MARLBOROUGH DISTRICT COUNCIL

State of the Environment

Surface Water Quality Monitoring Report, 2016

Technical Report No: 16-006
October 2016

State of the Environment Surface Water Quality Monitoring Report, 2016

MDC Technical Report No: 16-006

ISSN 1179-8181 (Online)
ISBN 978-1-927159-71-2 (Online)

File Reference/Record No: E375-001-001-03/16206728

October 2016

Report Prepared by:
Steffi Henkel
Environmental Scientist - Water Quality
Environmental Science & Monitoring Group

Marlborough District Council
Seymour Square
PO Box 443
Blenheim 7240
Phone: 520 7400
Website: www.marlborough.govt.nz

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 a Water Quality Index. The calculation of the Index is based on the exceedance of guideline values and combines the data of the last three years (2013-2015). The Index categorises water quality into five classes, excellent, good, fair, marginal and poor.

A site on the lower Goulter River is the most recent addition to the monitoring programme. The Goulter is one of the few large tributaries of the Wairau River that remains largely unmodified by human activity. Although we do not as yet have a full three year data set, a preliminary Water Quality Index was calculated and the result shows that 'excellent' water quality is achievable by a relatively large river. This is good confirmation for the choice of guidelines values used for the calculation of the Water Quality Index.

Three sites have a Water Quality Index in the 'good' category, the Upper Te Hoiere/Pelorus, the Wakamarina River and Black Birch Stream. The main reason for the good water quality in these rivers is that more than 80% of their catchments remain in native vegetation. Unfortunately, large areas of native forest, shrub and tussock in a catchment do not guarantee good water quality. Less than 15% of the Branch, Graham and Waitohi River catchments have been modified for human use. Yet, despite this limited area of human influence, the water quality of these waterways is only 'fair'.

The majority of the sites monitored as part of the State of the Environment programme have Water Quality Indices in the 'fair' and 'marginal' categories. Soluble Inorganic Nitrogen, which is predominantly in the form of nitrate, is the main parameter causing reductions in the Water Quality Index for a number of sites, particularly groundwater-fed streams and waterways with large areas of irrigated pasture. Two waterways, the Kaituna River and Waima River, have unusually high soluble inorganic nitrogen concentrations that cannot be explained by the land use in their catchments alone.

With the exception of the Tuamarina River, water quality of sites in the 'poor' category is predominantly reduced by natural causes.

To determine changes in water quality, Seasonal Kendall Trend Analysis was applied to the last five years and where possible, to the last nine years of data. The results of this analysis show a significant increase in turbidity over the last five years for both Awatere River sampling sites.

Analysis of nitrate data revealed an increasing trend over the last five years for a number of sites north of the Wairau River. The wide range of this phenomenon indicates that a change in rainfall patterns is the most likely explanation. Most spring-fed streams show a significant decrease in nitrate concentrations, which can be linked to the widespread conversion of pastures into vineyards in the lower Wairau catchment.

E. coli data were also analysed for trends and results show increases in concentrations for a number of sites, including the Taylor River, Flaxbourne River, mid Ōpaoa, Spring Creek, the Kaituna River and the Wairau Diversion. Investigations of the Taylor River have linked the faecal contamination to ducks, dogs and recently also to human sewage entering the river due to infrastructure damaged by recent earthquakes. For the other waterways investigation similar to those undertaken in the Taylor River would be needed to identify the causes of increased E. coli concentrations.

Table of Contents

1. Introduction

1.1. Purpose

Rivers and streams are an integral part of the environment. Good water quality is important for the ecological health of our water ways, but it is also essential for the wellbeing of the people in Marlborough. We use our freshwater in many ways, including recreational uses, such as swimming, fishing and boating, but our rivers and streams are also essential for the economic health of our region, providing water for farming, viticulture and industry. However, use and modifications of our waterways can adversely affect the quality of the water and the health of aquatic ecosystems.

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. Monitoring consists of monthly measurements of physical and chemical parameters at 35 sites. The monitoring is usually carried out as close to the bottom of each catchment as possible to allow the assessment of cumulative effects of land use and uses of surface water resources.

The 2013 Surface Water State of the Environment Report [14] introduced the Canadian Water Quality Index as a method of summarising water quality data into a simple single score. Unlike common statistics, the purpose of Water Quality Indices is to provide information for a non-technical audience that allows comparison between sites. The intended outcome is the inclusion of a wider range of interested parties into the discussions around surface water quality and the effectiveness of policies and rules.

Apart from providing information about the current state of water quality in the rivers and streams of the region, this report also focuses on changes.

1.2. The Region

The four largest rivers in the Marlborough region are the Te Hoiere/Pelorus River in the north-west, the Wairau River, the Waihopai River (the Wairau River's main tributary), 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 predictably has 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 large variation in rainfall across the region (Figure 1). 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. This is less than a third of the total annual rainfall in the Te Hoiere/Pelorus and Waihopai catchments, 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.

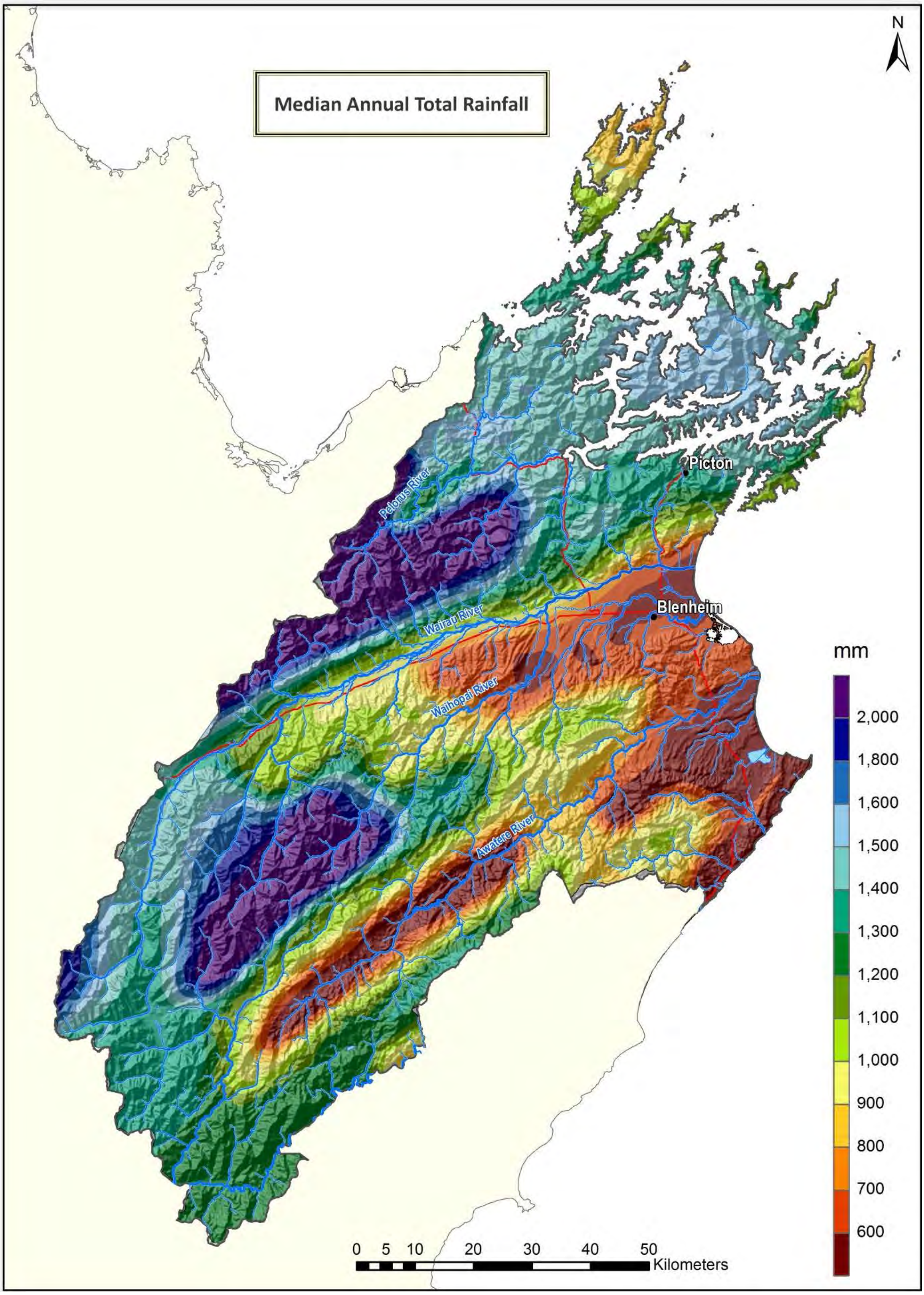


Figure 1: Median Annual Total Rainfall in Marlborough. **Source: NIWA (modified – original map with disclaimer can be found at www.niwa.co.nz/gallery/rainfall-14) .**

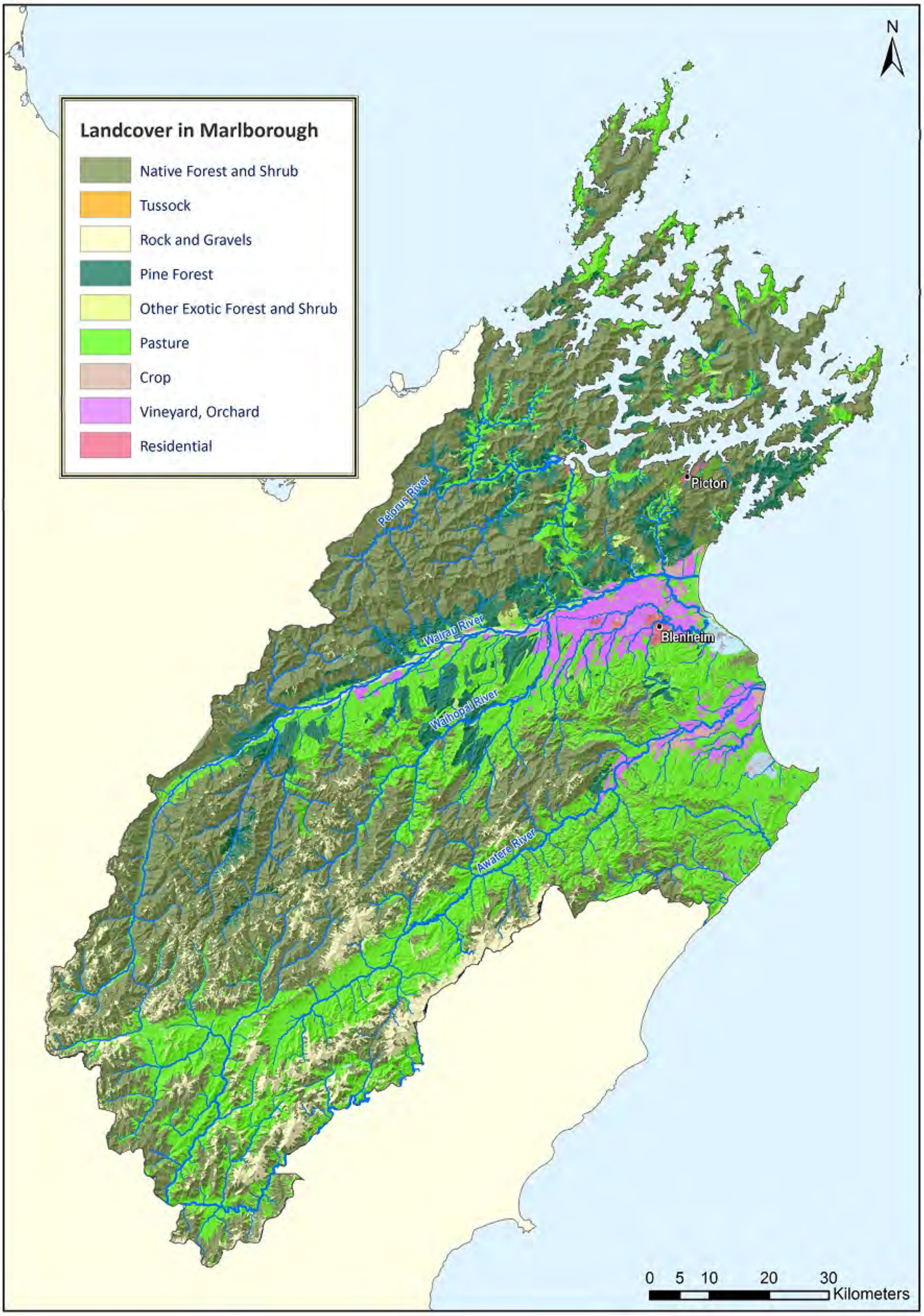


Figure 2: Land cover in Marlborough as of 2012.

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 the water way. 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 forest. Since the arrival of humans there has been a systematic clearance of large tracts of forest and as a result the majority of our waterways are no longer pristine. The map in Figure 2 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 and along the Lower Wairau River. Production forest (mainly *Pinus radiate*) covers around 7% of the region.

Marlborough is most renowned for its viticulture and more and more land is being utilized. Still, vineyards cover less than 3% of the region and are concentrated on the Wairau Plain and the Lower Awatere.

2. Methodology

2.1. Chemical and Physical Water Quality

Monthly water quality samples and field measurements are taken at 35 sites across the region. Two of these sites are part of the national monitoring network and the water quality samples are collected by NIWA. NIWA kindly provides sampling data for these sites to the Marlborough District Council. At the remaining 33 sites, water samples are collected by Marlborough District Council staff and sent to an independent, accredited laboratory for analysis. Water temperature and dissolved oxygen saturation are measured in the field using YSI handheld meters.

In August 2011 the laboratory service provider was changed from ELS Ltd to Hill Laboratories Ltd. A table comparing the detection limits and analysis methods for the parameters measured can be found in Appendix 6.4.

The field measurements and laboratory analysis results from three consecutive years (2013 to 2015 inclusive) were used to calculate a Water Quality Index for each site.

2.2. Water Quality Index

The Marlborough District Council uses the Canadian Water Quality Index (CCME WQI) for the reporting of surface water quality. Based on guideline values the CCME 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 and are based on the protection of aquatic life and recreational uses of rivers and streams. It was also taken into consideration that most sampling sites are located at the bottom of the catchment and a certain degree of water quality deterioration will occur naturally [25]. Table 1 lists the parameters and the associated guidelines used for the calculation of the CCME WQI. The table also provides information about the relevance of the parameters in regard to the protection of waterway values. More detailed justification and discussion of these guidelines can be found in the 2013 report [13].

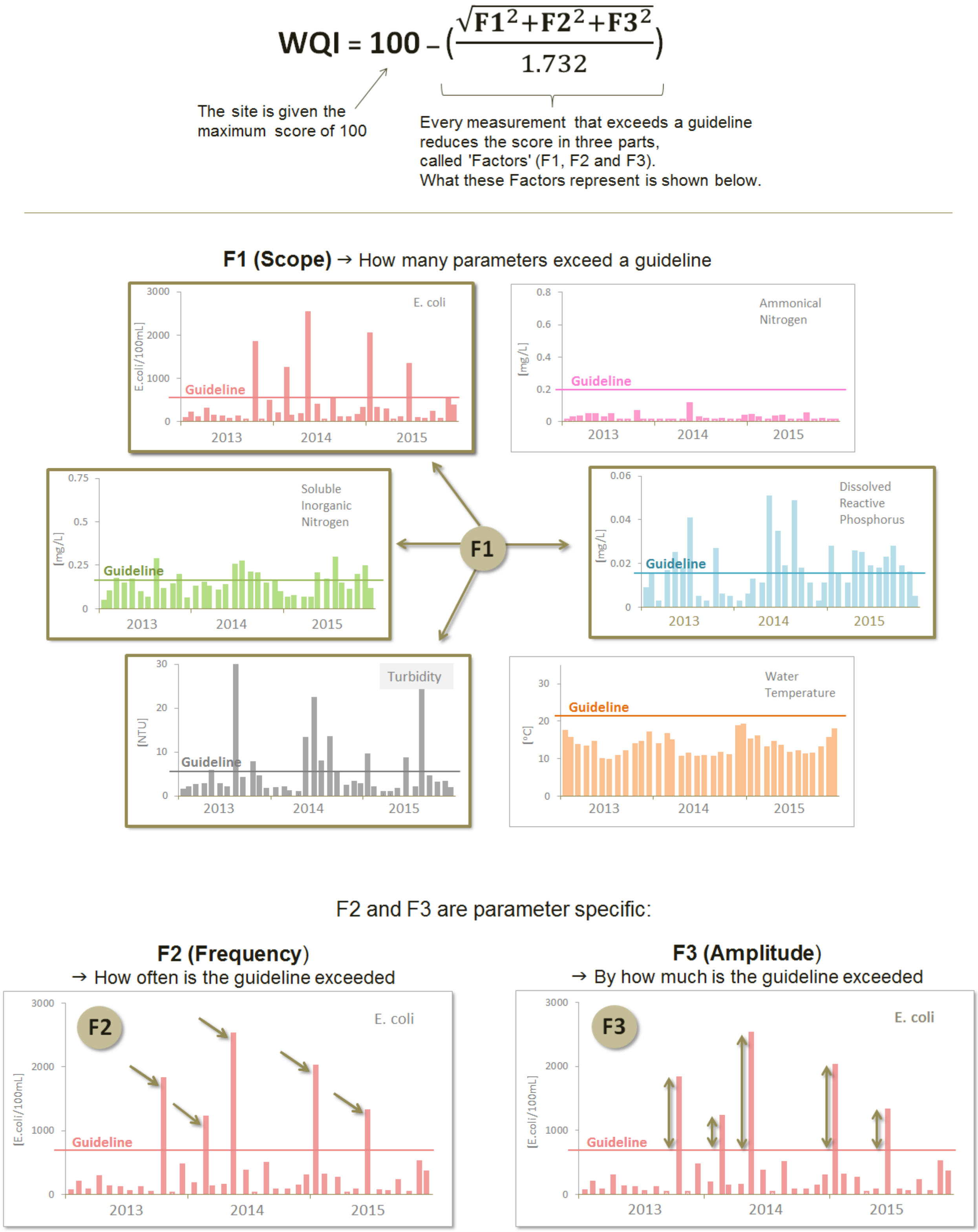
Parameter	Guideline Value	Importance
Water Temperature	21.5 °C	Aquatic life supporting capacity; High Water Temperatures effect the survival of some aquatic insects and fish.
Dissolved Oxygen Saturation	70 %	Aquatic life supporting capacity; Low Dissolved Oxygen levels effect the survival of some aquatic insects and fish.
pH	Lower: 6.7 Upper: 7.8	Aquatic life supporting capacity; Deviations from natural pH can impact the growth and reproduction of fish.
Nitrate-Nitrogen	2.4 mg/L	Aquatic life supporting capacity; High Nitrate concentrations are toxic to aquatic life.
Ammonical-Nitrogen	winter: 0.76 mg/L summer: 0.2 mg/L	Aquatic life supporting capacity; High Ammonia concentrations are toxic to aquatic life. Only some of the Ammonical Nitrogen is in the form of the toxic Ammonia. With increasing Water Temperature and pH, more and more of the Ammonical Nitrogen is converted into Ammonia - hence the lower guideline for the summer months.
Soluble Inorganic Nitrogen	0.165 mg/L	Aquatic life supporting capacity and amenity values; Soluble Inorganic Nitrogen represents the form of Nitrogen that is easily taken up by aquatic plants (i.e. algae); High concentrations can cause nuisance algae mats that effect the habitat and food availability for aquatic insects.
Dissolved Reactive Phosphorus	0.015 mg/L	Aquatic life supporting capacity and amenity values; Dissolved Reactive Phosphorus represents the form of Phosphorus that is easily taken up by aquatic plants (i.e. algae); High concentrations can cause nuisance algae mats that effect the habitat and food availability for aquatic insects.
E. coli concentration	550 E.coli/100mL	Human health; E. coli are an indicator for faecal contamination and consequently the risk to human health from water borne diseases (i.e. Campylobacteriosis).
Turbidity	5.6 NTU	Recreational and amenity value; ANZEEC (2000) trigger level.

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

It has been shown that 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 3).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.

A detailed description of the calculation is given in Appendix 6.1.



The formulas for the calculation of the Factors can be found in the Appendix.

Figure 3: The Factors of the Water Quality Index calculation.

Once calculated, the Water Quality Index is a number between 0 and 100. Based on that number the water quality of a river or stream can then be categorised into one of five quality classes. Table 2 shows the water quality classes assigned to different values of the Index [1]. As can be seen, the higher the Water Quality Index the better the water quality.

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.

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 [12], 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 'median 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 [24] and the number of 'seasons' should be set to 12 (one for each month) [1]. Because for many parameters, increased flow is associated with either dilution or increased values due to run-off from land, flow adjustment of the data is carried out where possible[1]. 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 unless the flow-adjusted trend had a lower P-value.

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 labs to allow adjustment of the earlier results. Since the step change will influence the results of the trend analysis, there were no trends calculated for dissolved reactive phosphorus concentrations.

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. In order to avoid ties[2], 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 trend changes.

Trend analysis was carried out for nitrate, but not soluble inorganic nitrogen to avoid problems that can arise from the combination of different measurements. Most of the soluble inorganic nitrogen is in the form of nitrate. Therefore trend results for nitrate concentrations are indicative of very similar trends for soluble inorganic nitrogen concentrations.

---

[1] 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].

[2] Ties are results with the same value.

This report presents the trends for two time periods, the last five years (2011-2015) and, where possible, the last nine years (2007-2015).

2.4. National Policy Statement

The National Policy Statement for Freshwater Management 2014 (NPS) defines numerical ranges for four states or bands (bands ‘A’, ’B, ‘C’ and ‘D’) for a number of water quality attributes based on ecosystem health and recreational values. The A-band represents best water quality, while the D-band characterises unacceptable water quality. The NPS requires that attribute limits are set for all waterways within a region, which are monitored at representative sites. Attributes relevant in regard to rivers and streams in Marlborough are Nitrate-Nitrogen, Ammonia-Nitrogen, Periphyton[3] and E. coli. Of these attributes, all, but Periphyton are currently monitored as part of the State of the Environment program.

To assist the setting of limits for the currently monitored attributes, the attribute states for State of the Environment monitoring sites were determined for the years 2011, 2012, 2013 and 2014. The analysis showed that the majority of sites had water quality within the A-band of the NPS limits for all of the relevant attributes. Six sites had Nitrate or E. coli concentrations (wadablility) within the B-band of the attribute limits (Table 3). The E. coli attribute has different limits that are applied based on the recreational use of a waterway. For rivers and streams that are not used for contact recreation, ie; swimming, a wadability limit applies. For sites that are known swimming locations, a more stringent limit is used. Three State of the Environment monitoring sites located on rivers with popular swimming sites were exceeding the A and B-Band limits for the E. coli (swimming) attribute.

The NPS requires that water quality is maintained or enhanced. Because of the large number of sites with water quality within the A-band, Objectives 15.1b-d of the Marlborough Environment Plan require that water quality in the region is maintained within or enhanced to the NPS A-band for Ammonia-Nitrogen, Nitrate-Nitrogen and wadable E. coli concentrations. For waterways that are used for swimming, Objective 15.e requires that water quality is to be maintained or enhance, so that E. coli concentrations are within the A- or B-band limits.

Attribute	Limits based on regional plan (MEP) Objectives 15.1b-e	NPS-Band	Sites exceeding this limit (as of 2014)
Ammonia-Nitrogen (toxicity)	0.03 mg/L (Annual Median) and 0.05 mg/L (Annual Maximum)	A	none
Nitrate-Nitrogen (toxicity)	1.0 mg/L (Annual Median) and 1.5 mg/L (Annual 95th Percentile)	A	Mill Creek, Murphys Creek
E. coli (wadability)	260 E.coli/100mL (Annual Median)	A	Are Are Creek, Cullens Creek, Doctors Creek, Kaituna River
E. coli (swimming)	540 E.coli/100mL (95th Percentile)	B	Rai River, Taylor River, Waihopai River

Table 3: NPS attributes and the associated objective limits in the Marlborough Environment Plan and the State of the Environment sites that were not meeting these objectives in 2014.

[3] Periphyton are algae (and bacteria) mats or filaments growing on the bed of streams and rivers (mostly brown or green in colour). The Periphyton attribute of the NPS uses the Chlorophyll-a concentration of the algae mats as a measure for nuisance algae growth, while council is assessing the potential for nuisance algae growth using guidelines values for dissolved nutrients.

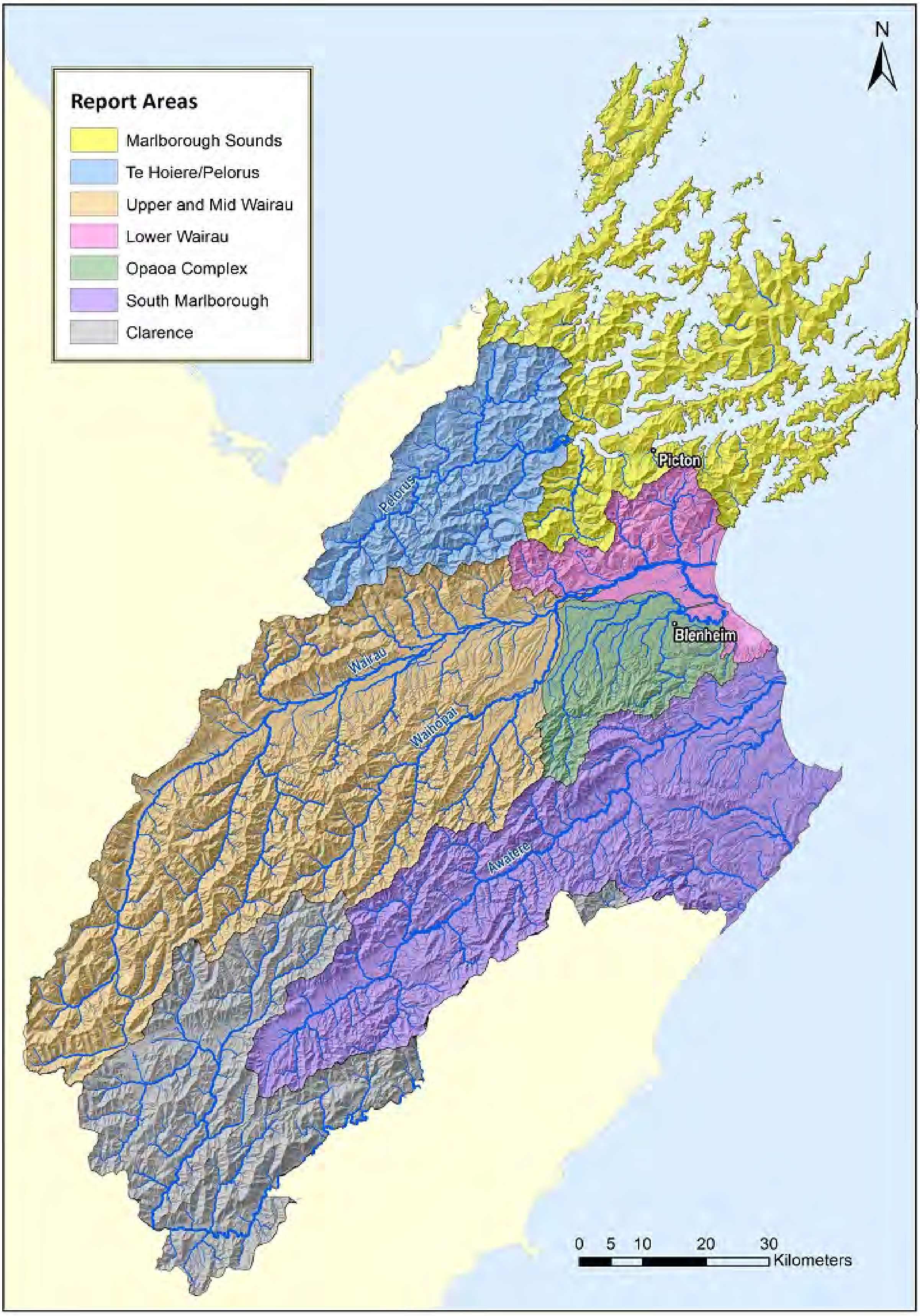


Figure 4: For the purpose of this report the Marlborough region was divided into seven areas. **(The parts of the Clarence River and its tributaries that are located in the Marlborough region will not be reported on in this report as water quality in the Clarence catchment is monitored by Environment Canterbury.)**

3. Results

As in the previous annual reports, the Marlborough region has been divided into seven sub-regions (Figure 4). This reduces the number of sites that will be reported on at once, but also allows the comparison of sites with similar rainfall and flow patterns. The results for each sub-region are presented in a separate section. These sections start with a map of the sub-region and a summary table outlining some of the site and catchment characteristics. This is followed by a large figure with a number of graphs. This figure has three parts. The top shows the Water Quality Index for each site together with the contribution of individual parameters to the reduction of the Index. Below that is a bar graph showing the parameter contributions based on the parameter specific factors, F2 and F3, only (excluding F1). This provides a better representation of the actual contribution of individual parameters to the deterioration in water quality. The lower half of the figure shows the parameter results as box and whiskers plots. These plots are a great way of showing the distribution of parameter values. Figure 5 explains how box and whiskers plots are created.

The main intention of the figure is to show patterns, distributions and relative differences. The actual numerical result values for the water quality indices and statistics, such as the Median, Percentile values and Maxima can be found in Appendices 6.5 and 6.6. Individual sampling results for most parameters can be downloaded from the LAWA website (www.lawa.org.nz)

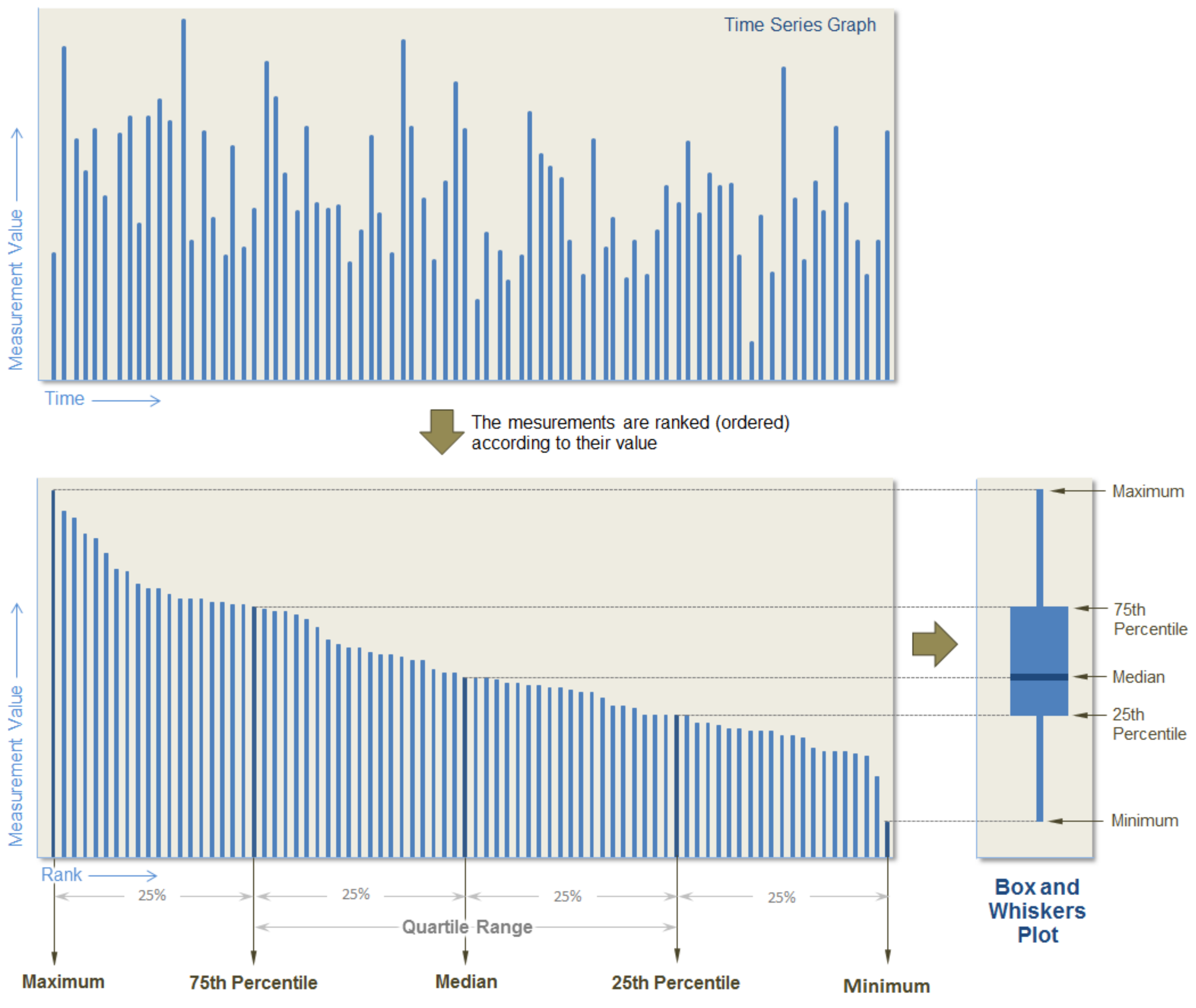
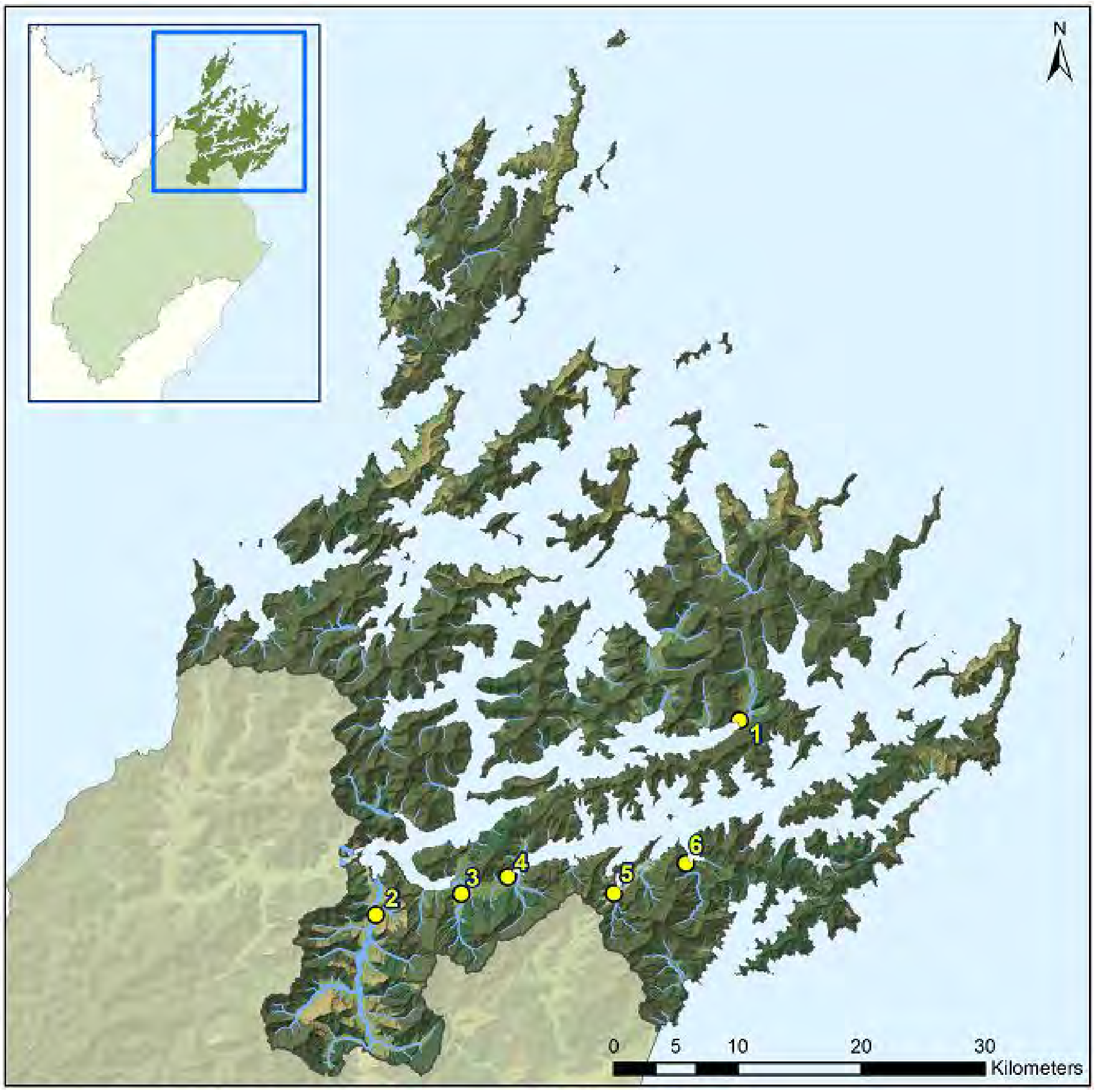


Figure 5: How Box and Whiskers Plots are created.

3.1. The Marlborough Sounds



No.	Site	Monthly Water Quality Sampling Since	Catchment Area [km²]	Landcover
1	**Kenepuru Rv**	Feb 2007	29.8	
2	**Kaituna Rv**	Feb 2007	135.6	
3	**Cullen Ck**	Jul 2009	19.5	
4	**Linkwater Stm***	Jul 2008	9.2	
5	**Waitohi Rv**	Aug 2007	15.0	
6	**Graham Rv**	Aug 2007	17.0	

* Was named "Duncan Stm" in previous reports

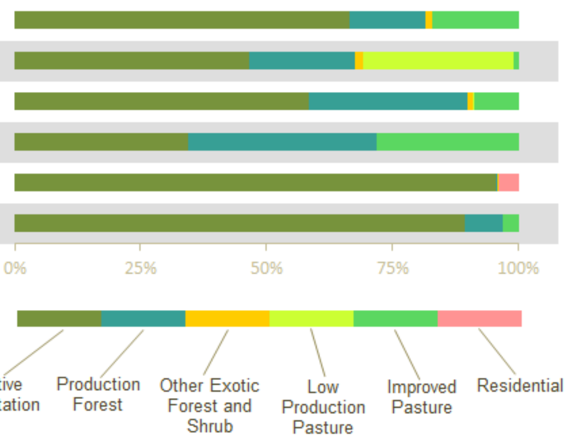


Figure 6: Sampling sites in the Marlborough Sounds.

Water Quality Indices and Parameter Contributions for the sites in the Sounds (2013-2015)

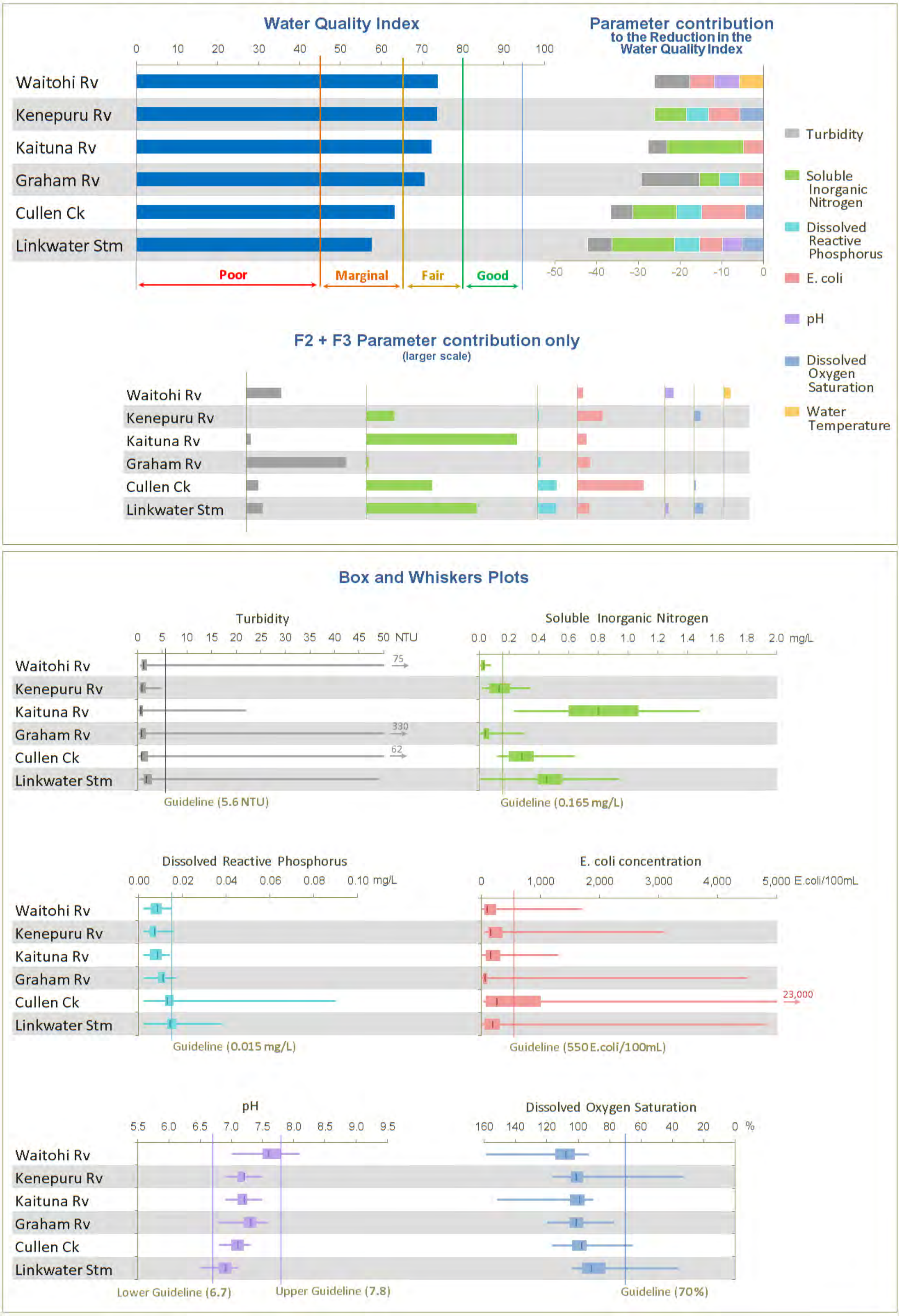


Figure 7: Water Quality Indices and Parameter contributions for the monitoring sites in the Marlborough Sounds for the period 2013‑2015.

Apart from the Te Hoiere/Pelorus River catchment, the majority of catchments in the Marlborough Sounds are relatively small. Due to its size the Te Hoiere/Pelorus catchment will be dealt with in a separate Section (3.2). The two largest rivers in the Sounds group are the Kaituna River with a catchment area of 136 km^2, followed by the significantly smaller Kenepuru River (30 km^2). Most of the smaller catchments in the Marlborough Sounds are covered in regenerating native vegetation. State of the Environment Monitoring however, focuses on catchments that are subject to significant anthropogenic pressures such as production forestry, pastoral land uses and impacts from urban areas.

The Water Quality Indices for the monitoring sites in the Sounds group are in either the fair or marginal categories. Linkwater Stream and Cullens Creek are catchments with a high predominance of dairy pastures along the stream flats and are the only two waterways with marginal water quality. Linkwater Stream has the lowest Water Quality Index and is degraded due to a number of factors, including elevated nitrogen and phosphorus concentrations, low dissolved oxygen levels and occasional low pH values. The Water Quality Index has been in the marginal category since monitoring began in 2008 (Figure 8). Trend analysis showed a slight increase in nitrate concentrations over the last five years (Table 4). Nitrate is the main component of soluble inorganic nitrogen, which in Linkwater Stream is almost always exceeding the guideline for nuisance algae growth. Despite the increase in nitrate concentrations, the Water Quality Index has been improving slightly in recent years. This is the result of a reduction in E. coli concentrations and turbidity, but due to their recent nature, these changes are not yet captured by the trend analysis. The improvements are a result of recent fencing efforts along Linkwater Stream, which are preventing direct stock access to the waterway. In the past, cattle could frequently be seen in the stream just upstream of the sampling site, dropping faeces into the water way and damaging the banks.

The degraded water quality in Linkwater Stream has been investigated in more detail in the recent months and the results of this investigation will be published in the near future.

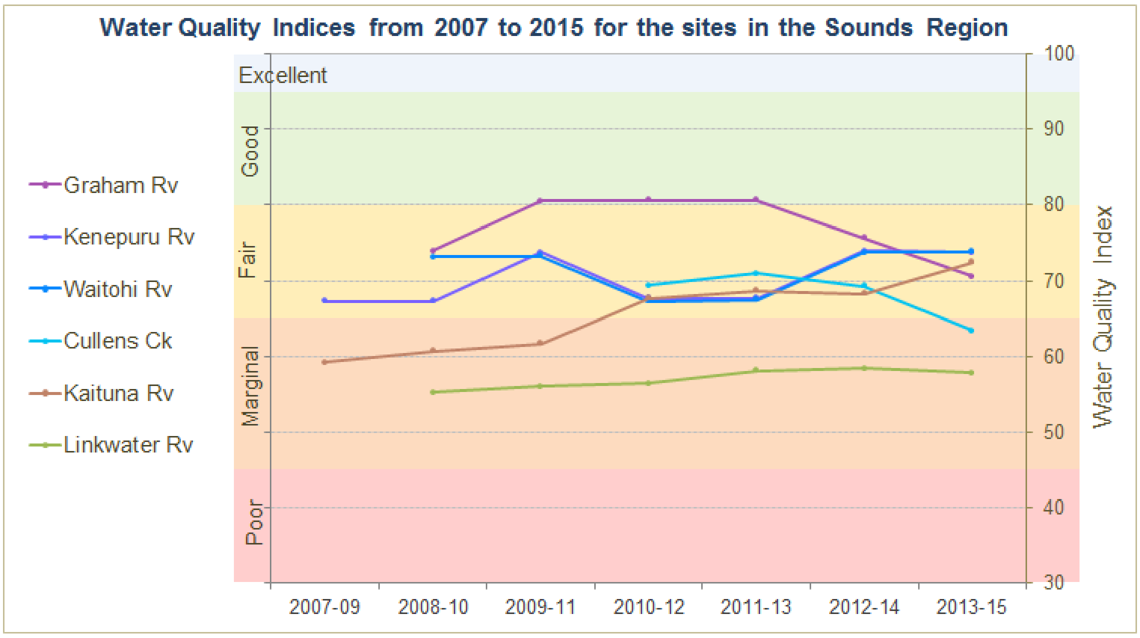


Figure 8: Change over time of the Water Quality Indices for the sites in the Sounds Region.

E. coli concentrations in Cullens Creek are higher than those in Linkwater Stream. This is despite a longer history of permanent fencing along Cullen Creek, which has mature riparian vegetation along most of its length. It appears that remaining stock access or run-off during irrigation and rainfall is having a substantial effect on the water quality of the creek.

The Kaituna River has the highest soluble inorganic nitrogen concentrations observed in this group. Although it has the greatest proportion of pastoral land use in its catchment, most of this pasture is not irrigated. Leaching of nitrate from pastoral land use is usually highest under irrigated pastures. Stocking rates and farm management also influence the concentration of dissolved inorganic nitrogen in the river. Nevertheless, pastoral land use practices might only be part of the explanation. Nitrogen concentrations in the Kaituna River are considerable higher than those observed in Linkwater Stream, despite similar percentages of pastoral land cover, and pastures in Linkwater being predominantly irrigated. This strongly points to the possibility of other sources. The outlet of the Havelock sewage treatment ponds discharging into the Kaituna River is located more than two kilometres downstream of the sampling site and is therefore not a contributing factor. It will require a targeted investigation to identify the source(s) of the high nitrogen concentrations in the Kaituna River.

The long-term nine-year trend for nitrate concentrations in the Kaituna River shows a slight decrease, while the shorter five-year trend shows an increase similar to that observed in Linkwater Stream. This indicates that rainfall patterns might be causing the short-term (5-year) changes. Nevertheless, the increase in nitrate concentrations has resulted in the exceedance of the NPS A-Band limit, so that the water quality of the Kaituna is now within the B-Band for the annual median of the nitrate attribute.

Annual change based on 9-year trend (2007-2015)

	pH	Turbidity [NTU]	E. coli [n/100ml]	Nitrate-N [mg/L]
Waitohi Rv	-0.04			
Kenepuru Rv				
Kaituna Rv	0.04		7.06	-0.02
Graham Rv		0.05		
Cullen Ck				
Linkwater Stm				

Annual change based on 5-year trend (2011-2015)

	pH	Turbidity [NTU]	E. coli [n/100ml]	Nitrate-N [mg/L]
Waitohi Rv				
Kenepuru Rv				
Kaituna Rv				0.05
Graham Rv				
Cullen Ck				
Linkwater Stm				0.04

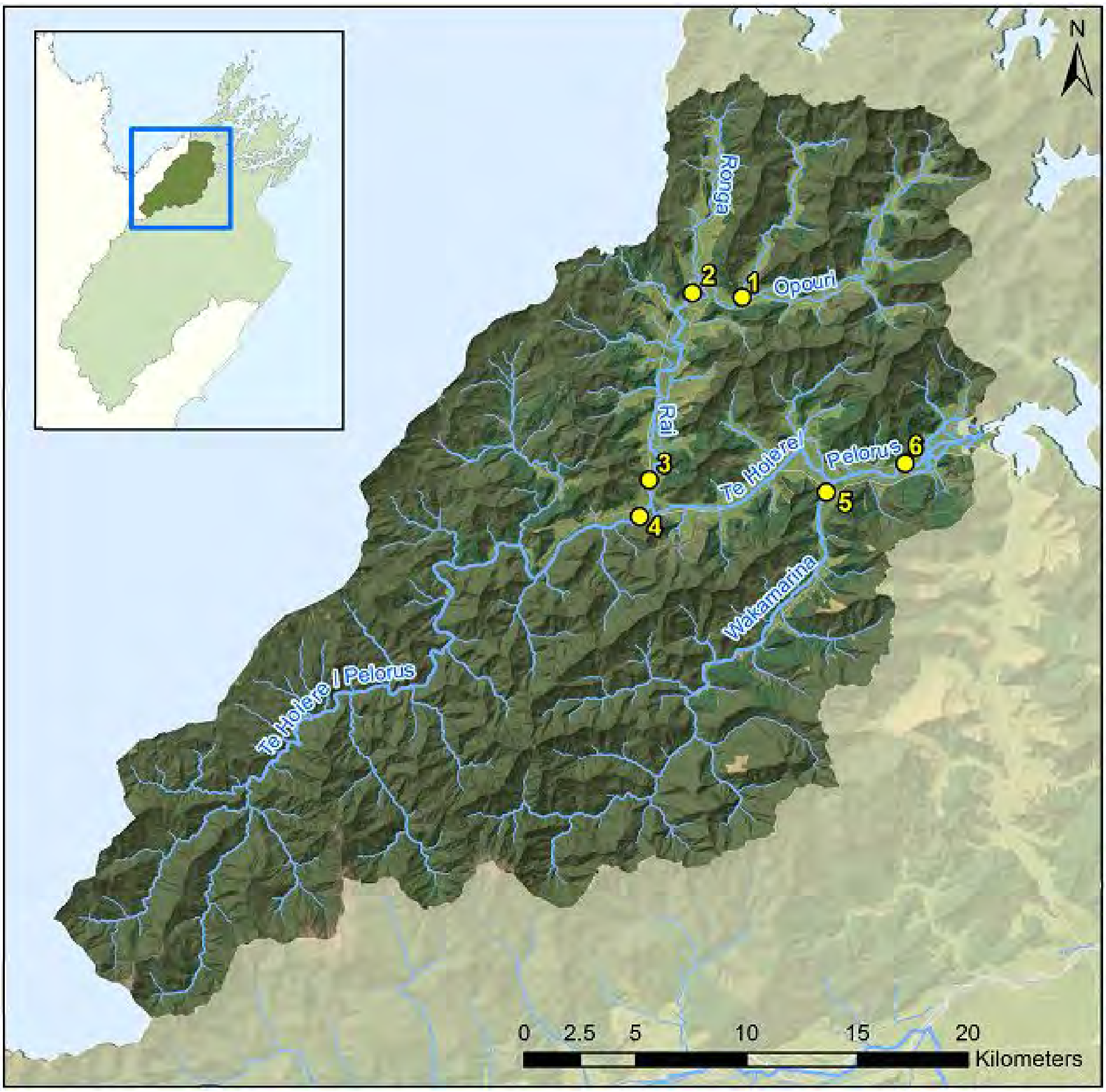
Table 4: Results of the trend analysis for the sites in the Marlborough Sounds.

The Waitohi River has the largest amount of native vegetation in its catchment, over 95%, but is also the only site in this group influenced by a substantial amount of urban development. The Water Quality Index for this river has consistently been in the fair category since monitoring began in 2007. The sampling site is located in Picton and impacts on the water quality at this site are most likely the result of urban influences. Occasional exceedances of the guidelines for E. coli concentrations and turbidity are mostly related to rainfall. However, removal of flood flow data from the calculation of the Water Quality Index results in very little change, which indicates that run-off from relatively small rainfall events is impacting on the water quality of the Waitohi. This is not surprising as sealed surfaces allow no infiltration into the ground. Instead rainfall on concrete and roof surfaces flows directly into the stormwater system and subsequently into the river, carrying contaminants from these surfaces with it. Relatively high pH values and high dissolved oxygen saturations are generally an indication of high photosynthetic activity by algae or other submerged aquatic plants. There are very few trees growing on the banks of the lower reaches of the river and sunlight can reach the bed of the river most of the time. This causes elevated temperatures during the summer and provides good conditions for algae growth. Algae production in the water supply dam, located less than four kilometres upstream of the sampling site is possibly adding to increased pH values.

Because of the urban influences, heavy metals such as Zinc, Arsenic and Copper are also monitored in the Waitohi River. Only Zinc exceeds the guideline value for 95% species protection [ANZEEC 2000, 1]. Exceedances only occur during rainfall events, but are usually below the higher 80% species protection guideline. During the more than eight years that the Waitohi River has been monitored, the 80% species protection guideline for Zinc was exceeded only once.

The Graham River has the second largest proportion of native vegetation in the catchment and was originally chosen as a reference site for the other smaller catchments in this group. The Water Quality Index had been in the ‘good’ category between 2009 and 2013, confirming the reference status. However in the last two years the water quality has deteriorated and has now reached the lowest value since monitoring began in late 2007. The main cause for the reduction in the Water Quality Index is a significant increase in turbidity. Field notes point to gravel extraction and bank erosion near the sampling site as the cause. Sporadically high E. coli concentrations in the Graham River are measured during rainfall periods, but also during low flows, which is likely an indication of direct stock access to the waterway. The guidelines for the dissolved nutrients, phosphorus and nitrogen are rarely exceeded and analysis of the data has shown no relationship with high E. coli concentrations. The example of the Graham River shows, that the anthropogenic modification of a relatively small proportion of the catchment can have significant implications for the water quality of a waterway.

3.2. The Te Hoiere/Pelorus River Catchment



No.	Site	Monthly Water Quality Sampling Since	Catchment Area [km^2]	Landcover
1	**Opouri Rv**	Sep 2008	70.3	
2	**Ronga Rv**	Sep 2008	32.7	
3	**Rai Rv**	Feb 2007	209.9	
4	**Upper Pelorus**	Feb 2007	376.6	
5	**Wakamarina**	Feb 2007	187.7	
6	**Lower Pelorus**	Aug 2007	857.5	

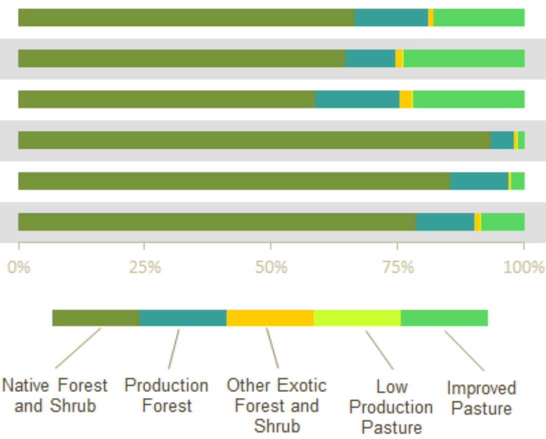


Figure 9: Sampling sites in the Te Hoiere/Pelorus River catchment.

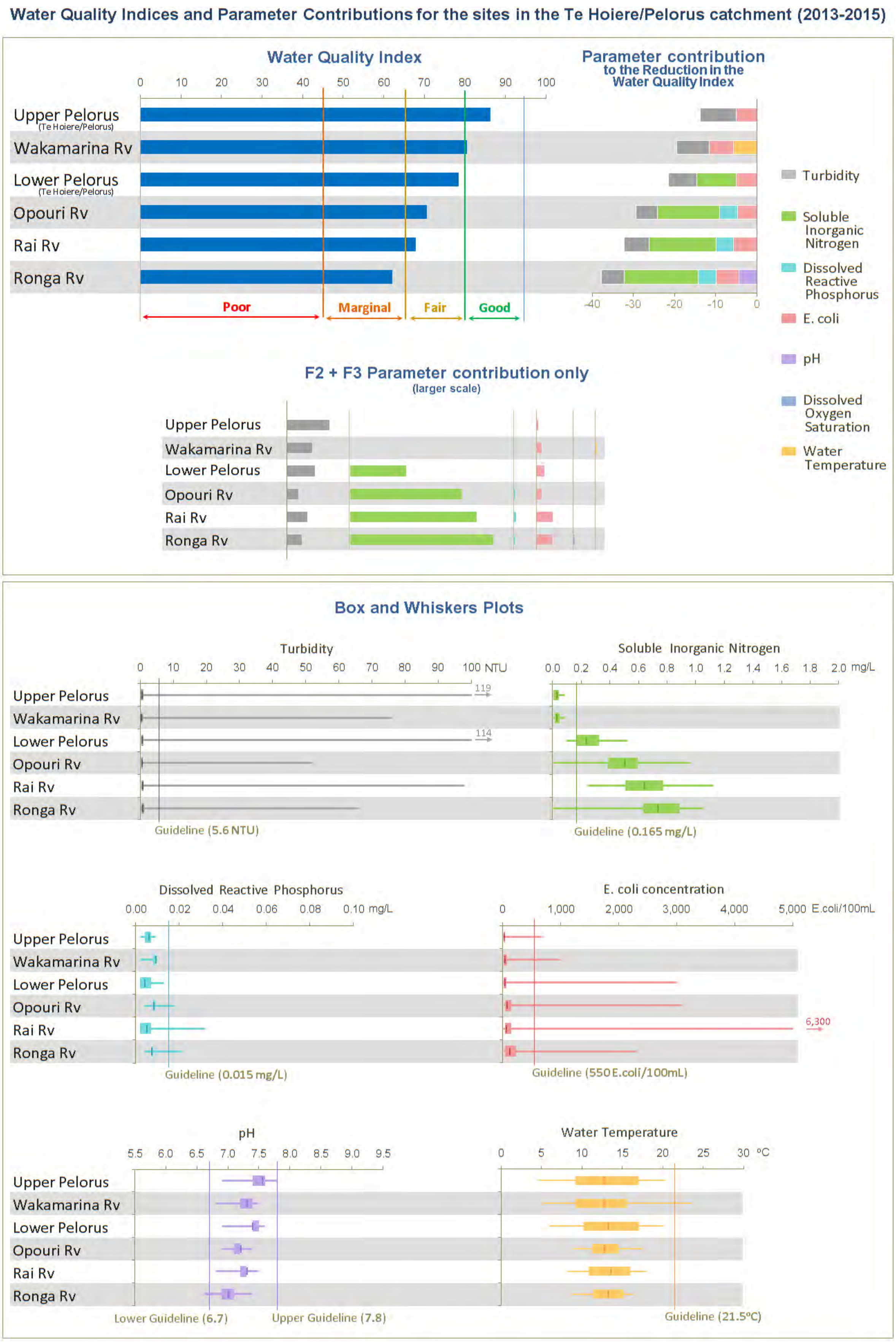


Figure 10: Water Quality Indices and parameter contributions for the monitoring sites in the Te Hoiere/Pelorus River catchment for the period 2013-2015.

Two of the monitoring sites in the Te Hoiere/Pelorus catchment are located on the main Te Hoiere/Pelorus River, while the other sites are located on four of the major tributaries. At least half of each catchment area is covered in native vegetation. The remaining developed areas have been converted to production forest or irrigated pasture. The majority of the pasture is utilized for dairy production.

The Water Quality Indices are generally a reflection of the amount of pasture in the catchment. Usually, the higher the proportion of pastoral land use, the lower the Water Quality Index. The parameter most closely related to pastoral land use is the concentration of soluble inorganic nitrogen, with higher concentrations in catchments with greater areas in irrigated pasture. The majority of the soluble inorganic nitrogen originates from leachate of nitrogen in urine patches from cattle [19], but fertiliser and effluent also contribute. During irrigation and rainfall, the nitrogen moves down through the soil until it reaches groundwater and subsurface flow, which eventually re-appears as surface flow in rivers and streams. Almost all of the soluble inorganic nitrogen in the catchment is in the form of nitrate. The nine-year trend analysis shows a slight decrease in nitrate concentrations for the Rai River, while the short-term five-year trend analysis shows increasing concentrations for the Rai and Opouri Rivers as well as the Lower Te Hoiere/Pelorus River (Table 5). These increases are similar to those observed nearby, in the Kaituna and Linkwater catchments (see Section 3.1) and are likely the result of changes in rainfall patterns. It is noticeable that the Ronga River does not show the same increasing trend. A reduction of nitrate losses due to possible changes in stocking rates or farm practices could have countered the increasing trend. However, an increase in stock numbers is planned for at least one of the farms in the Ronga catchment, which is likely to have an effect on nitrate concentrations in the future. Work by other councils has shown that the amount of nitrate leachate is closely linked to stocking rates [11].

Annual change based on 9-year trend (2007-2015)

	pH	Turbidity [NTU]	E. coli [n/100ml]	Nitrate-N [mg/L]
Upper Pelorus		0.02	2.68	
Wakamarina Rv				
Lower Pelorus				
Opouri Rv				
Rai Rv	0.01			-0.01
Ronga Rv				

Annual change based on 5-year trend (2011-2015)

	pH	Turbidity [NTU]	E. coli [n/100ml]	Nitrate-N [mg/L]
Upper Pelorus			3.54	
Wakamarina Rv				
Lower Pelorus				0.02
Opouri Rv	0.03			0.04
Rai Rv				0.04
Ronga Rv	0.05			

Table 5: Results of the trend analysis for the sites in the Te Hoiere/Pelorus catchment.

The five-year trends show slight increases in pH levels for the Ronga and Opouri Rivers. The pH levels of the Ronga River are still more acidic than in other waterways in the Te Hoiere/ Pelorus catchment, but now rarely fall below the Lower Guideline of 6.7.

The occasional exceedances of the turbidity guideline for all sites in this group exclusively occur as a result of flood flows. In contrast, E. coli concentrations exceed guideline levels during flood flows as well as lower flows in the Rai and Ronga Rivers and subsequently the Lower Te Hoiere/Pelorus River. This indicates that despite recent efforts to prevent direct stock access to waterways, the Rai and Ronga Rivers are still occasionally contaminated with stock faeces. This could be the result of run-off during irrigation or stock access to unfenced swales and small tributaries. Nevertheless, improved riparian management practices, better effluent systems and other improvements in farm management on some farms have resulted in positive changes to the Water Quality Indices of the Rai River and the Lower Te Hoiere/Pelorus River (Figure 11). The Lower Te Hoiere/Pelorus River has improved the most, moving from the marginal to the fair category with recent values close to good water quality. The water quality in the Rai River has also improved from marginal to fair, but the current Water Quality Index is still in the lower part of the fair category.

Water quality in the Ronga River has consistently been in the marginal category, while on the opposite end of the scale, the Upper Te Hoiere/Pelorus River has remained in the good category since monitoring began in 2007. The Wakamarina River has good water quality as well, but the Water Quality Index for this site is much more variable. This is caused by occasional exceedances of the guidelines for several parameters, including E. coli, turbidity and pH.

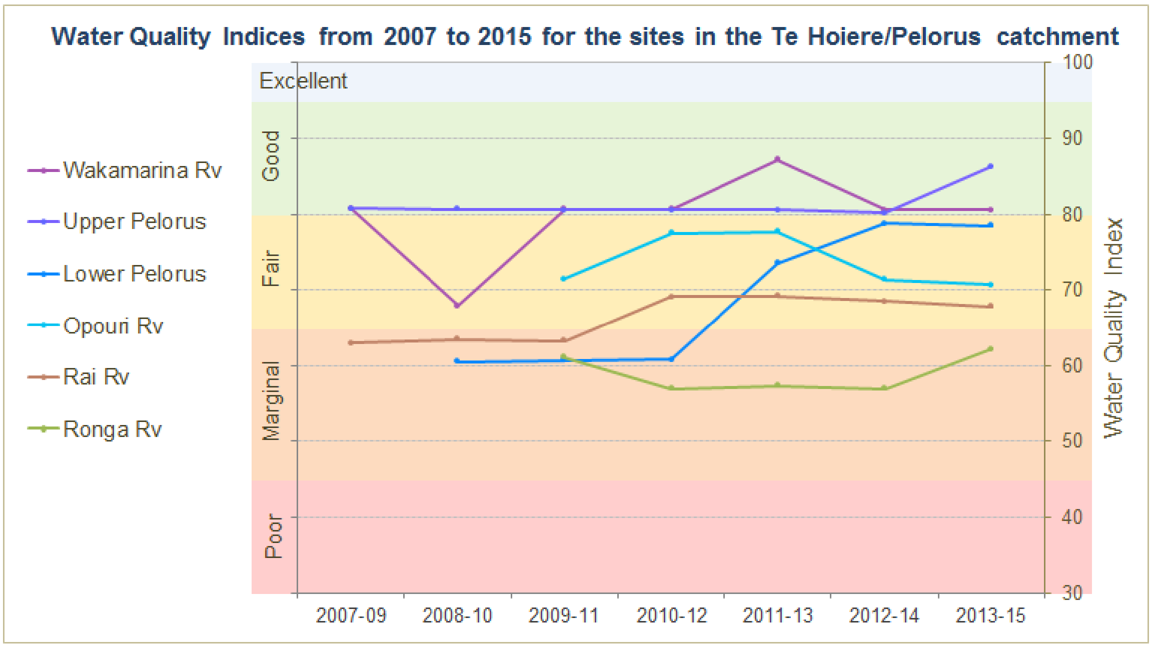
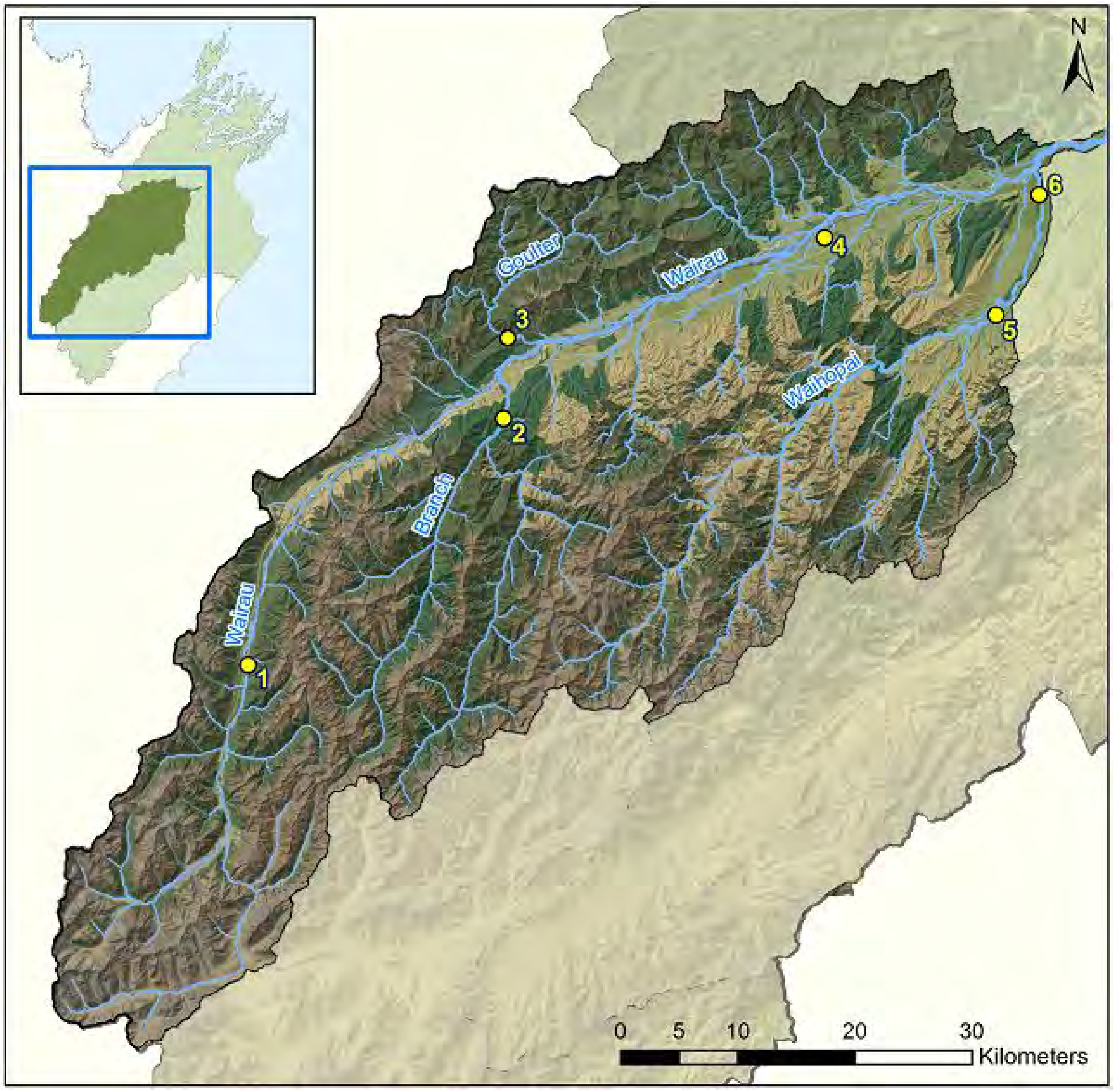


Figure 11: Change over time of the Water Quality Indices for the sites in the Te Hoiere/Pelorus catchment.

Figure 12: Riparian planting along a small fenced tributary of the Lower Te Hoiere/Pelorus River.

3.3. The Upper and Mid Wairau Catchment



No.	Site	Monthly Water Quality Sampling Since	Catchment Area [km²]
1	**Upper Wairau**	Jan 1989 (NIWA)	517.8
2	**Branch Rv**	Jul 2009	551.0
3	**Goulter Rv**	Oct 2013	146.0
4	**Mill Ck**	Sep 2008	19.8 *
5	**Mid Waihopai**	Jul 2007	737.8
6	**Lower Waihopai**	Feb 2007	769.7

* The baseflow of Mill Creek is dominated by groundwater that originates from a greater area than the surface catchment.

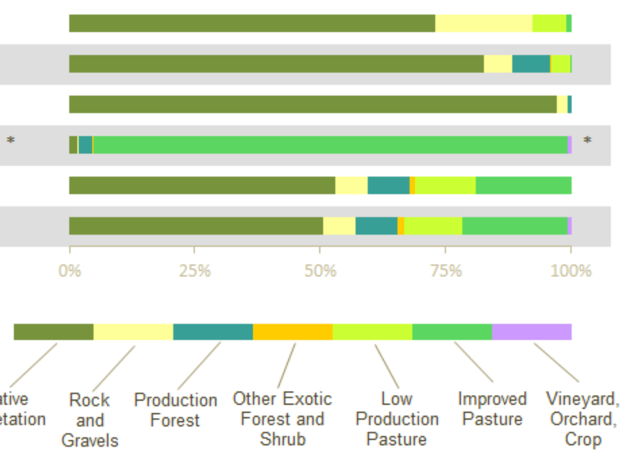


Figure 13: Sampling sites in the Upper and Mid Wairau catchment.

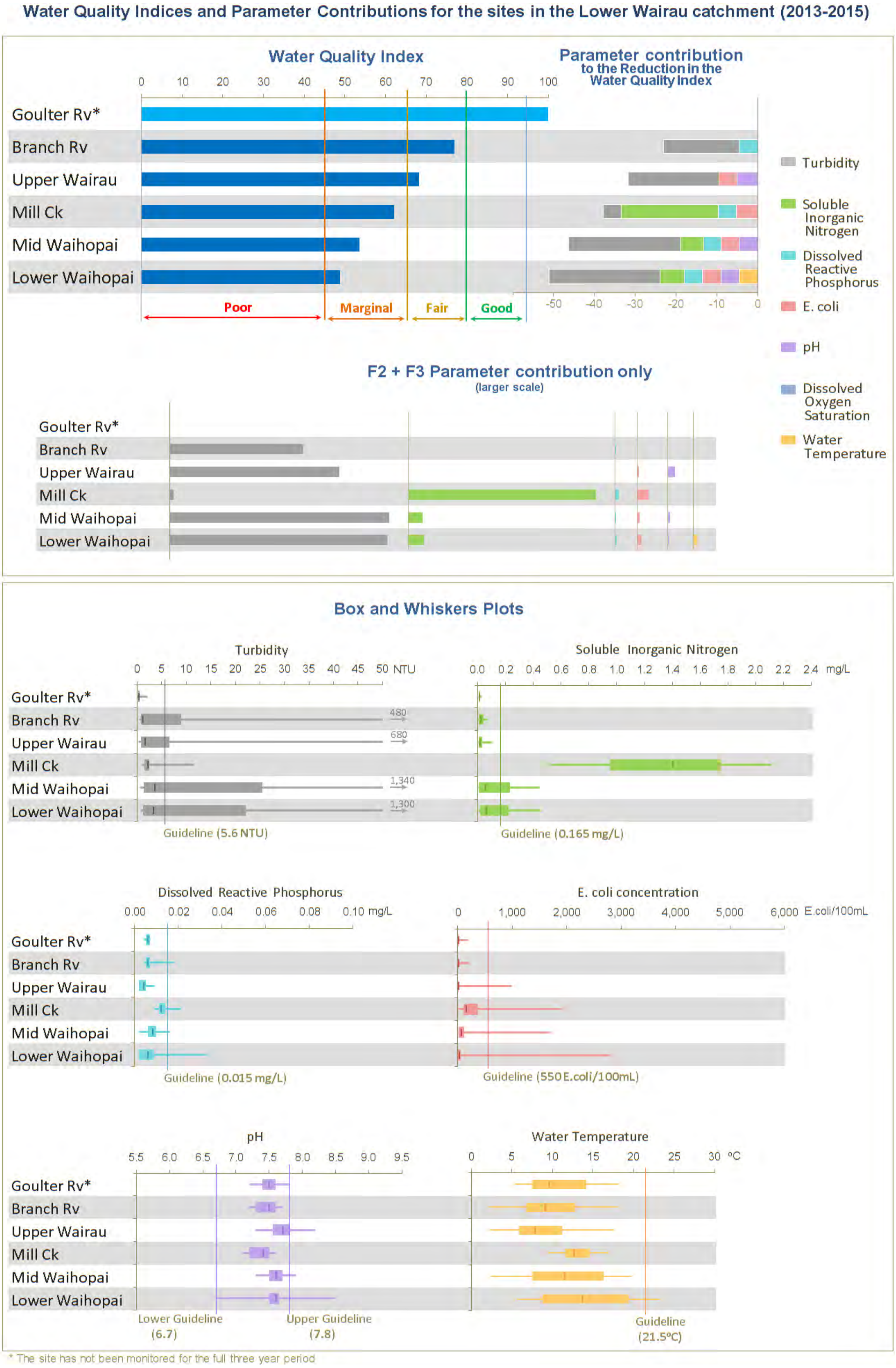


Figure 14: Water Quality Indices and parameter contributions for the monitoring sites in the Upper and Mid Wairau catchment for the period 2013-2015.

This group is comprised of tributaries connecting to the upper and mid sections of the Wairau River as well as the upper Wairau River itself, upstream of these tributaries.

The Goulter River monitoring site is the most recent addition to the program. Although the data falls nine months short of the three years required, a Water Quality Index was calculated. The Goulter River is one of the very few larger tributaries of the Wairau River that remains predominantly in native vegetation. Measurements for this river will therefore give an excellent indication of natural water quality in a large river. Indeed, the current monitoring data shows no exceedances of any of the guideline values, resulting in the highest possible Water Quality Index of 100. This is encouraging, as it confirms that measurements below guideline values can regularly be achieved by un-modified waterways.

The other sites in this group have water quality in the fair or marginal categories (Figure 14). With the exception of Mill Creek, elevated turbidity is causing most of the reduction in the Water Quality Indices. The highest turbidity is measured in the Waihopai River and is the result of the combination of frequent thunderstorms in the catchment as well as high mudstone content in the underlying geology in some areas. Localised high intensity rainfall events in the upper catchment commonly cause slips, which wash away slowly, causing elevated turbidity for weeks or sometimes months after the event [15]. Although these slips occur upstream of the Mid Waihopai sampling site, trend analysis only shows an increasing trend for the Lower Waihopai River (Table 6). This indicates human activity may be further increasing turbidity in the lower parts of the Waihopai River.

Table 6: Results of the trend analysis for the sites in upper and mid Wairau River catchment.

Annual change based on 9-year trend (2007-2015)

	pH	Turbidity [NTU]	E. coli [n/100ml]	Nitrate-N [mg/L]
Branch Rv				
Upper Wairau		0.1	0.25	
Mill Ck				
Mid Waihopai	-0.02		2.99	
Lower Waihopai				

Annual change based on 5-year trend (2011-2015)

	pH	Turbidity [NTU]	E. coli [n/100ml]	Nitrate-N [mg/L]
Branch Rv	-0.03	0.52		
Upper Wairau				
Mill Ck	0.04			
Mid Waihopai				0.02
Lower Waihopai		0.94		0.01

Elevated turbidity in the Branch River is the main cause for the reduction in the Water Quality Index for this waterway too. Despite a large proportion of native vegetation in the catchment, the water quality is graded as fair. High turbidity is generally associated with higher flows, but it appears that relatively small increases in flows that did not cause exceedances of the guideline in the past are now resulting in significantly higher turbidity. This is reflected in the results of the trend analysis, which shows an increasing trend for the last five years. Some of the production forest in the Branch River catchment has been harvested in recent years. A number of studies have shown increases in fine sediment loads and subsequently higher turbidity in rivers and streams following clear-felling of production forests [7]. Despite the increase in turbidity, the Water Quality Index for the Branch River has improved in the last two years (Figure 16). This is a result of lower E. coli concentrations and pH values.

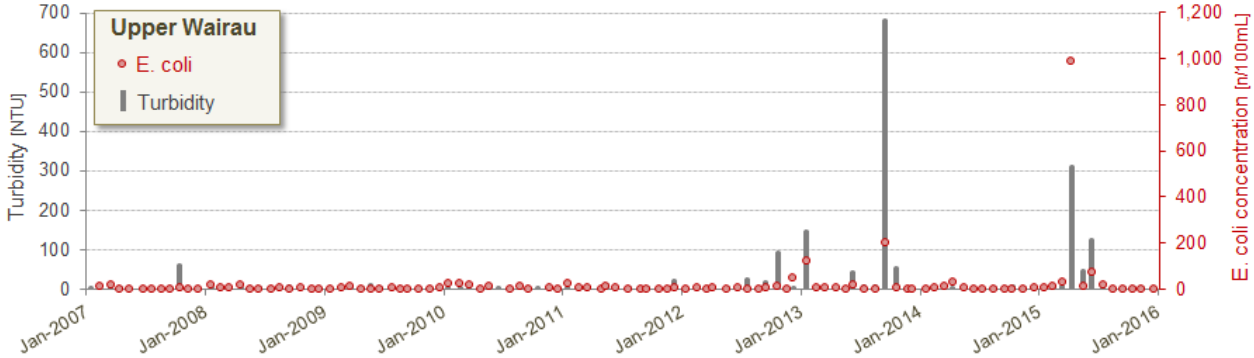


Figure 15: Turbidity and E. coli concentrations in the Upper Wairau.

There is no production forestry in the upper Wairau River catchment. Nevertheless, there have been significantly more samples with higher turbidity in recent years (Figure 15). This is reflected in a decreasing Water Quality Index, which now has a value in the fair category (Figure 16). However, trend analysis does not show a significant change for turbidity, apart from a very minor increase for the nine-year trend (Table 6). Unlike Water Quality Index data, trend analysis data is adjusted to the flow at the time of sampling. Therefore the trend results indicate, that most of the increased turbidity is explained by changes in river flows during sampling. Exceedances of the E. coli guideline in the Upper Wairau River are exclusively associated with elevated turbidity (Figure 15) and are therefore explained by the same phenomenon.

The water quality in Mill Creek is reduced by high soluble inorganic nitrogen concentrations, which are the most elevated measured at any of the sites monitored in the State of the Environment program. The nitrogen is predominantly in the form of nitrate. As a result, Mill Creek is also the only site with nitrate concentrations consistently exceeding the A-Band limit of the NPS nitrate attribute (see Section 2.4). Groundwater sampling near Mill Creek indicates that almost all the nitrate originates from groundwater inflows and is therefore the result of nitrogen leaching from the surface, through the soil and into groundwater. Nearly 95% of the catchment is currently in irrigated pasture, which has the greatest potential for nitrogen leaching [11]. However, groundwater is also flowing in from areas west of the catchment, increasing the land area that influences the water quality in Mill Creek. Although a new regional policy objective requires maintenance or enhancement of water quality so that nitrate concentrations are within the A-Band of the NPS nitrate attribute, there are currently no provisions in the regional rules allowing Council to actively manage the impact of nitrogen leaching. The development of practical and effective rules will be a focus of work in the coming years.

Compared to the other sites in this group, Mill Creek also has the highest E. coli concentrations. Exceedances of the E. coli guideline are not limited to flood flows, indicating that direct stock access is having a significant impact on the creeks water quality.

Soluble inorganic nitrogen concentrations in the Waihopai River only exceed the guideline value during the winter months when higher soil saturation combined with rainfall increases the leaching of nitrogen; additionally, reduced algae growth in the river results in less nutrient removal from the water. During the summer months concentrations are often below the detection limit. As in most other waterways, the majority of the soluble inorganic nitrogen is in the form of nitrate. The trend analysis shows an increase in nitrate concentrations over the last five years for both Waihopai sampling sites. It is possible that this is the result of changes in rainfall patterns, as was observed for waterways in the northern part of the region (see Sections 3.1 and 3.2).

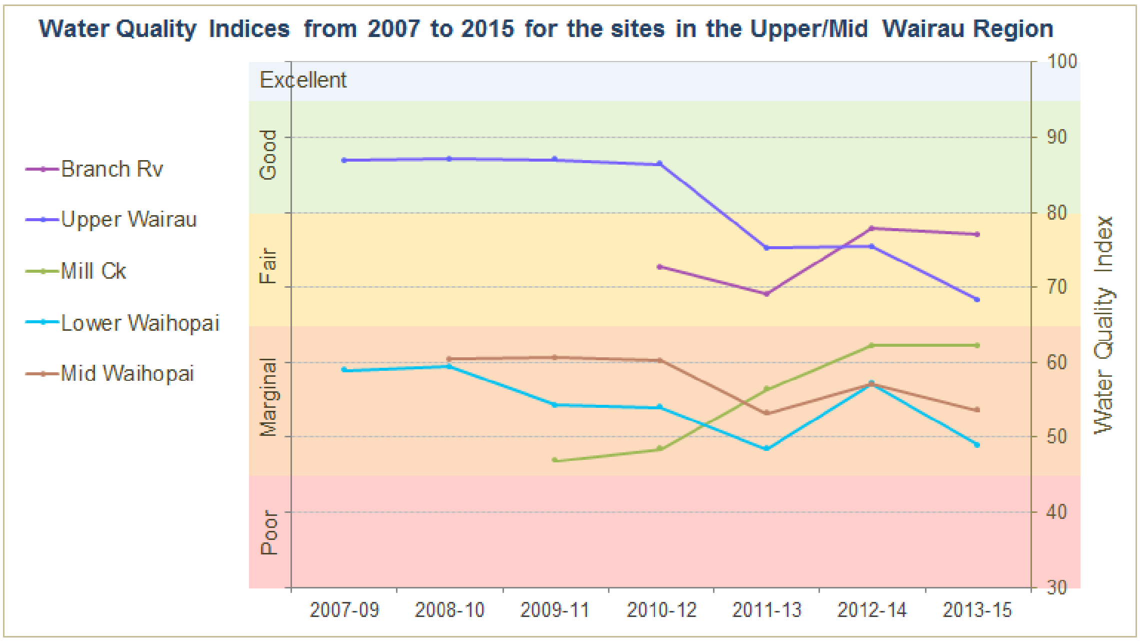
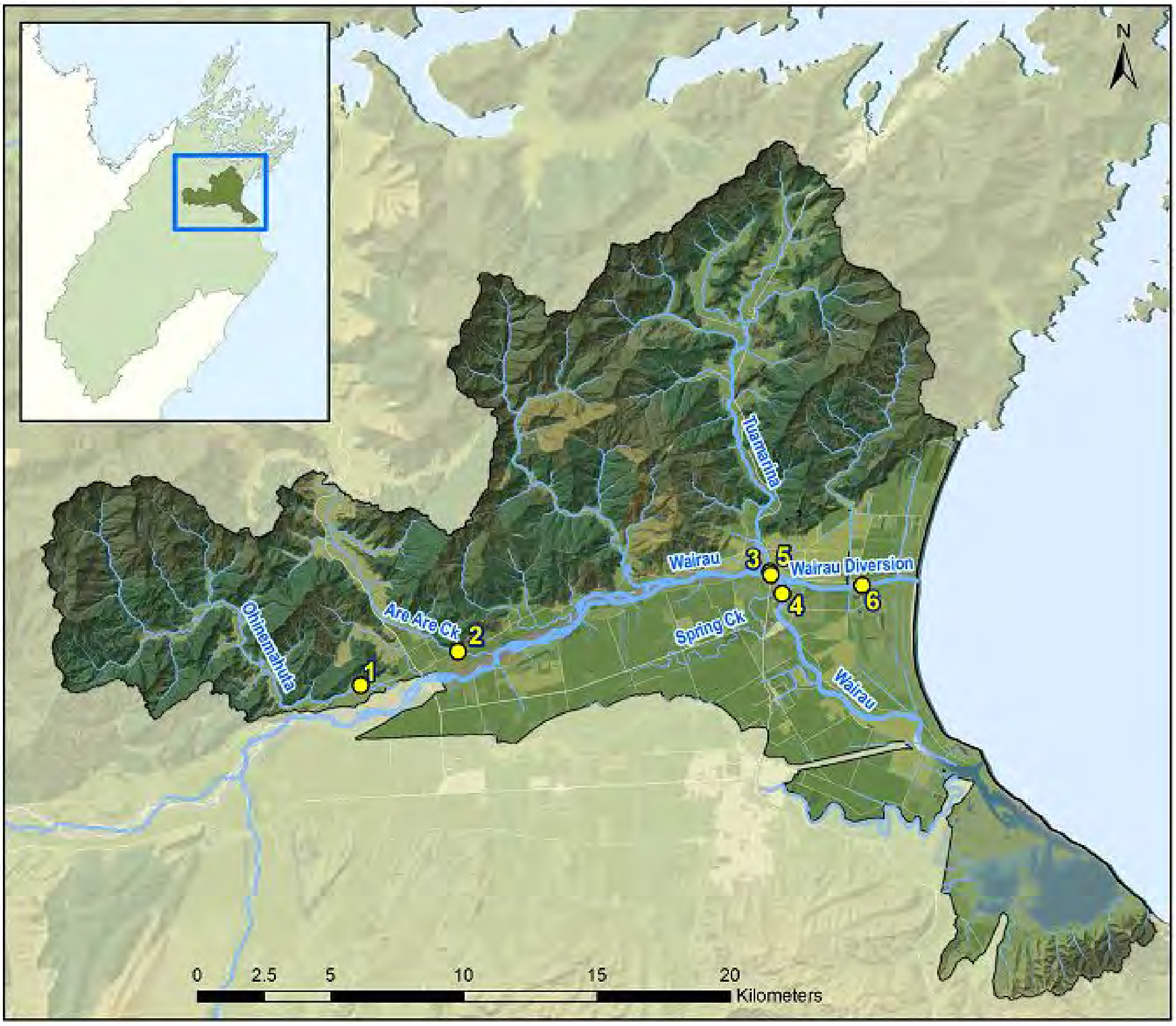
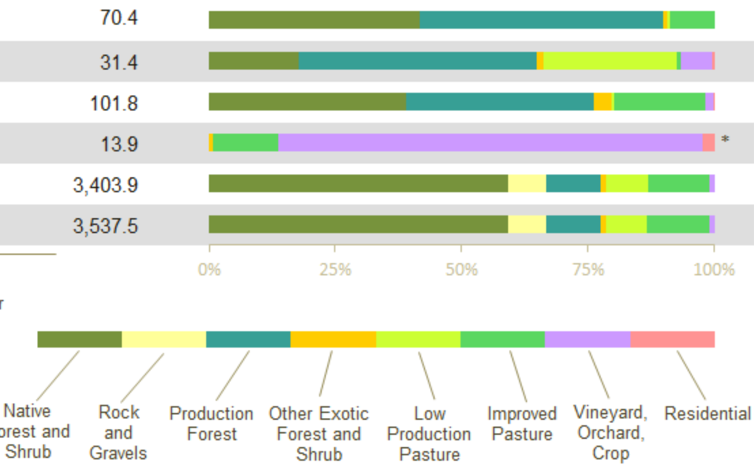


Figure 16: Change over time of the Water Quality Indices in Upper and Mid Wairau catchment.

3.4. The Lower Wairau Catchment



No.	Site	Monthly Water Quality Sampling Since	Catchment Area [km²]	Landcover
1	**Ōhinemahuta Rv***	Feb 2007	70.4	
2	**Are Are Creek**	Jul 2009	31.4	
3	**Tuamarina Rv**	Feb 2007	101.8	
4	**Spring Ck****	Feb 2007	13.9	*
5	**Lower Wairau**	Jan 1989 (NIWA)	3,403.9	
6	**Wairau Diversion**	Aug 2007	3,537.5	



* formerly Onamalutu Rv

** The baseflow of Spring Creek is dominated by groundwater that originates from a greater area than the surface catchment.

Figure 17: Sampling sites in the Lower Wairau catchment.

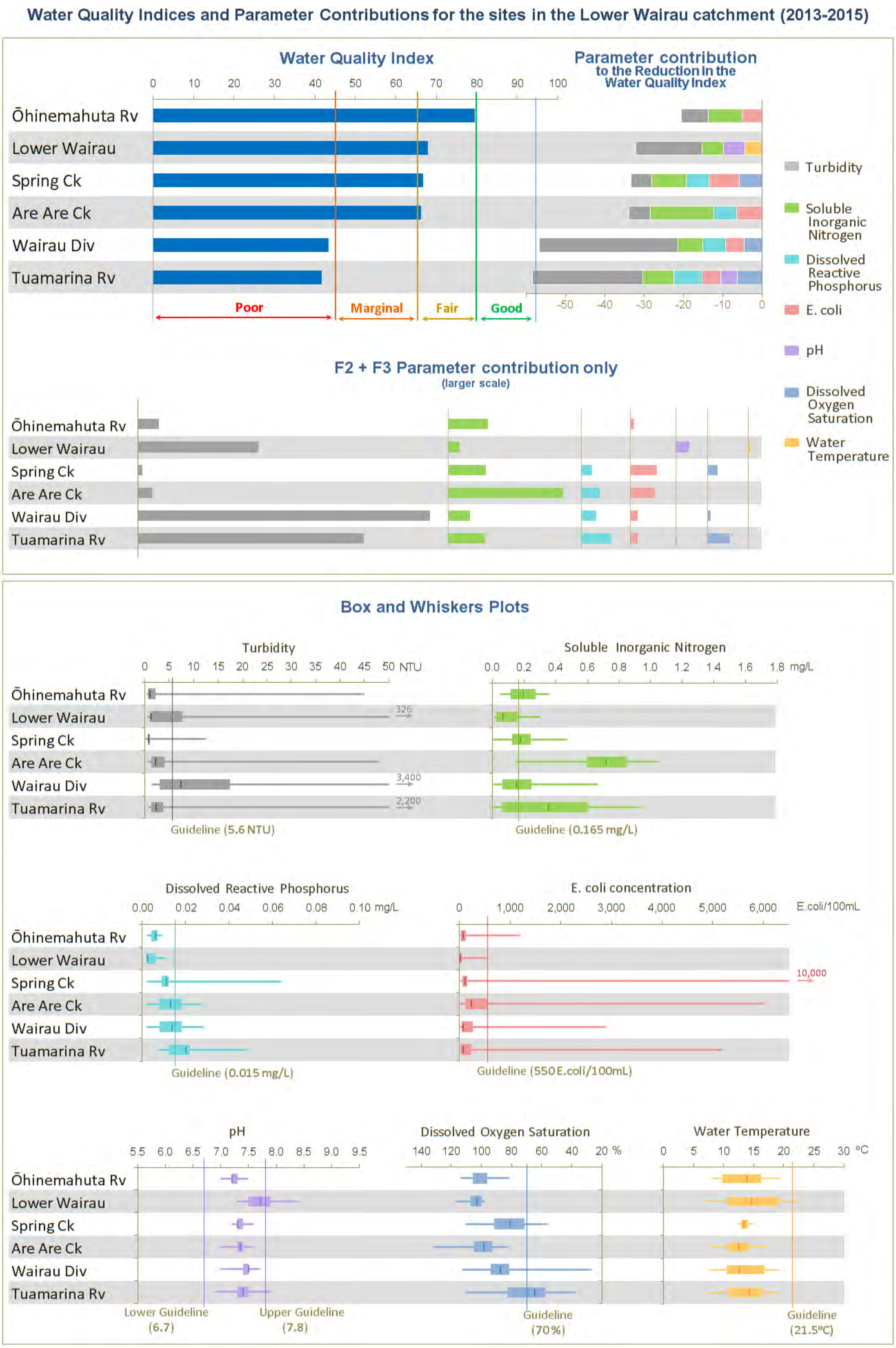


Figure 18: Water Quality Indices and parameter contributions for the monitoring sites in the Lower Wairau catchment for the period 2013-2015.

This group is comprised of Wairau River tributaries in the lower reaches of the river as well as two sites on the lower Wairau River itself. The Wairau River monitoring sites are located downstream of an artificial split that divides the river into the Wairau Diversion and the lower Wairau River. In light of the large shared catchment, it is surprising that the water quality of the Wairau Diversion is much poorer compared to that of the Lower Wairau River (Figure 18). The main reason for this difference is the influence of the Tuamarina River. The Tuamarina River flows into the Wairau River just upstream of the split, which directs the entire flow of the Tuamarina River into the Wairau Diversion. In preceding years, the split was located further downstream allowing more of the main Wairau River water to flow into the Diversion as well. However, after the split was extended upstream in recent years, the Water Quality Indices of the Wairau Diversion and the Tuamarina River have become very closely linked (Figure 19), showing that Tuamarina River water is now dominating in the Wairau Diversion.

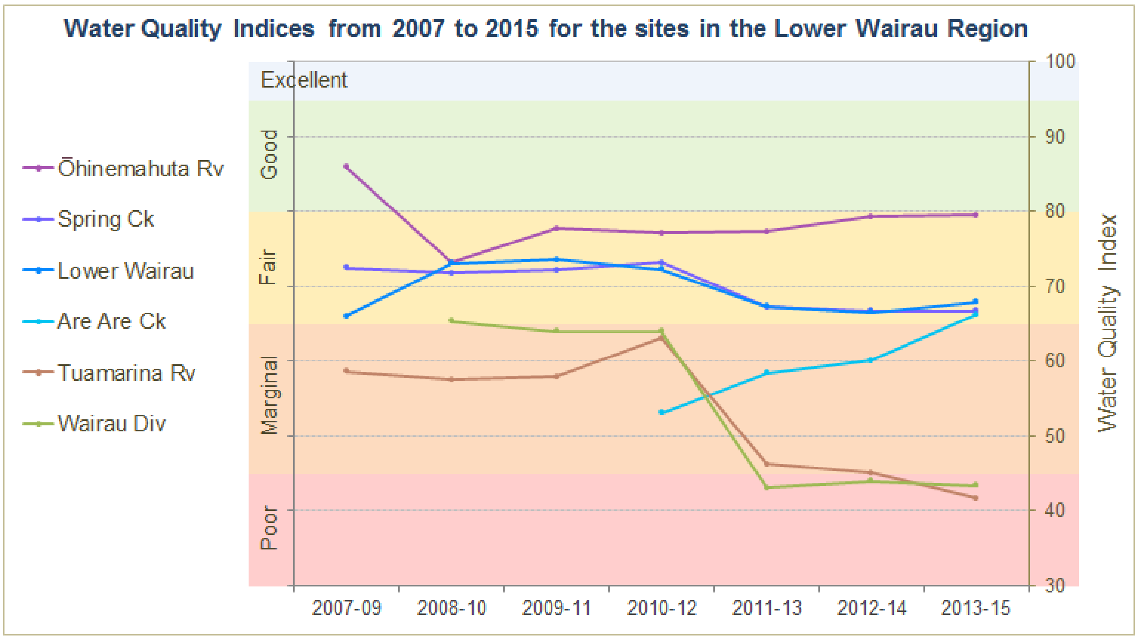


Figure 19: Change over time of the Water Quality Indices in the Lower Wairau catchment.

Turbidity is the main parameter causing poor water quality in the Tuamarina River. Two record floods in 2013 caused extensive scouring of the banks, particularly in the lower reaches, resulting in very high water turbidity [15]. As a result the Water Quality Index for the Tuamarina River sampling site declined significantly and with it, the Index for the Wairau Diversion. Surprisingly, trend analysis shows a slight reduction in turbidity for the last five years (Table 7). However, trend data is flow adjusted, so the trend results confirm that some of the reduction of the Water Quality Index was caused by large flood events.

Table 7: Results of the trend analysis for the sites in the Lower Wairau catchment.

Annual change based on 9-year trend (2007-2015)

	pH	Turbidity [NTU]	E. coli [n/100ml]	Nitrate-N [mg/L]
Ōhinemahuta Rv	0.02	0.07		
Lower Wairau				-0.01
Spring Ck	0.04	0.03	9.91	-0.02
Are Are Ck				
Wairau Div	0.02		8.67	-0.01
Tuamarina Rv	0.06		3.69	

Annual change based on 5-year trend (2011-2015)

	pH	Turbidity [NTU]	E. coli [n/100ml]	Nitrate-N [mg/L]
Ōhinemahuta Rv				0.02
Lower Wairau				
Spring Ck				
Are Are Ck				
Wairau Div				
Tuamarina Rv		-0.27		0.06

Further decline in the Water Quality Index of the Tuamarina in the last two years are the result of increasing soluble inorganic nitrogen concentrations and higher pH values. Trend analysis confirms the significant rise in nitrate concentrations, which makes up the majority of the soluble inorganic nitrogen. An increasing trend has been observed in several waterways in the northern part of the region and is likely a result of increased leaching due to changes in rainfall patterns (see Sections 3.1 and 3.2). However, the increase is quite significant when compared with other waterways that have generally higher rainfall and a greater proportion of irrigated pasture in the catchment (ie; Te Hoiere/Pelorus catchment). It is possible that land use or management changes in the catchment have also contributed to the rise in nitrate concentrations.

Trend analysis also shows an increase in E. coli concentrations over the last nine years, but not the last five years. This means that E. coli levels in the Tuamarina River have increased in the early years of monitoring and have remained at a higher level in recent years. E. coli concentrations are not always associated with flood flows, which means there are several potential sources for E. coli contamination, including stock grazing on the river banks, residential development and wildfowl.

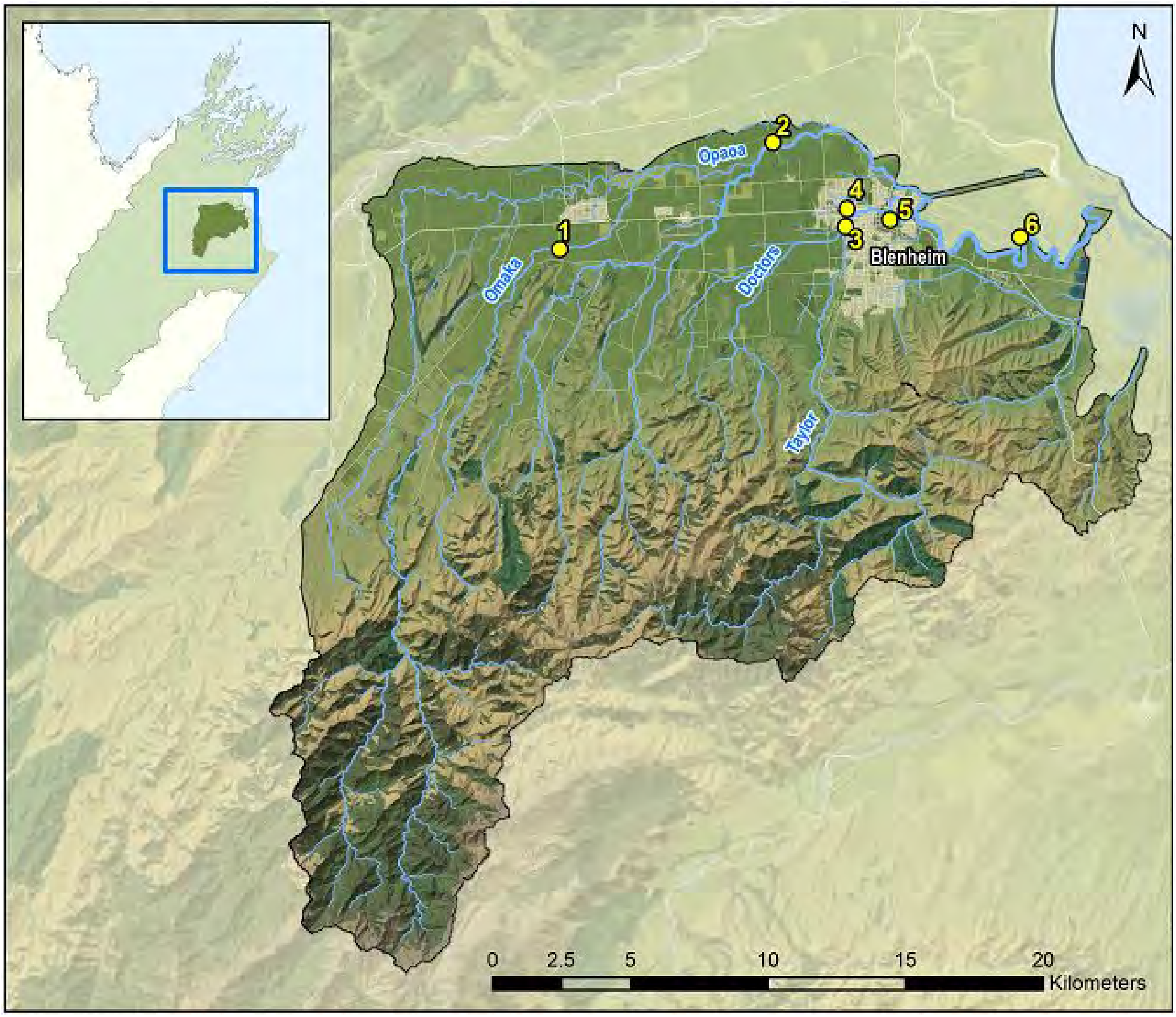
The water quality at the Tuamarina River monitoring site is strongly influenced by a large wetland. More than three kilometres of the lower Tuamarina River traverse through the Para Swamp, one of the largest remaining wetlands in the region. Preliminary results of an investigation into the water quality of the Tuamarina River in 2015 suggest that the wetland is acting as a nitrogen sink, buffering the effects of dairy farming upstream. However, the results also suggest that the wetland is currently a source for phosphorus, explaining the generally high dissolved reactive phosphorus concentrations at the sampling site. Short-term continuous monitoring of dissolved oxygen concentrations at several sites along the lower reaches of the Tuamarina River showed that oxygen levels are substantially lower downstream of the wetland. Subsequently, the Tuamarina sampling site has some of the lowest dissolved oxygen saturations measured at any of the sites monitored as part of the State of the Environment program. A report, summarising the results of the Tuamarina catchment investigation is expected to be finalised by the end of this year.

Low dissolved oxygen saturations in Spring Creek are a result of the large inflow of groundwater, which naturally has lower oxygen levels. Most of the soluble inorganic nitrogen in the creek also originates from these groundwater inflows. Trend analysis shows a reduction in nitrate concentrations over the last nine years. This is likely the result of conversions from pastoral land use into vineyards, which have been shown to leach significantly less nitrogen [10]. Changes of the Water Quality Index for Spring Creek are closely following those of the Lower Wairau River, which is not surprising as groundwater from the Wairau aquifer contributes most of the flow in Spring Creek.

The nine-year trend analysis of Spring Creek data shows an increase in E. coli concentrations. The samples with the two highest E. coli levels were taken during flood flows in 2013 and 2014, but monitoring data also shows an increase in E. coli concentrations during base flow conditions. Groundwater has generally very low E. coli concentrations. Subsequently, contamination with E. coli is occurring within the relatively small surface catchment of the creek. More than 80% of the catchment has been planted in vines and the grazing of sheep during the winter months is one possible source of contamination. However, E. coli levels show no significant seasonal pattern, ruling out the winter grazing as the main cause. Other possible sources include stock access to the waterway on the remaining pasture or damage to sewerage infrastructure of residential housing.

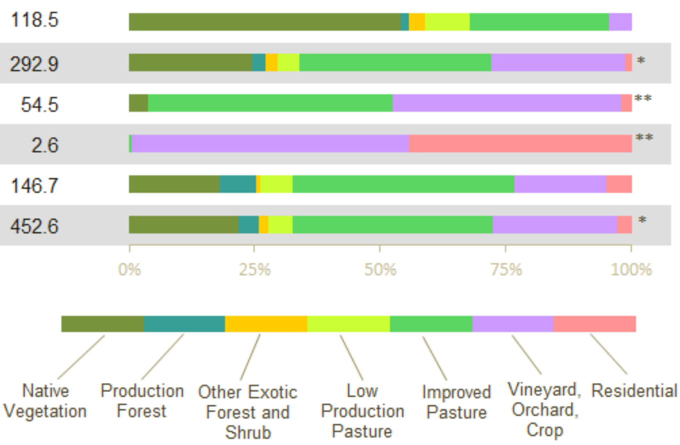
Are Are Creek is the only site in this group with a significant improvement of the Water Quality Index in recent years. Water quality in this waterway has changed from the marginal into the fair category. A catchment investigation in 2013/2014 identified several causes for degraded water quality, including stock access, sewage contamination and poor effluent management. A number of these causes have now been mitigated, leading to the observed improvements in water quality. Nevertheless, there are a number of problem areas that need to be addressed in order to ensure that water quality remains in the fair category; these include bank management and stock access.

3.5. The Ōpaoa Complex



No.	Site	Monthly Water Quality Sampling Since	Catchment Area [km^2]
1	**Omaka Rv**	Feb 2007	118.5
2	**Mid Ōpaoa***	Feb 2007	292.9
3	**Doctors Ck****	Jul 2009	54.5
4	**Murphys Ck****	Jul 2009	2.6
5	**Taylor Rv**	Feb 2007	146.7
6	**Lower Ōpaoa***	Feb 2007	452.6

Landcover



* Water from the Wairau and Waihopai River is diverted into the Ōpaoa River influencing its water quality particularly at base flow.

** The baseflow of Doctors Ck and particularly Murphys Creek is dominated by groundwater that orignates from a greater area than the surface catchments of the creeks.

Figure 20: Sampling sites in the Ōpaoa Complex.

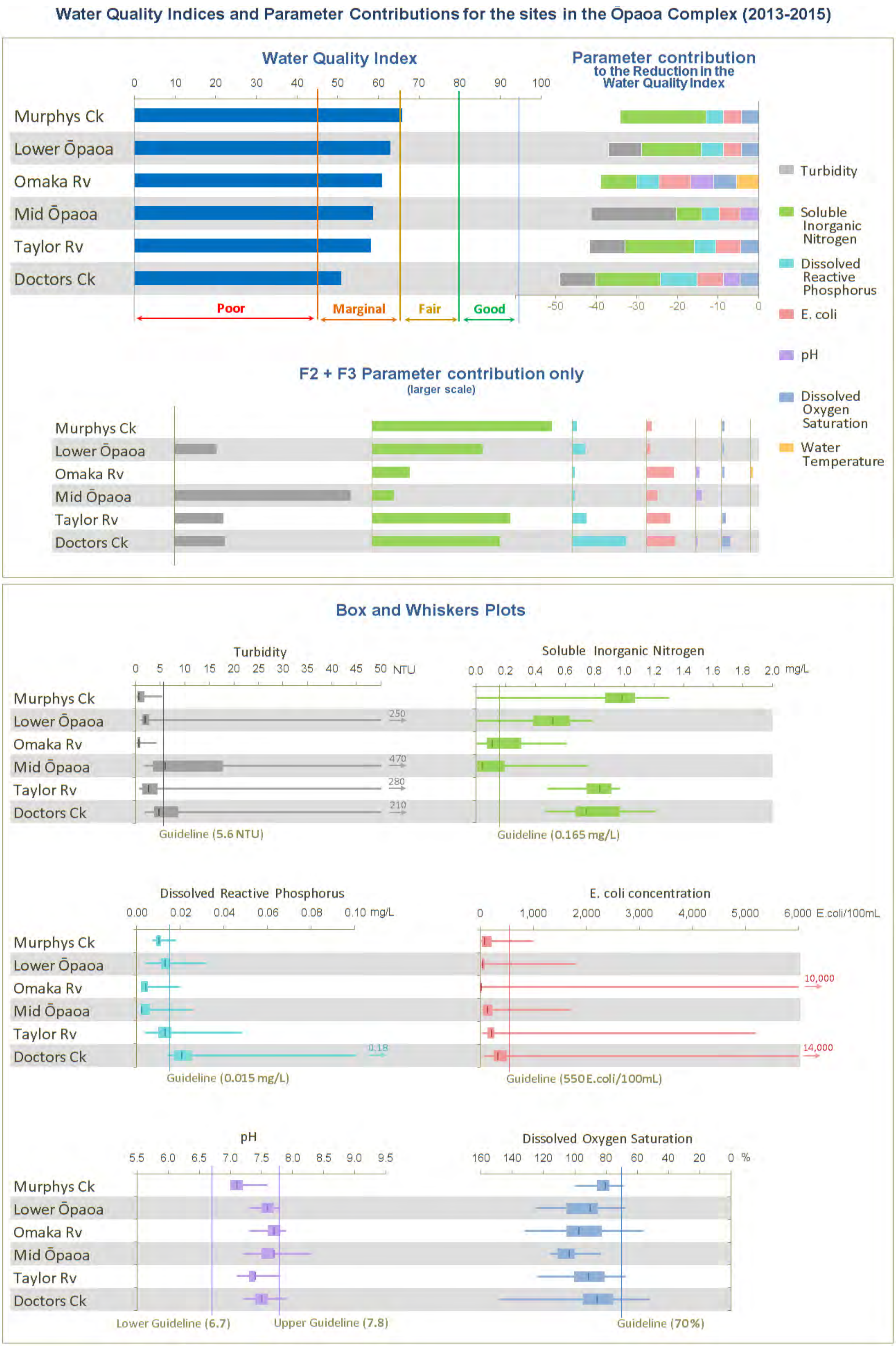


Figure 21: Water Quality Indices and parameter contributions for the monitoring sites in the Ōpaoa Complex for the period 2013-2015.

The water quality of sites in this group is classified as marginal, only Murphys Creek has a Water Quality Index that barely puts it in the fair category. A number of waterways are part of the spring-belt, characterised by a significant inflow of groundwater. For these rivers and streams high soluble inorganic nitrogen concentrations are the main parameter causing a reduction in the Water Quality Index. Soluble inorganic nitrogen and dissolved reactive phosphorus concentrations in Murphys Creek and the Taylor River are similar to those in nearby groundwater wells [15], indicating that the elevated nutrient concentrations in these streams originate from inflowing groundwater. Most of the nitrogen and phosphorus in Doctors Creek also originates from upwelling groundwater, but additional sources of phosphorus are causing concentrations that are significantly higher than those at other sites. An investigation into the causes of poor water quality in Doctors Creek in 2014 showed that bank management and winter grazing of sheep in vineyards was a significant source of phosphorus in this waterway [16]. Doctors Creek also has the highest E. coli concentrations of the sites in this group. The catchment investigation identified the main causes as direct stock access and ducks, but in one of the tributaries contamination with human sewage was also found. Following the release of the investigation results in a report [16], it is known that at least one landowner fenced off his cattle from the creek and council are encouraging other land owners in the rural part of the catchment to follow his lead. The source of human sewage has not been found yet, but further investigations have shown the contamination is not reaching the creek via the stormwater system; instead the sewage is likely to be flowing into the creek as seepage from a property adjacent to the creek. Although Council was able to narrow down the area of contamination through additional sampling, it appears to be an exceptionally difficult source to find, particularly as there are no visible signs in or along the banks of the creek. Additionally, the inflow of sewage appears to be quite small, so investigative sampling can only occur during low flow conditions. Nevertheless, Council will continue work until the source has been found and eliminated.

The sites with a strong groundwater influence show significant decreasing trends in nitrate concentrations for the nine year as well as the five year periods (Table 8). This is linked to conversions of pastures into vineyards in the wider Wairau catchment (the source of the groundwater). Lysimeter measurements under a Marlborough vineyard have shown that nitrate leaching under this type of land use is significantly lower than under pasture [10].

Table 8: Results of the trend analysis for the sites in the Ōpaoa Complex.

Annual change based on 9-year trend (2007-2015)

	pH	Turbidity [NTU]	E. coli [n/100ml]	Nitrate-N [mg/L]
Murphys Ck				
Lower Ōpaoa	0.03		2.09	-0.08
Omaka Rv	0.05			-0.02
Mid Ōpaoa	-0.08	0.21	12.29	-0.01
Taylor Rv	0.06	0.14	24.35	-0.11
Doctors Ck				

Annual change based on 5-year trend (2011-2015)

	pH	Turbidity [NTU]	E. coli [n/100ml]	Nitrate-N [mg/L]
Murphys Ck	0.11			-0.05
Lower Ōpaoa				-0.04
Omaka Rv			-2.99	
Mid Ōpaoa	-0.09	0.59		
Taylor Rv	0.06		26.11	-0.07
Doctors Ck	0.03			-0.08

The trend analysis shows changes in pH values for most of the sites with the most significant being an increasing trend for Murphys Creek and a decreasing trend for the Mid Ōpaoa. Both changes had a positive impact on water quality, particularly for Murphys Creek, which now has pH values that are consistently within the bounds of the guidelines. It is one of the reasons for the creeks highest Water Quality Index since monitoring began in 2010 (Figure 22). Another reason is the non-exceedance of the turbidity guideline. Due to its small surface catchment and high groundwater inflow, the water in Murphys Creek is naturally very clear. Field observations indicate that the only exceedance of the turbidity guideline was the result of river works near the sampling site in 2012.

Another noticeable result of the trend analysis is a significant increase in E. coli concentrations in the Taylor River for both the nine year and the five year periods. The high E. coli concentrations have also been identified through sampling of the Taylor River as part of the Recreational Water Quality program [18]. Early investigations have shown that ducks and dogs are the main sources of elevated E. coli levels [13], but it remained unclear if very high concentrations are the result of other sources. A recent report, summarising the results of stormwater sampling, points to contamination of stormwater by earthquake damaged sewerage pipes as a source of the sporadic, very high spikes in E. coli concentrations. Many of the effected sewers have been repaired recently and a number are due to be inspected and if necessary, repaired in the near future.

Despite the increase in E. coli concentrations, the Water Quality Index for the Taylor River is showing improvements (Figure 22). This is due to a combination of factors, including a significant reduction in nitrate concentration and improved pH levels (Table 8).

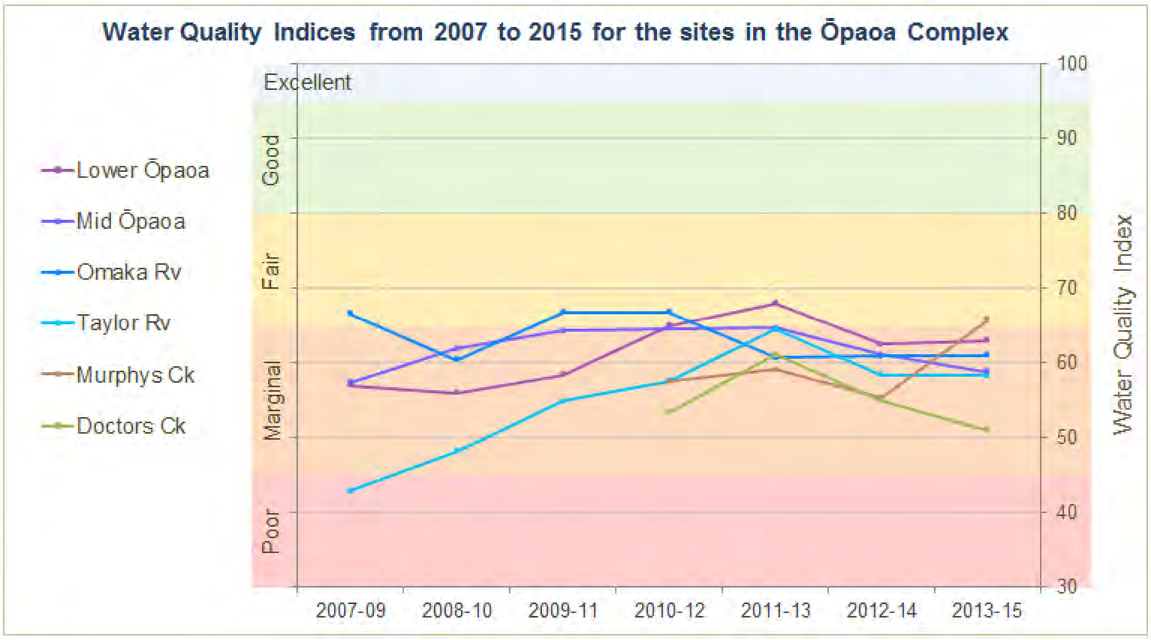


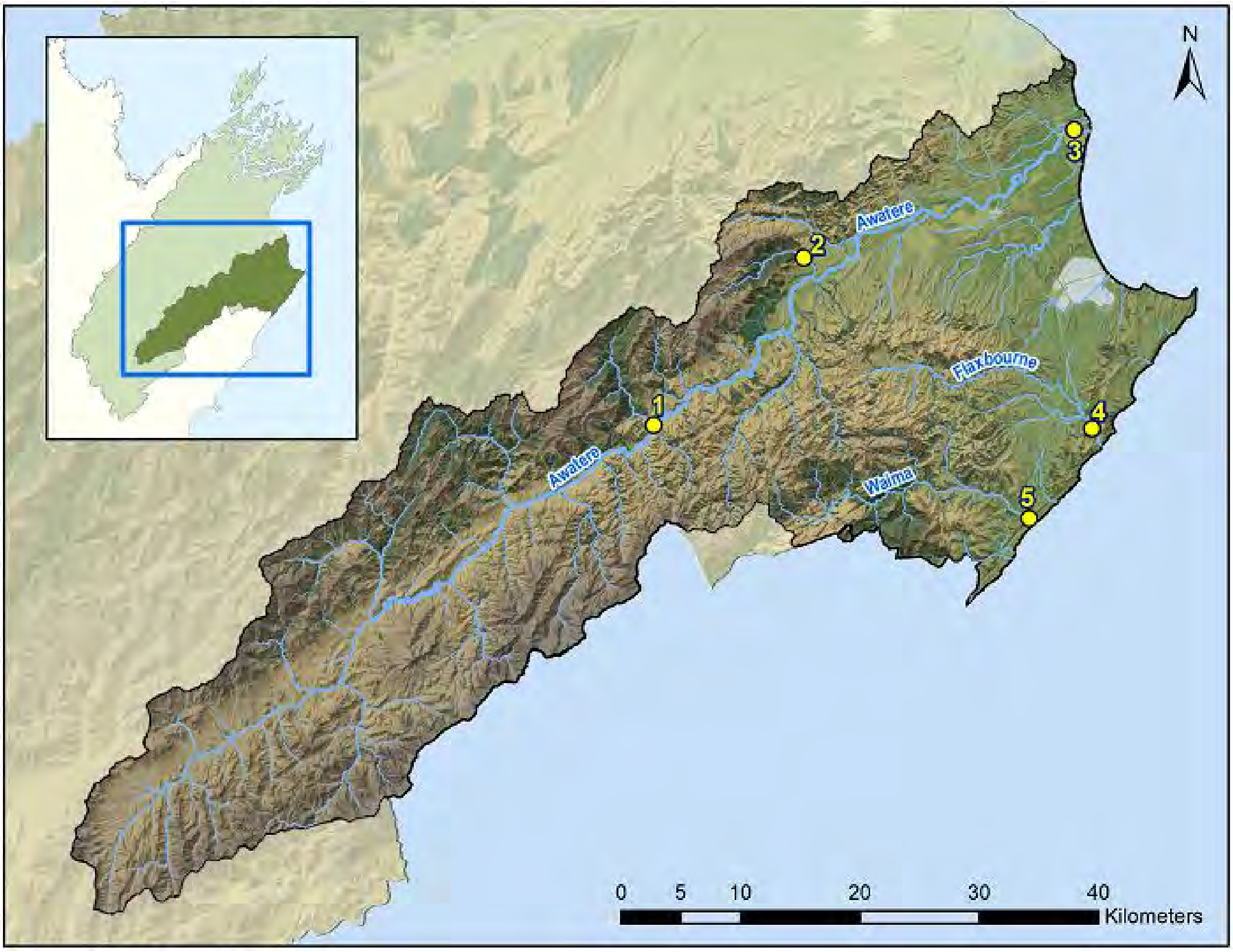
Figure 22: Change over time of the Water Quality Indices in the Ōpaoa Complex.

The Omaka and mid Ōpaoa Rivers are the only two waterways in this group that are not dominated by groundwater inflows. The low Water Quality Index for the Omaka River is not the result of one particular parameter, but rather occasional exceedances of guideline values for almost all of the parameters measured. Although guideline exceedances are quite rare and mostly associated with rainfall events or very low flows, they indicate noteworthy stressors for the aquatic ecosystem.

The water of the Mid Ōpaoa is influenced by the water quality of the Omaka River. However, as a result of the Southern Valley Irrigation Scheme, water from the Wairau and Waihopai Rivers is flowing into the Ōpaoa River as well and is in fact contributing most of the flow during base flow conditions. Large flood events in the Wairau River have changed the distribution of river gravels in the channel and in recent years, these changes have significantly modified the intake for the Irrigation Scheme. As a result, both, the Waihopai and Wairau River intakes are now predominantly diverting water from the Waihopai River into the Scheme. As the Waihopai River is generally more turbid than the Wairau River, turbidity in the Ōpaoa River has increased. This is, particularly noticeable at the Mid Ōpaoa sampling site and is confirmed by the results of the trend analysis.

Most of the sites in this group are located in or downstream of Blenheim and water quality is therefore influenced by residential stormwater runoff. Stormwater can contain high concentrations of heavy metals, such as Zinc and Copper. These originate mainly from roofing iron and cars, but commercial and industrial activities are also potential sources. For this reason, Copper, Zinc and Arsenic are measured at all sites in this group with the exception of the Omaka River, which is the only waterway with no substantial residential development in the catchment. The results show that during rainfall events, Copper and Zinc concentrations are occasionally elevated at all sites. High concentrations of these metals can be toxic to aquatic animals and the ANZECC Guideline document [1] provides trigger levels to protect aquatic ecosystems. The 95% Species protection trigger levels are recommended for slight to moderately disturbed ecosystems and are the most commonly used. These trigger levels apply to median concentrations and none of the sites monitored has median concentrations above the triggers for 95% Species protection.

3.6. South Marlborough



No.	Site	Monthly Water Quality Sampling Since	Catchment Area [km^2]	Landcover
1	**Mid Awatere**	Feb 2007	983.8	
2	**Black Birch Stm**	Feb 2007	29.9	
3	**Lower Awatere**	Feb 2007	1,572.7	
4	**Flaxbourne Rv**	Feb 2007	150.6	
5	**Waima Rv**	Aug 2007	158.2	

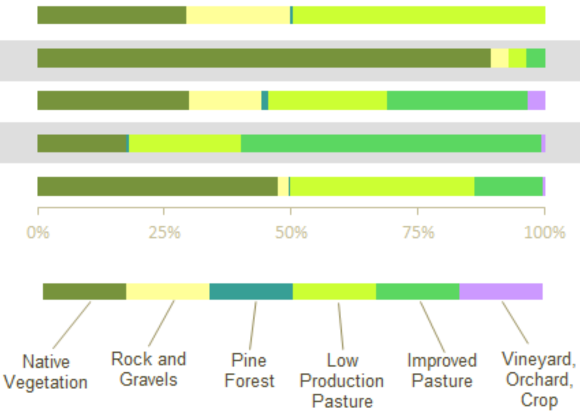


Figure 23: Sampling sites in the South Marlborough region.

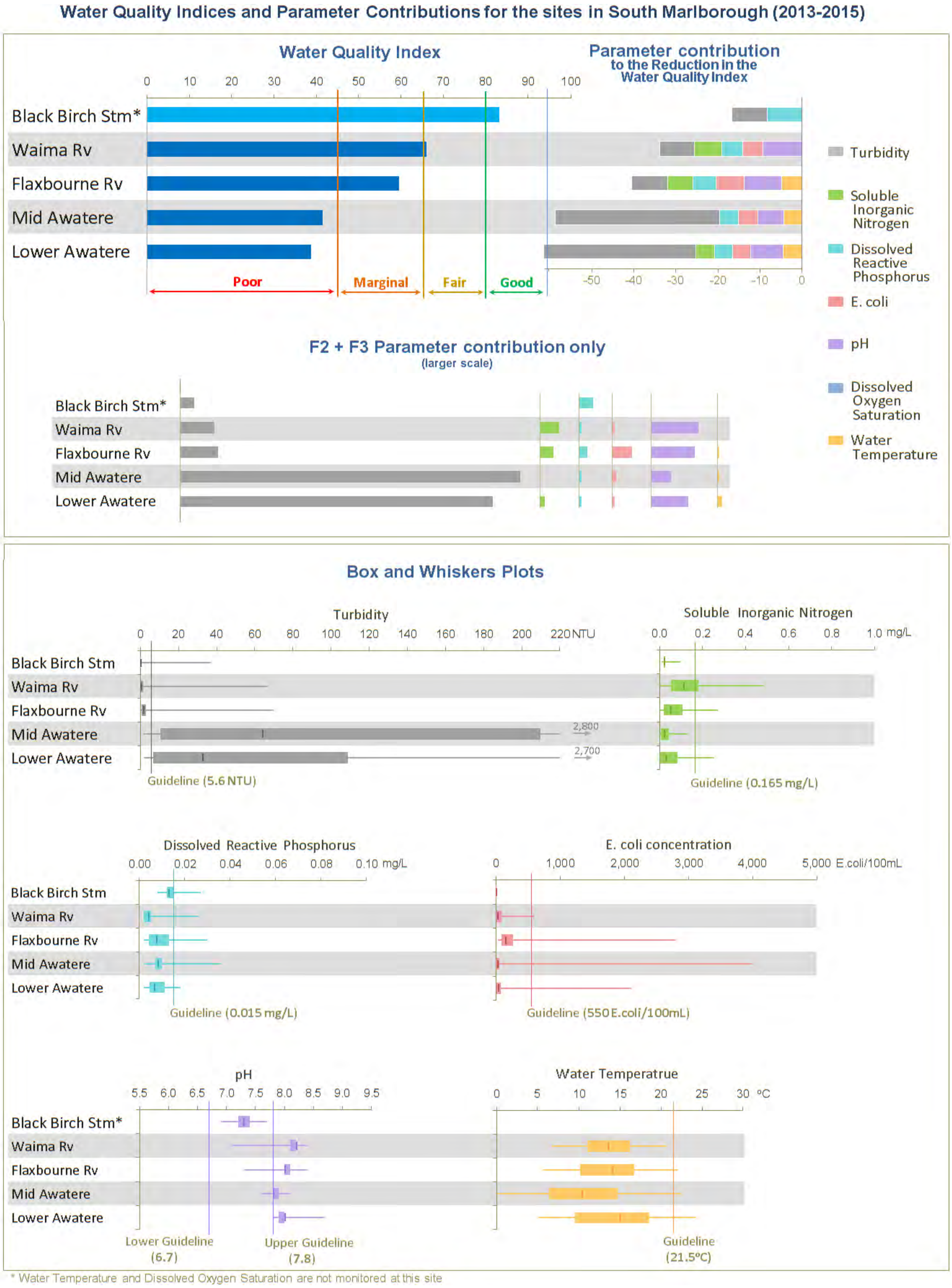


Figure 24: Water Quality Indices and parameter contributions for the monitoring sites in South Marlborough for the period 2013-2015.

The driest parts of the region are located in South Marlborough, which receives less than half the annual rainfall of the Te Hoiere/Pelorus catchment. Monitoring is carried out in the three largest catchments with monitoring sites on the Flaxbourne and Waima Rivers and two sites on the Awatere River. Black Birch Stream, a tributary of the Awatere River is the smallest catchment in this group.

The large amount of native vegetation in the Black Birch Stream catchment ensures good water quality, which is the reason for its use as a community drinking water supply. Occasional exceedances of the guidelines for turbidity and dissolved reactive phosphorus are the only reason that the Water Quality Index for Black Birch Stream does not reach the 'excellent' category. Exceedances of both parameters are generally associated with rainfall events. Nevertheless, there is no correlation between turbidity and dissolved reactive phosphorus, which indicates that the sediment washed into the stream is not the source of the phosphorus. Dissolved reactive phosphorus concentrations are consistently high, which, based on the limited anthropogenic modification, could be a natural phenomenon.

Black Birch Stream flows into the Awatere River, which has substantially poorer water quality. However, the parameters which cause the greatest reduction in the Water Quality Index are elevated predominantly due to natural causes. High turbidity and pH values are the result of high mudstone and limestone content in the geology of the Awatere River catchment. Nevertheless, there is a large amount of infrastructure associated with irrigation water takes in the lower Awatere. Maintenance of these intakes generally causes significant increases of turbidity during the work. Trend analysis shows a significant increase in turbidity for both sampling sites, however, which indicates that the source is likely to be located in the upper catchment (Table 9). Since trend data is flow adjusted, the increase in turbidity is not a result of changes in flows during sampling. The majority of the upper catchment is extensively farmed pasture and it is unclear what is causing the increased turbidity, but greater erosion is the most likely explanation. The increase in turbidity caused a significant reduction in the Water Quality Indices for the two Awatere River sites, which have shifted from the marginal into the poor category (Figure 25).

Table 9: Results of the trend analysis for the sites in South Marlborough.

Annual change based on 9-year trend (2007-2015)

	pH	Turbidity [NTU]	E. coli [n/100ml]	Nitrate-N [mg/L]
Black Birch Stm				
Flaxbourne Rv		0.07	25.75	
Waima Rv		0.04		
Mid Awatere	-0.02		1.17	
Lower Awatere	-0.05			

Annual change based on 5-year trend (2011-2015)

	pH	Turbidity [NTU]	E. coli [n/100ml]	Nitrate-N [mg/L]
Black Birch Stm				
Flaxbourne Rv				
Waima Rv				0.03
Mid Awatere		8.49		
Lower Awatere		5.76		

Despite a large portion of the Awatere catchment in pastoral land use, nutrient concentrations are generally low. This is the case for most sites in this group and is a result of low stock numbers and a limited amount of nitrogen leaching due to low rainfall and predominantly un-irrigated pastures. Low stock numbers are also the reason that E. coli concentrations in the Awatere River are generally low, despite the lack of fencing along the river banks. Dilution of faecal contamination due to the large size of the river is further reducing the impact of stock access on water quality.

The significantly lower flow in the Flaxbourne River does not provide the same diluting effect as in the Awatere River. Therefore, in this waterway, direct stock access by low intensity farming often causes high E. coli concentrations. Trend analysis shows a significant increase over the last nine years. The lack of a trend for the five-year period indicates that this increase is not a recent phenomenon. Instead, after the initial rise in the early years of monitoring, E. coli concentrations have remained at higher levels.

A unique phenomenon for the larger rivers in this group is the occurrence of consistently elevated pH values as a result of limestone deposits in the catchments. The Waima River catchment contains the largest area of pure limestone, which manifests in the highest pH values of any river currently monitored. Subsequently, exceedances of the pH guideline account for a large part of the reduction in the Water Quality Index for this waterway (Figure 24).

The unusually high soluble inorganic nitrogen concentrations in the Waima River, however, are not a natural phenomenon. Concentrations are often higher than in the Flaxbourne River, which has a significantly larger proportion of pasture in the catchment. It is unknown what is causing the high nitrogen concentrations with leachate from large piles of organic material or direct discharges of organic waste being only two of the possible sources. This would need to be investigated further, particularly, if the Water Quality Index for the Waima River declines into the 'marginal' category as it has done in the past.

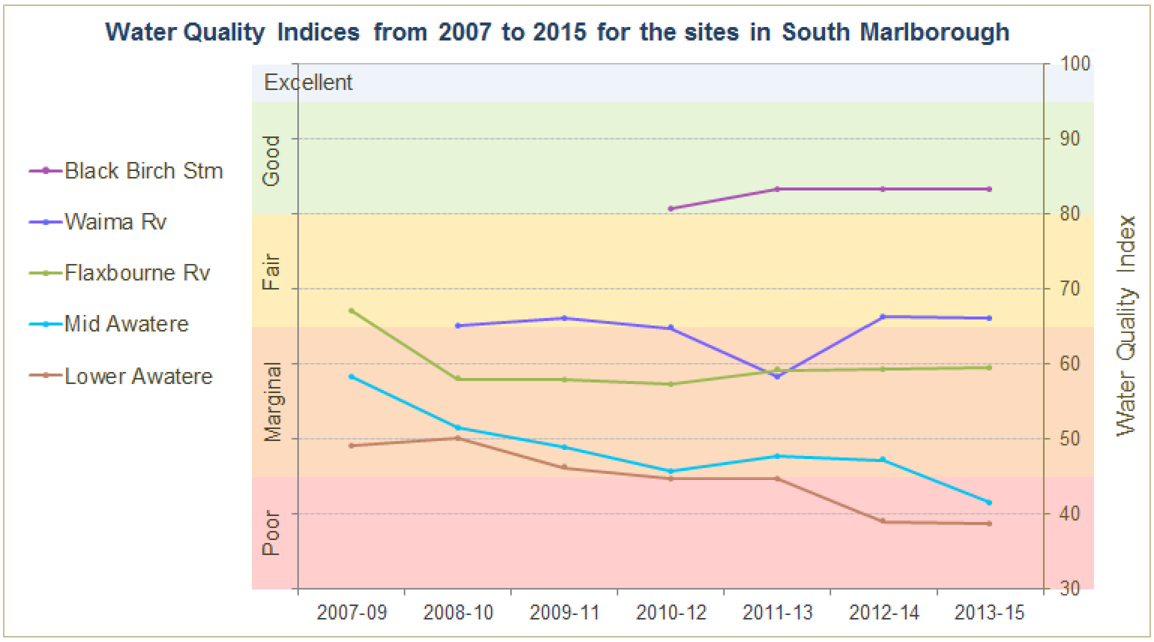


Figure 25: Change over time of the Water Quality Indices in South Marlborough.

Figure 26: Typical turbid appearance of the Awatere River at the mid Awatere monitoring site.

4. Summary and Discussion

The Goulter River was added to the State of the Environment programme recently and although we do not have a complete three-year data set, a Water Quality Index was calculated. The river has the highest possible Index of 100, representing excellent water quality. This reaffirms that the guideline values chosen for the calculation of the Water Quality Index allow even comparatively large rivers to achieve the excellent category.

There are three sites with water quality in the 'good' category, the Upper Te Hoiere/Pelorus River, Black Birch Stream and the Wakamarina River (Figure 27). All three waterways have more than 80% of the catchment remaining in native vegetation. However, a large proportion of native vegetation is not a guarantee for good water quality. The Waitohi, Branch, Graham and Upper Wairau Rivers, all have had less than 15% of their catchments converted from native vegetation, but have Water Quality Indices in the fair category. In the Waitohi River the influence of urban development is the main cause for the degradation in water quality. For the other rivers mentioned, turbidity is the parameter causing the most significant reduction of the Indices. The Water Quality Index for the Upper Wairau River had been in the good category in the past, but has declined considerably in recent years. Analysis in an earlier report showed that the increase of turbidity is a result of higher flows during sampling [15]. A similar phenomenon was also identified for the Branch River.

Unlike Water Quality Index data, the data used for trend analysis is flow adjusted. Trend analysis, done as part of this report, identified an increasing trend for turbidity in the Branch River, but not the Upper Wairau River (Figure 28). This indicates that some of the increases in the Branch River are not flow related. Recent harvesting of production forestry in the catchment is a possible source of additional fine sediment in this waterway. Field notes for the Graham River identify gravel extraction and associated bank erosion as the cause for elevated turbidity.

Turbidity is also the most significant parameter influencing the Water Quality Index for the five monitoring sites with the lowest Indices (Figure 27). Highly erodible mudstone in the geology of the catchment is responsible for the majority of exceedances of the turbidity guideline in the Awatere River and Waihopai River. Trend analysis shows a significant increase in turbidity for the two Awatere River sampling sites, but these increases are not related to changes in flows. Since both sites are affected, the source of additional sediment must be located in the upper catchment. High turbidity in the Tuamarina River was the result of exceptionally large floods in 2013, causing extensive scouring and bank erosion in the lower reaches.

The majority of sites monitored have fair water quality, while a slightly smaller number of sites have water quality in the marginal category. Fair water quality means that conditions are sometimes departing from desirable levels, while a Water Quality Index in the marginal category represents conditions that often depart from desirable levels. Based on these definitions, 'fair' water quality is considered to be acceptable, especially in light of the significant human pressures on these waterways. 'Marginal' water quality, however, is not acceptable, unless caused by natural phenomena. This is reflected in Policy 15.1.7 of the Marlborough Management Plan, which requires that actions are taken to enhance water quality in waterways, which are currently in the marginal category. The policy requires investigation into the causes of degradation with the aim to develop catchment-specific plans aimed at enhancing water quality. Catchment investigations were carried out and reported on for Are Are Creek and Doctors Creek. Major non-compliances identified were rectified immediately, while a collaborative approach has been chosen for activities that are allowed under current rules, but were shown to impact on water quality. The development of water quality enhancement plans for these waterways will be the next step. For the Tuamarina River, Linkwater Stream and Cullens Creek the initial step of investigating the causes of degradation is close to completion and reports summarising the findings will be released in the near future.

High soluble inorganic nitrogen concentrations are causing a significant reduction in the Water Quality Index for a number of streams and rivers in the marginal or fair category. Nearly all of the nitrogen in these waterways is a result of leaching from animal urine, effluent or other organic material deposited on unsealed surfaces. Rain or irrigation water carries the nitrogen from these surfaces into the soil. When soils become over-saturated with water, the nitrogen is moved further down into subsurface flows and groundwater, which later re-appears in rivers and streams. Consequently, nitrogen leaching increases with the amount of rainfall and is higher on pasture that is irrigated. The type of stock also has a considerable impact on the amount of nitrogen leached, with the highest values under dairy pastures [21]. This explains the high soluble inorganic nitrogen concentration in the Rai River and its tributaries, which receive some of the highest rainfall of the region and have pastures predominantly grazed by dairy cattle.

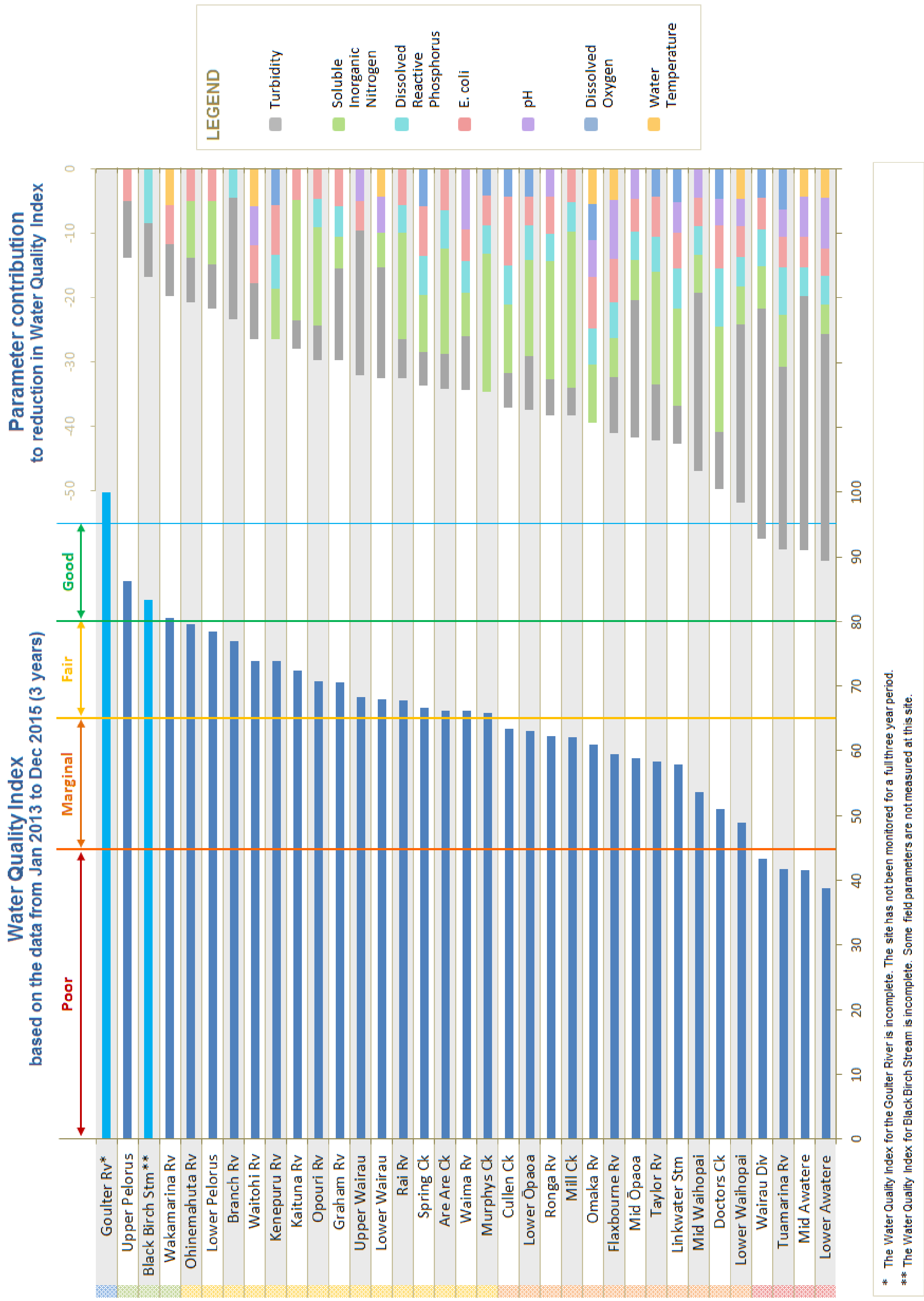


Figure 27: Water Quality Indices and Parameter contributions to the reduction in the Water Quality Indices for the three years from 2013 to 2015 for all sites monitored.

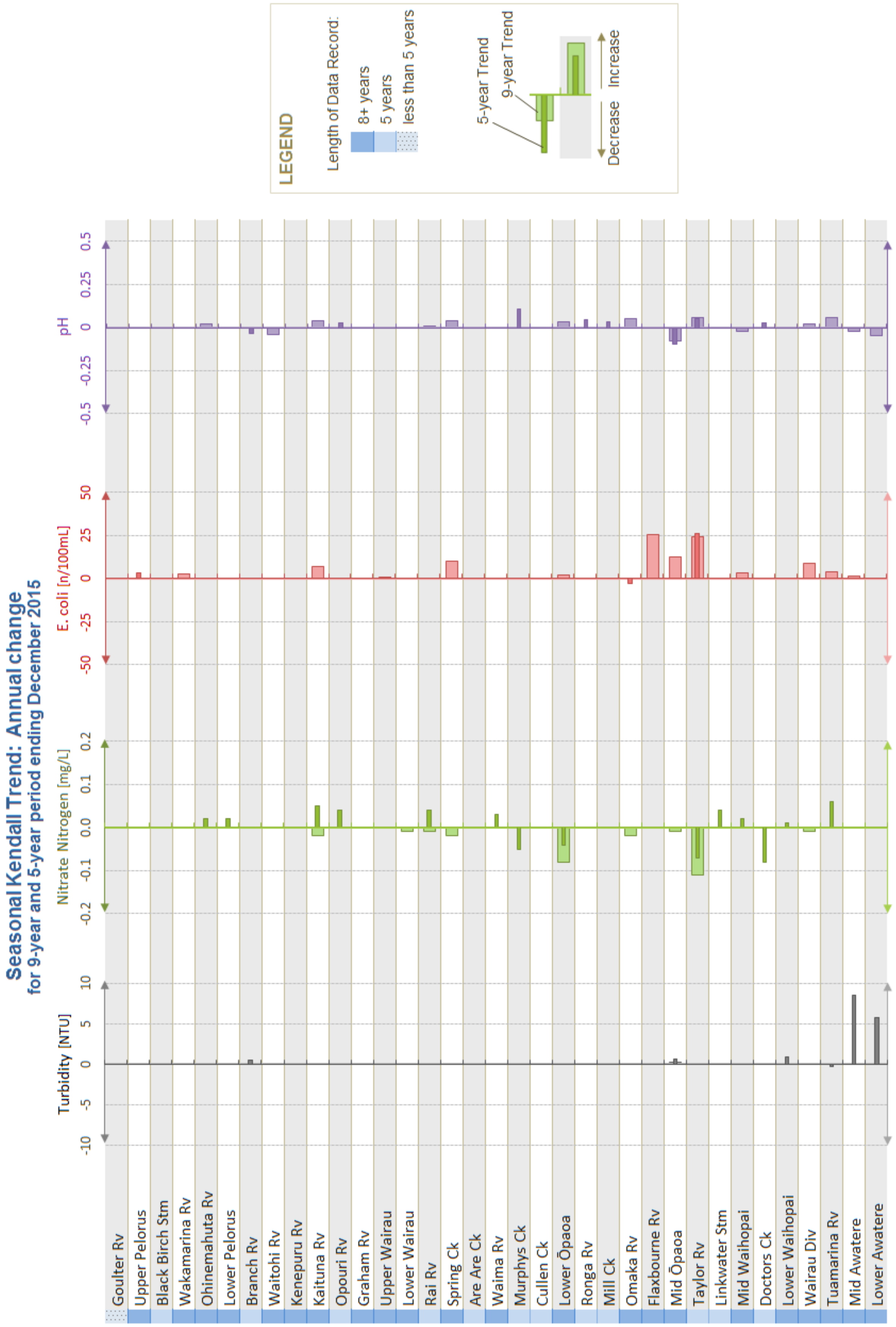


Figure 28: Annual change based on the five-year (2011-2015) and nine-year (2007-2015) trend analysis for all sites monitored.

In contrast, soluble inorganic nitrogen concentrations in the Flaxbourne River are comparatively low, despite a significantly larger proportion of pasture in the catchment. However, most of the land is not irrigated and is used for low intensity sheep and beef pasture. Additionally, this part of the region receives less than half of the annual rainfall of the Rai River catchment.

Streams that are predominantly spring-fed generally have high soluble inorganic nitrogen concentrations. The nitrogen almost exclusively originates from upwelling groundwater, which comes from areas significantly larger than the actual surface catchments of the streams. Management of nitrogen in these spring-fed streams is therefore particularly difficult as it requires an approach that needs to cover a large part of the region, not just single catchments. The diffuse nature of the soluble inorganic nitrogen sources makes their management generally quite difficult as it requires substantial changes in farm management to achieve significant reductions. Developing efficient and effective regional rules for the management of nitrogen is one of the challenges facing most councils across the country.

The majority of soluble inorganic nitrogen is in the form of nitrate. The trend analysis for nitrate concentrations shows a range of decreasing and increasing trends (Figure 28). Many of the waterways north of the Wairau River show an increasing five-year trend of similar magnitude. The widespread nature indicates that changes in rainfall patterns provide the most likely explanation as increases in rainfall intensity and/or duration can lead to more nitrate leaching.

Many streams with significant groundwater inflows show the opposite trend, with decreases in nitrate concentrations for the five-year, as well as the nine-year periods. The greatest changes occurred in Doctors Creek and Murphys Creek, with a follow-on effect for the Taylor and Lower Ōpaoa River downstream. This is caused by the extensive conversion of pastures in the lower Wairau River catchment into vineyards. Monitoring of leachate under a Marlborough vineyard has shown that comparatively little nitrate is lost to groundwater when compared to pastoral land uses [10].

Elevated nitrogen concentrations effect aquatic waterways in two ways, direct toxicity and algae growth. Very high nitrate-nitrogen concentrations are toxic to aquatic animals by interfering with their internal oxygen transport. Fortunately, only two of the currently monitored waterways, Mill Creek and the Kaituna River, exceed the A-Band limits of the NPS attribute for nitrate toxicity. All other monitoring sites have nitrate concentrations within the A-Band, which represents the best of the four bands.

High soluble inorganic nitrogen concentrations also lead to excessive growth of algae and other aquatic vegetation. This growth smothers aquatic habitat and causes large fluctuations in dissolved oxygen concentrations in the water, which in turn reduces the number of fish and aquatic invertebrate species that can survive. The guideline used for the calculation of the Water Quality Index is based on this effect. However, aquatic plants will only grow, if sufficient amount of light reaches the stream bed. Tall, dense riparian vegetation can therefore prevent excessive algae and macrophyte[4] growth. This provides an alternative solution to manage the effects of high soluble inorganic nitrogen concentrations. This approach can only be applied to waterways less than eight to ten meters in width [26], but fortunately this excludes only a relatively small number of rivers in the region.

Riparian vegetation has a number of additional benefits. These include lower water temperatures, improved bank stability and a filter-like function in regard to run-off from adjacent land uses [21, 23]. In order to establish an effective buffer, access to the buffer as well as the waterway by livestock needs to be prevented. This would result in additional improvements to water quality. The benefits of keeping stock out of waterways have long been known and are now also acknowledged by the recent move of the national government to introduce stock exclusion rules.

Elevated E. coli concentrations during base flow conditions are usually an indication of stock access to a waterway. Results from catchment investigations in Doctors Creek and Are Are Creek have confirmed this, but have also shown that significant impacts are observed at comparatively low stocking rates, especially if the pasture is grazed by cattle. A mature riparian buffer does not guarantee low E. coli numbers, if stock faeces still enter the waterway at weak spots such as raceways in close proximity to the waterway, stock access to small tributaries or stock crossings. An example is Cullens Creek, which has the highest E. coli concentrations of all sites monitored, despite a mature riparian buffer along most of its length.

[4] Macrophytes are leafy plants growing in the water or on the water surface. They are sometimes referred to as water weeds.

In other waterways, different sources are causing high E. coli concentrations. Analysis of genetic markers of faecal bacteria in the Taylor River identified that ducks and dogs are causing elevated E. coli concentrations. However, recent results of stormwater sampling showed that damage of the sewerage system in Blenheim is likely to be a contributing factor. Trend analysis has shown a significant increase in E. coli concentrations for the Taylor River, which was confirmed by monitoring of the waterway as part of the Recreational Water Quality programme. However, recent repair efforts should result in improvements.

Significant increases of E. coli concentrations were also observed in the Flaxbourne River, the Mid Ōpaoa, Spring Creek, the Wairau Diversion and the Kaituna River. However, further investigation would be needed to identify the sources of additional faecal contamination in these waterways.

Trend analysis of pH data showed only minor changes, nevertheless, these were sufficient enough to contribute to improvements in the Water Quality Index at number of sites, including the Taylor River, Murphys Creek, the Lower Ōpaoa and the Kaituna River.

4.1. Influence of Flood Flows

In order to investigate the influence of flood flows on the values of the Water Quality Indices for the sites monitored, data associated with large floods was removed. Removal of data was based on river or stream flows that exceeded three times the median flow at the time of sampling. Where flow data was not available at a sampling site, the data from nearby sites on the same waterway or from the nearest flow recorders in a neighbouring catchment were used. The results of this analysis are summarised in Figure 29. For nearly all of the sites monitored, the removal of flood data resulted in a higher Water Quality Index. This means that during non-flood conditions the number of sites with excellent water quality rises to two and the number of sites with good water quality increases to eight.

The majority of the parameter contributions show a reduction, but there are also some increases. These are due to lower concentrations as a result of dilution during flood events. Removal of these results from the calculation of the Water Quality Index causes an increase in the proportion of results above guideline levels and consequently a higher parameter contribution to the reduction of the Index.

The parameter that is most affected by the exclusion of flood data is turbidity. This is not surprising as bank erosion predominantly occurs during flood flows. Only data for large floods was removed and the removal of this data often did not eliminate all of the parameter contribution for turbidity. For a number of sites, these remaining exceedances of the turbidity guideline are mostly the result of erosion during smaller increases in flow. Examples are the Graham River, the Waitohi River, Doctors Creek and Linkwater Stream. Better bank management, such as stock exclusion and riparian planting, could improve water quality in these rivers by stabilising the banks.

For a number of waterways, removal of flood data also resulted in the removal of high dissolved reactive phosphorus concentrations, but increases for the contribution of soluble inorganic nitrogen to the reduction of the Water Quality Index. Phosphorus is more strongly bound to the soil than nitrogen. Only when phosphorus concentrations in the soil reach very high level, does phosphorus leaching occur. Nitrogen, on the other hand, leaches easily into subsurface flows and subsequently into water ways. For this reason, soluble inorganic nitrogen levels are higher during low flow, while the additional water during flooding causes a dilution of nitrogen concentrations. The phosphorus bound in soil, however, is released into the water only when the soil is removed from the banks or adjacent land areas during erosion processes. Subsequently, for a number of sites, high phosphorus concentrations are observed during large flood events only.

For a number of waterways E. coli concentrations are substantially decreased with the removal of flood data. In these cases, run-off carrying faecal contamination, such as animal droppings from surrounding land surfaces into these waterways is the main case for high E. coli concentrations.

It could be argued that flood data should generally be removed from the analysis, as flood flows are comparatively rare extreme events. Yet, floods are natural influences on aquatic systems and anthropogenic modifications can greatly exacerbate this natural stressor on aquatic life. Therefore, to obtain an overall evaluation of the state of water quality and assess the impact of human activities on the waterways in the region, State of the Environment sampling and data analysis needs to encompass all flow conditions. Removal of flood data provides a filtered view on water quality and should only be used in the context of discriminating between the effects of human activities at different flows.

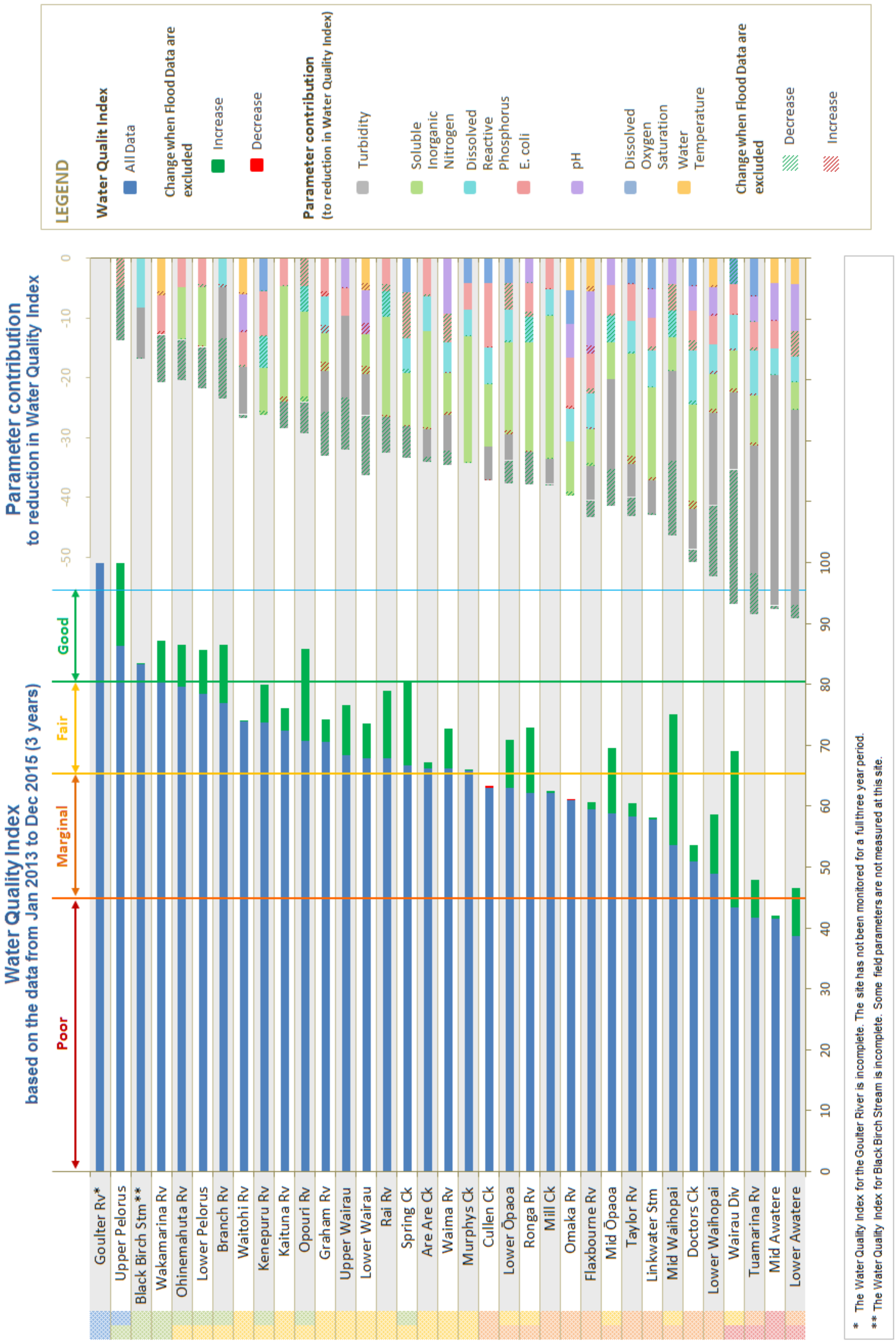


Figure 29: Changes to Water Quality Indices and Parameter contribution as a result of the removal of flood flow data.

5. References

1. ANZECC (2000) Australia and New Zealand Guidelines for Fresh and Marina Water Quality. Australian and New Zealand Environment and Conservation Council. Agriculture and Resource Management Council of Australia and New Zealand.

2. Ballantine D, Booker D, Unwin M and Snelder T (2010) Analysis of national river water quality data for the period 1998-2007. NIWA Client Report No.: CHC2010-038 for Ministry for the Environment

3. Ballantine D (2012) Water quality trend analysis for the Land and Water New Zealand website (LAWNZ). Report No. HAM12-080 prepared for the Ministry for the Environment by NIWA, Hamilton.

4. Basher, LR, Hicks, DM, Clapp, B, Hewitt, T (2011). *Sediment yield response to large storm events and forest harvesting, Motueka River, New Zealand*. New Zealand Journal of Marine and Freshwater Research, 45(3), 333–356.

5. CCME (2001) *Canadian water quality guidelines for the protection of aquatic life: DDME Water Quality Index 1.0, Technical Report*. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment.

6. CCME Water Quality Steering Committee (2004) *CCME National Water Quality Index Workshop Proceedings*. Canadian Council of Ministers of the Environment.

7. Duncan MJ (1987) *River hydrology and sediment transport*. In Viner A. B. (ed.) Inland Waters of New Zealand. DSIR Bulletin 241, Wellington (Chapter 4) 113-137.

8. Fahey, B, & Marden, M In Eyles G, Fahey B (Eds.) (2006). *Forestry effects on sediment yield and erosion. The Pakuratahi land use study*. Hawke's Bay Regional Council, Napier, New Zealand.

9. Gartner Lee Ltd (2006) *A sensitivity Analysis of the Canadian Water Quality Index*. Canadian Council of Ministers of the Environment.

10. Green S, Agnew R and Greven M (2014) *Monitoring nitrate loss under vineyard soils on the Wairau Plains, Marlborough*. Report prepared by Plant and Food Research for Marlborough District Council.

11. Lilburne L, Webb T, Robson M and Watkins N (2013) *Estimating nitrate-nitrogen leaching rates under rural land uses in Canterbury (updated)*. Environment Canterbury Report No R14/19.

12. McBride GB (2005) *Using Statistical Methods for Water Quality Management: Issues, Problems and Solutions*. John Wiley & Sons Inc.

13. MDC (2013) *Investigation into High E. coli concentrations in the Taylor River during low flow.* Marlborough District Council.

14. MDC (2013) *State of the Environment Surface Water Quality Monitoring Report 2013*. Marlborough District Council Technical Report No: 13-011.

15. MDC (2014) *State of the Environment Surface Water Quality Monitoring Report 2014*. Marlborough District Council Technical Report No: 14-006.

16. MDC (2015a) *Taylor River Catchment Characterisation – Doctors Creek*. Marlborough District Council Technical Report No: 15-001.

17. MDC (2015b) *Water Quality in the Are Are Creek Catchment*. Marlborough District Council Technical Report No: 15-004.

18. MDC (2016) *Recreational Water Quality Report 2015-2016*. Marlborough District Council Technical Report No: 16-003.

19. Monaghan RM, Semadeni-Davies A, Muirhead RW, Elliott S and Shankar U (2010) *Land use and land management risks to water quality in Southland*. Report prepared for Environment Southland.

20. New Zealand Government (2014) *National Policy Statement for Freshwater Management 2014.*

21. Osmond DL, Gilliam JW and Evans RO (2002) *Riparian Buffers and Controlled Drainage to Reduce Agricultural Nonpoint Source Pollution*. North Carolina Agricultural Research Service Technical Bulletin 318, North Carolina State University, Raleigh, NC.

22. Palliser C and Elliott S (2013) *Water Quality Modelling for the Southland Region*. Report prepared by NIWA for Ministry for the Environment. Report No: HAM2013-021

23. Parkyn S (2004) *Review of Riparian Buffer Zone Effectiveness*. MAF Technical Paper No: 2004/05. Prepared for MAF Policy by NIWA

24. Smith DG, McBride GB, Bryers GG, Wisse J and Mink DFJ (1996) Trends in New Zealand's National River Water Quality Network. New Zealand Journal of Marine and Freshwater Research. Vol.30(4):485-500.

25. Stark JD (2008) *Trends in river health of the Manawatu-Wanganui region 2008 with comments on the* SoE biomonitoring programme. Stark Environmental Report: 2008-07 prepared for Horizons Regional Council.

26. Wilcock B, Biggs B, Death R, Hickey C, Larned S and Quinn J (2007) *Limiting nutrients for controlling undesirable periphyton growth*. NIWA Client Report No: HAM2007-006 for Horizons Regional Council

6. Appendices

6.1. 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.

6.2. Site Information

Report Region	Site Name				Catchment Size [km²]		Flow
	Short Name	Database (Hilltop) Name	Easting	Northing	Sampling Site	Water Management Unit	at site, (simulated or nearby)
Marlborough Sounds	Waitohi Rv	Waitohi River at State Highway One	2594144	5989933	15.0	17.9	(✓)
	Kenepuru Rv	Kenepuru River at Kenepuru Head	2604300	6003929	29.8	29.8	✓
	Kaituna Rv	Kaituna River at Higgins Bridge	2574884	5988168	135.6	146.9	✓
	Graham Rv	Graham River at Road Bridge	2599962	5992336	17.0	18.2	✓
	Cullens Ck	Cullens Creek at Road Bridge	2581811	5989883	20.5	20.7	(✓)
	Linkwater Stm	Duncan Stream at Outlet	2585561	5991258	9.3	10.3	(✓)
Te Hoiere/Pelorus catchment	Upper Pelorus	Pelorus River at Kahikatea Flat	2557587	5989317	378.1	378.1	✓
	Wakamarina Rv	Wakamarina River at SH6	2566016	5990425	187.7	187.7	✗
	Lower Pelorus	Pelorus River at Fishermans Flat	2569576	5991721	862.4	1003.8	(✓)
	Opouri Rv	Opouri River at Tunakino Valley Road	2562207	5999209	103.4	106.9	(✓)
	Rai Rv	Rai River at Rai Falls	2558020	5990970	209.9	211.3	✓
	Ronga Rv	Ronga River at Upstream Rai River	2559969	5999418	32.7	32.7	(✓)
Upper and Mid Wairau	Goulter River	Goulter River at Horseshoe Bend	1615687	5390226	146.0	159.1	✗
	Branch Rv	Branch River at Weir Intake	2525306	5944887	550.7	563.5	✓
	Upper Wairau	Wairau River at Dip Flat	2503477	5923767	517.9	797.4	✓
	Mill Ck	Mill Creek at Ormonds	2552750	5960325	19.8	21.5	✓
	Mid Waihopai	Waihopai River at Craiglochart	2567405	5953749	737.8	737.8	✓
	Lower Waihopai	Waihopai River at SH63 Bridge	2571094	5964027	769.8	769.8	(✓)

Report Region	Site Name				Catchment Size [km²]		Flow
	Short Name	Database (Hilltop) Name	Easting	Northing	Sampling Site	Water Management Unit	at site, (simulated or nearby)
Lower Wairau	Ohinemahuta Rv	Onamalutu River at Northbank Road	2575229	5969594	70.4	72.0	✗
	Lower Wairau	Wairau River at Tuamarina	2590635	5973743	4414.8	4414.8	✓
	Spring Ck	Spring Creek at Wairau River Floodgates	2591064	5973037	13.9	13.9	✗
	Are Are Ck	Are Are Creek at Kaituna Tuamarina Road	2578900	5970850	31.4	32.4	✓
	Wairau Diversion	Wairau Diversion at Neals Road	2594060	5973353	4537.3	4537.3	(✓)
	Tuamarina Rv	Tuamarina River at State Highway One	2590600	5973846	101.8	101.8	(✓)
Ōpaoa Complex	Murphys Ck	Murphys Creek at Nelson Street	2588597	5966040	2.6	2.6	✗
	Lower Ōpaoa	Opawa River at Swamp Road	2594901	5965020	447.3	448.2	(✓)
	Omaka Rv	Omaka River at Hawkesbury Road Bridge	2578160	5964570	119.1	119.1	(✓)
	Mid Ōpaoa	Opawa River at Hammerichs Road	2585909	5968470	292.9	292.9	(✓)
	Taylor Rv	Taylor River at Rail Bridge	2590161	5965648	86.9	86.9	(✓)
	Doctors Ck	Doctors Creek Upstream Taylor	2588550	5965400	54.5	54.5	✗
South Marlborough	Black Birch Stm	Black Birch Stream at Awatere Intake	2583282	5944040	29.9	33.5	✗
	Waima Rv	Waima (Ure) River at SH1 Bridge	2602200	5922200	158.1	158.1	✗
	Flaxbourne Rv	Flaxbourne River at Quarry	2607501	5929727	150.6	154.1	(✓)
	Mid Awatere	Awatere River at Awapiri	2570719	5929995	895.6	1041.4	✓
	Lower Awatere	Awatere River at River Mouth	2605963	5954796	1432.5	1432.5	(✓)

6.3. Land Cover

			Native Forest, Shrub and Tussock	Rock and Gravels	Production Forest	Other Exotic Forest and Shrub	Low Production Pasture	Improved Pasture	Vinyard/ Orchard/ Crop	Residential	Other	TOTAL
Marlborough Sounds	Waitohi Rv	Area [km^2]	14.3	0.0	0.0	0.1	0.0	0.0	0.0	0.6	0.0	15.0
		% cover	95.4	0.0	0.3	0.4	0.0	0.0	0.0	3.8	0.1	100.0
	Kenepuru Stm	Area [km^2]	19.8	0.0	4.5	0.4	0.0	5.0	0.0	0.0	0.1	29.8
		% cover	66.3	0.0	15.0	1.5	0.0	16.9	0.0	0.0	0.3	100.0
	Kaituna Rv	Area [km^2]	62.7	0.3	28.3	2.1	40.2	1.4	0.4	0.0	0.1	135.6
		% cover	46.3	0.3	20.8	1.5	29.7	1.1	0.3	0.0	0.1	100.0
	Graham Rv	Area [km^2]	16.3	0.0	1.4	0.0	0.0	0.5	0.0	0.0	0.0	18.2
		% cover	89.3	0.0	7.7	0.0	0.0	3.0	0.0	0.0	0.0	100.0
	Cullens Ck	Area [km^2]	11.4	0.0	6.1	0.2	0.1	1.7	0.0	0.0	0.0	19.5
		% cover	58.4	0.0	31.4	1.2	0.3	8.7	0.0	0.0	0.0	100.0
	Linkwater Stm (Duncan Stm)	Area [km^2]	3.2	0.0	3.5	0.0	0.0	2.6	0.0	0.0	0.0	9.2
		% cover	34.4	0.0	37.6	0.0	0.0	28.0	0.0	0.0	0.0	100.0
Te Hoiere/Pelorus	Upper Pelorus	Area [km^2]	348.4	2.6	17.8	1.8	1.0	4.6	0.0	0.0	0.4	376.6
		% cover	92.5	0.7	4.7	0.5	0.3	1.2	0.0	0.0	0.1	100.0
	Wakamarina Rv	Area [km^2]	159.4	0.5	21.4	0.8	0.4	4.8	0.0	0.0	0.4	187.7
		% cover	84.9	0.3	11.4	0.4	0.2	2.5	0.0	0.0	0.2	100.0
	Lower Pelorus	Area [km^2]	669.4	3.9	98.1	8.9	2.4	72.5	0.0	0.0	1.8	857.5
		% cover	78.1	0.5	11.4	1.0	0.3	8.5	0.0	0.0	0.2	100.0
	Opouri Rv	Area [km^2]	46.5	0.2	10.2	0.7		12.5	0.0	0.0	0.0	70.3
		% cover	66.2	0.3	14.6	1.1		17.8	0.0	0.0	0.0	100.0
	Rai Rv	Area [km^2]	123.4	0.5	35.3	5.1	0.2	46.4	0.0	0.0	0.1	211.0
		% cover	58.5	0.2	16.7	2.4	0.1	22.0	0.0	0.0	0.0	100.0
	Ronga Rv	Area [km^2]	21.1	0.0	3.2	0.4	0.1	7.8	0.0	0.0	0.0	32.7
		% cover	64.6	0.0	9.9	1.3	0.2	23.9	0.0	0.0	0.0	100.0

			Native Forest, Shrub and Tussock	Rock and Gravels	Production Forest	Other Exotic Forest and Shrub	Low Production Pasture	Improved Pasture	Vinyard/ Orchard/ Crop	Residential	Other	TOTAL
Upper and Mid Wairau	Goulter Rv	Area [km^2]	140.7	3.1	1.0	0.0	0.0	0.0	0.0	0.0	1.2	146.0
		% cover	96.4	2.1	0.7	0.0	0.0	0.0	0.0	0.0	0.8	100.0
	Branch Rv	Area [km^2]	451.8	30.7	42.2	1.4	20.7	0.5	0.0	0.0	3.6	551.0
		% cover	82.0	5.6	7.7	0.3	3.8	0.1	0.0	0.0	0.7	100.0
	Upper Wairau	Area [km^2]	375.1	98.7	0.0	0.0	34.5	5.5	3.9	0.0	3.9	517.8
		% cover	72.4	19.1	0.0	0.0	6.7	1.1	0.8	0.0	0.8	100.0
	Mill Ck	Area [km^2]	0.3	0.1	0.5	0.1	0.0	18.7	0.1	0.0	0.0	19.8
		% cover	1.5	0.4	2.6	0.3	0.0	94.6	0.6	0.0	0.0	100.0
	Mid Waihopai	Area [km^2]	386.7	47.0	61.9	7.4	87.8	139.5	0.0	0.0	1.0	731.4
		% cover	52.9	6.4	8.5	1.0	12.0	19.1	0.0	0.0	0.1	100.0
	Lower Waihopai	Area [km^2]	2.0	1.6	2.6	3.0	1.3	21.5	5.6	0.0	0.9	38.4
		% cover	5.1	4.1	6.7	7.8	3.3	56.1	14.6	0.0	2.3	100.0
Lower Wairau	Ohinemahuta Rv	Area [km^2]	29.4	0.0	33.9	0.5	0.5	6.1	0.0	0.0	0.0	70.4
		% cover	41.8	0.1	48.1	0.7	0.8	8.6	0.0	0.0	0.0	100.0
	Lower Wairau	Area [km^2]	1871.1	240.1	341.6	35.4	256.7	386.7	30.4	0.3	24.5	3186.8
		% cover	58.7	7.5	10.7	1.1	8.1	12.1	1.0	0.0	0.8	100.0
	Spring Ck	Area [km^2]	0.0	0.0	0.0	0.1	0.0	1.8	11.6	0.3	0.1	13.9
		% cover	0.0	0.0	0.0	0.7	0.0	12.8	83.6	2.4	0.5	100.0
	Are Are Creek	Area [km^2]	5.5	0.0	14.8	0.4	8.3	0.3	1.9	0.1	0.0	31.4
		% cover	17.6	0.1	47.0	1.4	26.3	1.0	6.2	0.3	0.0	100.0
	Wairau Diversion	Area [km^2]	1871.1	240.3	341.6	35.5	256.7	387.0	30.7	0.3	24.9	3188.0
		% cover	58.7	7.5	10.7	1.1	8.1	12.1	1.0	0.0	0.8	100.0
	Tuamarina Rv	Area [km^2]	39.5	0.0	37.4	3.5	0.6	18.2	1.7	0.2	0.7	101.8
		% cover	38.8	0.0	36.8	3.5	0.6	17.9	1.7	0.2	0.7	100.0

			Native Forest, Shrub and Tussock	Rock and Gravels	Production Forest	Other Exotic Forest and Shrub	Low Production Pasture	Improved Pasture	Vinyard/ Orchard/ Crop	Residential	Other	TOTAL
Ōpaoa Complex	Murphys Ck	Area [km^2]	0.0	0.0	0.0	0.0	0.0	0.0	1.5	1.2	0.0	2.6
		% cover	0.0	0.0	0.0	0.0	0.0	0.6	55.1	44.3	0.0	100.0
	Lower Ōpaoa	Area [km^2]	98.1	1.0	18.5	8.0	21.8	179.8	111.9	12.6	1.1	452.6
		% cover	21.7	0.2	4.1	1.8	4.8	39.7	24.7	2.8	0.2	100.0
	Omaka Rv	Area [km^2]	63.8	0.4	1.9	3.9	10.3	32.7	5.4	0.0	0.1	118.5
		% cover	53.9	0.4	1.6	3.3	8.7	27.6	4.5	0.0	0.1	100.0
	Mid Ōpaoa	Area [km^2]	71.8	0.7	7.8	6.8	12.1	112.0	77.7	3.4	0.6	292.9
		% cover	24.5	0.2	2.7	2.3	4.1	38.2	26.5	1.2	0.2	100.0
	Taylor Rv	Area [km^2]	26.3	0.2	10.6	1.2	9.6	64.3	27.1	7.1	0.2	146.7
		% cover	18.0	0.2	7.2	0.8	6.6	43.8	18.4	4.9	0.1	100.0
	Doctors Ck	Area [km^2]	2.0	0.0	0.1	0.0	0.0	26.5	24.7	1.1	0.0	54.5
		% cover	3.6	0.0	0.2	0.1	0.0	48.7	45.4	2.0	0.1	100.0
South Marlborough	Black Birch Stm	Area [km^2]	26.7	1.1	0.0	0.0	1.1	1.1	0.0	0.0	0.0	29.9
		% cover	89.3	3.5	0.0	0.0	3.5	3.6	0.0	0.0	0.0	100.0
	Waima Rv	Area [km^2]	73.5	3.4	0.4	0.0	56.7	20.8	0.7	0.0	2.5	158.2
		% cover	46.5	2.2	0.3	0.0	35.8	13.2	0.5	0.0	1.6	100.0
	Flaxbourne Rv	Area [km^2]	18.1	0.1	0.3	0.2	22.8	61.3	0.6	0.0	0.7	104.1
		% cover	17.4	0.1	0.3	0.2	22.0	58.9	0.6	0.0	0.7	100.0
	Mid Awatere	Area [km^2]	287.3	202.7	0.7	2.9	308.1	180.6	0.0	0.0	1.4	983.8
		% cover	29.2	20.6	0.1	0.3	31.3	18.4		0.0	0.1	100.0
	Lower Awatere	Area [km^2]	466.9	223.2	13.2	7.1	368.4	434.6	53.1	0.8	5.5	1572.7
		% cover	29.7	14.2	0.8	0.4	23.4	27.6	3.4	0.1	0.3	100.0

6.4. Laboratory Analysis

	Feb 2007 - Jul 2011 **Environmental Laboratories Services (ELS) Ltd**		Since Aug 2011 **Hill Laboratories Ltd.**	
Parameter	Method Description	Detection Limit	Method Description	Detection Limit
Turbidity	Analysis using a Turbidity meter. APHA 2130 B 21st ed. 2005	0.01 NTU	Analysis using a Hach 2100 Turbidity meter. APHA 2130 B 21st ed. 2005	0.05 NTU
Nitrate Nitrogen	Ion Chromatography following USEPA 300.0 (modified)	0.010 mg/L	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	Flow Injection Autoanalyser following APHA 4500 NH3 H 21st ed. 2005	0.010 mg/L	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
Soluble Inorganic Nitrogen	Calculation NH_4-N + NO_3-N + NO_2-N	0.010 mg/L	Calculation NH_4-N + NO_3-N + NO_2-N	0.010 mg/L
Dissolved Reactive Phosphorus	Flow Injection Autoanalyser following APHA 4500-P G 21st ed. 2005	0.005 mg/L	Filtered sample. Molybdenum blue colorimetry. Discrete Analyser. APHA 4500-P E (modified from manual analysis) 21st ed. 2005	0.004 mg/L
pH	pH meter. APHA 4500-H^+ B 21st ed. 2005	0.1	pH meter. APHA 4500-H^+ B 21st ed. 2005	0.1
E. coli	APHA 9222G 21st ed. 2005	1 cfu/100mL	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
Total Arsenic	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 21st ed. 2005/US EPA 200.8	0.002 mg/L	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 21st ed. 2005/US EPA 200.8	0.0011 mg/L
Total Copper	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 21st ed. 2005/US EPA 200.8	0.002 mg/L	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 21st ed. 2005/US EPA 200.8	0.00053 mg/L
Total Zinc	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 21st ed. 2005/US EPA 200.8	0.005 mg/L	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 21st ed. 2005/US EPA 200.8	0.0011 mg/L
Filtration	Sample filtration through 0.45µm membrane filter		Sample filtration through 0.45µm membrane filter	

6.5. Summary Statistics

Turbidity [NTU]

Report Region	Short Site Name	Number of Samples	Minimum	25th Percentile	Median	75th Percentile	Maximum
Marlborough Sounds	Waitohi Rv	36	0.4	0.7	1.2	1.9	75.0
	Kenepuru Rv	36	0.3	0.5	0.8	1.6	4.8
	Kaituna Rv	36	0.2	0.4	0.6	1.0	22.0
	Graham Rv	36	0.2	0.5	0.7	1.6	330.0
	Cullen Ck	36	0.2	0.6	0.8	2.1	62.0
	Linkwater Stm	36	0.3	1.2	1.7	3.0	49.0
Te Hoiere/ Pelorus catchment	Upper Pelorus	36	0.1	0.2	0.4	1.1	119.0
	Wakamarina Rv	36	0.2	0.3	0.4	0.7	76.0
	Lower Pelorus	35	0.2	0.3	0.5	1.0	114.0
	Opouri Rv	35	0.2	0.3	0.4	0.8	52.0
	Rai Rv	36	0.3	0.5	0.7	1.1	98.0
	Ronga Rv	35	0.1	0.4	0.6	1.2	66.0
Upper and Mid Wairau	Goulter Rv	27	0.0	0.2	0.3	0.5	2.1
	Branch Rv	35	0.4	0.8	1.1	9.0	480.0
	Upper Wairau	36	0.3	0.8	1.6	6.6	680.0
	Mill Ck	35	1.0	1.5	2.1	2.5	11.6
	Mid Waihopai	36	0.6	1.4	3.5	25.5	1340.0
	Lower Waihopai	36	0.7	1.2	3.2	22.2	1300.0
Lower Wairau	Ohinemahuta Rv	36	0.4	0.6	1.0	2.2	45.0
	Lower Wairau	36	0.5	1.0	1.3	7.8	326.0
	Spring Ck	35	0.2	0.6	0.7	1.1	12.6
	Are Are Ck	36	0.5	1.3	2.1	4.0	48.0
	Wairau Div	32	1.4	3.1	7.4	17.5	3400.0
	Tuamarina Rv	35	0.7	1.4	2.3	3.8	2200.0
Ōpaoa Complex	Murphys Ck	35	0.1	0.4	0.6	1.7	5.4
	Lower Opaoa	35	0.9	1.3	1.9	2.8	250.0
	Omaka Rv	35	0.2	0.3	0.5	0.9	4.3
	Mid Opaoa	35	1.7	3.4	5.9	17.7	470.0
	Taylor Rv	35	0.7	1.4	2.5	4.5	280.0
	Doctors Ck	35	1.8	3.7	4.6	8.7	210.0
South Marlborough	Black Birch Stm	24	0.1	0.2	0.2	0.4	37.0
	Waima Rv	27	0.2	0.4	0.6	1.3	67.0
	Flaxbourne Rv	30	0.3	0.8	1.5	2.9	70.0
	Mid Awatere	36	1.4	10.5	64.0	210.0	2800.0
	Lower Awatere	36	1.7	6.8	32.5	109.0	2700.0

E. coli [cfu/100mL]

Report Region	Short Site Name	Number of Samples	Minimum	25th Percentile	Median	75th Percentile	Maximum
Marlborough Sounds	Waitohi Rv	36	12	50	95	250	1700
	Kenepuru Rv	36	40	115	150	360	3100
	Kaituna Rv	36	5	70	150	320	1300
	Graham Rv	36	2	22	60	100	4500
	Cullen Ck	36	33	70	260	1000	23000
	Linkwater Stm	36	7	45	190	310	4800
Te Hoiere/ Pelorus catchment	Upper Pelorus	36	0	10	18	32	700
	Wakamarina Rv	36	4	14	27	78	1000
	Lower Pelorus	35	7	17	26	60	3000
	Opouri Rv	36	14	38	65	140	3100
	Rai Rv	36	11	39	59	145	6300
	Ronga Rv	35	21	40	110	230	2300
Upper and Mid Wairau	Goulter Rv	27	0	2	3	8	180
	Branch Rv	34	0	1	4	9	210
	Upper Wairau	36	0	2	4	13	987
	Mill Ck	34	7	100	145	370	1900
	Mid Waihopai	36	2	14	52	110	1700
	Lower Waihopai	36	0	5	18	50	2800
Lower Wairau	Ohinemahuta Rv	36	5	27	65	125	1200
	Lower Wairau	36	0	1	6	43	548
	Spring Ck	35	26	61	110	150	10000
	Are Are Ck	36	0	115	230	550	6000
	Wairau Div	32	0	49	65	270	2900
	Tuamarina Rv	35	13	30	70	230	5200
Ōpaoa Complex	Murphys Ck	35	14	31	80	210	1000
	Lower Opaoa	35	15	26	40	80	1800
	Omaka Rv	35	0	3	12	23	10000
	Mid Opaoa	35	30	61	130	220	1700
	Taylor Rv	35	40	140	200	270	5200
	Doctors Ck	35	80	250	330	500	14000
South Marlborough	Black Birch Stm	32	0	0	0	2	13
	Waima Rv	27	0	4	25	90	600
	Flaxbourne Rv	29	31	80	150	270	2800
	Mid Awatere	36	1	8	20	47	4000
	Lower Awatere	35	0	6	30	70	2100

Soluble Inorganic Nitrogen [mg/L]

Report Region	Short Site Name	Number of Samples	Minimum	25th Percentile	Median	75th Percentile	Maximum
Marlborough Sounds	Waitohi Rv	36	0.004	0.012	0.025	0.040	0.080
	Kenepuru Rv	36	0.017	0.064	0.128	0.206	0.343
	Kaituna Rv	36	0.233	0.598	0.798	1.073	1.483
	Graham Rv	36	0.006	0.031	0.036	0.064	0.303
	Cullen Ck	36	0.121	0.197	0.283	0.368	0.643
	Linkwater Stm	36	0.004	0.388	0.445	0.556	0.945
Te Hoiere/ Pelorus catchment	Upper Pelorus	36	0.004	0.007	0.027	0.045	0.084
	Wakamarina Rv	36	0.004	0.014	0.029	0.047	0.084
	Lower Pelorus	35	0.095	0.172	0.233	0.323	0.523
	Opouri Rv	36	0.003	0.388	0.499	0.593	0.963
	Rai Rv	36	0.243	0.509	0.640	0.773	1.123
	Ronga Rv	36	0.000	0.633	0.733	0.883	1.053
Upper and Mid Wairau	Goulter Rv	27	0.004	0.007	0.008	0.017	0.031
	Branch Rv	35	0.004	0.008	0.019	0.044	0.069
	Upper Wairau	36	0.004	0.007	0.015	0.032	0.102
	Mill Ck	35	0.523	0.953	1.403	1.753	2.115
	Mid Waihopai	36	0.004	0.007	0.056	0.231	0.443
	Lower Waihopai	36	0.004	0.017	0.058	0.222	0.463
Lower Wairau	Ohinemahuta Rv	36	0.049	0.112	0.189	0.273	0.363
	Lower Wairau	36	0.007	0.024	0.065	0.160	0.300
	Spring Ck	35	0.003	0.123	0.173	0.243	0.470
	Are Are Ck	36	0.152	0.595	0.713	0.848	1.051
	Wairau Div	32	0.004	0.061	0.150	0.246	0.666
	Tuamarina Rv	35	0.004	0.064	0.353	0.603	0.937
Ōpaoa Complex	Murphys Ck	35	0.003	0.873	0.983	1.073	1.303
	Lower Opaoa	35	0.003	0.383	0.513	0.633	0.783
	Omaka Rv	35	0.004	0.071	0.108	0.303	0.613
	Mid Opaoa	35	0.003	0.004	0.041	0.191	0.750
	Taylor Rv	35	0.482	0.746	0.833	0.913	0.970
	Doctors Ck	35	0.473	0.668	0.743	0.968	1.208
South Marlborough	Black Birch Stm	33	0.011	0.019	0.022	0.026	0.095
	Waima Rv	27	0.004	0.054	0.112	0.181	0.483
	Flaxbourne Rv	30	0.004	0.018	0.052	0.108	0.582
	Mid Awatere	36	0.003	0.004	0.021	0.044	0.130
	Lower Awatere	36	0.004	0.004	0.027	0.083	0.253

Dissolved Reactive Phosphorus [mg/L]

Report Region	Short Site Name	Number of Samples	Minimum	25th Percentile	Median	75th Percentile	Maximum
Marlborough Sounds	Waitohi Rv	36	0.002	0.006	0.009	0.011	0.015
	Kenepuru Rv	36	0.002	0.005	0.007	0.008	0.016
	Kaituna Rv	36	0.002	0.005	0.009	0.011	0.014
	Graham Rv	35	0.002	0.009	0.011	0.012	0.017
	Cullen Ck	36	0.002	0.012	0.013	0.016	0.090
	Linkwater Stm	36	0.002	0.013	0.014	0.017	0.038
Te Hoiere/ Pelorus catchment	Upper Pelorus	36	0.002	0.004	0.006	0.007	0.009
	Wakamarina Rv	36	0.002	0.008	0.009	0.009	0.010
	Lower Pelorus	35	0.002	0.002	0.004	0.007	0.013
	Opouri Rv	36	0.004	0.008	0.008	0.009	0.018
	Rai Rv	36	0.002	0.002	0.005	0.007	0.032
	Ronga Rv	35	0.004	0.007	0.007	0.008	0.021
Upper and Mid Wairau	Goulter Rv	27	0.004	0.005	0.006	0.007	0.007
	Branch Rv	35	0.004	0.005	0.006	0.007	0.018
	Upper Wairau	36	0.002	0.002	0.004	0.005	0.009
	Mill Ck	35	0.009	0.011	0.012	0.014	0.021
	Mid Waihopai	36	0.002	0.006	0.008	0.010	0.016
	Lower Waihopai	36	0.002	0.002	0.006	0.009	0.033
Lower Wairau	Ohinemahuta Rv	36	0.002	0.004	0.006	0.007	0.009
	Lower Wairau	36	0.002	0.002	0.002	0.006	0.011
	Spring Ck	35	0.002	0.009	0.011	0.012	0.064
	Are Are Ck	36	0.002	0.008	0.013	0.018	0.027
	Wairau Div	32	0.002	0.008	0.014	0.018	0.028
	Tuamarina Rv	35	0.007	0.012	0.020	0.022	0.048
Ōpaoa Complex	Murphys Ck	35	0.007	0.009	0.010	0.011	0.018
	Lower Opaoa	35	0.004	0.011	0.013	0.015	0.032
	Omaka Rv	35	0.002	0.002	0.004	0.005	0.020
	Mid Opaoa	35	0.002	0.002	0.002	0.006	0.026
	Taylor Rv	35	0.004	0.010	0.013	0.016	0.048
	Doctors Ck	34	0.014	0.017	0.021	0.025	0.184
South Marlborough	Black Birch Stm	27	0.008	0.012	0.013	0.015	0.027
	Waima Rv	27	0.002	0.002	0.004	0.005	0.026
	Flaxbourne Rv	30	0.002	0.004	0.008	0.013	0.030
	Mid Awatere	36	0.002	0.007	0.008	0.010	0.036
	Lower Awatere	36	0.002	0.005	0.007	0.011	0.018

pH

Report Region	Short Site Name	Number of Samples	Minimum	25th Percentile	Median	75th Percentile	Maximum
Marlborough Sounds	Waitohi Rv	36	7.0	7.5	7.6	7.8	8.1
	Kenepuru Rv	36	6.9	7.1	7.2	7.2	7.5
	Kaituna Rv	36	6.9	7.1	7.2	7.3	7.5
	Graham Rv	36	6.8	7.2	7.3	7.4	7.6
	Cullen Ck	36	6.8	7.0	7.1	7.2	7.3
	Linkwater Stm	36	6.5	6.8	6.9	7.0	7.1
Te Hoiere/ Pelorus catchment	Upper Pelorus	36	6.9	7.4	7.6	7.6	7.8
	Wakamarina Rv	36	6.8	7.2	7.3	7.4	7.5
	Lower Pelorus	35	6.9	7.4	7.4	7.5	7.6
	Opouri Rv	35	6.9	7.1	7.2	7.2	7.4
	Rai Rv	36	6.8	7.2	7.3	7.3	7.5
	Ronga Rv	35	6.6	6.9	7.0	7.1	7.4
Upper and Mid Wairau	Goulter Rv	27	7.2	7.4	7.5	7.6	7.8
	Branch Rv	35	7.2	7.3	7.5	7.6	7.7
	Upper Wairau	36	7.3	7.6	7.7	7.8	8.2
	Mill Ck	34	7.1	7.2	7.4	7.5	7.6
	Mid Waihopai	36	7.3	7.5	7.6	7.7	7.9
	Lower Waihopai	36	6.7	7.5	7.6	7.7	8.5
Lower Wairau	Ohinemahuta Rv	36	7.0	7.2	7.2	7.3	7.5
	Lower Wairau	36	7.3	7.5	7.7	7.9	8.4
	Spring Ck	35	7.2	7.3	7.3	7.4	7.6
	Are Are Ck	36	7.0	7.3	7.4	7.4	7.6
	Wairau Div	32	7.0	7.4	7.5	7.5	7.7
	Tuamarina Rv	35	6.9	7.3	7.4	7.5	7.9
Ōpaoa Complex	Murphys Ck	35	7.0	7.0	7.1	7.2	7.6
	Lower Opaoa	35	7.3	7.5	7.6	7.7	7.8
	Omaka Rv	35	7.3	7.6	7.7	7.8	7.9
	Mid Opaoa	35	7.2	7.5	7.7	7.7	8.3
	Taylor Rv	35	7.1	7.3	7.4	7.4	7.8
	Doctors Ck	35	7.2	7.4	7.5	7.6	7.9
South Marlborough	Black Birch Stm	24	6.9	7.2	7.3	7.4	7.7
	Waima Rv	27	7.1	8.1	8.2	8.2	8.4
	Flaxbourne Rv	30	7.3	8.0	8.0	8.1	8.4
	Mid Awatere	36	7.6	7.8	7.8	7.9	8.1
	Lower Awatere	36	7.8	7.9	8.0	8.0	8.7

Dissolved Oxygen Saturation [%]

Report Region	Short Site Name	Number of Samples	Minimum	25th Percentile	Median	75th Percentile	Maximum
Marlborough Sounds	Waitohi Rv	35	93.0	102.1	108.0	114.5	158.7
	Kenepuru Rv	34	32.8	97.0	101.5	104.7	116.2
	Kaituna Rv	35	90.7	96.0	99.4	105.4	151.5
	Graham Rv	34	77.3	97.1	101.6	105.3	119.8
	Cullen Ck	35	65.2	94.5	98.1	104.0	116.7
	Linkwater Stm	35	36.6	82.9	91.6	97.7	103.8
Te Hoiere/ Pelorus catchment	Upper Pelorus	32	74.5	98.0	104.4	107.7	122.3
	Wakamarina Rv	33	83.4	97.3	103.7	108.8	122.3
	Lower Pelorus	33	80.2	92.6	99.5	103.7	146.6
	Opouri Rv	34	79.5	90.4	96.8	100.2	110.7
	Rai Rv	33	82.7	97.1	101.7	105.4	115.4
	Ronga Rv	34	70.0	79.5	87.3	93.0	99.3
Upper and Mid Wairau	Goulter Rv	24	81.4	93.5	95.7	102.5	125.7
	Branch Rv	31	88.5	99.3	101.8	106.6	122.1
	Upper Wairau	35	96.6	100.4	100.7	101.0	102.7
	Mill Ck	31	79.3	90.0	96.0	103.2	111.9
	Mid Waihopai	35	90.5	99.9	101.2	105.3	117.6
	Lower Waihopai	34	94.5	99.2	101.9	106.3	125.0
Lower Wairau	Ohinemahuta Rv	35	81.8	96.0	100.1	105.7	113.7
	Lower Wairau	35	97.7	99.6	103.2	106.9	116.8
	Spring Ck	35	56.0	71.4	81.4	91.6	110.4
	Are Are Ck	36	82.0	92.8	98.4	104.7	131.6
	Wairau Div	31	26.9	81.5	87.8	93.6	112.6
	Tuamarina Rv	33	37.9	57.4	64.8	82.4	110.4
Ōpaoa Complex	Murphys Ck	33	68.9	77.7	80.9	85.7	100.4
	Lower Opaoa	33	67.5	85.6	90.5	105.4	125.1
	Omaka Rv	34	56.0	82.9	97.5	105.3	131.9
	Mid Opaoa	34	83.3	100.2	103.7	111.1	115.7
	Taylor Rv	34	67.6	80.8	91.5	100.3	123.8
	Doctors Ck	33	51.8	75.8	86.2	94.7	148.7
South Marlborough	Black Birch Stm	0					
	Waima Rv	25	78.3	97.5	101.5	108.1	118.6
	Flaxbourne Rv	28	70.9	94.4	104.2	121.5	204.2
	Mid Awatere	35	84.2	95.4	101.0	104.0	112.2
	Lower Awatere	35	85.0	99.4	105.4	109.3	128.3

Water Temperature [°C]

Report Region	Short Site Name	Number of Samples	Minimum	25th Percentile	Median	75th Percentile	Maximum
Marlborough Sounds	Waitohi Rv	36	7.7	10.9	12.5	16.3	25.9
	Kenepuru Rv	36	7.5	10.3	11.4	13.6	17.8
	Kaituna Rv	36	4.5	10.9	13.2	15.8	19.0
	Graham Rv	36	8.7	12.2	14.0	17.4	19.3
	Cullen Ck	36	6.4	10.1	12.1	13.4	15.8
	Linkwater Stm	36	7.0	11.4	12.9	13.9	15.8
Te Hoiere/ Pelorus catchment	Upper Pelorus	35	4.5	9.2	12.8	17.0	20.3
	Wakamarina Rv	36	5.3	9.3	12.8	15.6	23.6
	Lower Pelorus	35	6.0	10.2	13.2	17.1	20.1
	Opouri Rv	36	9.0	11.3	12.8	14.5	17.5
	Rai Rv	36	8.2	10.8	13.5	16.0	18.0
	Ronga Rv	36	8.9	11.4	13.2	15.2	16.4
Upper and Mid Wairau	Goulter Rv	26	5.4	7.5	9.6	14.2	18.2
	Branch Rv	33	2.2	6.8	9.1	12.8	18.0
	Upper Wairau	35	2.3	5.9	7.8	11.2	17.6
	Mill Ck	33	9.5	11.6	12.6	14.6	16.9
	Mid Waihopai	36	2.4	7.5	11.5	16.3	19.8
	Lower Waihopai	35	5.6	8.8	13.7	19.4	23.3
Lower Wairau	Ohinemahuta Rv	35	8.1	9.8	13.8	16.2	19.4
	Lower Wairau	36	7.0	10.7	14.6	19.3	22.6
	Spring Ck	35	12.3	12.9	13.3	14.1	14.9
	Are Are Ck	36	7.8	10.9	12.5	14.2	17.4
	Wairau Div	32	7.6	10.6	12.7	16.8	19.3
	Tuamarina Rv	34	7.4	10.8	14.2	16.4	19.1
Ōpaoa Complex	Murphys Ck	34	13.2	13.4	13.7	14.2	14.6
	Lower Opaoa	34	10.1	12.4	14.9	16.9	20.7
	Omaka Rv	34	8.1	12.1	16.1	18.9	22.8
	Mid Opaoa	35	5.4	9.6	13.8	17.5	21.0
	Taylor Rv	35	10.8	12.8	14.1	15.2	16.9
	Doctors Ck	34	10.8	12.2	13.3	14.9	18.0
South Marlborough	Black Birch Stm	0					
	Waima Rv	25	6.8	11.0	13.5	16.2	20.7
	Flaxbourne Rv	29	5.7	10.1	14.0	16.7	22.1
	Mid Awatere	36	0.1	6.4	10.3	14.7	22.4
	Lower Awatere	35	5.1	9.5	15.0	18.6	24.3

6.6. Water Quality Indices

Report Region	Short Site Name	Water Quality Indices						
		2007-09	2008-10	2009-11	2010-12	2011-13	2012-14	2013-15
Marlborough Sounds	Waitohi Rv		73.1	73.3	67.3	67.5	73.7	73.9
	Kenepuru Rv	67.2	67.3	73.8	67.6	67.7	74.0	73.8
	Kaituna Rv	59.2	60.7	61.7	67.6	68.6	68.3	72.4
	Graham Rv		74.0	80.5	80.6	80.6	75.6	70.6
	Cullen Ck				69.4	70.9	69.2	63.3
	Linkwater Stm		55.2	56.0	56.4	58.1	58.4	57.8
Te Hoiere/ Pelorus catchment	Upper Pelorus	80.7	80.6	80.6	80.5	80.6	80.2	86.3
	Wakamarina Rv	80.7	67.9	80.7	80.7	87.1	80.5	80.5
	Lower Pelorus		60.5	60.7	60.8	73.6	78.8	78.5
	Opouri Rv			71.5	77.5	77.6	71.3	70.7
	Rai Rv	63.0	63.5	63.2	69.1	69.2	68.5	67.9
	Ronga Rv			61.1	56.9	57.3	56.9	62.2
Upper and Mid Wairau	Branch Rv				72.6	69.1	77.8	77.0
	Upper Wairau	86.9	87.1	87.0	86.4	75.2	75.4	68.3
	Mill Ck			46.9	48.4	56.4	62.2	62.1
	Mid Waihopai		60.4	60.6	60.2	53.1	57.0	53.6
	Lower Waihopai	58.9	59.5	54.3	54.0	48.5	57.1	48.9

Report Region	Short Site Name	Water Quality Indices						
		2007-09	2008-10	2009-11	2010-12	2011-13	2012-14	2013-15
Lower Wairau	Ohinemahuta Rv	85.9	73.2	77.8	77.1	77.3	79.3	79.6
	Lower Wairau	66.1	73.1	73.6	72.3	67.3	66.5	68.0
	Spring Ck	72.4	71.8	72.2	73.2	67.2	66.8	66.7
	Are Are Ck				53.1	58.4	60.1	66.3
	Wairau Diversion		65.3	63.9	63.9	43.1	44.0	43.4
	Tuamarina Rv	58.6	57.6	58.0	63.1	46.3	45.1	41.7
Ōpaoa Complex	Murphys Ck				57.5	59.1	55.3	65.8
	Lower Ōpaoa	57.0	56.1	58.4	65.0	68.0	62.5	63.0
	Omaka Rv	66.6	60.4	66.8	66.8	60.8	60.9	61.0
	Mid Ōpaoa	57.4	62.0	64.3	64.6	64.7	61.1	58.8
	Taylor Rv	43.0	48.2	54.9	57.6	64.5	58.4	58.3
	Doctors Ck				53.4	61.1	55.0	51.0
South Marlborough	Black Birch Stm				80.7	83.3	83.3	83.3
	Waima Rv		65.1	66.1	64.8	58.3	66.3	66.1
	Flaxbourne Rv	67.1	58.0	57.9	57.3	59.2	59.3	59.5
	Mid Awatere	58.3	51.5	48.9	45.7	47.8	47.2	41.5
	Lower Awatere	49.2	50.1	46.3	44.7	44.8	39.0	38.8

6.7. Results of Trend Analysis

Only statistically significant trends (P≤0.05) are shown.

9-year Trends (2007-2015)

Turbidity [NTU]

Short Site Name	Median annual Sen slope	P	Flow adjustment	Variation explained by Flow [%]	Number of Samples	Kendall statistic	Z
Graham	0.05	0.01	No	-5.1	101	81	2.66
Wakamarina	0.02	0.04	Yes	27.0	107	67	2.01
Upper Wairau	0.1	0	Yes	38.4	101	92	3
Ohinemahuta	0.07	0	No	N/A	107	93	2.83
Spring Ck	0.03	0.02	No	N/A	105	74	2.35
mid Opaoa	0.21	0	Yes	58.0	105	96	2.97
Taylor Rv	0.14	0	Yes	94.5	105	96	2.97
Flaxbourne	0.07	0.04	Yes	11.2	98	60	2.03
Waima	0.04	0	No	-7.8	87	76	3.07

Nitrate Nitrogen [mg/L]

Short Site Name	Median annual Sen slope	P	Flow adjustment	Variation explained by Flow [%]	Number of Samples	Kendall statistic	Z
Rai	-0.01	0.02	Yes	15.3	106	-76	-2.31
Kaituna	-0.02	0.04	Yes	19.2	107	-70	-2.1
Spring Ck	-0.02	0	No	N/A	105	-140	-4.36
Wairau Div	-0.01	0.05	Yes	-11.2	99	-59	-1.97
Lower Wairau	-0.01	0.05	Yes	19.7	107	-66	-1.98
Omaka	-0.02	0	Yes	19.7	103	-118	-3.76
mid Opaoa	-0.01	0	Yes	35.7	105	-142	-4.41
Taylor	-0.11	0	No	-0.1	105	-277	-8.63
Lower Opaoa	-0.08	0	No	5.6	105	-246	-7.67

E. coli [cfu/100mL]

Short Site Name	Median annual Sen slope	P	Flow adjustment	Variation explained by Flow [%]	Number of Samples	Kendall statistic	Z
Wakamarina	2.68	0.01	Yes	14.0	106	90	2.75
Kaituna	7.06	0.02	Yes	1.2	107	76	2.29
Upper Wairau	0.25	0.03	No	1.5	99	66	2.23
Tuamarina	3.69	0.01	Yes	32.2	105	80	2.47
Mid Waihopai	2.99	0.01	Yes	0.5	101	76	2.48
Spring Ck	9.91	0	No	N/A	105	185	5.77
Wairau Div	8.67	0	No	-3.8	99	133	4.48
mid Opaoa	12.29	0	Yes	30.0	104	164	5.16
Taylor Rv	24.35	0	No	4.9	104	195	6.16
Lower Opaoa	2.09	0.05	Yes	23.6	104	64	1.99
Mid Awatere	1.17	0.01	No	-2.8	105	81	2.51
Flaxbourne	25.75	0	Yes	8.1	97	113	3.89

pH

Short Site Name	Median annual Sen slope	P	Flow adjustment	Variation explained by Flow [%]	Number of Samples	Kendall statistic	Z
Kaituna	0.04	0	Yes	12.7	107	142	4.3
Waitohi	-0.04	0	Yes	42.9	101	-90	-2.94
Rai	0.01	0.01	Yes	16.2	106	88	2.68
Ohinemahuta	0.02	0.03	No	N/A	107	74	2.22
Spring Ck	0.04	0	No	N/A	105	154	4.78
Mid Waihopai	-0.02	0.03	Yes	11.6	101	-66	-2.15
Tuamarina Rv	0.06	0	No	-1.0	105	174	5.41
Wairau Div	0.02	0	Yes	-17.1	99	99	3.32
Omaka	0.05	0	Yes	20.0	103	170	5.42
mid Opaoa	-0.08	0	No	-3.5	105	-118	-3.66
Taylor Rv	0.06	0	No	0.2	105	204	6.34
Lower Opaoa	0.03	0	No	4.8	105	142	4.41
Mid Awatere	-0.02	0	No	-0.1	105	-102	-3.16
Lower Awatere	-0.05	0	No	4.7	104	-160	-5.03

5-year Trends (2011-2015)

Turbidity [NTU]

Short Site Name	Median annual Sen slope	P	Flow adjustment	Variation explained by Flow [%]	Number of Samples	Kendall statistic	Z
Branch	0.52	0.04	Yes	-6.5	57	28	2.04
Lower Waihopai	0.94	0.01	Yes	21.1	60	40	2.76
Tuamarina	-0.27	0.01	Yes	62.7	58	-36	-2.58
mid Opaoa	0.59	0.05	Yes	54.7	58	28	1.99
Mid Awatere	8.49	0.02	Yes	16.9	58	32	2.29
Lower Awatere	5.76	0.05	Yes	15.3	58	28	1.99

Nitrate Nitrogen [mg/L]

Short Site Name	Median annual Sen slope	P	Flow adjustment	Variation explained by Flow [%]	Number of Samples	Kendall statistic	Z
Linkwater	0.04	0	Yes	12.3	60	52	3.61
Kaituna	0.05	0.02	Yes	20.0	60	34	2.33
Opouri	0.04	0	Yes	21.2	59	64	4.55
Rai	0.04	0.01	Yes	18.0	60	38	2.62
Lower Pelorus	0.02	0.04	Yes	24.4	59	30	2.09
Ohinemahuta	0.02	0	Yes	32.7	60	50	3.46
Tuamarina	0.06	0	Yes	19.4	58	56	4.05
Mid Waihopai	0.02	0	Yes	46.2	60	70	4.88
Lower Waihopai	0.01	0	Yes	48.4	60	42	2.9
Doctors	-0.08	0	Yes	14.0	57	-58	-4.3
Murphys	-0.05	0	No	-3.2	58	-54	-3.91
Taylor	-0.07	0	No	3.3	58	-66	-4.79
Lower Opaoa	-0.04	0	Yes	21.1	58	-46	-3.32
Waima	0.03	0	No	4.9	49	43	3.82

E. coli [cfu/100mL]

Short Site Name	Median annual Sen slope	P	Flow adjustment	Variation explained by Flow [%]	Number of Samples	Kendall statistic	Z
Upper Pelorus	3.54	0	Yes	38.3	60	44	3.04
Omaka	-2.99	0	No	-2.5	59	-42	-2.99
Taylor	26.11	0.05	Yes	19.8	58	28	1.99

pH

Short Site Name	Median annual Sen slope	P	Flow adjustment	Variation explained by Flow [%]	Number of Samples	Kendall statistic	Z
Opouri	0.03	0	Yes	20.5	59	42	2.96
Ronga	0.05	0.04	Yes	27.2	59	30	2.09
Branch	-0.03	0.03	Yes	12.6	57	-30	-2.19
Mill Ck	0.04	0.01	No	-3.3	59	36	2.53
mid Opaoa	-0.09	0	No	0.4	58	-42	-3.02
Doctors	0.03	0.01	No	2.4	57	36	2.64
Murphys	0.11	0	No	5.9	58	54	3.91
Taylor	0.06	0	No	3.5	58	44	3.17