the conversion of pasture into vineyards.

Lower pH values in the Taylor River in the recent five years is likely related to increases in E. coli concentrations caused by earthquake damage to sewerage infrastructure. The main breaks have since been fixed, but repairs are ongoing.

Similarly, a sewage spill into Murphys Creek was discovered as part of the Recreational Water Quality programme in March 2020. The decreasing pH trend over the last five years might mean that similar events occurred before the problem was fixed early last year.

The reasons for decreasing pH values in the Mid Ōpaoa, however, are unclear. A potential cause could be increased application of winery waste water to land with well-draining soils adjacent to the river.

Figure 15: Limestone geology in parts of the Waima catchment (top) causes naturally high pH values in the Waima River (bottom).

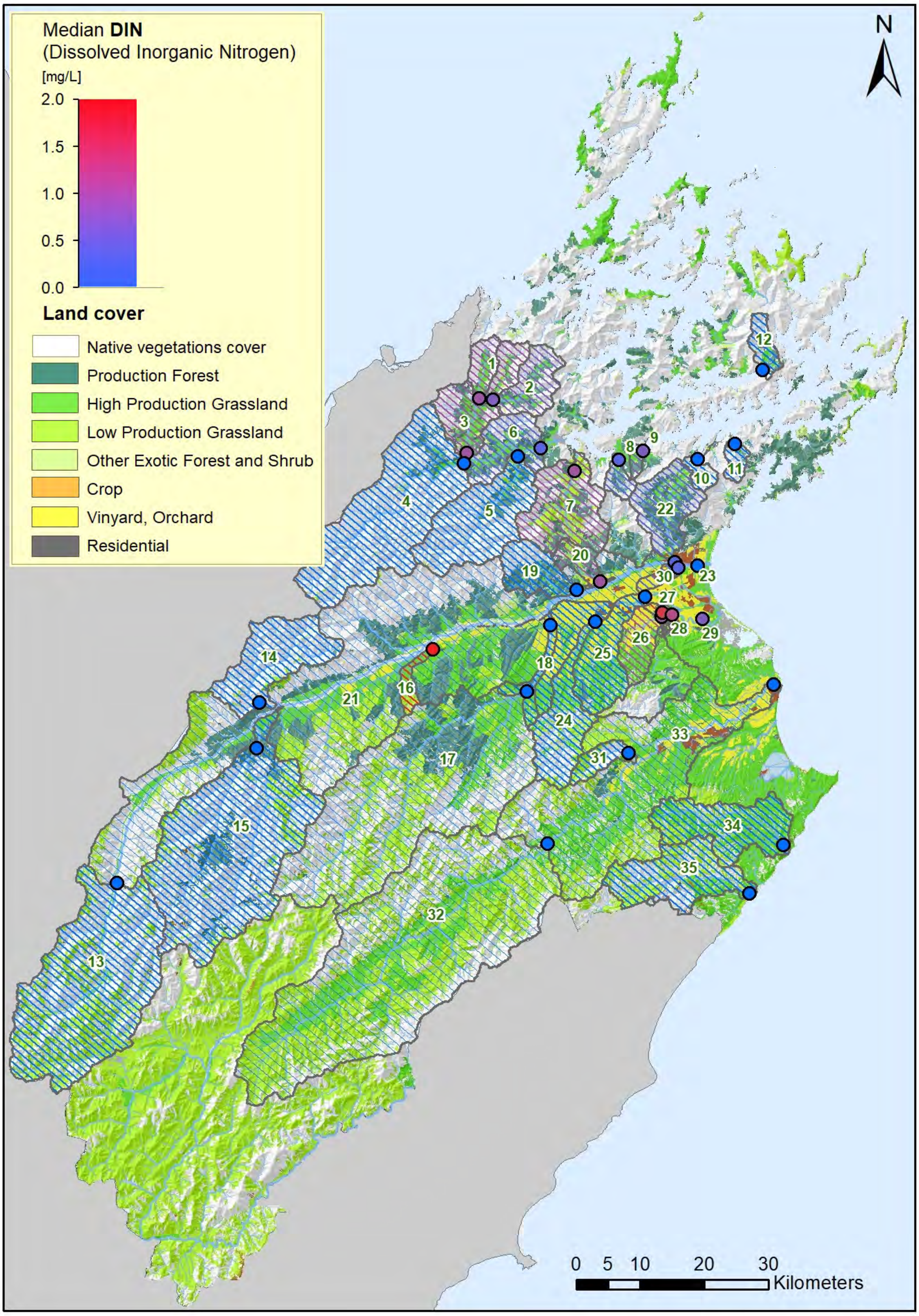

Figure 16: Dissolved Inorganic Nitrogen (DIN) concentration at the SoE monitoring sites. Shown is the Median over three years (2017-2019). The shaded areas represent the associated catchments. The numbers relate to the graph on the next page. Lighter shading indicates areas where monitoring is less representative. Unshaded areas are currently not monitored. Also shown is the Landcover in 2018 (LCDb5).

3.5. Dissolved Inorganic Nitrogen (DIN)

Nitrate, Ammoniacal nitrogen and Nitrite are soluble forms of nitrogen that are easily taken up by plants. They are collectively referred to as ‘Dissolved Inorganic Nitrogen’, abbreviated as DIN. High DIN concentrations can cause excessive growth of aquatic plants such as algae. This is not only visually unpleasing, but the algae smother available habitat for many aquatic insects, which in turn are a food source for fish. This can cause a significant reduction in biodiversity.

Naturally, DIN concentrations are low. This can be seen in catchments that remain almost entirely covered in native vegetation. Examples are the Goulter River, the Upper Te Hoiere/Pelorus River and Black Birch Stream (Figure 17).

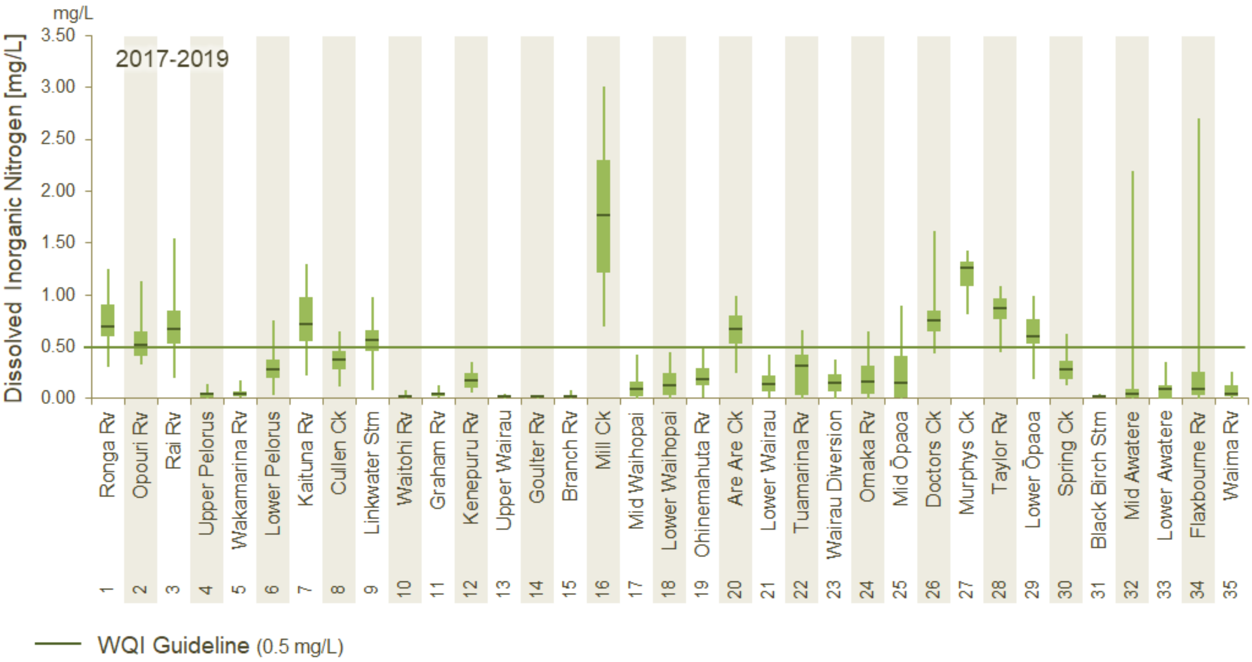

Figure 17: Box and Whiskers Plot of DIN concentrations at SoE sites, 2017 – 2019.

The main pathway for nitrogen into rivers and streams is via leaching. Any nitrogen in animal waste or nitrogen fertilizer applied to land that is not taken up by vegetation is carried into groundwater by rainfall or irrigation water. When groundwater enters streams it carries the nitrogen with it. This is the reason that spring-fed streams such as Mill Creek and Murphys Creek often have the highest DIN concentrations.

Mill Creek has the highest DIN concentrations of all waterways monitored. The creek has a comparatively small surface catchment, but the groundwater emerging in Mill Creek originates from a significantly larger area reaching far to the West. The DIN concentrations also have the widest distribution in measurement values, which indicates that direct input also play a role. The surface catchment of Mill Creek is dominated by beef and sheep pasture, some cropping, production forests and vineyards.

Groundwater inflow into Doctors Creek is also the main source for elevated DIN concentrations in this waterway. However, occasional very higher values are caused by surface run-off after rainfall. Doctors Creek and Murphys Creek are the main sources of flow for the Taylor River, which subsequently flows into the Lower Ōpaoa, explaining the elevated DIN levels in these two rivers.

Cattle urine is one of the main sources of nitrogen leaching [27]. It is therefore not surprising, that some of the dairy catchments have generally higher DIN concentrations. The highest values are observed in the Ronga, Rai and Kaituna rivers as well as Linkwater Stream.

Are Are Creek has similar DIN concentrations to these dairy catchments, but land use is dominated by sheep and beef pasture. The last dairy farm was converted into a beef farm several years ago. Possible sources of nitrogen in this creek are fertilizer application on crops and a residential area in the mid-catchment.

The highest spikes in DIN concentrations were observed in the Mid Awatere and the Flaxbourne River. In both cases, the high DIN values were observed during dry weather condition, ruling out rainfall run-off as the source. The most likely cause is aerial fertilizer application over small tributaries or the main river.

3.6. Nitrate and Total Ammoniacal Nitrogen

Two forms of DIN, Nitrate and Ammoniacal Nitrogen, are toxic to aquatic organisms at high concentrations. For this reason, separate guidelines are applied to account for the different effect on freshwater ecosystems. The NPS-FM limits for these two parameters are also based on this toxicity.

Nitrate is the main form of DIN in almost all samples taken from rivers and streams in the region. Subsequently, the box and whiskers graph showing Nitrate concentrations is almost identical to the graph showing DIN concentrations. However, the NPS-FM state is calculated using data over a period of only one year, rather than combining three years of data as for the Water Quality Index calculation.

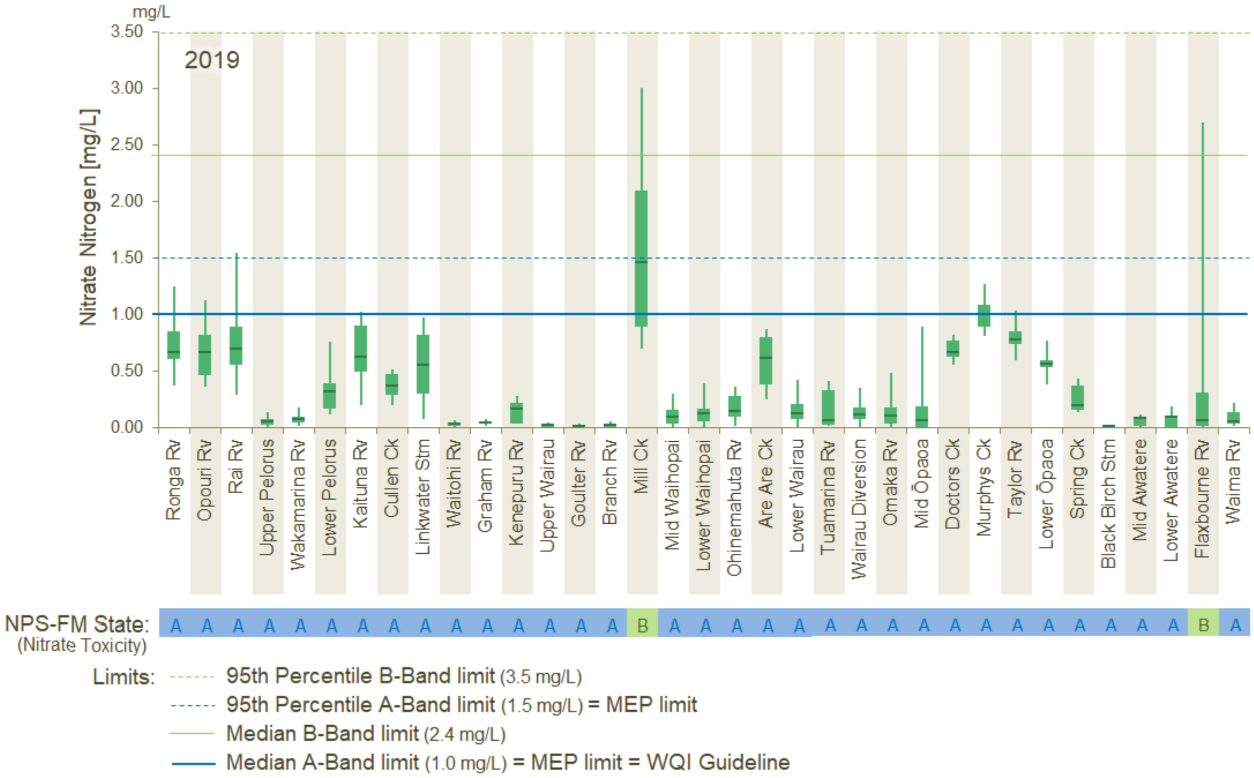

Figure 18: Box and Whiskers Plot of Nitrate Nitrogen concentrations in 2019 at SoE sites. Also shown are the states based on NPS-FM limits.

Apart from Mill Creek and the Flaxbourne River, all sites are within the A-Band of the NPS-FM limits. For the Flaxbourne River, this is the first year with Nitrate levels in the B-band. The cause is a single very high measurement in February 2019, likely a direct input of fertilizer as the water was clear and E. coli concentrations were low.

Mill Creek has had Nitrate concentrations almost consistently within the B-band since monitoring began in 2009. Additionally, trend analysis shows Nitrate levels have substantially increased in the last five years. This appears to be at odds with changes in land use in the wider catchment. Much of the pasture is being converted to vineyards. Measurements from Marlborough vineyards has shown that considerably less nitrogen is leached compared to pasture. However, this applies to older vineyards and it is possible that more fertilizer is lost during vineyard establishment, when grounds are bare and vines are small.

Nitrate concentrations in Murphys Creek have been within the B-band for a number of years, but were within the A-band in 2019. Other rivers with occasional states in the B-band are Doctors Creek and the Kaituna River. Both waterways show decreasing trends. The reduction in Nitrate concentrations in Doctors Creek is likely a result of the conversion from pasture to vineyard, which began much earlier than in Mill Creek. Falling Nitrate levels in Doctors Creek have a positive follow-on effect on the Taylor River, which also shows a decreasing long-term trend.

In the Kaituna River, Nitrogen concentrations decreased significantly over the last five years. It is unclear what the cause is and whether this is a short-lived phenomenon or a long-term change.

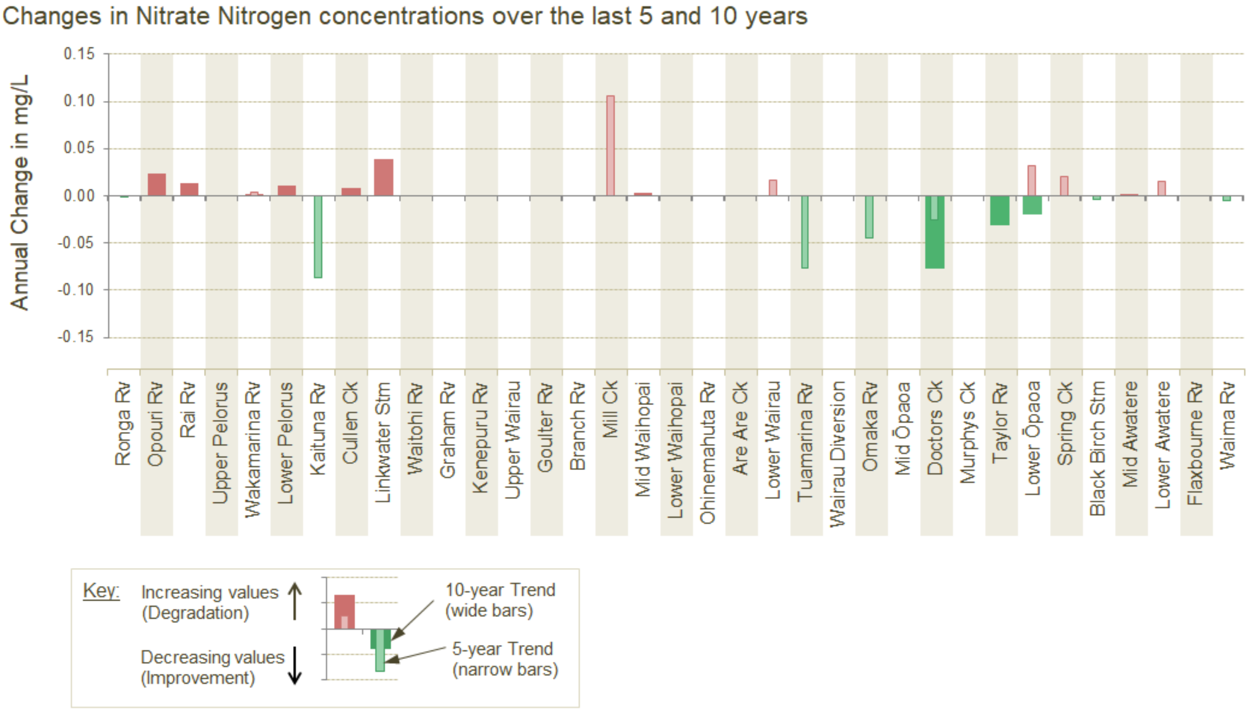

Figure 19: Changes in Nitrate Nitrogen concentrations at the SoE sites over the last five (2015-2019) and ten years (2009-2019)[4].

Nitrate concentrations in the Tuamarina River have also significantly decreased over the last five years. A possible reason are restoration efforts in the Para Swamp. Additional monitoring as part of a catchment study in 2016 had shown that the wetland was removing nitrogen from the river water [22]. Restoration of the Para Swamp is likely improving this natural filtering function.

Nitrate concentrations in several of the diary catchments have increased over the last ten years, with the highest increase in Linkwater Stream. However, this does not apply to all dairy catchments. Surprisingly, the catchment with the greatest proportion of dairy pasture, the Ronga, shows a very slight improvement in Nitrate levels. The varying trends would indicate that changes in land management practices might be responsible.

Ammoniacal Nitrogen concentrations in the region’s rivers and streams are generally low with only rare exceedances of the WQI guideline. All SoE sites are within the A-Band of the NPS-FM limits for this parameter. Trend analysis did not show any changes in Ammoniacal Nitrogen.

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[4] Trend analysis was carried out for Nitrate, but not DIN to avoid problems that can arise from the combination of different measurements. Since most of the DIN is in the form of Nitrate, trend results for Nitrate concentrations are indicative of very similar trends for DIN.

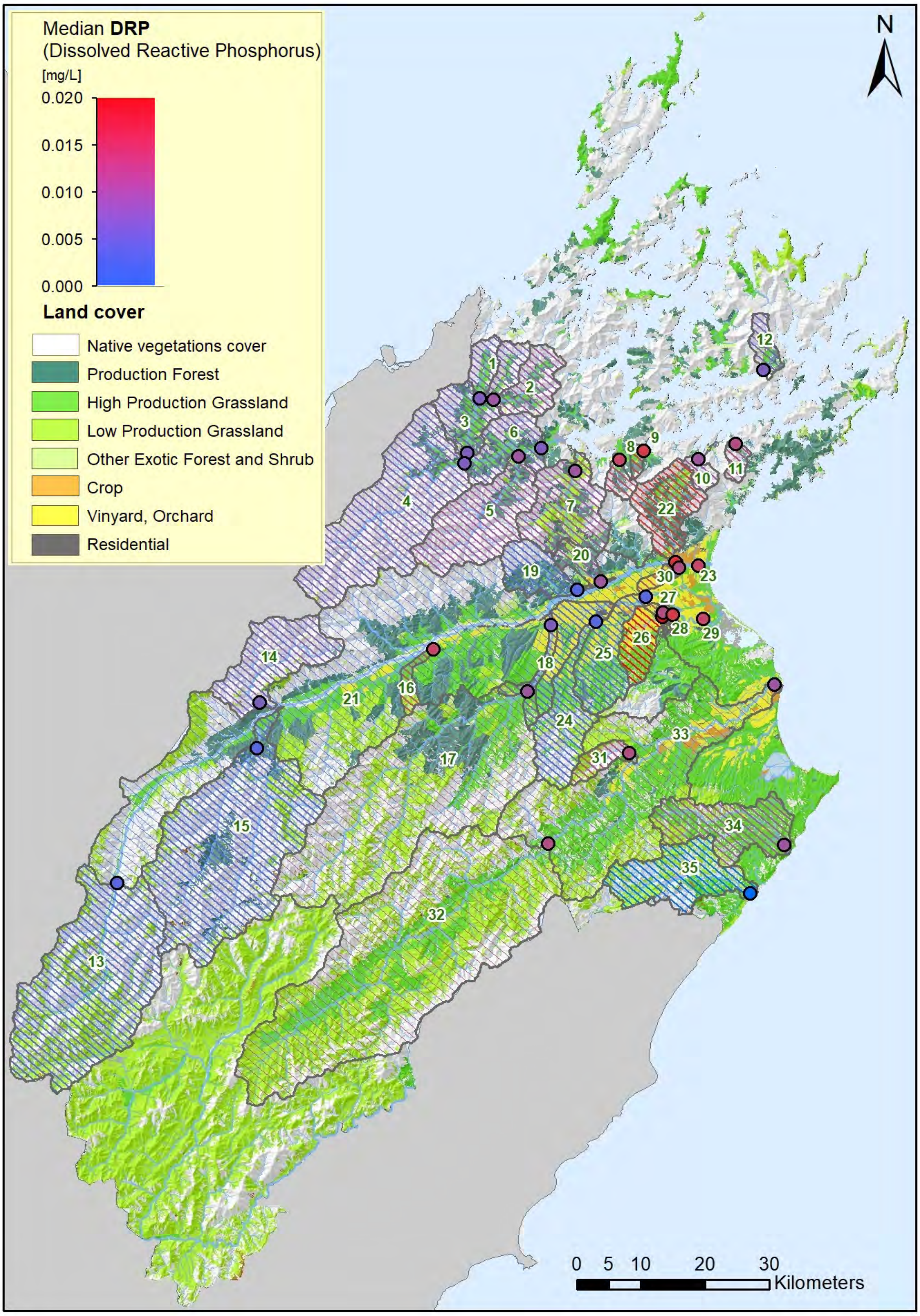


Figure 20: Dissolved Reactive Phosphorus (DRP) concentration at the SoE monitoring sites. Shown is the Median over three years (2017-2019). The shaded areas represent the associated catchments. The numbers relate to the graph on the next page. Lighter shading indicates areas where monitoring is less representative. Unshaded areas are currently not monitored. Also shown is the Landcover in 2018 (LCDb5).

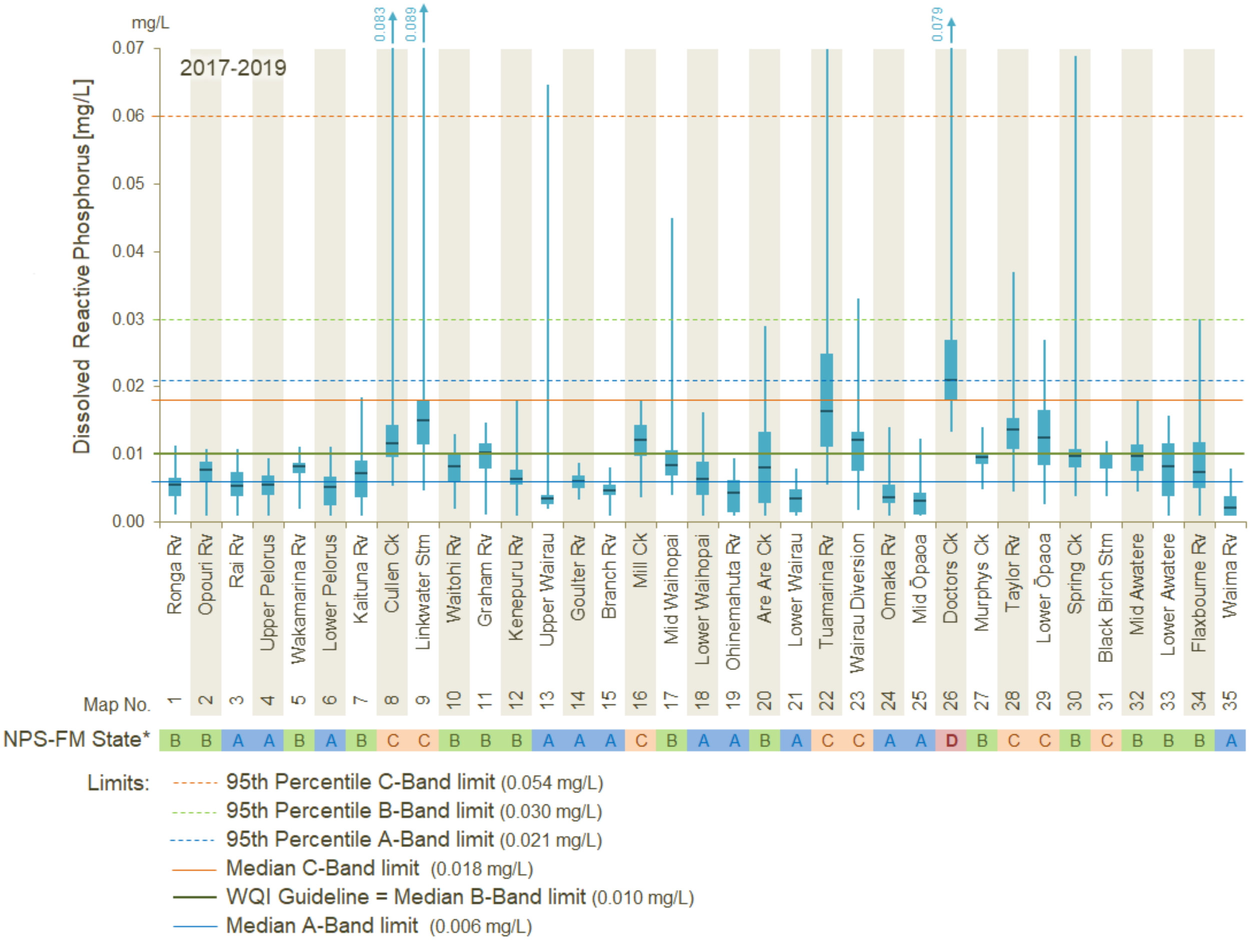
3.7. Dissolved Reactive Phosphorus (DRP)

Dissolved Reactive Phosphorus (DRP) is a measure for the amount of phosphorus in the water column that can easily be taken up by plants. Together with elevated DIN concentrations, high levels of DRP can result in excessive algae growth. The algae can smother the stream bed, effecting habitat quality and food supply for fish and aquatic insects. Excessive algae cover also impacts on the amenity and recreational values of waterways.

Occasional, very high DRP concentrations are unlikely to cause an increase in algae growth, as these short-term events are generally associated with flood flows, which are more likely to remove algae from the river bed.

In most streams, phosphorus concentrations are significantly lower than nitrogen concentrations, particularly in impacted catchments. Phosphorus is easily absorbed onto soil particles and therefore less mobile than nitrogen. Leaching of phosphorus does, however occur if the soil becomes saturated with phosphorus due to frequent application of fertilizer.

Comparison with water from nearby wells, has shown that most of the DRP in Murphys Creek originates from groundwater [19]. This is also the case for Mill Creek and Spring Creek, but DRP concentrations in these waterways are more variable, indicating that there are additional sources.



* Note that the NPS-FM state is calculated using data over a period of 5 years (2015-19), while the graph shows data over the last 3 years (2017-19)

Figure 21: Box and Whiskers Plot of DRP concentrations at SoE sites for the period 2017 – 2019. Also shown are the states based on the NPS-FM limits for the DRP attribute.

Rivers in some parts of the region have naturally elevated DRP levels caused by phosphorus-rich rock in the catchment. An examples is the Black Birch Stream, which is almost un-impacted by human activities. This waterway has DRP concentrations in C-band of the NPS-FM. This means that phosphorus concentrations within the A-Band are likely to be unachievable for other waterways as well.

Overall, Doctors Creek has the highest DRP concentrations of the sites monitored. Although groundwater is a major source of flow, DRP levels are significantly higher and more variable than in nearby Murphys Creek. The lower parts of Doctors Creek consist of artificially straightened channels that have been dug through a former swamp to drain the land for agricultural use. The deep channels have almost vertical banks, which consist of clay rich swamp deposits. The slightest water movement causes fine sediment from these banks to be washed into the creek. Sediment is one of the main sources of phosphorus in Doctors Creek. A catchment study in 2013 showed that stock access, spraying of bank and in-stream vegetation as well as drain works further exacerbates the problem [20]. Doctors Creek is the only waterway with DRP concentrations in the D-band. The poor water quality in Doctors Creek is likely contributing to elevated DRP levels in the Taylor River and the Lower Ōpaoa River downstream.

The Tuamarina River is another waterway with comparatively high and variable DRP concentrations. Additional monitoring in 2017 as part of a catchment study showed that the Para Swamp is a significant source of phosphorus for the lower river [22]. One potential cause is the large-scale removal of willows from the wetland (see Figure 23). Another source could be fine sediment deposited in the wetland. The catchment study showed that exceptionally high turbidity during flood flows in 2013 was likely caused by forestry harvest. Trend analysis reveals that phosphorus concentrations have decreased over the last five years (Figure 22). This might indicate that the high phosphorus levels are a temporary phenomenon

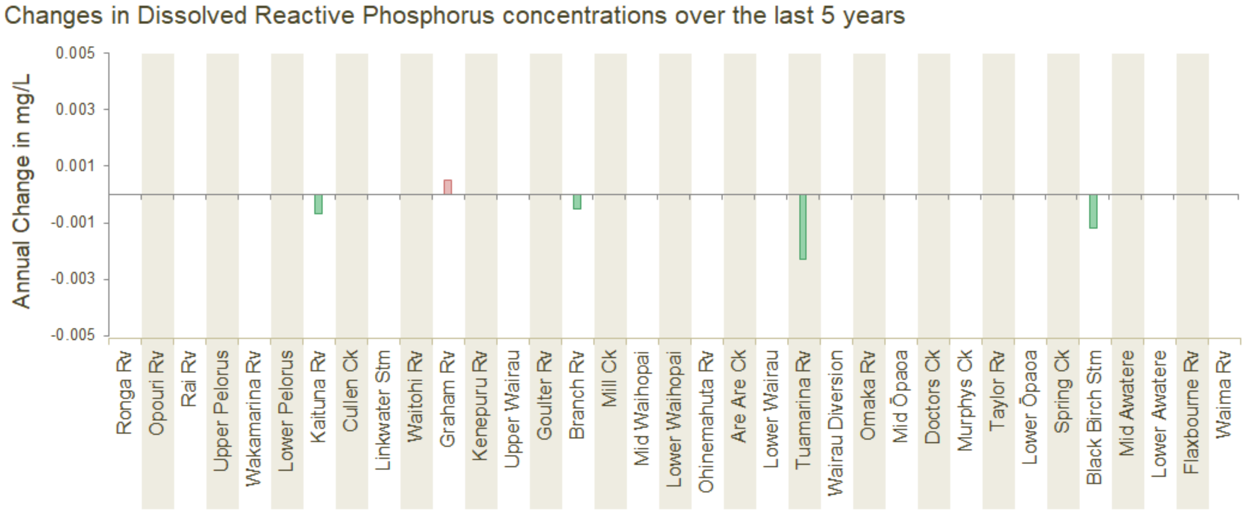


Figure 22: Changes in DRP concentrations over the last five years.

Figure 23: Large areas of the Para Swamp were sprayed to remove willows from the wetland. The dead willows might be the source of additional phosphorus in the Tuamarina River, which flows through the wetland.

Linkwater Stream and Cullen Creek also have DRP concentrations in the C-band. The two waterways have the highest spikes during rainfall, strongly pointing to surrounding landuse as significant source of phosphorus. A report investigating the causes of degraded water quality in the catchments was released in 2019 [24]. The report found that pasture in the lower river flats contributed some of the phosphorus. However, DRP concentrations were already comparatively high in the streams flowing out of mature production forests covering the hills in the mid-catchments. Although, it is likely that phosphorus-rich rock was causing naturally elevated DRP levels, the stream beds were also covered in fine sediment, an additional source of phosphorus. Further investigation found no point sources for the fine sediment. Instead a lack of undergrowth combined with steep slopes meant that the bare soils were being washed into the streams during frequent rainfall events. Future trend analysis is likely to show the effect of forestry harvest that recently began in parts of the catchments.

Overall, trend analysis showed very few changes in DRP concentrations. However, it needs to be noted that only the last five years could be analysed for changes (see Section 2.3). Interestingly, one of the streams with significant changes in phosphorus levels, Black Birch Stream, has a catchment that largely remains in native vegetation. This shows that DRP levels can naturally change over time.

Figure 24: Although more than 90 percent of the catchment is covered in native vegetation, DRP concentrations in Black Birch Stream are in the B-band. The cause is phosphorus-rich rock in the geology of the catchment.

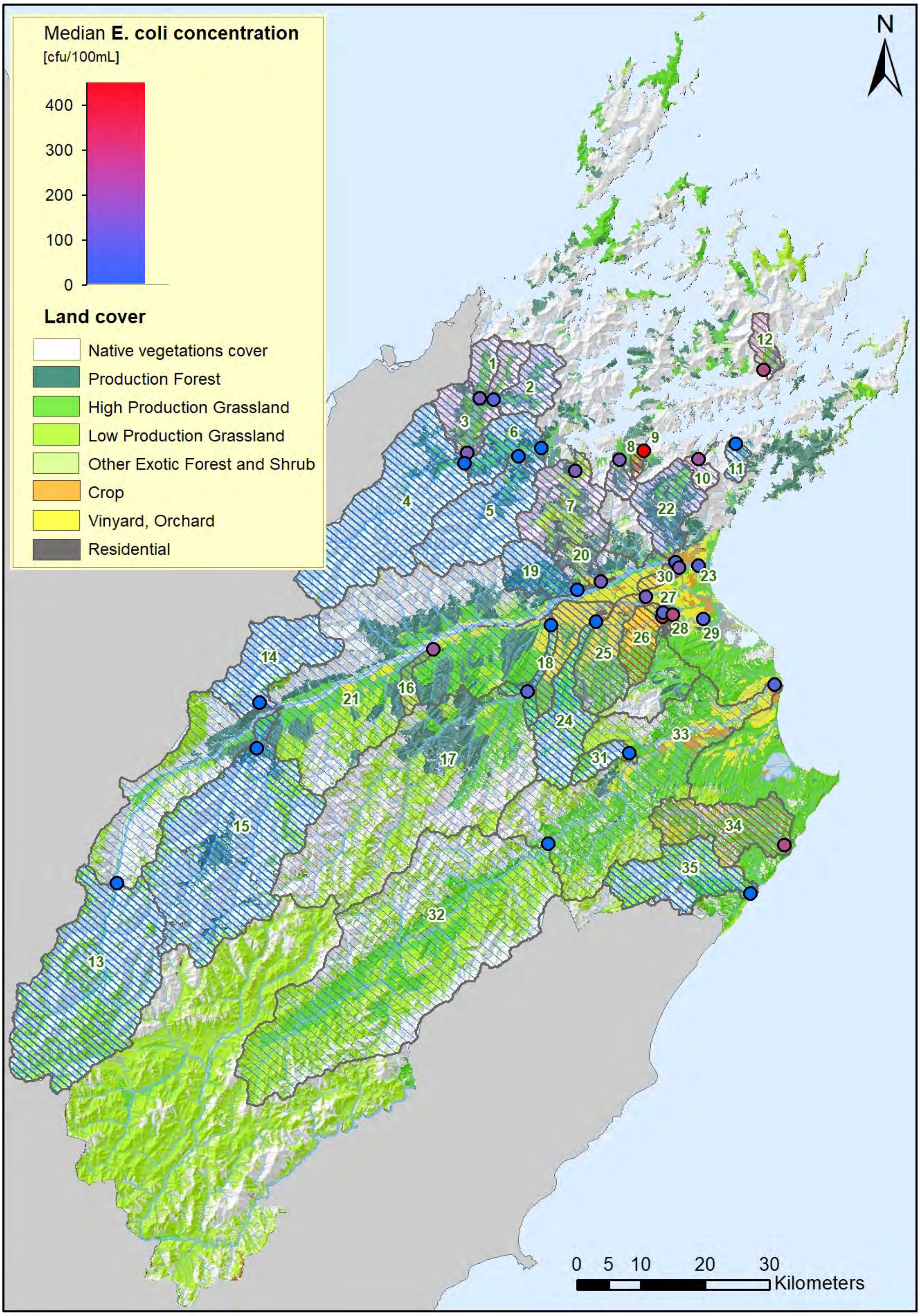


Figure 25: E. coli concentration at the SoE monitoring sites. Shown is the Median over three years (2017-2019). The shaded areas represent the associated catchments. The numbers relate to the graph on the next page. Lighter shading indicates areas where monitoring is less representative. Unshaded areas are currently not monitored. Also shown is the Landcover as of 2018 (LCDb5).

3.8. E.coli

E.coli are bacteria found in the gut of warm-blooded animals and humans. Most E. coli strains are not harmful to human health, but their presence indicates contamination with faecal matter, which might contain harmful organisms such as Campylobacter or Cryptosporidium.

Rivers and streams that flow through catchments with predominantly native vegetation have usually very low E.coli concentrations. Examples are the Goulter River, Branch River and Black Birch Stream. This shows that native bush generally is not a significant source of faecal contamination.

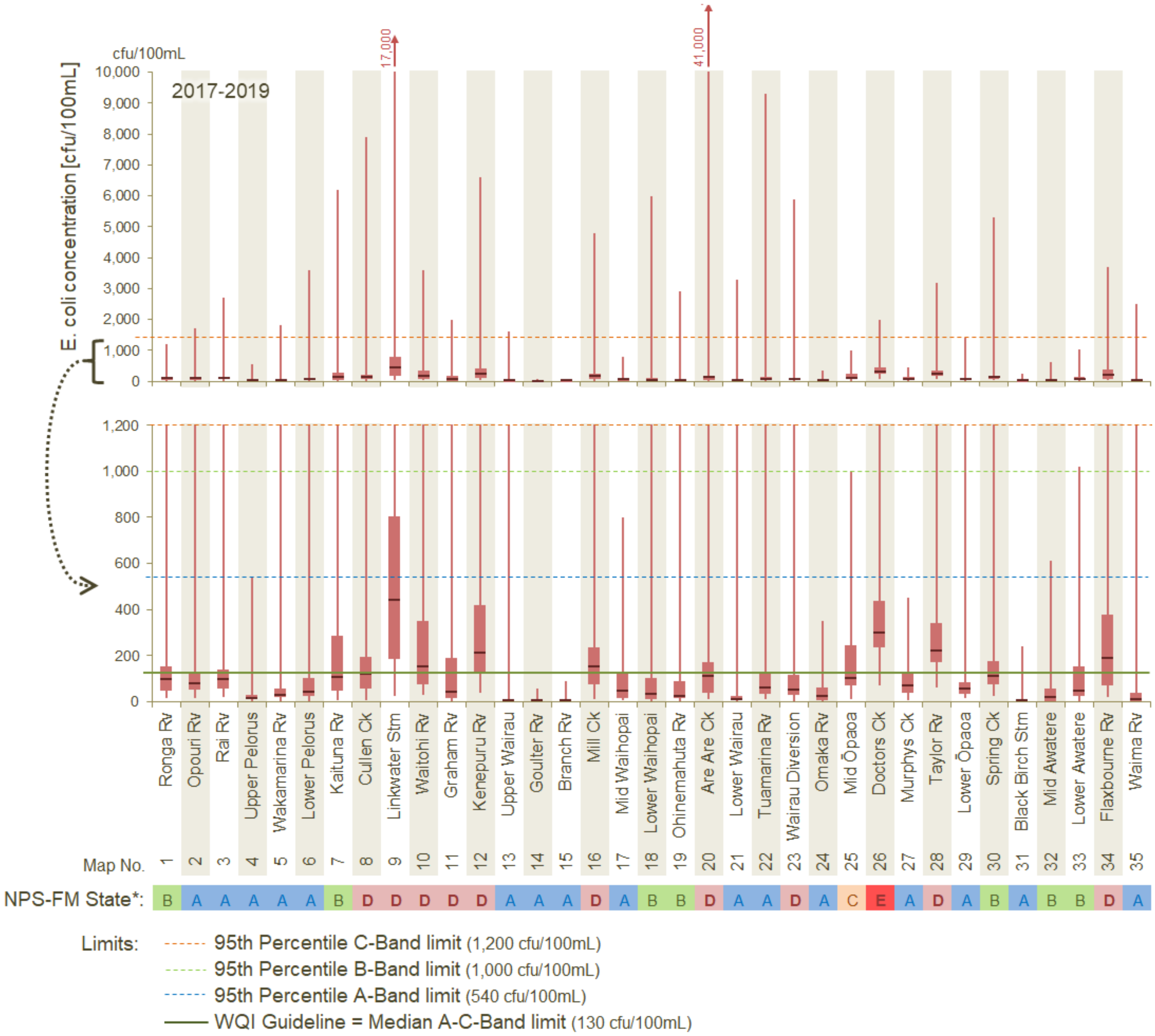


Figure 26: Box and Whiskers Plot of E. coli concentrations at SoE sites, 2017 – 2019. Also shown are the water quality states for the E. coli attribute based on NPS-FM limits.

E. coli concentrations can reach very high levels during rainfall when faecal material from livestock is washed from paddocks into nearby streams. This can occur after relatively small rainfall events, particularly when the ground is dry. The highest E. coli concentration observed in the last three years was measured during a small fresh in Are Are Creek. There are many factors that influence the amount of faecal material washed into rivers and streams. These include stocking intensity, duration of grazing and type of livestock. Physical factors such as land slope and soil type determine the amount of surface run-off that can transport contaminants into waterways. Dense riparian vegetation can act as buffer and reduce the amount of faecal matter reaching rivers and streams.

Spikes in E. coli concentrations during rainfall were observed at most sites. However, in some rivers and streams, E. coli concentrations are also elevated during low flow conditions. This represents a much more serious issue, particularly in regard to the recreational use of these waterways and receiving environments.

Of the waterways monitored, Linkwater Stream had generally the highest E. coli concentrations. The lower flats of the catchment are covered in pasture, which is mainly grazed by dairy cattle. Additional monitoring as part of a catchment study in 2016/17 showed that small areas of unfenced beef pasture were a significant contributor to elevated E. coli concentrations [24]. However, additional sources on dairy farms included irrigation water run-off from grazed pasture and cattle access to small tributaries. Trend analysis shows a significant increase in E. coli concentrations in Linkwater Stream, particularly in the last five years. A closer look at the data revealed that the increase began after monitoring for the catchment study was completed and it is therefore unclear what the causes are. The relatively recent increase also results in a noticeable mismatch between the data shown in Figure 26 and the NPS-FM state. Linkwater Stream has a state in the D-band despite significantly higher E. coli concentrations than Doctors Creek, the only waterway with a state in the E-band. The reason is that the graph shows data over the last three years, which is used for the calculation of the Water Quality Index. The NPS-FM state is calculated using data over a period of five years and therefore includes data from earlier years when E. coli concentrations were significantly lower. Unless the new sources of E. coli in the Linkwater catchment are identified and mitigated, Linkwater Stream will become the second waterway in the region with a NPS-FM state in the E-band.

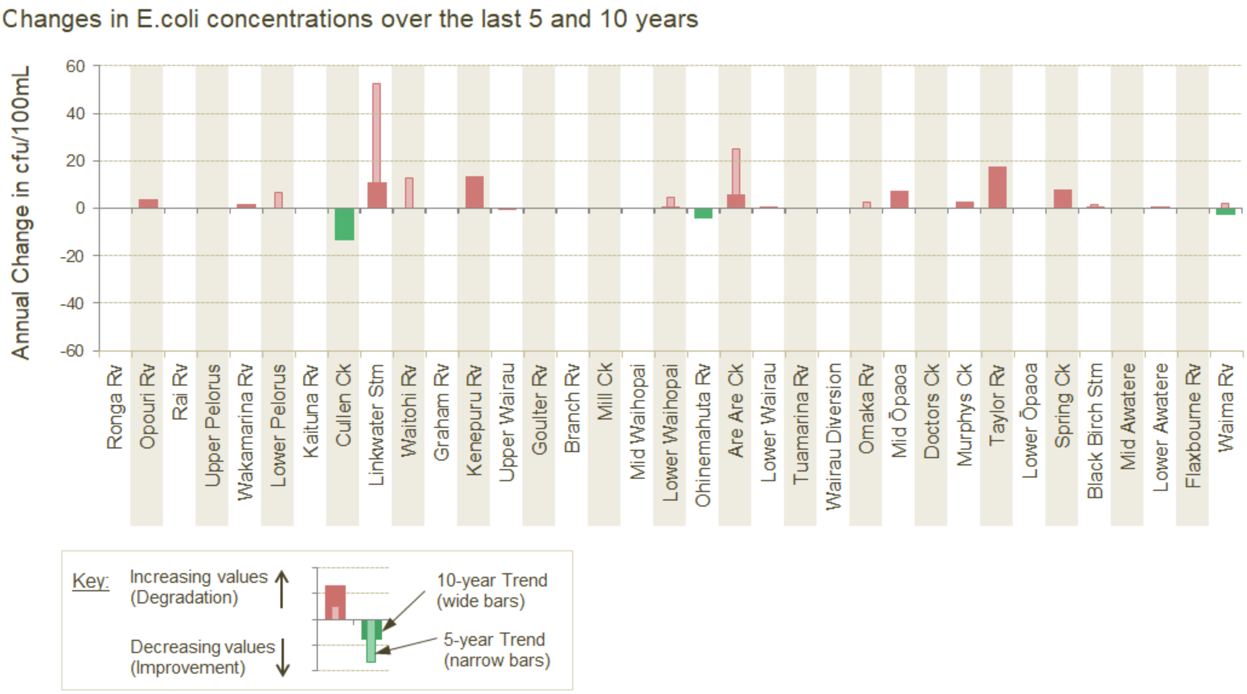


Figure 27: Changes in E. coli concentrations at the SoE sites over the last five (2015-2019) and ten years (2009-2019).

A catchment study of water quality in the Doctors Creek catchment was carried out in 2013 [20]. Trend analysis shows no change in E. coli concentrations. It can therefore be assumed that the sources today are predominantly those identified during the study. These sources include livestock access, ducks and potential human sources from semi-rural properties.

Increasing E. coli concentrations in the lower Taylor River are known to have been caused by earthquake damage to sewerage and stormwater infrastructure. Repairs are ongoing and will likely reverse the current trend over the coming years.

Some of the region's dairy catchments, such as the Rai River, have comparatively low E. coli concentrations, represented by NPS-FM states in the A-band. Furthermore, the greatest improving trend is observed in Cullen Creek, a catchment with almost exclusive dairy pasture on the river flats.

Compulsory fencing of waterways on dairy farms was introduced several years ago, while the majority of beef cattle still has access to waterways. This explains the generally higher E. coli concentrations in catchments where sheep and beef pasture is one of the main land uses. Examples are the Kaituna River, Are Are Creek and Mill Creek. In fact, increasing E. coli concentrations in Are Are Creek could potentially be caused by a change from dairy to beef pasture.

Extensive beef and sheep farming dominate the catchment of the Flaxbourne River. The area receives relatively little rainfall and river flows are subsequently low. This means, that despite low stock densities, access of livestock to the river has a significant impact on water quality.

Livestock access to streams is also contributing to elevated E. coli concentrations in the Marlborough Sounds. All monitoring site in that area have E. coli states in the D-band. Rural residential sewage systems are likely additional sources of faecal contamination. Investigations as part of the Recreational Water Quality Programme have shown that high bacteria concentration were often caused by failing septic tank systems [25].

The Waitohi River is the only waterway in the Marlborough Sounds with a significant urban area in the catchment. Breaks in aging parts of the sewerage system are therefore the most likely cause for an increase in E. coli concentrations in recent years.

Figure 28: The dry climate in the Flaxbourne River catchment means, that although livestock is grazed at low intensity, the impact of stock access to the waterway is relatively high.

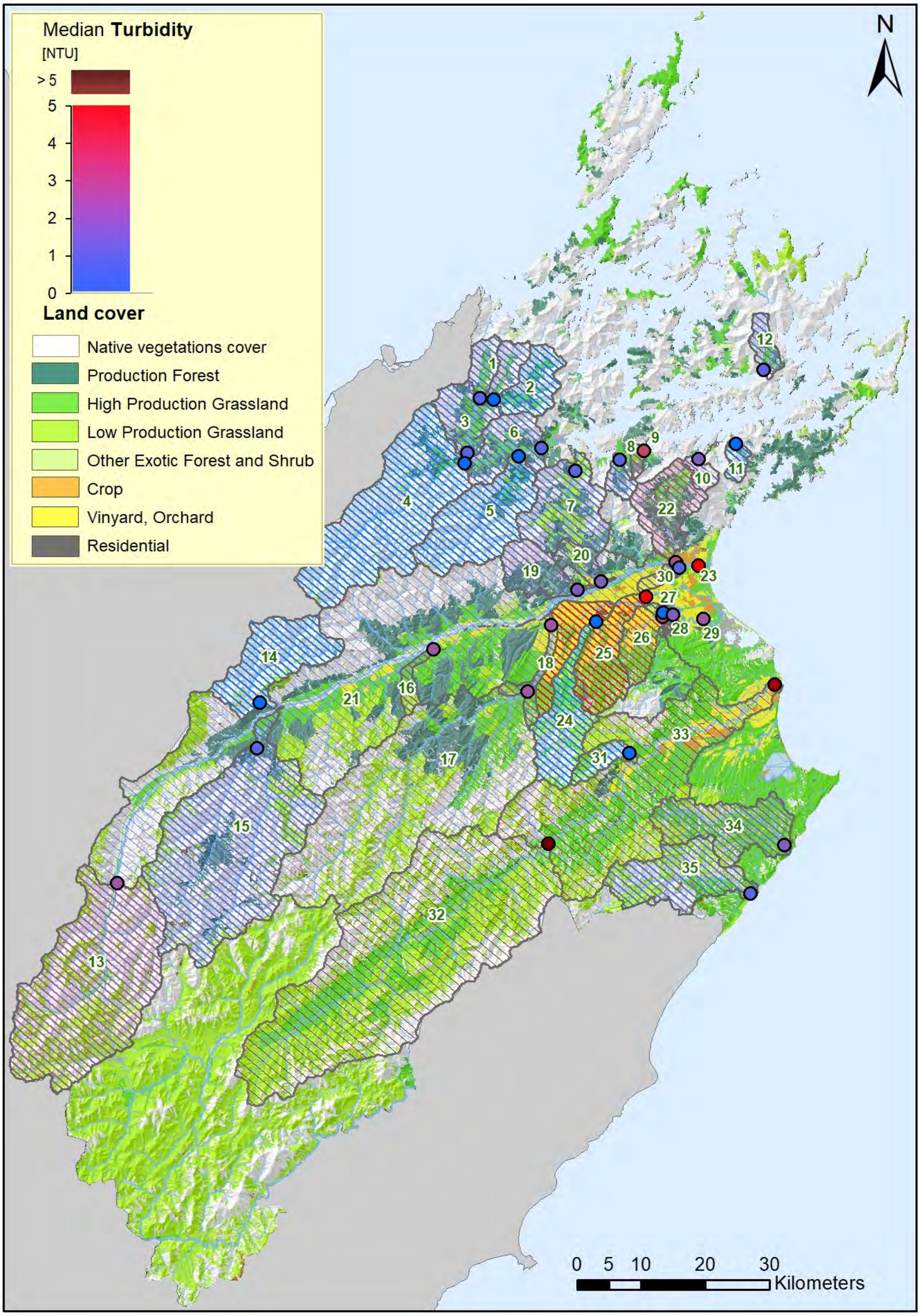


Figure 29: Turbidity at the SoE monitoring sites. Shown is the Median over three years (2017-2019). The shaded areas represent the associated catchments. The numbers relate to the graph on the next page. Lighter shading indicates areas where monitoring is less representative. Unshaded areas are currently not monitored. Also shown is the Landcover in 2018 (LCDb5).

3.9. Turbidity

Turbidity is a measure for the amount of sediment in the water. Measurements are obtained using a sensor that emits light and measures the scattering of that light by particles suspended in the water column. Turbidity measurements are expressed in Nephelometric Turbidity Units (NTU).

High turbidity is usually associated with flood flows, during which fine sediment enters rivers and streams from surrounding land surfaces via surface run-off. The main sources are slips or bare land, such as cultivated or harvested fields and unsealed roads. During high flows sediment is also removed from stream and river banks due to the erosive action of flowing water. Removal of vegetation along the edges of water ways can significantly increase the erosion of the banks.

During lower flows, rivers and streams in the region are generally characterised by clear water. Exceptions are the Waihopai River and Awatere River. Highly erodible mudstone geology causes comparatively high turbidity, which only reduces after longer dry spells. However, most of the original native vegetation in these catchments has been removed and low production grassland is now the main land cover. This is likely to increased erosion. Because so little native vegetation remains, it is difficult to determine the contribution of human activity to high turbidity in these rivers.

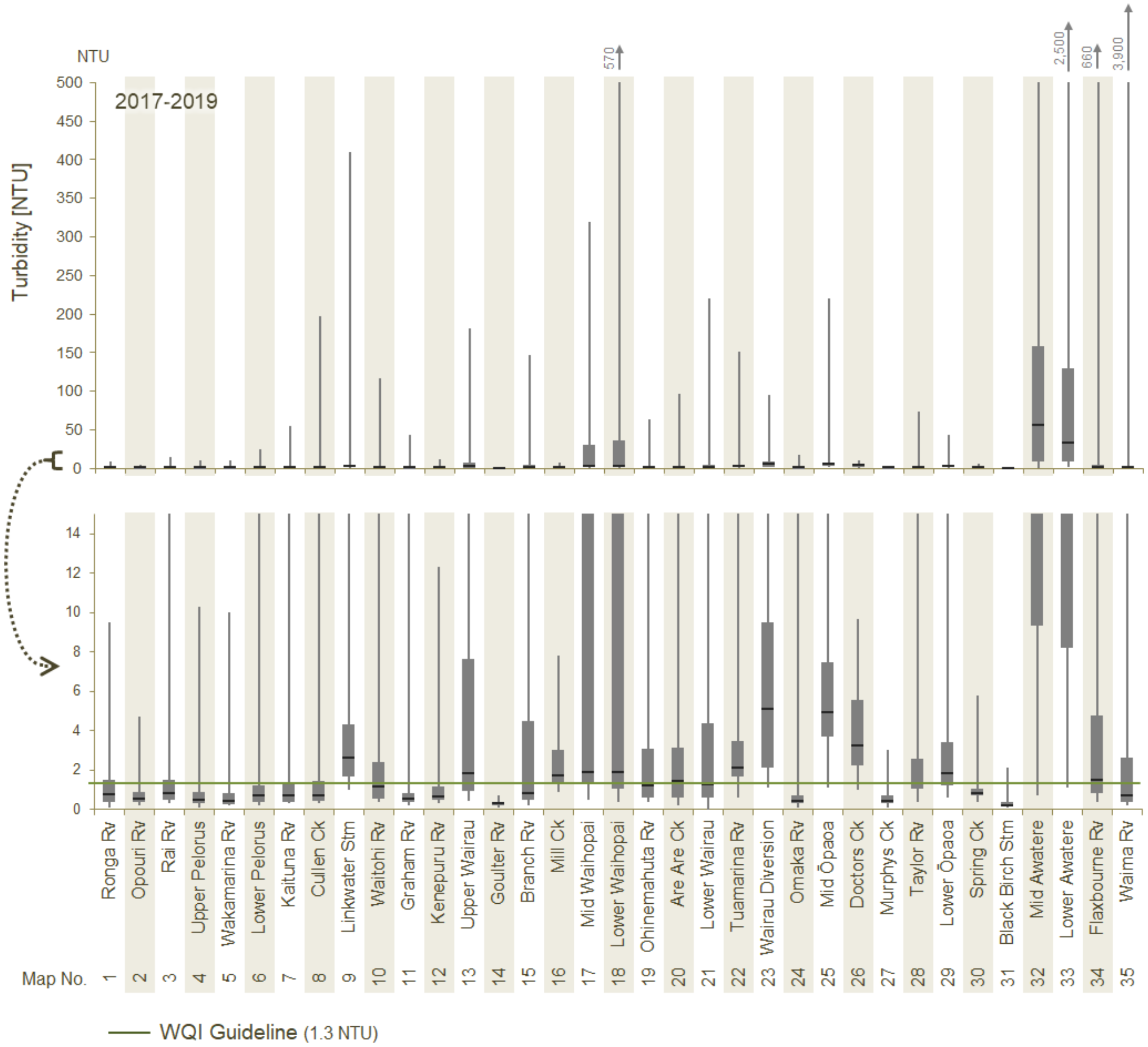


Figure 30: Box and Whiskers Plot of Turbidity at SoE sites, 2017 – 2019.

Turbidity in Black Birch Stream is generally very low. The stream is a small tributary of the Lower Awatere River and most of its catchment is still covered in native vegetation. It could therefore be considered a representative of conditions before human arrival. However differences in Turbidity at the two Awatere

River site, together with anecdotal evidence from observations during flood flow suggests that the main source of turbidity is located in the upper Awatere catchment. This means that the geology of the Black Birch catchment is likely different from the erosion-prone areas that cause high turbidity in the Awatere River.

Trend analysis shows that Turbidity in the Awatere River has significantly decreased over the last five years. The change is greater at the mid Awatere River, but turbidity is also generally higher at this site. This means the percentage decrease is roughly the same at both Awatere sites, around 20%. This is a significant change, but the causes are unknown and it is quite possible that the timing of sampling in relation to flood flows could be a contributing factor.

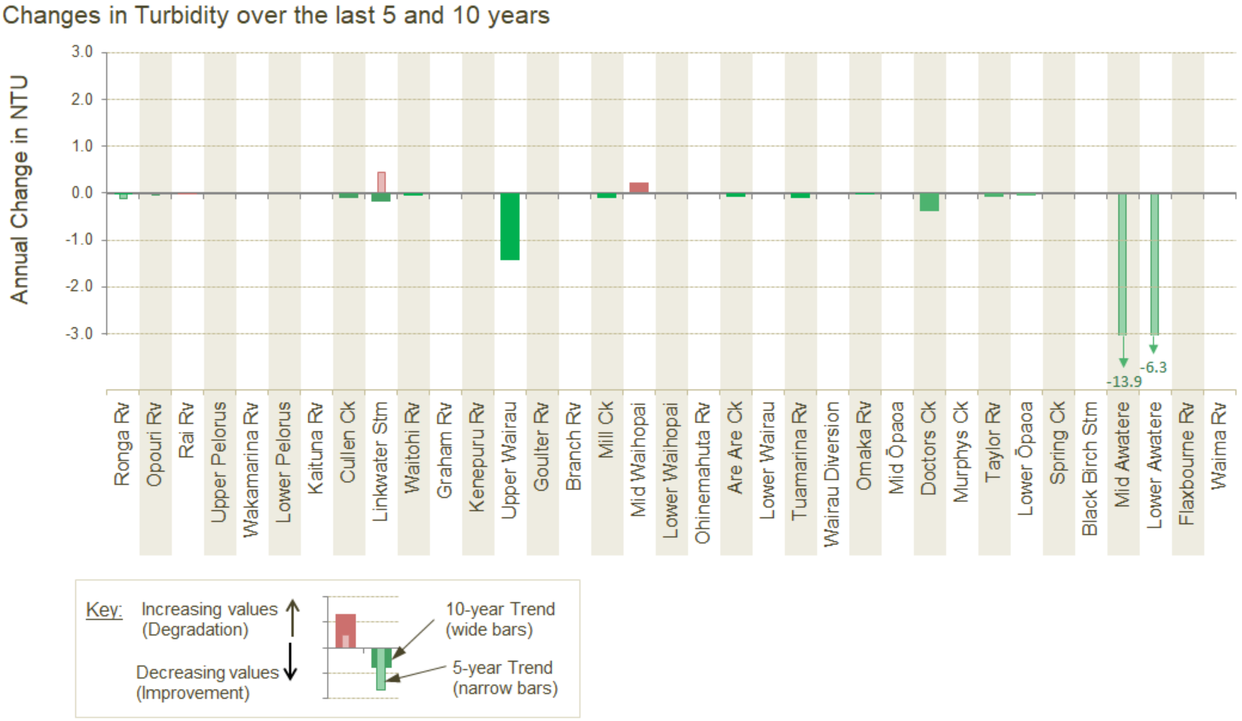


Figure 31: Changes in Turbidity at the SoE sites over the last five (2015-2019) and ten years (2009-2019).

The eastern part of the Branch catchment shares geological characteristics with that of the Waihopai River catchment. This might explain the elevated turbidity in the Branch River, which has a catchment of over 80% native vegetation. However, clear felling of production forestry in the lower parts of the catchment is likely contributing to sediment in the water.

More unclear are the reasons for high turbidity in the upper Wairau River. The geology is very different to the Waihopai or Awatere rivers. The site is monitored by NIWA, which also undertakes the analysis of the samples. Recent research has revealed that there can be notable disparity in turbidity values when different measurement devices are used [15, 35]. This might mean that the turbidity measured for the upper Wairau River is not directly comparable with MDC data. The upper Wairau River showed the greatest change in turbidity over the last 10 years. Data analysis suggests that sampling occurs slightly more frequently at higher flows during earlier years. This is likely to contribute to the trend, but it is unclear if other factors also play a role. Unfortunately, we do not have field observation that might assist in the interpretation of the trend result.

High turbidity in the Wairau Diversion is likely related to characteristics of the monitoring site rather than a reflection of conditions in the catchment. The main sources of water in the Wairau Diversion are the Lower Wairau River and the Tuamarina River. Both, have noticeably lower turbidities. The Wairau Diversion is an artificial channel that is part of the flood protection system for residential areas in the Wairau Plain. At the sampling site, fine sediment is covering almost the entire riverbed. Disturbance of the riverbed by waves, animal or human activity causes the sediment to be re-suspended into the water, resulting in elevated turbidity.

A similar effect can be observed in Doctors Creek, which also has a layer of fine sediment covering parts of the stream bed. Apart from causing high turbidity, the sediment also releases phosphorus into the water, evident as high DRP concentrations. The sources of sediment in Doctors Creek were previously discussed in Section 3.7.

The mid Ōpaoa receives water from the Waihopai River as part of the Southern Irrigation Scheme. Therefore, the majority of fine sediment in the Ōpaoa originates from the Waihopai River.

Apart from Linkwater Stream and the Waitohi River, streams and rivers in the northern part of the region are among those with the lowest turbidity. In Linkwater, fine sediment appears to be mainly caused by a lack of undergrowth in the forested hills (see Section 3.7). In the Waitohi River, urban surface run-off from sealed surfaces and stream bank vegetation management are the main reasons for higher turbidity.

Elevated turbidity in the Flaxbourne and Waima Rivers are partially a result of slips during recent earthquakes.

Figure 32: Most of the Branch River catchment is covered in native vegetation, but some of the lower slopes have been planted in production forest. Harvesting of this forest is likely increase turbidity in the river.

The NPS-FM has limits for clarity rather than turbidity. Clarity is not routinely measured in Marlborough as it less practical, potentially more subjective and introduces greater Health and Safety concerns compared to the measurement of turbidity. It also cannot be measured continuously. The NPS-FM allows limits for clarity to be converted into turbidity limits using site-specific correlations. However, for the majority of monitoring sites these correlations have not been established yet.

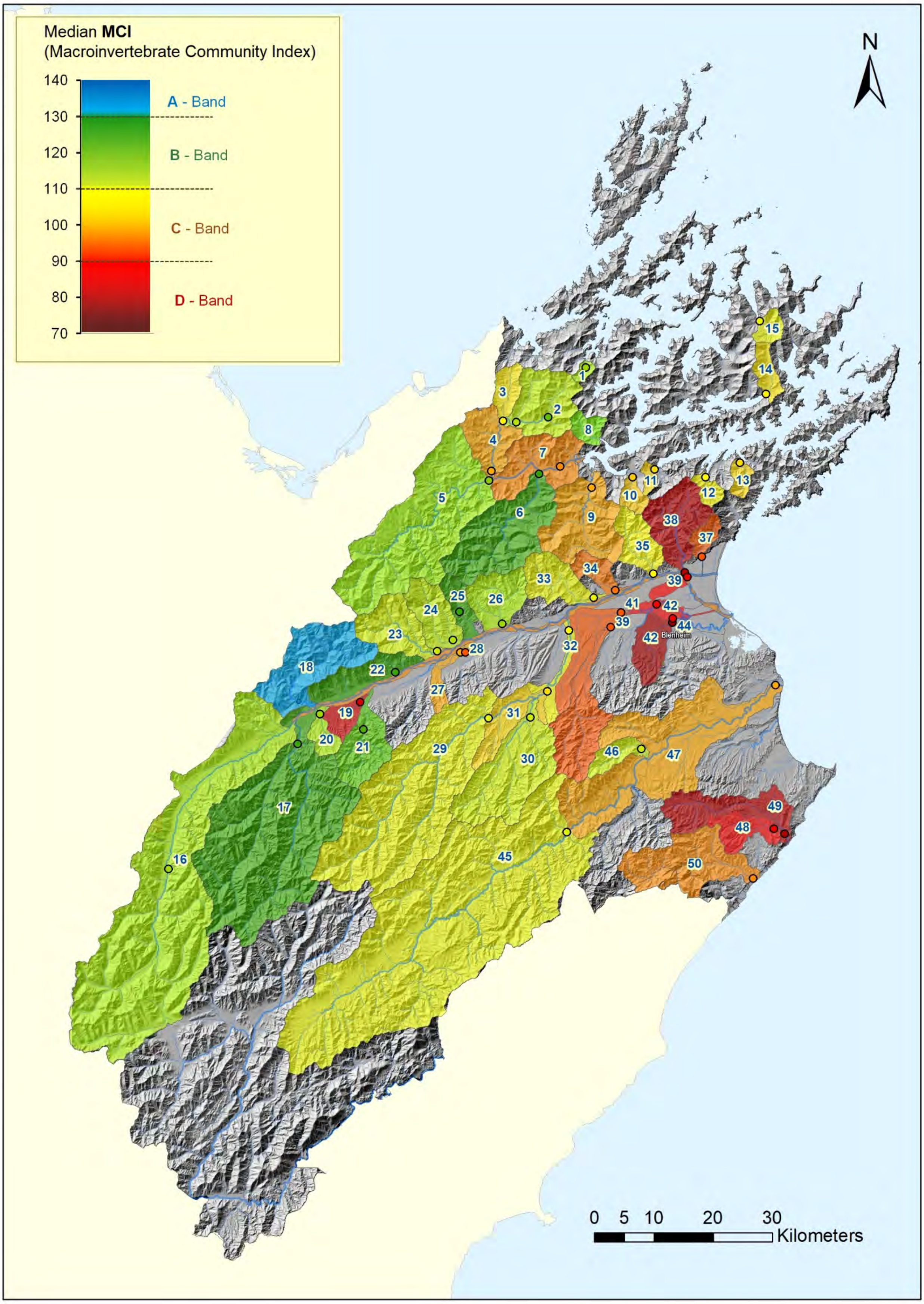


Figure 33: Median MCI (Macroinvertebrate Community Index) at the SoE monitoring sites and associated catchments. Shown is the Median over five years (2015-2019). The numbers relate to the graph on the next page.

3.10. Macroinvertebrates

Macroinvertebrates are aquatic insects and other soft-bodied animals that can be seen with the naked eye. The different species have a varying degree of resistance to contamination. Some sensitive species, will not be present in streams with degraded water quality. Stark [33] developed a pollution index based on the number of macroinvertebrates from different species found in a sample. This is the Macroinvertebrate Community Index (MCI). The higher the MCI score the better the water quality.

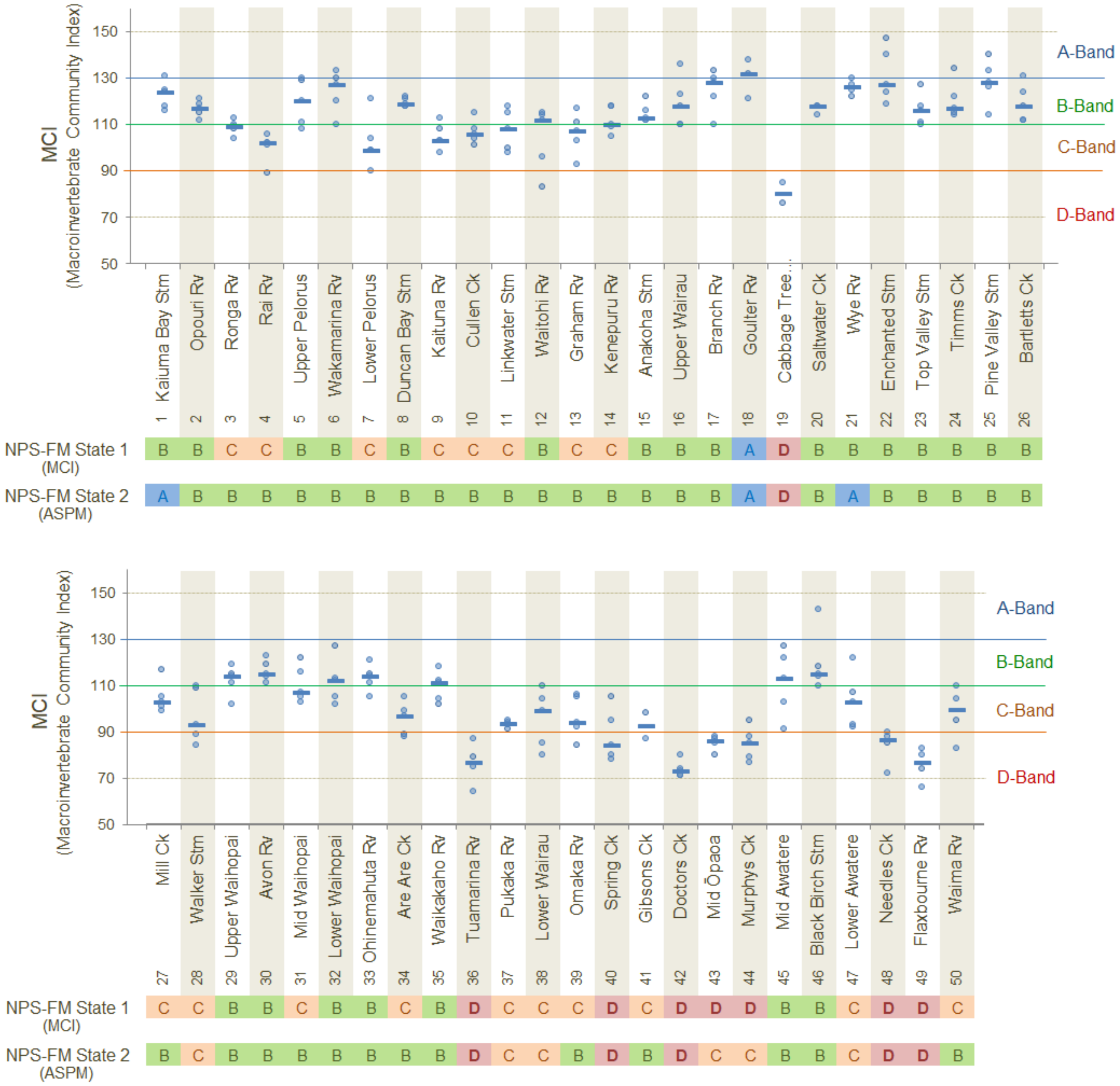


Figure 34: MCI at SoE sites for 2016-2019. Dots are individual sample scores, short lines represent the Median of the MCI over the five year period. Also shown are the NPS-FM bands and states.

Macroinvertebrates are monitored at a larger number of sites, but are only sampled once per year, in summer. This limits the number of data points and it is also the reason Macroinvertebrate data cannot be included in the Water Quality Index.

The NPS-FM has two attributes that are based on Macroinvertebrate data. Both use the MCI to determine the state. The first attribute has limits for the MCI itself, which are used in Figure 33 and Figure 34. The state for the second attribute is based on limits for the ASPM (Average Score Per Metric). Calculation of the ASPM is based on the MCI as well as the number of EPT species and their proportion in the sample [7]. EPT are Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly). They are a group a species that are sensitive to pollution.

Few monitoring sites achieve a NPS-FM state in the A-Band, which are mostly represented by streams with catchments in native vegetation, such Black Birch Stream or Enchanted Stream. The Goulter River is the only waterway within the A-band for both NPS-FM state attributes.

Overall, MCI limits appear more stringent than the limits for the ASPM. Therefore many sites are in a better state based on the ASPM attribute.

Attribute states for groundwater dominated streams, such as Murphys Creek and Spring Creek, need to be treated with caution. Dissolved oxygen levels are naturally lower and the stream bed substrate contains a higher proportion of sand. This results in a naturally different Macroinvertebrate community compared to other streams.

Doctors Creek also receives a large proportion of its flow from groundwater, but MCI scores are significantly lower than in nearby Murphys Creek. Monthly water quality monitoring shows significant human impacts for a number of parameters, which were discussed in previous sections. The low MCI score simply confirms the negative effect on the aquatic ecology.

Low Oxygen levels are one of the main reasons for low MCI and ASPM scores for the Tuamarina River. It is unlikely that higher scores are achievable for this waterways as the oxygen depletion is caused by the large Para Swamp (see Section 3.2) and is therefore predominantly a natural phenomenon.

Other streams with scores in the D-Band, however, have the potential for better ecological health. In these waterways the majority of negative impacts are caused by human activity in the catchment. Examples are the Flaxbourne River, Needles Creek and Cabbage Tree Gully. The catchments of these waterways have little native vegetation remaining and landcover is now dominated by sheep and beef pastures. Naturally lower flows mean that the ecological system is more susceptible to changes from the natural conditions. Lack of riparian vegetation and livestock access to the streams are examples of preventable impacts on aquatic life.

Livestock access is also a potential contributing cause for a MCI in the D-band in the mid Ōpaoa. Most noticeable in the Ōpaoa is the higher turbidity due to diversion of water from the Waihopai River into Gibsons Creek and subsequently the Ōpaoa River as part of the Southern Irrigation Scheme. However, the Macroinvertebrate scores for the Waihopai River show that it is in relatively good ecological health. During sampling it is noticeable that the stream beds of Gibson Creek and the mid Ōpaoa are more embedded, meaning that larger rocks and stones are cemented together. This indicates that the fine sediment (represented by higher turbidity) is having a greater effect on these smaller streams, compared to the Waihopai River. The reason is likely the lack of large flood flows with high water velocities, which would usually mobilise the stream bed and thereby remove fine sediment. Instead, in Gibsons Creek and the mid Ōpaoa, the fine sediment remains on the streambed becoming more compacted and harder over time. This reduces suitable habitat for Macroinvertebrates.

Although high turbidity is known to affect the ecological health of rivers, the relatively good Macroinvertebrate scores for the Waihopai River and the mid Awatere River show that aquatic life can still thrive.

Trend analysis using the data collected over the last 10 years shows changes in the MCI for 11 out of the 50 monitoring sites. All trends show a decrease in MCI scores (Figure 35).

The majority of sites with significant trends is not part of the monthly monitoring programme that measures chemical and physical parameters. It is therefore difficult to determine what the causes of decreasing ecological health might be.

Of the sites with additional monitoring, the Lower Wairau shows the greatest decrease in MCI scores. However, the monthly monitoring shows no significant changes apart from a relatively small increase in E. coli concentrations.

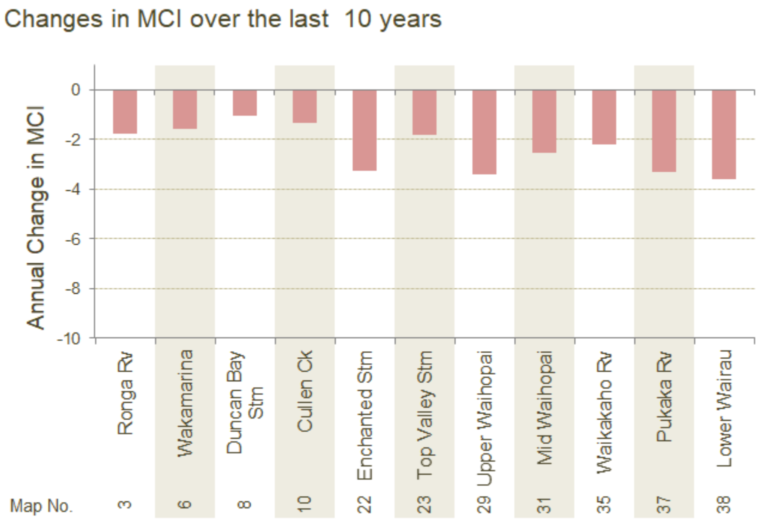


Figure 35: Changes in MCI scores over the last ten years (2009-2019). Only shown are the sites with significant trends.

The variation in MCI scores for many sites is equal to or greater than the widths of NPS-FM bands. This large variability of MCI values, together with the very limited number of data points due to annual sampling means that trend analysis needs to be treated with caution. Further analysis has shown that trends can easily change with additional data points. However, should trends persist over several years, they are more likely to represent actual changes in ecological health.

3.11. Periphyton

Periphyton is the community of algae and bacteria growing on the bed of rivers and streams. Too much periphyton growth causes Dissolved Oxygen and pH to vary more than in natural conditions, leading to greater extremes for these parameters. Stream beds dominated by thick algae mats or long filamentous algae also do not provide suitable food and habitat for many macroinvertebrate species. This, in turn effects the abundance of fish and subsequently the functioning of the aquatic ecosystem.

The NPS-FM Periphyton attribute is monitored by measuring the amount of Chlorophyll-a[5] per square meter of stream bed. This method is time consuming and representative monitoring requires crossing of the waterway. This means that periphyton sampling can only be carried out at a sub-set of the monthly SoE monitoring sites. Currently, ten sites are monitored for Periphyton

There are a number of factors that influence the growth of Periphyton. One of these factors is the supply of nutrients. The NPS-FM requires management of periphyton growth by setting limits for DRP and DIN. Figure 36 shows the monitoring results for the Periphyton attribute as well as DRP and DIN concentrations in the water. Overall, there appears to be a limited relationship between Periphyton growth and nutrient concentrations at the sites monitored. For example, the Ohinemahuta River and Omaka River have similar nutrient concentrations, but periphyton growth is significantly higher in the Omaka River. The two monitoring sites are less than 10 kilometers apart and both rivers have a similar sized catchment. The important difference is the amount of rainfall the catchments receive. The Ohinemahuta River is a Northbank tributary of the Wairau River, while the Omaka is on the dryer Southbank. The frequency of flood flows is one of the most significant factors influencing the amount of Periphyton on stream beds. During flood flows the higher water velocities mobilise the bed, lifting stones off and moving them downstream. This removes the Periphyton from the stream bed. Subsequently, high rainfall areas are less prone to excessive Periphyton growth as the algae are removed more frequently.

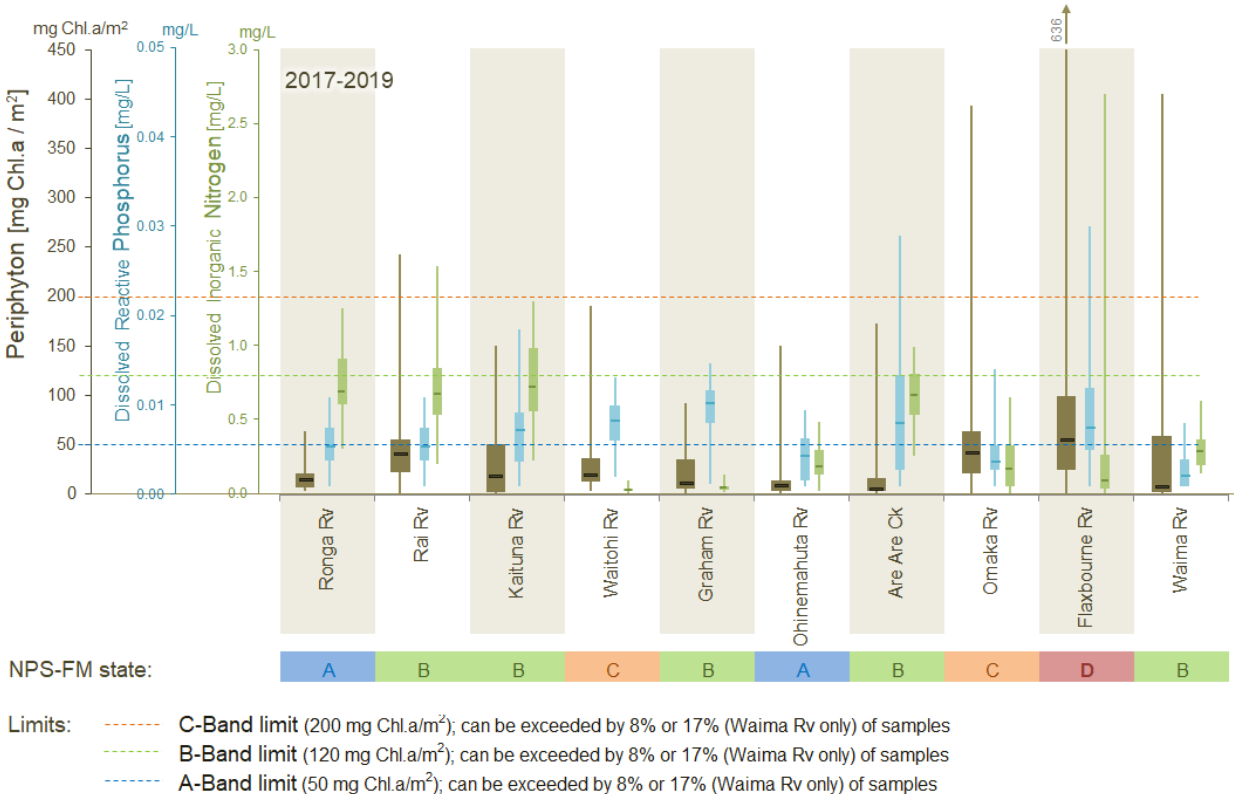


Figure 36: Box and Whiskers Plot of Periphyton cover as measured according to the NPS-FM at SoE sites, 2017 – 2019.

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[5] Chlorophyll-a (Chl.a) is the main pigment in many algae species.

This also explains the significantly higher periphyton measurements in the Flaxbourne River. However, elevated DRP concentrations are likely to exacerbate the problem. The Flaxbourne River is the only monitoring site with Periphyton cover in the D-band.

The amount of sunlight that reaches the riverbed is another important factor influencing Periphyton growth. It is the main reason for the difference in Periphyton in the Ronga River and Rai River despite similar nutrient concentrations and rainfall. Both rivers have quite steep banks, but the Rai River is significantly wider than the Ronga River (the Ronga is a tributary of the Rai River). Mature trees on the banks of the lower Rai River provide some shading, but the river is too wide to allow shading of the whole bed. The lower Ronga River is comparatively more narrow with high banks and mature trees in the riparian buffer. This shades the majority of the river, slowing the growth of algae, resulting in lower Periphyton cover.

The channel of Are Are Creek is so incised, that it provides sufficient shading of the stream bed, despite a lack of tall riparian vegetation.

Figure 37: Periphyton is the term for the community of algae and bacteria growing on the bed of rivers and streams. Many Macroinvertebrates prefer thin algae mats. In this photo most of the stones are covered in a thin mat of brown algae. The green, long and stringy algae is a species of filamentous algae.

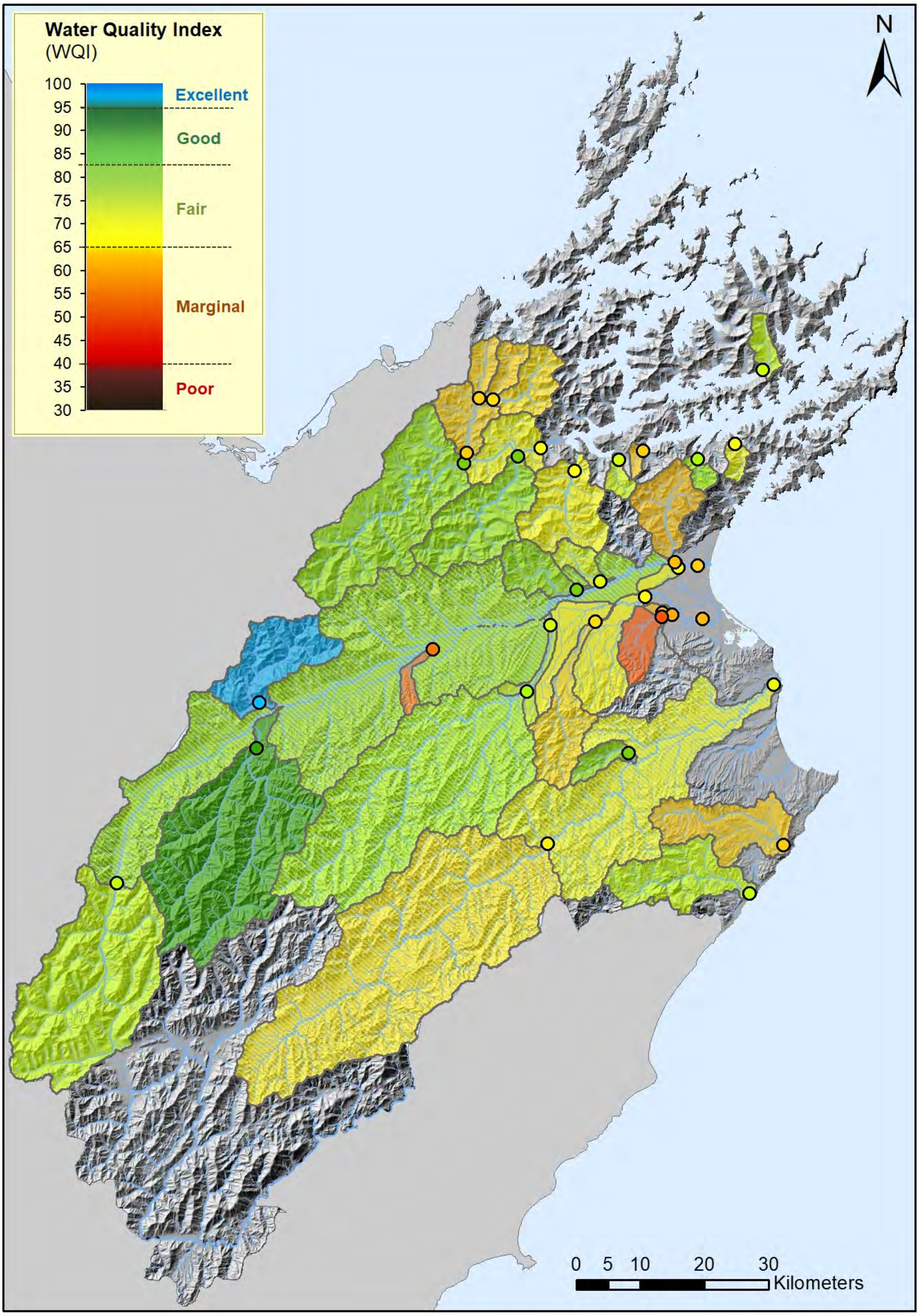

Figure 38: Water Quality Index for SoE monitoring sites and associated catchments for the period 2017-2019. Light shading indicates catchments where monitoring is less representative.

4. Water Quality Index

The Water Quality Index combines the data presented in the previous sections, with the exception of Macroinvertebrates and Periphyton.

Based on the Water Quality Index for the years 2017-2019, the majority of sites have acceptable water quality in the Excellent, Good or Fair category (Figure 39). 14 sites are in the Marginal category, which means that water quality needs to be improved where possible.

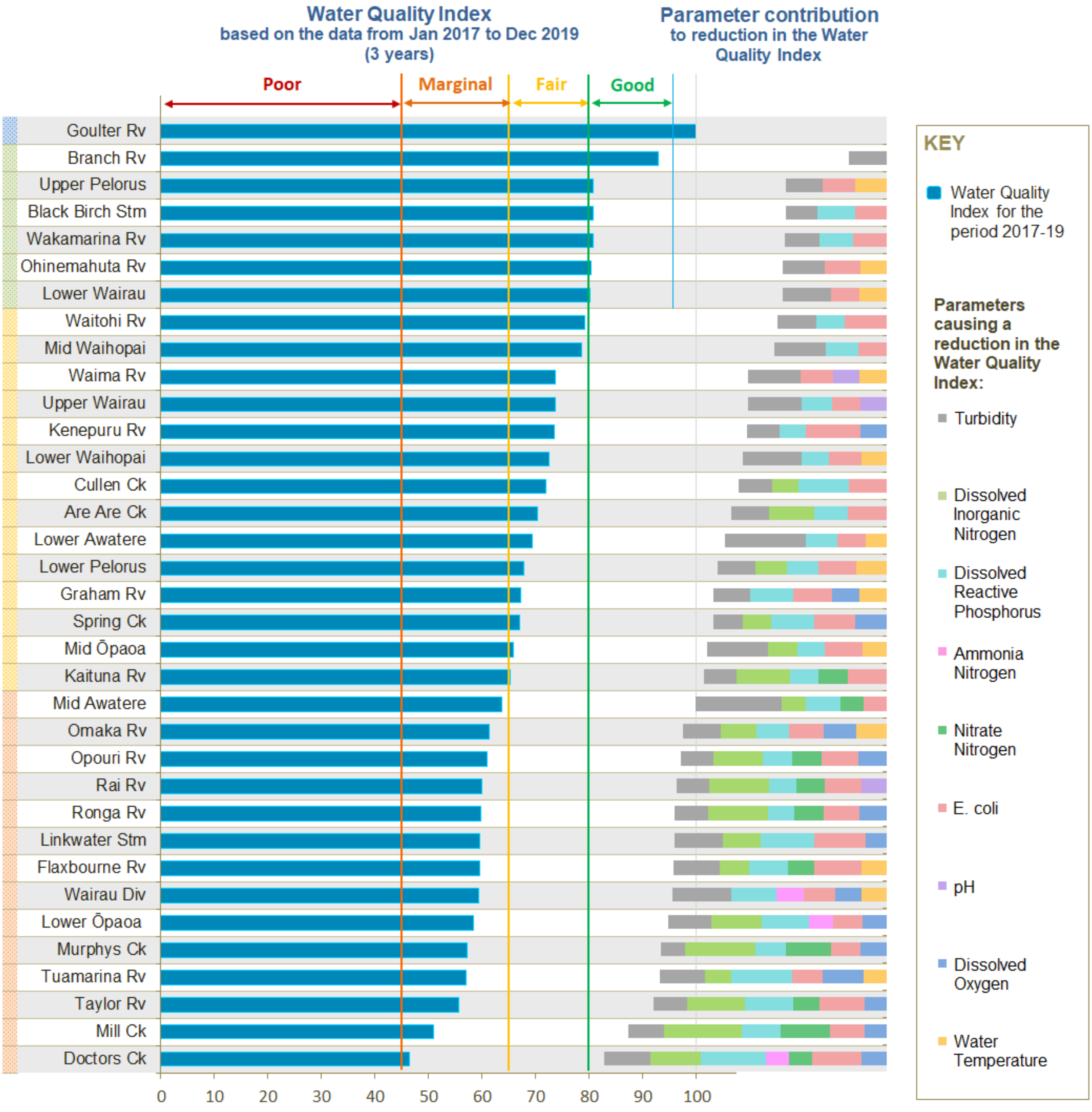

Figure 39: Water Quality Index for the SoE site for the period 2017-2019 (dark blue bars on the left side of the graph). Also shown are the parameters that cause a reduction in the Water Quality Index (right side of the graph).

A review of the guideline values used to calculate the Water Quality Index, means that the Indices presented in this report are not directly comparable to those in previous reports. However, it was necessary to review the guidelines to align reporting with the latest NPS-FM limits and more recent research (see Section 2.2).

Many of the new guidelines are more stringent. For example, lower Nitrate toxicity limits mean that a number of sites now exceed the guideline for this parameter. DIN limits on the other hand are more lenient. Still some catchments with elevated nitrogen concentrations, such as dairy catchments and spring-fed stream now have generally lower Water Quality Indices as two parameter guidelines are exceeded[6]. Examples are Murphys Creek and the Ronga River.

A more stringent Ammonia Toxicity guideline, which is again based on NPS-FM limits, cause an additional parameter to exceed the guideline for the Lower Ōpaoa and Doctors Creek. Doctors Creek exceeds guidelines for the greatest number of parameters monitored and subsequently has the lowest Water Quality Index of all sites. Macroinvertebrate monitoring confirms that the ecological health of Doctors Creek is significantly impacted. The creek has the lowest MCI score of all sites monitored (see Section 3.10).

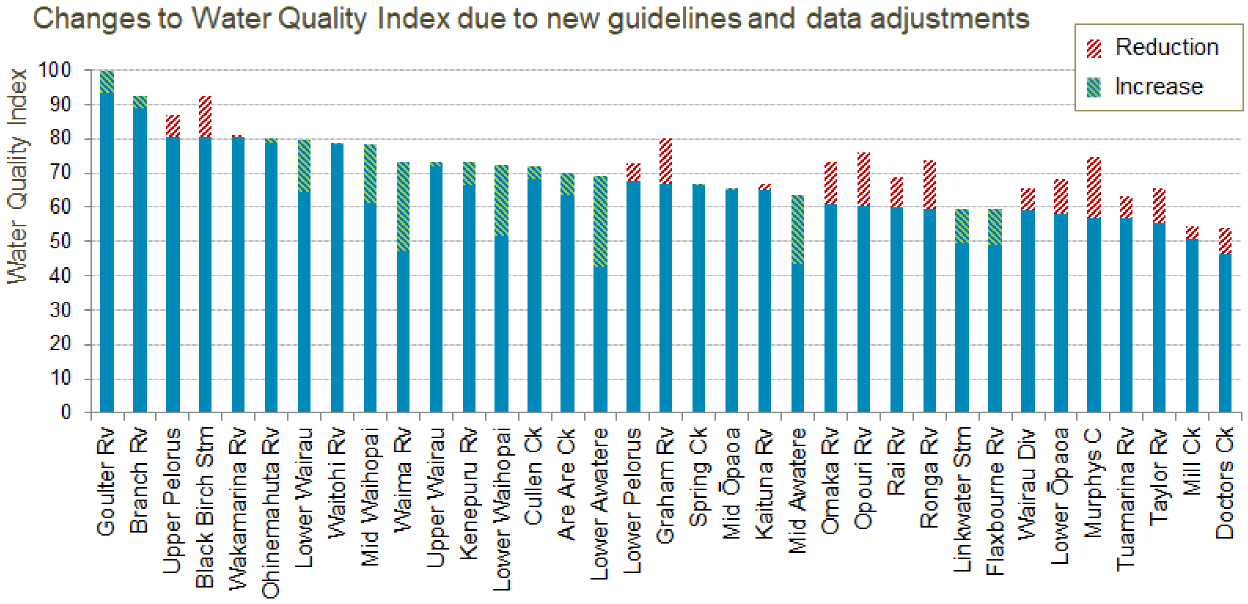

Figure 40: Changes to the Water Quality Index as a result of changes to the guidelines and adjustment of Turbidity and E. coli data.

Apart from the Mid Awatere River, all rivers and streams with marginal water quality are listed in the Marlborough Environment Plan as degraded or at risk from degradation. These sites exceed the guidelines for five or six different parameters which represents a multitude of stressors for the ecosystems.

At other end of the scale are sites with very few guideline exceedances, such as the Goulter River and the Branch River. Apart from the Graham River, all sites that were in the Excellent or Good category using the old Water Quality Index remain there despite the application of new guidelines. The Graham River has moved down the ranks due to more stringent E. coli and DRP guidelines.

The calculation of the Water Quality Index was also adjusted to reduce the impact of parameters with occasionally very high measurements, such as turbidity and E. coli concentrations. Particularly turbidity was having a disproportionate influence on the index. For example, the previous Water Quality Index classed water quality in the Awatere River as Poor due to high turbidity levels. Macroinvertebrate monitoring however showed that this classification is not appropriate. MCI scores for the Awatere River are in the B- or C-band, meaning that ecological health is somewhat impacted, but not poor (see Section 3.10). The same applies to the Waihopai River, which is also characterised by high turbidity.

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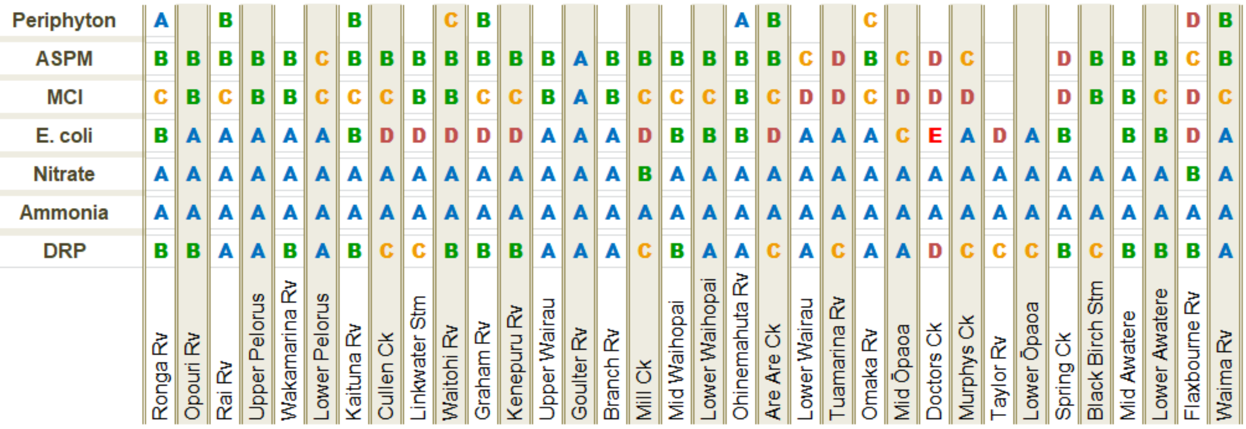
[6] The Water Quality Index markedly decreases when a larger number of parameters exceed their guideline.

Overall, the new guidelines and the adjustments of E. coli and turbidity data make the Water Quality Index more representative of water quality and subsequently the ecological health of the rivers and streams monitored.

5. State of River Water Quality based on NPS-FM

Not all attributes for the assessment of river health in the NPS-FM are currently monitored as part of the Marlborough SoE programme (see Section 2.4). Figure 41 shows a summary of states for the attributes that are monitored.



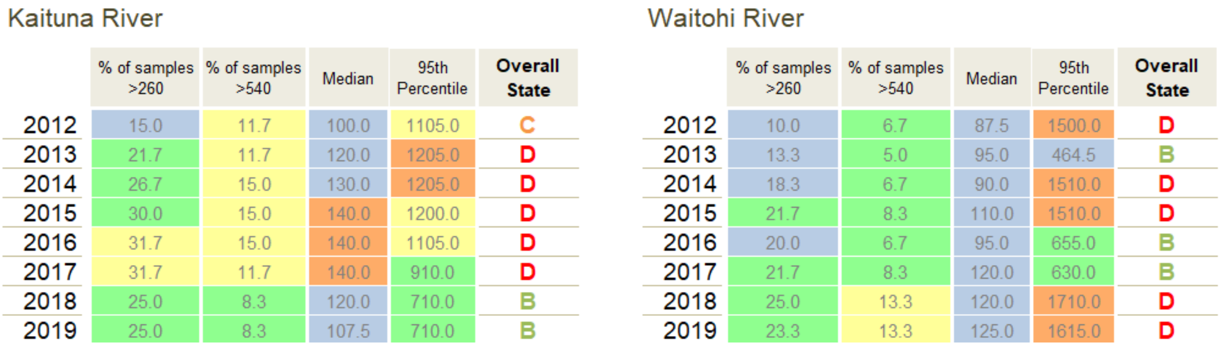
	Ronga Rv	Opouri Rv	Rai Rv	Upper Pelorus	Wakamarina Rv	Lower Pelorus	Kaituna Rv	Cullen Ck	Linkwater Stm	Waitohi Rv	Graham Rv	Kenepuru Rv	Upper Wairau	Goulter Rv	Branch Rv	Mill Ck	Mid Waihopai
Periphyton	A		B				B			C	B						
ASPM	B	B	B	B	B	C	B	B	B	B	B	B	B	A	B	B	B
MCI	C	B	C	B	B	C	C	C	B	B	C	C	B	A	B	C	C
E. coli	B	A	A	A	A	A	B	D	D	D	D	D	A	A	A	D	B
Nitrate	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	B	A
Ammonia	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
DRP	B	B	A	A	B	A	B	C	C	B	B	B	A	A	A	C	B

	Lower Waihopai	Ohinemahuta Rv	Are Are Ck	Lower Wairau	Tuamarina Rv	Omaka Rv	Mid Ōpaoa	Doctors Ck	Murphys Ck	Taylor Rv	Lower Ōpaoa	Spring Ck	Black Birch Stm	Mid Awatere	Lower Awatere	Flaxbourne Rv	Waima Rv
Periphyton		A	B			C										D	B
ASPM	B	B	B	C	D	B	C	D	C			D	B	B	B	C	B
MCI	C	B	C	D	D	C	D	D	D			D	B	B	C	D	C
E. coli	B	B	D	A	A	A	C	E	A	D	A	B		B	B	D	A
Nitrate	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	B	A
Ammonia	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
DRP	A	A	C	A	C	A	A	D	C	C	C	B	C	B	B	B	A

Figure 41: NPS-FM Attribute states for SoE monitoring sites as of 2019.

The Goulter River is the only waterway with a state in the A-band for all attributes. A number of sites have states consistently in the A- and B-bands. The majority of these are reference sites with predominantly native vegetation in the catchment, but they also include the Opouri River and Ohinemahuta River, which flow through pasture and production forest. Overall, Doctors Creek and the Flaxbourne River have the poorest states.

States in the D- and E-bands are considered "below the national bottom line", which represents an unacceptable state unless caused by natural sources. A number of sites have states below the national bottom line for Macroinvertebrate attributes (MCI and ASPM) and/or the E. coli attribute. For spring-fed streams and the Tuamarina River low states for the Macroinvertebrate attributes are at least to some degree natural. In contrast, high E. coli concentrations are not caused by natural sources at any of the monitoring sites. Nevertheless, analysis of the data shows that the E. coli attribute is one of the most variable and can change significantly from one year to the next. The reason is that very high E. coli concentrations are generally a result of run-off during rainfall events. The attribute state for a certain time period therefore depends on the number and type of rainfall events during which samples were taken. Figure 42 shows examples of the variability in E. coli state for two rivers with comparatively small changes in land use over time.



Kaituna River

	% of samples >260	% of samples >540	Median	95th Percentile	**Overall State**
2012	15.0	11.7	100.0	1105.0	C
2013	21.7	11.7	120.0	1205.0	D
2014	26.7	15.0	130.0	1205.0	D
2015	30.0	15.0	140.0	1200.0	D
2016	31.7	15.0	140.0	1105.0	D
2017	31.7	11.7	140.0	910.0	D
2018	25.0	8.3	120.0	710.0	B
2019	25.0	8.3	107.5	710.0	B

Waitohi River

	% of samples >260	% of samples >540	Median	95th Percentile	**Overall State**
2012	10.0	6.7	87.5	1500.0	D
2013	13.3	5.0	95.0	464.5	B
2014	18.3	6.7	90.0	1510.0	D
2015	21.7	8.3	110.0	1510.0	D
2016	20.0	6.7	95.0	655.0	B
2017	21.7	8.3	120.0	630.0	B
2018	25.0	13.3	120.0	1710.0	D
2019	23.3	13.3	125.0	1615.0	D

Figure 42: Examples of variability for the E. coli attribute in two rivers that have had very little change in land use over the years. The E. coli attribute is calculated using four different statistics. The colours of the cells showing the results for the individual statistics indicate the state (A=blue, B=green, C=yellow, D=orange). The lowest of the four statistics determines the Overall state.

The Periphyton attribute could only be monitored at a small number of sites. The sites cover the range of attribute states, with the Ronga and Ohinemahuta rivers in the A-band and the Flaxbourne River at the other end of the scale, with a state in the D-band (see Section 3.11).

6. Marlborough Environment Plan (MEP)

The Marlborough Environment Plan (MEP) contains several Policies and Objectives that relate to the health of rivers and streams in the region. Also included are anticipated environmental results (AERs), which are targets to be achieved within ten years. One of these AERs relates to river water quality.

Table 4 lists the indicators for the effectiveness of the MEP and associated current progress towards the AER.

AERs (Anticipated environmental result)	Monitoring effectiveness	Current progress
15.AER.1 Water quality in Marlborough's rivers, lakes and wetlands is suitable to support and sustain swimming, fishing, aquatic ecosystems and customary harvesting	The quality of water in all surface waterbodies routinely monitored is classified as good, very good or excellent	Although the majority of rivers and streams have water quality in the required classification, 14 waterways are classified as marginal.
	The annual median nitrate concentration in each Freshwater Management Unit is <1 milligram nitrate-nitrogen per litre and the annual 95th percentile concentration is <1.5 milligrams nitrate-nitrogen per litre.	Most rivers and stream meet this target. Only Mill Creek and the Flaxbourne River have Nitrate concentrations above these limits.
	The annual median ammonia concentration in each Freshwater Management Unit is <0.03 milligrams ammoniacal nitrogen per litre and the annual maximum concentration is <0.05 milligrams ammoniacal nitrogen per litre.	All rivers and stream meet this target.
	The annual median E. coli level in each Freshwater Management Unit is <260 per 100 ml.	Freshwater Management Units have not been defined yet. When applying this target to all monitored rivers and streams, Linkwater Stream and the Flaxbourne River are the only waterways that do not meet this target.
	Water quality which was degraded is enhanced so that the waterbodies can support natural and human use values. Increase in the number of catchment enhancement plans developed and implemented for waterbodies deemed degraded.	There are a number of projects currently in progress with the aim to improve water quality in several degraded rivers and streams (further discussed in the next Section). Catchment enhancement plans will be prepared for the majority of degraded waterways in the coming years.

Table 4: Anticipated environmental results for water quality, associated targets and current progress towards the targets.

7. Improving Water Quality

An increase in staff resources for land management in recent years has made it possible to initiate a number of different projects that aim to improve water quality in the region’s rivers and streams. Additionally, with the increased interest in water quality on a national scale, central government funding has been made available to restore the ecological health of waterways. Council has been successful in securing some of this funding, which allows positive action on a greater and more effective scale than would have been possible with ratepayer funding alone.

The first of these projects is the TRIP (Taylor Improvement Project) which has been running for several years. This project has the aim improve water quality in the Taylor River and its tributaries, which include Doctors Creek.

In 2020 the Te Hoiere Project was launched. Council is one of many partners in this initiative to restore the ecological health of this very large catchment.

MEP Policy 15.1.7 requires improvement action to be taken for waterways that are listed in tables 15.1 and 15.2 as degraded or at risk from degradation (Table 5 and Table 6 in this report). The methodology specified in the MEP (15.M.5) is to establish the causes of degraded water quality and the subsequent development of Catchment Enhancement Plans. The causes of degradation are identified through Catchment Studies, which have been completed for a number of waterways. Catchment Enhancement Plans will be developed through Council’s Catchment Care Programme. Central government funding has also been secured for this programme, which aims to improve water quality in collaboration with the communities in the catchments.

Table 15.1 Waterbodies identified as being **degraded**	River	Improvement Actions
	Are Are Creek	Catchment Study completed; Catchment Care Project in progress
	Doctors Creek	Catchment Study completed; Taylor Improvement Project
	Duncan (Linkwater) Stream	Catchment Study completed; Catchment Care Project
	Flaxbourne River	Catchment Study in progress
	Mill Creek	Nitrate sensor to be installed
	Murphys Creek	Taylor Improvement Project
	Omaka River	
	Ōpaoa River	Taylor Improvement Project will also have positive effect on Lower Ōpaoa
	Ronga River	Te Hoiere Project
	Taylor River	Taylor Improvement Project
	Tuamarina River	Catchment Study completed; Catchment Care Project
	Wairau Diversion	Will benefit from Tuamarina River improvements

Table 5: Rivers and stream identified in the MEP as degraded and actions to improve their ecological health.

Table 15.1 Waterbodies identified as being **at risk of degradation**	River	Improvement Actions
	Cullens Creek	Catchment Study completed; Te Hoiere Project
	Kaituna River	Te Hoiere Project
	Kenepuru River	Investigation into sources of E. coli
	Lower Pelorus River (downstream of the Rai River)	Te Hoiere Project
	Lower Wairau River from SH1 bridge to the sea	
	Opouri River	Te Hoiere Project
	Rai River	Te Hoiere Project
	Spring Creek	Investigation into sources of E. coli
	Waitohi River	Catchment Study completed

Table 6: Rivers and stream identified in the MEP as being at risk of degradation and actions to improve their ecological health.

New National Environment Standards for Freshwater and regulations for Stock exclusion released in 2020 will significantly aid the improvement efforts.

To bring the monitoring programme into alignment with the requirements of the NPS-FM, a programme review was carried out in 2020 [26]. It showed gaps in the regional coverage of the monitoring network and identified additional parameters that need to be added to the programme. The final configuration of the revised programme depends on a number of factors, including the implementation of the many new requirements of the NPS-FM.

8. Acknowledgements

I would like to thank the Environment Monitoring team for reliably sampling water quality every month no matter what the conditions - rainfall, cold winter days or smouldering hot summer days. I'm also grateful for advice on Groundwater and Hydrology from Peter Davidson and Val Wadsworth. Lastly, I'm thankful for the general support and the hours spent editing by Rob Watson and inspirational music by Audiomachine.

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10. Appendices

10.1. Water Quality Index calculation

The following section has been taken from the Canadian Water Quality Guidelines for the Protection of Aquatic Life [1].

“The index consists of three factors:

Factor 1: Scope

F1 (Scope) represents the extent of water quality guideline non-compliance over the time period of interest. It has been adopted directly from the British Columbia Index:

$$F_1 = \left(\frac{\text{Number of failed variables}}{\text{Total number of variables}} \right) \times 100$$

Where variables indicates those water quality variables with objectives which were tested during the time period for the index calculation.

Factor 2: Frequency

F2 (Frequency) represents the percentage of individual tests that do not meet objectives (“failed tests”):

$$F_2 = \left(\frac{\text{Number of failed tests}}{\text{Total number of tests}} \right) \times 100$$

Factor 3: Amplitude

F3 (Amplitude) represents the amount by which failed test values do not meet their objectives. F3 is calculated in three steps. The formulation of the third factor is drawn from work done under the auspices of the Alberta Agriculture, Food and Rural Development.

(i) The number of times by which an individual concentration is greater than (or less than, when the objective is a minimum) the objective is termed an “excursion” and is expressed as follows. When the test value must not exceed the objective:

$$excursion_i = \left(\frac{FailedTestValue_i}{Objective_j} \right) - 1$$

For the cases in which the test value must not fall below the objective:

$$excursion_i = \left(\frac{Objective_j}{FailedTestValue_i} \right) - 1$$

ii) The collective amount by which individual tests are out of compliance is calculated by summing the excursions of individual tests from their objectives and dividing by the total number of tests (both those meeting objectives and those not meeting objectives). This variable, referred to as the normalized sum of excursions, or nse, is calculated as:

$$nse = \frac{\sum_{i=1}^{n} excursion_i}{\#\ of\ tests}$$

iii) F3 is then calculated by an asymptotic function that scales the normalized sum of the excursions from objectives (*nse*) to yield a range between 0 and 100.

$$F_3 = \left(\frac{nse}{0.01nse + 0.01} \right)$$

The CCME WQI is then calculated as:

$$CCMEWQI = 100 - \left(\frac{\sqrt{F_1^{\,2} + F_2^{\,2} + F_3^{\,2}}}{1.732} \right)$$

The factor of 1.732 arises because each of the three individual index factors can range as high as 100. This means that the vector length can reach

$$\sqrt{100^2 + 100^2 + 100^2} = \sqrt{30000} = 173.2$$

as a maximum. Division by 1.732 brings the vector length down to 100 as a maximum.

10.2. Site Information

Short Name	Database (Hilltop) Name	Easting	Northing	NZ Reach	Flow*
Ronga Rv	Ronga River at Upstream Rai River	1649966	5437711	11010920	(✓)
Opouri Rv	Opouri River at Tunakino Valley Road	1652204	5437502	11010920	(✓)
Rai Rv	Rai River at Rai Falls	1648018	5429266	11010920	✓
Upper Pelorus	Pelorus River at Kahikatea Flat	1647585	5427613	11010920	✓
Wakamarina Rv	Wakamarina River at SH6	1656011	5428720	11010920	×
Lower Pelorus	Pelorus River at Fishermans Flat	1659571	5430016	11010920	(✓)
Kaituna Rv	Kaituna River at Higgins Bridge	1664877	5426463	11011383	✓
Cullens Ck	Cullens Creek at Road Bridge	1671802	5428178	11011585	(✓)
Linkwater Stm	Duncan Stream at Outlet	1675552	5429552	11011381	(✓)
Waitohi Rv	Waitohi River at State Highway One	1684133	5428227	11011620	(✓)
Graham Rv	Graham River at Road Bridge	1689949	5430629	11010999	✓
Kenepuru Rv	Kenepuru River at Kenepuru Head	1694287	5442220	11008448	×
Upper Wairau	Wairau River at Dip Flat	1593486	5362089	11023270	✓
Goulter River	Goulter River at Horseshoe Bend	1615505	5390310	11022446.0	✓
Branch Rv	Branch River at Weir Intake	1615310	5383200	11024749	✓
Mill Ck	Mill Creek at Ormonds	1642747	5398630	11019984	✓
Mid Waihopai	Waihopai River at Craiglochart	1657397	5392054	11018880	✓
Lower Waihopai	Waihopai River at SH63 Bridge	1661086	5402329	11018880	(✓)
Ohinemahuta Rv	Onamalutu River at Northbank Road	1665221	5407894	11015812	(✓)
Are Are Ck	Are Are Creek at Kaituna Tuamarina Road	1668891	5409150	11027449	✓
Lower Wairau	Wairau River at Tuamarina	1680623	5412041	11016624	✓
Tuamarina Rv	Tuamarina River at State Highway One	1680588	5412144	11016362	(✓)
Wairau Diversion	Wairau Diversion at Neals Road	1684047	5411651	11016624	(✓)
Omaka Rv	Omaka River at Hawkesbury Road Bridge	1668150	5402871	11018918	(✓)
Mid Ōpaoa	Opawa River at Hammerichs Road	1675898	5406769	11018918	(✓)
Doctors Ck	Doctors Creek Upstream Taylor	1678538	5403700	11018918	×
Murphys Ck	Murphys Creek at Nelson Street	1678585	5404340	11018918	×
Taylor Rv	Taylor River at Rail Bridge	1680148	5403948	11018918	(✓)
Lower Ōpaoa	Opawa River at Swamp Road	1684887	5403319	11018918	(✓)
Spring Ck	Spring Creek at Wairau River Floodgates	1681052	5411335	11016643	×
Black Birch Stm	Black Birch Stream at Awatere Intake	1673268	5382346	11021883	×
Mid Awatere	Awatere River at Awapiri	1660707	5368307	11021883	✓
Lower Awatere	Awatere River at River Mouth	1695945	5393096	11021883	(✓)
Flaxbourne Rv	Flaxbourne River at Quarry	1697479	5368033	11028279	(✓)
Waima Rv	Waima (Ure) River at SH1 Bridge	1692178	5360509	11030144	(✓)

* ✓ = flow at the site; (✓) = flow is at a nearby site or simulated, × = no flow data available

10.3. Laboratory Analysis

Parameter	Laboratory	Method Description	Detection Limit
Turbidity	Hill Laboratories	Analysis using a Hach 2100 Turbidity meter. APHA 2130 B 21st ed. 2005	0.05 NTU
Nitrate Nitrogen	Hill Laboratories	Calculation: Nitrite/Nitrate-Nitrogen - Nitrite Nitrogen; Nitrite/Nitrate Nitrogen analysed from filtered sample as total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3- I 21st ed. 2005	0.002 mg/L
Total Ammonical Nitrogen	Hill Laboratories	Filtered sample. Phenol/hypochlorite colorimetry. Discrete Analyser. (NH_4-N = NH_4-N + NH_3-N). APHA 4500-NH3 F (modified from manual analysis) 21st ed. 2005	0.010 mg/L
	Hill Laboratories	Since 2017: Filtered sample. Phenol/hypochlorite colorimetry. Discrete Analyser. (NH4-N = NH4-N + NH3-N). APHA 4500-NH3 H 23rd ed. 2017	0.005 mg/L
Dissolved Inorganic Nitrogen	Hill Laboratories	Calculation NH_4-N + NO_3-N + NO_2-N	0.010 mg/L
Dissolved Reactive Phosphorus	Hill Laboratories	Filtered sample. Molybdenum blue colorimetry. Discrete Analyser. APHA 4500-P E (modified from manual analysis) 21st ed. 2005	0.004 mg/L
	Hill Laboratories	Since 2017: Filtered sample. Molybdenum blue colorimetry. Flow injection analyser. APHA 4500-P G 23rd ed. 2017	0.0010 mg/L
pH	Hill Laboratories	pH meter. APHA 4500-H^+ B 21st ed. 2005	0.1
E. coli	Hill Laboratories	Membrane filtration. Count on mFC agar, incubated at 44.5°C for 22 hours, MUG Confirmation. APHA 9222 G, 22nd ed. 2012	1 cfu/100mL
Filtration	Hill Laboratories	Sample filtration through 0.45µm membrane filter	
Chlorophyll a (Periphyton)	Cawthron	NIWA Periphyton Monitoring Manual (Mod)	

10.4. Summary Statistics

10.4.1. Water Temperature

Values are in ^{o}C, 2017-2019, inclusive.

Site	Minimum	25th Percentile	Median	75th Percentile	Maximum	N
Ronga Rv	9.5	11.5	12.2	14.9	17.4	36
Opouri Rv	9.6	11.1	12.3	14.5	16.0	36
Rai Rv	5.1	11.0	12.3	15.6	20.2	36
Upper Pelorus	5.6	9.1	10.8	14.9	23.6	36
Wakamarina Rv	5.5	9.2	10.9	14.6	19.5	36
Lower Pelorus	6.5	10.1	11.9	15.4	22.4	36
Kaituna Rv	9.1	10.7	13.0	16.2	18.5	36
Cullen Ck	7.5	9.7	11.1	13.3	15.7	35
Linkwater Stm	7.5	10.9	12.1	14.5	19.6	35
Waitohi Rv	7.2	10.2	12.9	16.9	20.7	36
Graham Rv	7.6	10.9	13.6	16.9	23.2	35
Kenepuru Rv	8.3	9.6	11.2	13.1	17.1	34
Upper Wairau	3.2	6.1	7.8	10.7	12.8	36
Goulter Rv	4.9	7.3	9.7	14.0	18.8	32
Branch Rv	2.7	5.9	8.8	12.3	17.8	36
Mill Ck	8.2	10.6	12.5	15.0	17.7	35
Mid Waihopai	3.9	7.2	10.1	15.5	20.9	36
Lower Waihopai	5.4	8.6	11.9	17.7	23.9	36
Ohinemahuta Rv	8.5	10.5	12.2	16.1	21.2	35
Are Are Ck	8.6	11.6	12.9	15.2	21.0	36
Lower Wairau	7.6	10.2	13.3	18.8	22.9	36
Tuamarina Rv	7.3	10.6	14.1	17.2	21.2	36
Wairau Diversion	6.2	9.9	13.3	16.2	23.4	35
Omaka Rv	6.0	10.2	14.2	19.3	23.5	36
Mid Ōpaoa	5.1	9.0	12.8	16.4	21.7	36
Doctors Ck	11.0	11.8	12.9	14.6	17.9	36
Murphys Ck	13.1	13.4	13.9	14.1	14.7	36
Taylor Rv	10.0	12.1	13.1	14.5	16.9	36
Lower Ōpaoa	9.3	11.9	13.9	16.1	20.9	36
Spring Ck	10.9	12.8	13.2	13.7	15.0	36
Black Birch Stm	6.8	8.5	12.2	15.5	19.3	36
Mid Awatere	2.2	6.3	10.8	14.5	21.0	36
Lower Awatere	4.2	8.1	12.0	15.6	21.1	36
Flaxbourne Rv	7.3	9.5	13.4	17.1	22.0	35
Waima Rv	8.8	11.1	14.1	17.0	23.0	35

10.4.2. Dissolved Oxygen

Values are in mg/L (milligrams per litre), 2017-2019, inclusive.

Site	Minimum	25th Percentile	Median	75th Percentile	Maximum	N
Ronga Rv	7.34	8.58	9.55	10.14	11.12	36
Opouri Rv	6.94	9.89	10.34	10.72	11.68	36
Rai Rv	8.84	9.88	10.51	11.13	11.94	36
Upper Pelorus	9.29	10.39	11.10	11.68	12.95	36
Wakamarina Rv	8.61	10.24	10.80	11.57	12.61	36
Lower Pelorus	8.49	10.09	10.68	11.31	12.16	36
Kaituna Rv	8.12	9.91	10.47	10.96	12.91	36
Cullen Ck	8.10	9.72	10.54	11.24	11.98	35
Linkwater Stm	7.13	9.04	9.71	10.17	11.60	35
Waitohi Rv	8.76	10.66	11.33	12.04	13.79	36
Graham Rv	7.99	10.10	10.76	11.22	15.76	35
Kenepuru Rv	3.14	10.58	11.00	11.39	12.25	34
Upper Wairau	9.86	10.29	10.97	11.52	12.50	36
Goulter Rv	9.17	10.21	11.05	11.60	12.45	32
Branch Rv	9.32	10.41	11.07	11.98	13.83	36
Mill Ck	7.54	9.11	9.85	10.62	12.17	35
Mid Waihopai	9.30	9.94	11.04	12.17	13.24	35
Lower Waihopai	8.67	9.64	10.74	11.78	12.90	35
Ohinemahuta Rv	9.12	10.24	10.67	11.17	12.37	35
Are Are Ck	8.56	10.02	10.42	10.84	13.53	36
Lower Wairau	8.64	10.06	10.60	11.27	12.14	36
Tuamarina Rv	2.08	6.79	7.73	9.20	12.13	36
Wairau Diversion	6.80	8.85	9.81	10.75	12.65	35
Omaka Rv	6.96	9.07	10.13	11.19	12.20	35
Mid Ōpaoa	8.65	10.45	11.47	12.72	13.55	36
Doctors Ck	4.58	8.60	9.55	10.40	13.50	36
Murphys Ck	7.49	8.06	8.32	8.80	9.60	36
Taylor Rv	7.61	8.93	9.79	10.55	13.86	36
Lower Ōpaoa	7.65	9.63	10.36	11.28	13.88	36
Spring Ck	6.54	8.47	9.24	9.84	11.92	35
Black Birch Stm	8.95	9.80	10.29	11.43	12.34	35
Mid Awatere	9.02	10.20	10.98	11.88	13.29	35
Lower Awatere	9.30	10.11	11.31	12.23	13.58	36
Flaxbourne Rv	8.49	10.65	11.41	12.06	15.05	35
Waima Rv	8.23	10.60	10.91	11.38	12.94	35

10.4.3. pH

Values are for the period of 2017-2019, inclusive.

Site	Minimum	25th Percentile	Median	75th Percentile	Maximum	N
Ronga Rv	6.7	7.0	7.0	7.2	7.5	36
Opouri Rv	6.9	7.1	7.1	7.2	7.4	36
Rai Rv	6.3	7.1	7.2	7.3	7.5	36
Upper Pelorus	7.2	7.4	7.5	7.6	7.8	36
Wakamarina Rv	7.1	7.2	7.3	7.4	7.5	36
Lower Pelorus	7.1	7.3	7.4	7.5	7.7	36
Kaituna Rv	7.0	7.2	7.2	7.3	7.7	36
Cullen Ck	6.7	7.0	7.1	7.2	7.4	35
Linkwater Stm	6.6	6.8	6.9	7.0	7.4	35
Waitohi Rv	7.1	7.4	7.6	7.7	8.3	36
Graham Rv	6.8	7.2	7.3	7.3	7.6	35
Kenepuru Rv	6.8	7.1	7.2	7.3	7.4	34
Upper Wairau	7.0	7.6	7.8	7.9	8.6	36
Goulter Rv	7.3	7.5	7.5	7.6	7.9	32
Branch Rv	7.3	7.5	7.5	7.6	7.8	36
Mill Ck	7.0	7.3	7.4	7.5	7.7	35
Mid Waihopai	7.5	7.6	7.7	7.7	7.9	36
Lower Waihopai	7.4	7.5	7.6	7.7	8.1	36
Ohinemahuta Rv	6.9	7.2	7.3	7.4	7.8	35
Are Are Ck	6.9	7.2	7.3	7.4	7.6	36
Lower Wairau	7.0	7.5	7.5	7.6	8.1	36
Tuamarina Rv	6.8	7.1	7.2	7.4	7.7	36
Wairau Diversion	7.0	7.4	7.5	7.5	7.8	36
Omaka Rv	7.5	7.7	7.7	7.7	7.9	36
Mid Ōpaoa	7.0	7.6	7.7	7.8	8.0	36
Doctors Ck	7.0	7.3	7.4	7.4	7.9	36
Murphys Ck	6.7	6.9	6.9	7.0	7.3	36
Taylor Rv	7.0	7.2	7.3	7.3	7.5	36
Lower Ōpaoa	7.0	7.4	7.5	7.6	7.8	36
Spring Ck	7.0	7.2	7.3	7.4	7.5	36
Black Birch Stm	7.5	7.8	7.9	8.0	8.4	36
Mid Awatere	7.6	7.8	7.9	7.9	8.1	36
Lower Awatere	7.8	8.0	8.0	8.0	8.5	36
Flaxbourne Rv	7.7	7.9	8.0	8.1	8.5	35
Waima Rv	8.0	8.2	8.2	8.4	8.6	35

10.4.4. Dissolved Inorganic Nitrogen (DIN)

Values are in mg/L[7], 2017-2019, inclusive. Values below detection limit have been set to the detection limit.

Site	Minimum	25th Percentile	Median	75th Percentile	Maximum	N
Ronga Rv	0.300	0.603	0.685	0.908	1.250	36
Opouri Rv	0.330	0.418	0.510	0.644	1.130	36
Rai Rv	0.197	0.530	0.671	0.848	1.540	36
Upper Pelorus	0.004	0.010	0.035	0.055	0.142	36
Wakamarina Rv	0.005	0.021	0.040	0.069	0.178	36
Lower Pelorus	0.034	0.196	0.279	0.383	0.760	36
Kaituna Rv	0.219	0.555	0.718	0.983	1.300	36
Cullen Ck	0.122	0.280	0.370	0.455	0.650	35
Linkwater Stm	0.081	0.460	0.560	0.660	0.980	35
Waitohi Rv	0.004	0.014	0.020	0.035	0.087	36
Graham Rv	0.007	0.025	0.036	0.048	0.126	35
Kenepuru Rv	0.059	0.108	0.169	0.243	0.355	34
Upper Wairau	0.001	0.009	0.017	0.024	0.048	36
Goulter Rv	0.004	0.006	0.013	0.020	0.040	32
Branch Rv	0.004	0.006	0.017	0.033	0.086	36
Mill Ck	0.700	1.215	1.759	2.300	3.007	35
Mid Waihopai	0.004	0.020	0.083	0.165	0.420	36
Lower Waihopai	0.004	0.036	0.126	0.253	0.450	36
Ohinemahuta Rv	0.016	0.126	0.178	0.295	0.480	35
Are Are Ck	0.250	0.528	0.664	0.805	0.986	36
Lower Wairau	0.005	0.065	0.134	0.225	0.420	36
Tuamarina Rv	0.004	0.037	0.317	0.419	0.660	36
Wairau Diversion	0.004	0.065	0.142	0.231	0.372	36
Omaka Rv	0.004	0.044	0.163	0.323	0.650	36
Mid Ōpaoa	0.004	0.015	0.141	0.410	0.900	36
Doctors Ck	0.430	0.648	0.750	0.852	1.614	36
Murphys Ck	0.810	1.090	1.260	1.325	1.430	36
Taylor Rv	0.450	0.767	0.870	0.965	1.080	36
Lower Ōpaoa	0.192	0.535	0.600	0.771	0.995	36
Spring Ck	0.133	0.193	0.280	0.365	0.625	36
Black Birch Stm	0.008	0.013	0.016	0.020	0.052	36
Mid Awatere	0.004	0.010	0.044	0.093	2.200	36
Lower Awatere	0.004	0.001	0.089	0.127	0.350	36
Flaxbourne Rv	0.004	0.036	0.087	0.260	2.700	35
Waima Rv	0.004	0.027	0.046	0.135	0.260	35

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[7] milligrams per litre, which is the same as g/m^3 (grams per cubic meter)

10.4.5. Nitrate Nitrogen

Values are in mg/L, 2017-2019, inclusive. Note that the NPS-FM attribute state is calculated on an annual basis (ie; 2019 only).

Values below detection limit have been set to the detection limit.

Site	Minimum	25th Percentile	Median	75th Percentile	Maximum	N
Ronga Rv	0.300	0.603	0.685	0.905	1.250	36
Opouri Rv	0.330	0.418	0.510	0.643	1.130	36
Rai Rv	0.194	0.530	0.665	0.845	1.540	36
Upper Pelorus	0.002	0.010	0.034	0.055	0.141	36
Wakamarina Rv	0.005	0.020	0.039	0.069	0.177	36
Lower Pelorus	0.032	0.195	0.275	0.383	0.760	36
Kaituna Rv	0.200	0.553	0.715	0.983	1.300	36
Cullen Ck	0.122	0.280	0.370	0.455	0.650	35
Linkwater Stm	0.080	0.430	0.540	0.655	0.970	35
Waitohi Rv	0.002	0.012	0.019	0.034	0.087	36
Graham Rv	0.006	0.025	0.035	0.048	0.125	35
Kenepuru Rv	0.013	0.105	0.169	0.238	0.350	34
Upper Wairau	0.001	0.007	0.015	0.020	0.045	36
Goulter Rv	0.002	0.006	0.012	0.019	0.040	32
Branch Rv	0.002	0.006	0.017	0.033	0.079	36
Mill Ck	0.700	1.215	1.750	2.300	3.000	35
Mid Waihopai	0.002	0.019	0.083	0.161	0.420	36
Lower Waihopai	0.002	0.036	0.122	0.253	0.450	36
Ohinemahuta Rv	0.016	0.122	0.176	0.295	0.480	35
Are Are Ck	0.250	0.520	0.655	0.805	0.980	36
Lower Wairau	0.005	0.059	0.134	0.225	0.420	36
Tuamarina Rv	0.002	0.036	0.310	0.405	0.660	36
Wairau Diversion	0.002	0.063	0.136	0.222	0.350	36
Omaka Rv	0.003	0.041	0.162	0.323	0.650	36
Mid Ōpaoa	0.002	0.014	0.139	0.405	0.890	36
Doctors Ck	0.420	0.630	0.750	0.830	1.500	36
Murphys Ck	0.810	1.090	1.250	1.325	1.430	36
Taylor Rv	0.420	0.765	0.870	0.965	1.080	36
Lower Ōpaoa	0.190	0.530	0.580	0.765	0.970	36
Spring Ck	0.132	0.191	0.280	0.365	0.610	36
Black Birch Stm	0.002	0.004	0.007	0.011	0.043	36
Mid Awatere	0.002	0.010	0.039	0.089	2.200	36
Lower Awatere	0.002	0.001	0.088	0.127	0.350	36
Flaxbourne Rv	0.002	0.035	0.086	0.255	2.700	35
Waima Rv	0.003	0.026	0.046	0.134	0.260	35

10.4.6. Total Ammoniacal Nitrogen

Values are in mg/L, 2017-2019, inclusive. Note that the NPS-FM attribute state is calculated on an annual basis (ie; 2019 only) and the data needs to be adjusted to a standard Temperature and pH to determine toxicity. The table below shows the un-adjusted data.

Values below detection limit have been set to the detection limit.

Site	Minimum	25th Percentile	Median	75th Percentile	Maximum	N
Ronga Rv	0.005	0.005	0.005	0.005	0.007	36
Opouri Rv	0.005	0.005	0.005	0.005	0.013	36
Rai Rv	0.005	0.005	0.005	0.005	0.012	36
Upper Pelorus	0.005	0.005	0.005	0.005	0.005	36
Wakamarina Rv	0.005	0.005	0.005	0.005	0.005	36
Lower Pelorus	0.005	0.005	0.005	0.005	0.009	36
Kaituna Rv	0.005	0.005	0.005	0.005	0.019	36
Cullen Ck	0.005	0.005	0.005	0.005	0.060	35
Linkwater Stm	0.005	0.005	0.007	0.010	0.170	35
Waitohi Rv	0.005	0.005	0.005	0.005	0.009	36
Graham Rv	0.005	0.005	0.005	0.005	0.006	35
Kenepuru Rv	0.005	0.005	0.005	0.005	0.120	34
Upper Wairau	0.001	0.001	0.002	0.005	0.009	36
Goulter Rv	0.005	0.005	0.005	0.005	0.006	32
Branch Rv	0.005	0.005	0.005	0.005	0.011	36
Mill Ck	0.005	0.005	0.005	0.007	0.011	35
Mid Waihopai	0.005	0.005	0.005	0.005	0.013	36
Lower Waihopai	0.005	0.005	0.005	0.005	0.013	36
Ohinemahuta Rv	0.005	0.005	0.005	0.005	0.011	35
Are Are Ck	0.005	0.005	0.005	0.007	0.046	36
Lower Wairau	0.005	0.005	0.005	0.005	0.037	36
Tuamarina Rv	0.005	0.005	0.005	0.005	0.047	35
Wairau Diversion	0.005	0.005	0.005	0.014	0.029	35
Omaka Rv	0.005	0.005	0.005	0.005	0.011	36
Mid Ōpaoa	0.005	0.005	0.005	0.005	0.023	35
Doctors Ck	0.005	0.005	0.005	0.011	0.094	35
Murphys Ck	0.005	0.005	0.005	0.005	0.009	35
Taylor Rv	0.005	0.005	0.005	0.009	0.024	35
Lower Ōpaoa	0.005	0.005	0.005	0.006	0.062	35
Spring Ck	0.005	0.005	0.005	0.005	0.015	34
Black Birch Stm	0.005	0.009	0.009	0.009	0.025	36
Mid Awatere	0.005	0.005	0.005	0.005	0.017	36
Lower Awatere	0.005	0.005	0.005	0.005	0.015	36
Flaxbourne Rv	0.005	0.005	0.005	0.005	0.023	35
Waima Rv	0.005	0.005	0.005	0.005	0.010	35

10.4.7. Dissolved Reactive Phosphorus (DRP)

Values are in mg/L, 2017-2019, inclusive. Values below detection limit have been set to the detection limit.

Site	Minimum	25th Percentile	Median	75th Percentile	Maximum	N
Ronga Rv	0.001	0.004	0.005	0.007	0.011	36
Opouri Rv	0.001	0.006	0.008	0.009	0.011	36
Rai Rv	0.001	0.004	0.005	0.007	0.011	36
Upper Pelorus	0.001	0.004	0.005	0.007	0.010	36
Wakamarina Rv	0.002	0.007	0.008	0.009	0.011	36
Lower Pelorus	0.001	0.002	0.005	0.007	0.011	36
Kaituna Rv	0.001	0.004	0.007	0.009	0.018	36
Cullen Ck	0.005	0.010	0.012	0.014	0.083	35
Linkwater Stm	0.005	0.011	0.015	0.018	0.089	35
Waitohi Rv	0.002	0.006	0.008	0.010	0.013	36
Graham Rv	0.001	0.008	0.010	0.012	0.015	35
Kenepuru Rv	0.001	0.006	0.006	0.008	0.018	34
Upper Wairau	0.002	0.003	0.003	0.004	0.065	36
Goulter Rv	0.003	0.005	0.006	0.007	0.009	32
Branch Rv	0.001	0.004	0.005	0.006	0.008	36
Mill Ck	0.004	0.010	0.012	0.014	0.018	35
Mid Waihopai	0.004	0.007	0.008	0.011	0.045	36
Lower Waihopai	0.001	0.004	0.006	0.009	0.016	36
Ohinemahuta Rv	0.001	0.002	0.004	0.006	0.009	35
Are Are Ck	0.001	0.003	0.008	0.013	0.029	36
Lower Wairau	0.001	0.002	0.003	0.005	0.008	36
Tuamarina Rv	0.006	0.011	0.016	0.025	0.070	35
Wairau Diversion	0.002	0.008	0.012	0.013	0.033	35
Omaka Rv	0.001	0.003	0.004	0.006	0.014	36
Mid Ōpaoa	0.001	0.001	0.003	0.004	0.012	35
Doctors Ck	0.013	0.018	0.021	0.027	0.079	35
Murphys Ck	0.005	0.009	0.010	0.010	0.014	35
Taylor Rv	0.005	0.011	0.014	0.015	0.037	35
Lower Ōpaoa	0.003	0.009	0.012	0.017	0.027	35
Spring Ck	0.004	0.008	0.010	0.011	0.069	34
Black Birch Stm	0.004	0.008	0.010	0.010	0.012	36
Mid Awatere	0.005	0.008	0.010	0.012	0.018	36
Lower Awatere	0.001	0.004	0.008	0.012	0.016	36
Flaxbourne Rv	0.001	0.005	0.007	0.012	0.030	35
Waima Rv	0.001	0.001	0.002	0.004	0.008	35

10.4.8. E. coli concentration

Values are in cfu/100mL[8], 2017-2019, inclusive. Values below detection limit have been set to the detection limit.

Site	Minimum	25th Percentile	Median	75th Percentile	Maximum	N
Ronga Rv	17	49	95	153	1200	36
Opouri Rv	15	54	80	133	1700	36
Rai Rv	19	59	95	140	2700	36
Upper Pelorus	4	10	16	29	540	36
Wakamarina Rv	3	23	29	56	1800	36
Lower Pelorus	3	27	42	103	3600	36
Kaituna Rv	5	49	108	285	6200	36
Cullen Ck	9	57	120	195	7900	35
Linkwater Stm	24	185	440	805	17000	35
Waitohi Rv	31	78	150	350	3600	36
Graham Rv	0	17	40	190	2000	35
Kenepuru Rv	40	123	210	418	6600	34
Upper Wairau	0	2	7	13	1597	36
Goulter Rv	0	2	3	7	58	32
Branch Rv	0	2	5	13	90	36
Mill Ck	10	75	150	235	4800	35
Mid Waihopai	9	15	48	120	800	36
Lower Waihopai	2	12	32	105	6001	36
Ohinemahuta Rv	3	15	24	87	2900	35
Are Are Ck	13	39	110	173	41000	36
Lower Wairau	0	5	9	24	3300	36
Tuamarina Rv	13	33	60	130	9300	36
Wairau Diversion	4	32	50	115	5900	36
Omaka Rv	1	6	21	60	350	36
Mid Ōpaoa	12	70	100	245	1000	36
Doctors Ck	69	235	300	440	2000	36
Murphys Ck	6	37	68	125	450	36
Taylor Rv	60	170	220	340	3200	36
Lower Ōpaoa	16	35	57	85	1400	36
Spring Ck	27	78	110	175	5300	36
Black Birch Stm	0	2	5	13	240	36
Mid Awatere	0	4	19	58	610	36
Lower Awatere	0	27	46	153	1020	36
Flaxbourne Rv	22	72	190	380	3700	35
Waima Rv	0	4	11	40	2500	35

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[8] colony forming units per 100 millilitres

10.4.9. Turbidity

Values are in NTU (Nephelometric Turbidity Units), 2017-2019, inclusive.

Site	Minimum	25th Percentile	Median	75th Percentile	Maximum	N
Ronga Rv	0.1	0.4	0.8	1.5	9.5	36
Opouri Rv	0.2	0.4	0.5	0.9	4.7	36
Rai Rv	0.3	0.5	0.8	1.5	15.0	36
Upper Pelorus	0.1	0.3	0.5	0.9	10.3	36
Wakamarina Rv	0.2	0.3	0.4	0.8	10.0	36
Lower Pelorus	0.2	0.4	0.7	1.2	25.0	36
Kaituna Rv	0.3	0.4	0.7	1.3	55.0	36
Cullen Ck	0.3	0.5	0.7	1.5	197.0	35
Linkwater Stm	1.0	1.7	2.6	4.4	410.0	35
Waitohi Rv	0.4	0.6	1.2	2.4	117.0	36
Graham Rv	0.2	0.4	0.5	0.9	44.0	35
Kenepuru Rv	0.3	0.5	0.7	1.2	12.3	34
Upper Wairau	0.4	0.9	1.8	7.7	181.0	36
Goulter Rv	0.1	0.2	0.3	0.4	0.7	32
Branch Rv	0.2	0.5	0.8	4.5	147.0	36
Mill Ck	0.9	1.4	1.7	3.0	7.8	35
Mid Waihopai	0.5	1.3	1.9	30.0	320.0	36
Lower Waihopai	0.4	1.1	1.9	35.8	570.0	36
Ohinemahuta Rv	0.4	0.6	1.2	3.1	64.0	35
Are Are Ck	0.2	0.6	1.4	3.1	97.0	36
Lower Wairau	0.0	0.6	1.3	4.4	220.0	36
Tuamarina Rv	0.6	1.7	2.1	3.5	151.0	36
Wairau Diversion	1.1	2.2	5.1	9.5	95.0	36
Omaka Rv	0.1	0.3	0.4	0.7	16.9	36
Mid Ōpaoa	1.1	3.7	4.9	7.5	220.0	36
Doctors Ck	1.0	2.3	3.2	5.6	9.7	36
Murphys Ck	0.1	0.3	0.4	0.7	3.0	36
Taylor Rv	0.4	1.1	1.3	2.6	74.0	36
Lower Ōpaoa	0.6	1.3	1.8	3.4	43.0	36
Spring Ck	0.4	0.7	0.8	1.1	5.8	36
Black Birch Stm	0.1	0.2	0.2	0.4	2.1	36
Mid Awatere	0.7	9.3	55.0	158.0	2100.0	36
Lower Awatere	1.1	8.2	33.0	129.3	2500.0	36
Flaxbourne Rv	0.4	0.9	1.5	4.8	660.0	35
Waima Rv	0.2	0.4	0.7	2.7	3900.0	35

10.4.10. Macroinvertebrates Community Index (MCI)

Shown are the MCIs for the five most recent summer seasons as well as the Median for these MCIs.

Site	Easting	Northing	2015/16	2016/17	2017/18	2018/19	2019/20		Median
Kaiuma Bay Stm	1657595	5438293	124	116	125	118	131		124
Opouri Rv	1652204	5437502	115	112	119	117	121		117
Ronga Rv	1649966	5437711	108	109	113	110	104		109
Rai Rv	1648018	5429266	89	102	102	101	106		102
Upper Pelorus	1647585	5427613	129	120	130	108	111		120
Wakamarina Rv	1656011	5428720	130	127	133	110	120		127
Lower Pelorus	1659571	5430016	99	104	121	90	99		99
Duncan Bay Stm	1663894	5446691	118	122	121	119	118		119
Kaituna Rv	1664877	5426463	108	98	113	103	103		103
Cullen Ck	1671802	5428178	101	108	115	104	106		106
Linkwater Stm	1675552	5429552	100	98	118	108	115		108
Waitohi Rv	1684133	5428227	83	114	115	112	96		112
Graham Rv	1689949	5430629	111	107	93	117	103		107
Kenepuru Rv	1694287	5442220	118	109	118	105	110		110
Anakoha Stm	1693260	5454525	122	113	112	112	116		113
Upper Wairau	1593486	5362089	118	110	136	110	123		118
Branch Rv	1615310	5383200	133	122	128	110	130		128
Goulter Rv	1615505	5390310	132	138	121				132
Cabbage Tree	1625856	5390229	76				85		80.5
Saltwater Ck	1619068	5388223	118	114	118				118
Wye Rv	1626403	5385627	122		127	130	125		126
Enchanted Stm	1631755	5395282	147	140	127	119	124		127
Top Valley Stm	1638848	5398855	127	111	116	110	118		116
Timms Ck	1641504	5400735	134	117	114	115	122		117
Pine Valley Stm	1642598	5405503	140	133	128	114	126		128
Bartletts Ck	1649816	5403453	118	124	112	112	131		118
Mill Ck	1642747	5398630	117	101	99	105	103		103
Walker Stm	1643573	5398609	109	110	84	93	89		93
Upper Waihopai	1647510	5387498	115	114	119	102	111		114
Avon Rv	1654552	5387697	119	111	123	115	114		115
Mid Waihopai	1657397	5392054	122	103	116	107	105		107
Lower Waihopai	1661086	5402329	127	113	112	105	102		112
Ohinemahuta Rv	1665221	5407894	115	121	114	111	105		114
Are Are Ck	1668891	5409150	89	99	88	97	105		97
Waikakaho Rv	1675301	5411934	102	118	112	104	111		111
Tuamarina Rv	1680588	5412144	79	87	75	64			77
Pukaka Rv	1683488	5414797	91	95		93	94		93.5
Lower Wairau	1680623	5412041	110	99	104	85	80		99
Omaka Rv	1668150	5402871	84	92	106	105	94		94
Spring Ck	1681052	5411335	105	78	80	95	84		84
Gibsons Ck	1669880	5405340				98	87		92.5
Doctors Ck	1678538	5403700	71	73	71	74	80		73
Mid Ōpaoa	1675898	5406769	80	88		87	85		86
Murphys Ck	1678585	5404340	95	77	79	85	88		85
Mid Awatere	1660707	5368307	127	91	113	103	122		113
Black Birch Stm	1673268	5382346	118	110	143	114	115		115
Lower Awatere	1695945	5393096	107	93	92	103	122		103
Needles Ck	1695638	5368880	85	72		88	90		86.5
Flaxbourne Rv	1697479	5368033	74	66		80	83		77
Waima Rv	1692178	5360509	95	83		110	104		99.5

10.4.11. Periphyton

Values are in mg Chl.a/m^2 (Chlorophyll a per square meter), 2017-2019, inclusive.

Site	Minimum	25th Percentile	Median	75th Percentile	Maximum	N
Ronga Rv	3	7	14	21	64	33
Rai Rv	1	22	40	55	243	33
Kaituna Rv	0	2	18	51	150	33
Waitohi Rv	3	13	19	36	191	34
Graham Rv	0	5	11	35	92	32
Ohinemahuta Rv	1	3	8	14	150	33
Are Are Ck	1	3	5	16	173	34
Omaka Rv	0	21	42	64	393	33
Flaxbourne Rv	0	24	55	100	636	32
Waima Rv	0	2	7	59	405	34

10.4.12. Water Quality Index

The table below lists the WQIs for the period 2017-2019. Also shown are the reduction in the WQI for each parameter.

Site	WQI	Parameter specific reduction in the WQI								
		Water Temperature	Dissolved Oxygen	pH	E. coli	Nitrate Nitrogen	Ammonia Nitrogen	DRP	DIN	Turbidity
Goulter Rv	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Branch Rv	92.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-7.2
Upper Pelorus	80.7	-6.1	0.0	0.0	-6.1	0.0	0.0	0.0	0.0	-7.1
Black Birch Stm	80.7	0.0	0.0	0.0	-6.1	0.0	0.0	-7.2	0.0	-6.1
Wakamarina Rv	80.6	0.0	0.0	0.0	-6.4	0.0	0.0	-6.4	0.0	-6.5
Ohinemahuta Rv	80.2	-5.1	0.0	0.0	-6.7	0.0	0.0	0.0	0.0	-7.9
Lower Wairau	80.1	-5.2	0.0	0.0	-5.5	0.0	0.0	0.0	0.0	-9.2
Waitohi Rv	79.1	0.0	0.0	0.0	-8.0	0.0	0.0	-5.5	0.0	-7.4
Mid Waihopai	78.5	0.0	0.0	0.0	-5.4	0.0	0.0	-6.3	0.0	-9.7
Waima Rv	73.7	-5.3	0.0	-5.1	-6.0	0.0	0.0	0.0	0.0	-9.9
Upper Wairau	73.6	0.0	0.0	-5.1	-5.4	0.0	0.0	-5.8	0.0	-10.1
Kenepuru Rv	73.4	0.0	-5.2	0.0	-10.2	0.0	0.0	-5.1	0.0	-6.0
Lower Waihopai	72.5	-4.9	0.0	0.0	-6.2	0.0	0.0	-5.3	0.0	-11.1
Cullen Ck	71.9	0.0	0.0	0.0	-7.3	0.0	0.0	-9.6	-4.9	-6.3
Are Are Ck	70.3	0.0	0.0	0.0	-7.5	0.0	0.0	-6.3	-8.7	-7.2
Lower Awatere	69.2	-4.1	0.0	0.0	-5.5	0.0	0.0	-5.9	0.0	-15.3
Lower Pelorus	67.8	-5.9	0.0	0.0	-7.2	0.0	0.0	-6.1	-6.0	-7.1
Graham Rv	67.1	-5.2	-5.2	0.0	-7.4	0.0	0.0	-8.1	0.0	-6.9
Spring Ck	67.1	0.0	-6.2	0.0	-7.7	0.0	0.0	-8.2	-5.3	-5.6
Mid Ōpaoa	65.8	-4.7	0.0	0.0	-7.2	0.0	0.0	-5.0	-5.7	-11.5
Kaituna Rv	65.2	0.0	0.0	0.0	-7.5	-5.5	0.0	-5.5	-10.0	-6.3
Mid Awatere	63.7	0.0	0.0	0.0	-4.6	-4.4	0.0	-6.4	-4.6	-16.3
Omaka Rv	61.3	-6.0	-6.0	0.0	-6.6	0.0	0.0	-6.3	-6.6	-7.2
Opouri Rv	60.8	0.0	-5.5	0.0	-7.1	-5.5	0.0	-5.6	-9.4	-6.2
Rai Rv	60.0	0.0	0.0	-5.0	-6.9	-5.4	0.0	-5.2	-11.3	-6.3
Ronga Rv	59.7	0.0	-5.4	0.0	-6.8	-5.6	0.0	-5.0	-11.3	-6.3
Linkwater Stm	59.6	0.0	-4.2	0.0	-9.8	0.0	0.0	-10.1	-7.2	-9.2
Flaxbourne Rv	59.5	-4.9	0.0	0.0	-9.0	-5.0	0.0	-7.3	-5.6	-8.7
Wairau Div	59.3	-4.9	-4.9	0.0	-6.1	0.0	-5.0	-8.6	0.0	-11.2
Lower Ōpaoa	58.4	0.0	-4.7	0.0	-5.6	0.0	-4.7	-8.9	-9.5	-8.3
Murphys Ck	57.1	0.0	-5.2	0.0	-5.5	-8.6	0.0	-5.7	-13.5	-4.4
Tuamarina Rv	57.0	-4.5	-7.8	0.0	-5.8	0.0	0.0	-11.4	-5.0	-8.5
Taylor Rv	55.6	0.0	-4.3	0.0	-8.6	-5.0	0.0	-9.1	-10.9	-6.5
Mill Ck	50.9	0.0	-4.2	0.0	-6.7	-9.4	0.0	-7.4	-14.7	-6.7
Doctors Ck	46.3	0.0	-5.0	0.0	-9.3	-4.5	-4.2	-12.4	-9.6	-8.8

10.5. Trend Analysis Results

10.5.1. 10-year Trends

Trends for the period 2010-2019, with P≤0.05.

Site	Parameter	Flow adjustment	Sample size	Variance	P	Percent annual change	Absolute annual change
Are Are Ck	Turbidity	Yes	120	1499	0	-7.47	-0.081
Are Are Ck	E.coli	Yes	120	1500	0.02	-10.1	5.997
Black Birch Stm	E.coli	No	116	1259.33	0	16.79	0.252
Black Birch Stm	Nitrate Nitrogen	No	117	1368	0.01	5.89	0.000
Black Birch Stm	pH	No	117	1400	0	1.93	0.143
Branch Rv	pH	Yes	119	1467	0.02	-0.09	-0.007
Branch Rv	Nitrate Nitrogen	Yes	119	1467	0.01	6.95	0.001
Cullen Ck	Turbidity	Yes	116	1368	0	-11.56	-0.083
Cullen Ck	E.coli	No	116	1360	0	-8.3	-13.280
Cullen Ck	Nitrate Nitrogen	No	116	1356.33	0.02	2.2	0.007
Doctors Ck	pH	No	118	1430.04	0.01	0.22	0.016
Doctors Ck	Turbidity	No	117	1402	0	-9.22	-0.387
Doctors Ck	Nitrate Nitrogen	No	118	1434	0	-9.43	-0.077
Kaituna Rv	pH	Yes	120	1500	0	0.16	0.012
Kenepuru Stm	E.coli	No	115	1326	0	8.9	13.350
Linkwater Stm	pH	Yes	119	1467	0.03	0.26	0.018
Linkwater Stm	Turbidity	No	119	1460	0.01	-6.76	-0.176
Linkwater Stm	E.coli	No	119	1457	0.02	4.76	10.948
Linkwater Stm	Nitrate Nitrogen	Yes	119	1467	0	7.46	0.039
Lower Awatere	pH	Yes	120	1500	0.04	-0.18	-0.014
Lower Awatere	E.coli	Yes	119	1467	0	8.97	0.599
Lower Opaoa	Turbidity	Yes	117	1407	0	-6.05	-0.045
Lower Opaoa	Nitrate Nitrogen	No	117	1402	0.02	-2.87	-0.017
Lower Pelorus	E.coli	No	119	1460	0.01	8.11	2.514
Lower Pelorus	Nitrate Nitrogen	No	119	1454.33	0	4.24	0.010
Lower Waihopai	E.coli	Yes	120	1500	0	8.43	0.146
Lower Wairau	E.coli	Yes	119	1467	0.01	8.14	0.292
Mid Awatere	Nitrate Nitrogen	Yes	120	1500	0	11.52	0.002
Mid Opaoa	pH	No	117	1403	0	-0.5	-0.038
Mid Opaoa	E.coli	No	117	1399.04	0.01	6.87	7.557
Mid Waihopai	Turbidity	Yes	120	1500	0.04	16.63	0.216
Mid Waihopai	Nitrate Nitrogen	No	120	1499	0.04	3.89	0.002
Mill Ck	pH	No	118	1422.33	0	0.25	0.018
Mill Ck	Turbidity	No	118	1418.33	0.01	-4.79	-0.101
Murphys Ck	E.coli	No	117	1398.02	0.03	4.09	2.822
Ohinemahuta Rv	E.coli	No	119	1461	0	-9.2	-4.324
Omaka Rv	pH	No	119	1458	0	0.2	0.015
Omaka Rv	Turbidity	Yes	119	1467	0	-6.94	-0.023
Opouri Rv	pH	Yes	120	1500	0	0.17	0.012
Opouri Rv	E.coli	Yes	120	1500	0	6.26	2.865
Opouri Rv	Nitrate Nitrogen	Yes	120	1500	0	4.35	0.024
Rai Rv	Turbidity	Yes	120	1500	0.02	-3.48	-0.023
Rai Rv	Nitrate Nitrogen	Yes	120	1500	0	2.29	0.014
Ronga Rv	pH	No	119	1460	0	0.39	0.028
Ronga Rv	Turbidity	Yes	119	1467	0.01	-4.52	-0.031
Spring Ck	E.coli	No	117	1395.02	0	8.75	7.875
Taylor Rv	Turbidity	Yes	118	1445	0	-7.62	-0.083
Taylor Rv	Nitrate Nitrogen	No	119	1476.09	0	-3.43	-0.031
Taylor Rv	E.coli	Yes	119	1485	0	8.98	17.530
Tuamarina Rv	Turbidity	Yes	117	1407	0	-4.41	-0.108

Site	Parameter	Flow adjustment	Sample size	Variance	P	Percent annual change	Absolute annual change
Upper Pelorus	pH	Yes	120	1500	0.04	-0.12	-0.009
Upper Wairau	pH	No	120	1483.67	0	0.26	0.020
Upper Wairau	Turbidity	Yes	120	1500	0	37.54	-1.434
Upper Wairau	E.coli	Yes	118	1432	0	17.55	-0.909
Waima Rv	E.coli	No	109	1139.67	0	-12.55	-2.636
Wairau Div	pH	No	117	1394	0.03	0.08	0.006
Waitohi Rv	Turbidity	No	120	1482.33	0.03	-4.17	-0.050
Wakamarina Rv	pH	No	120	1483.67	0.02	-0.1	-0.007
Wakamarina Rv	E.coli	No	120	1489	0.01	7.42	2.003

10.5.2. 5-year Trends

Trends for the period 2015-2019, with P≤0.05.

Site	Parameter	Flow adjustment	Sample size	Variance	P	Percent annual change	Absolute annual change
Are Are Ck	pH	Yes	59	7.32	192	0	-0.46
Are Are Ck	E.coli	Yes	60	-74.97	200	0.03	-33.53
Black Birch	pH	No	59	7.71	192	0	1.71
Black Birch	E.coli	No	58	2	162.33	0	66.71
Black Birch	DRP	No	59	0.01	176	0	-11.84
Black Birch	Nitrate Nitrogen	No	59	0.01	190	0	-32.84
Branch Rv	DRP	No	60	0.01	184.67	0.03	-4.26
Doctors Ck	Nitrate Nitrogen	No	59	0.73	194.67	0.94	0.69
Doctors Ck	Nitrate Nitrogen	Yes	59	0.69	194.67	0.04	-3.77
Doctors Ck	Nitrate Nitrogen	Yes	59	0.69	194.67	0.04	-3.77
Flaxbourne Rv	pH	No	55	8.02	160	0.01	0.79
Graham Rv	DRP	No	59	0.01	187	0.04	5.04
Kaituna Rv	DRP	Yes	60	0.01	200	0.03	-5.25
Kaituna Rv	Nitrate Nitrogen	No	60	0.81	200	0	-10.66
Linkwater Stm	Turbidity	No	59	1.9	190	0.01	23.67
Linkwater Stm	E.coli	No	59	260	190	0	20.17
Lower Awatere	Turbidity	Yes	60	30.98	200	0.04	-20.49
Lower Awatere	Nitrate Nitrogen	No	60	0.05	200	0	29.88
Lower Opaoa	Nitrate Nitrogen	No	59	0.57	193.67	0.03	5.49
Lower Pelorus	E.coli	No	59	42	190	0.02	16.19
Lower Waihopai	E.coli	No	60	24.5	198	0.01	19.11
Lower Wairau	pH	No	60	7.51	200	0.01	-0.42
Lower Wairau	Nitrate Nitrogen	No	60	0.11	197	0	14.57
Mid Awatere	Turbidity	Yes	60	63.74	200	0.01	-21.8
Mill Ck	pH	No	59	7.43	192	0.03	-0.18
Mill Ck	Nitrate Nitrogen	No	59	1.56	190	0.02	6.78
Murphys Ck	pH	No	59	7.05	194.67	0	-1.04
Omaka Rv	E.coli	No	59	14	185.33	0	19.63
Omaka Rv	Nitrate Nitrogen	Yes	59	0.14	192	0.05	-31.75
Opouri Rv	Turbidity	Yes	59	0.48	192	0.01	-7.83
Ronga Rv	Turbidity	Yes	59	0.66	192	0	-16.01
Ronga Rv	Nitrate Nitrogen	No	59	0.01	190	0.01	-8.65
Spring Ck	Nitrate Nitrogen	No	59	0.25	193.53	0	8.02
Taylor Rv	pH	No	59	7.32	194.67	0.01	-0.5
Tuamarina Rv	pH	No	59	7.32	194.67	0.02	-0.36
Tuamarina Rv	DRP	Yes	59	0.02	194.67	0	-11.56
Tuamarina Rv	Nitrate Nitrogen	Yes	59	0.35	194.67	0	-21.77
Waima Rv	pH	No	50	8.26	126	0	0.48
Waima Rv	E.coli	No	50	8	122	0.01	25.09
Waima Rv	Nitrate Nitrogen	Yes	50	0.01	126	0.04	-45.44
Waitohi Rv	E.coli	No	60	125	199	0.02	10.31
Wakamarina Rv	Nitrate Nitrogen	No	60	0.04	190.67	0.04	9.73