River and stream water quality and ecology in the Wellington region

State and trends

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Main cover photo: The Hutt River at Silverstream

Executive summary

Greater Wellington Regional Council (Greater Wellington) manages water quality in rivers and streams of the Wellington region for natural state, public water supply, recreation and amenity, trout habitat, and aquatic ecosystem health. Regular monitoring of physico-chemical and microbiological water quality, together with assessments of ecosystem health, are integral in managing rivers and streams for these purposes. This monitoring is also important for understanding the potential flow-on effects for the health of downstream receiving environments such as lakes and estuaries.

This report provides a comprehensive assessment of state and trends in river and stream health across the Wellington region. The assessment focuses on the results of state of the environment (SoE) water quality and ecological monitoring undertaken at 55 river and stream sites since 2004 (although the analysis of current state only uses the most recent three years of data, July 2008 to June 2011). The report also includes an assessment of state and trends in native fish communities in the Wellington region, drawing largely on data from NIWA's National Freshwater Fish Database collected between 1990 and 2010.

Analysis of water quality, periphyton and macroinvertebrate data collected at 55 SoE sites (46 in the case of periphyton) over the period July 2008 to June 2011 found clear linkages between river and stream health and catchment land use. Sites classified as having 'good' or 'excellent' water quality (49% of sites) and ecosystem health (59% and 65% of sites for periphyton and macroinvertebrate indicators, respectively) tend to be located on the upper reaches of rivers and streams that drain the forested Tararua, Rimutaka and Aorangi ranges. As the proportion of pastoral and/or urban landcover increases within a site's upstream catchment, water quality and macroinvertebrate health tend to decline while nuisance periphyton and macrophyte growth increases. Of the 15 sites graded 'poor' for water quality, five are located in urban areas and ten drain predominantly pastoral catchments – of which most support at least some intensive agriculture. Similar patterns were observed with periphyton growth and macroinvertebrate health, although geological and climatic factors in part account for some sites (particularly those in the eastern Wairarapa hill country) being assigned to 'fair' or 'poor' classes for these indicators.

Analysis of New Zealand Freshwater Fish Database records also showed that a significant relationship exists between fish community condition and upstream catchment landcover in the Wellington region. Fish community condition is significantly higher at sites located on rivers and streams draining predominantly indigenous forest catchments than at those draining pastoral or urban catchments. Based on limited monitoring, fish community condition at some RSoE sites contrasts significantly with the water quality, periphyton and macroinvertebrate indicators measured at these sites.

The majority of SoE sites exhibited relatively stable water quality and ecological health over the time periods examined (2006 to 2011 and 2004 to 2011, respectively). Generally speaking, the majority of statistically significant trends tended to be indicative of improving water quality (predominantly declining nutrient concentrations) but deteriorating ecological condition (increasing periphyton cover/biomass and declining macroinvertebrate community health). In most cases the reasons for the

observed trends were unclear. The presence of improving nutrient concentrations across a wide spectrum of sites, including several reference (pristine) sites, suggests that the improvements are more likely related to natural factors such as climate variability than changes in land use or land management practices. Similarly, variation in river and stream flow probably influenced many of the trends identified in periphyton and macroinvertebrate metrics.

Overall, while the absence of wide scale deteriorating trends in water quality and ecological health is positive, many of the RSoE sites are considered 'degraded', with some very degraded when considered in the national context. For example, most urban sites and several lowland pastoral sites recorded nutrient concentrations well above their respective national median values for similar urban and rural streams. The RSoE sites in poorest condition – in particular those with small catchments dominated by urban or intensive agricultural land uses – share in common one or more of the following 'stressors': nutrient enrichment, poor water clarity, nitrate or heavy metal toxicity, microbiological contamination and instream habitat degradation. Management of these stressors requires a whole of catchment approach that addresses municipal wastewater discharges to water (in the Wairarapa Valley in particular), nutrient loss (from both overland runoff and leaching via shallow groundwater) in intensively farmed rural catchments, sediment runoff associated with erosion-prone farmland, exotic forestry and urban development, sewer infrastructure leaks/faults, urban stormwater discharges, water abstraction, and direct stock access to streams and riparian margins.

Contents

1. Introduction

Greater Wellington Regional Council (Greater Wellington) manages water quality in rivers and streams of the Wellington region for natural state, public water supply, recreation and amenity, trout habitat, and aquatic ecosystem health. Regular monitoring of physico-chemical and microbiological water quality, together with assessments of ecosystem health, are integral in managing rivers and streams for these purposes. This monitoring is also important for understanding the potential flow-on effects for the health of downstream receiving environments such as lakes and estuaries.

This report provides a comprehensive assessment of the results of state of the environment water quality and ecological monitoring undertaken at 55 river and stream sites in the Wellington region over the period January 2004 to June 2011. Monitoring the state of the environment is a specific requirement for regional councils under Section 35(2)(a) of the Resource Management Act (RMA) 1991.

1.1 Report purpose

This technical report is one of eight covering air, land and water resources prepared with the primary purpose of informing the review of Greater Wellington's five regional plans. These plans were established to sustainably manage the region's natural resources, including fresh waters. The review of the regional plans follows the recently completed review of the overarching Regional Policy Statement (RPS) for the Wellington region (GWRC 2010).

The focus of the eight technical reports is on providing an up-to-date analysis of monitoring information on state and trends in resource health as opposed to assessing the effectiveness of specific policies in the existing RPS (WRC 1995) or regional plans. Policy effectiveness reports were prepared in 2006 following the release of Greater Wellington's last formal State of the Environment (SoE) report, *Measuring up* (GWRC 2005).

The last technical report on state and trends in river and stream health in the Wellington region was prepared by Milne and Perrie (2005); this report focussed on 51 sites monitored over the period 1997 to 2003. In a more recent report following changes to the monitoring network in 2003/04, Perrie (2007) documented the state of river and stream health at 56 sites for the three-year period ending in August 2006[1].

1.2 Report scope

This report assesses the current state of river and stream health across the Wellington region and whether or not this has improved, deteriorated or remained the same over the reporting period. The assessment focuses on routine SoE water quality, periphyton and macroinvertebrate monitoring data collected since 2004 (although the analysis of current state only uses the most recent three years of data, July 2008 to June 2011). The report also includes an assessment of state and trends in native fish communities in the Wellington

[1] Greater Wellington also prepares annual summary reports documenting SoE monitoring results obtained in the last financial year. Refer to Perrie and Cockeram (2010) for the most recent annual freshwater quality monitoring report.

region, drawing largely on data from NIWA's National Freshwater Fish Database collected between 1990 and 2010.

Note that the water quality data presented in this report are primarily assessed in relation to ecosystem health. Microbiological water quality is also assessed, but not in relation to contact recreation – the suitability of the region's rivers for swimming is reported separately under Greater Wellington's recreational water quality monitoring programme (see Greenfield et al. 2012 for a comprehensive analysis of state and trends in recreational water quality).

1.3 Report outline

The report comprises nine sections:

- Section 2 outlines Greater Wellington's river and stream water quality monitoring network, sampling methods and core water quality and ecological indicators.
- Section 3 provides a brief overview of the main types of rivers and streams in the Wellington region. Land use and consented activities with the potential to influence river and stream health are also outlined.
- Section 4 presents an assessment of the current state of physico-chemical and microbiological water quality in the region's rivers and streams, followed by an assessment of temporal trends in river and stream water quality. Two water quality indices are also presented, providing a summary of overall water quality based on compliance with relevant guidelines for selected variables.
- Section 5 assesses state and trends in periphyton cover and biomass across the region's rivers and streams.
- Section 6 assesses state and trends in macroinvertebrate health across the region's rivers and streams.
- Section 7 presents an analysis of freshwater fish monitoring information for the region's rivers and streams, drawing on data from the New Zealand Freshwater Fish Database as well as the results of recent monitoring undertaken by Greater Wellington.
- Section 8 revisits the main findings from Sections 4 to 7 and places these in a national context. The primary issues affecting river and stream health in the Wellington region are discussed, and monitoring limitations and knowledge gaps are also outlined.
- Section 9 presents conclusions and recommendations.

1.4 Terms and definitions

A number of environmental variables, reference documents and organisations have been abbreviated in this report. Generally, the names are mentioned in full on their first use in each section. The principal acronyms used are listed in Table 1.1.

Table 1.1: List of main abbreviations used in this report

Abbreviation	Definition
ANZECC	Australia and New Zealand Environment and Conservation Council
DRP	Dissolved reactive phosphorus
E. coli	*Escherichia coli*
EPT	Ephemeroptera-Plecoptera-Trichoptera
FDR	False Discovery Rate
GWRC	Greater Wellington Regional Council
IBI	Index of Biotic Integrity
Amm N	Ammoniacal nitrogen
NIWA	National Institute of Water & Atmospheric Research
NNN	Nitrite-nitrate nitrogen (also known as *total oxidised nitrogen*)
NZFFD	New Zealand Freshwater Fish Database
MCI	Macroinvertebrate Community Index
MfE	Ministry for the Environment
REC	River Environment Classification
RFP	Regional Freshwater Plan
RPS	Regional Policy Statement
RSoE	Rivers State of the Environment
SoE	State of the Environment
TN	Total nitrogen
TOC	Total organic carbon
TP	Total phosphorus
TSS	Total suspended solids
TV	Trigger value (in relation to the ANZECC guidelines)
USEPA	United States Environmental Protection Authority

2. Overview of river and stream health monitoring in the Wellington region

2.1 Background

Greater Wellington has routinely monitored surface water quality in the western half of the Wellington region since 1987 and in the Wairarapa since 1991. In the early years, this monitoring was effectively conducted under two separate monitoring programmes until a comprehensive review of the surface water quality monitoring programme was undertaken in 2002 (Warr 2002). Following this review, a large number of changes were implemented in September 2003 to improve the representativeness and quality of the information collected; changes included the number and location of monitoring sites, the range of variables monitored and both field and analytical methods (see Milne and Perrie 2005 for details).

Since September 2003, the Rivers State of Environment (RSoE) monitoring programme has remained largely unchanged, with only minor changes to the existing suite of monitoring sites and variables (outlined later in Sections 2.3 through 2.5). However, in 2006 there was a change in analytical laboratory (for both water quality analyses and periphyton and macroinvertebrate identification). The scope of the programme has also recently increased, with assessments of macrophyte cover and habitat undertaken at selected sites in 2011. In addition, fish monitoring has been recently trialled at several sites.

2.2 Monitoring objectives

The aims of Greater Wellington's RSoE water quality monitoring programme are to:

1. Assist in the detection of spatial and temporal changes in fresh waters;
2. Contribute to our understanding of freshwater biodiversity in the region;
3. Determine the suitability of fresh waters for designated uses;
4. Provide information to assist in targeted investigations where remediation or mitigation of poor water quality is desired; and
5. Provide information required to determine the effectiveness of regional plans and policies.

2.3 Monitoring sites

Water quality and ecosystem health are currently monitored at 55 river and stream sites (Figure 2.1, Appendix 1). These sites were chosen to represent the major land uses and human activities, and also the natural diversity of rivers and streams in the region (Warr 2002). The latter was determined using the River Environment Classification (REC) documented by Snelder et al. (2004). REC classifies different river and stream environments based on environmental factors, including climate, source-of-flow, geology and landcover. REC classes for each site can be found in Appendix 1 and information on REC environmental factors is provided in Appendix 2.

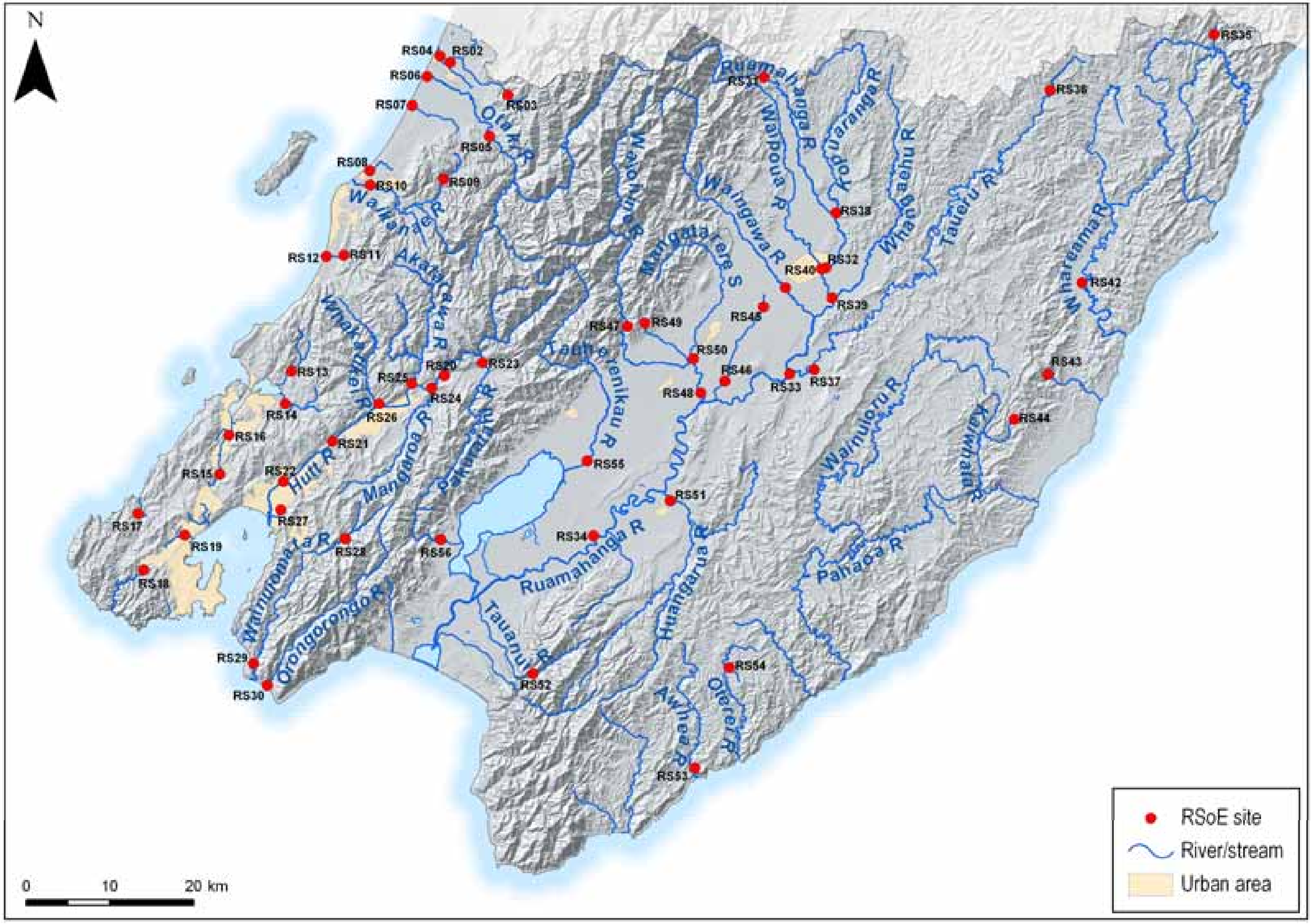

Figure 2.1: RSoE monitoring sites as at June 2011

Of the 55 sites, seven meet 'reference' site criteria (≥ 95% of the upstream catchment in indigenous forest or scrub) and are considered representative of minimally impacted conditions (Appendix 1). Nine RSoE sites are 'best available' which means they are affected by varying degrees of human impact but are considered to be the best remaining examples of that stream type. The other 39 sites are classed as 'impacted' and represent varying degrees of impact from a range of land use and instream activities.

Only two changes have been made to the Rivers SoE (RSoE) monitoring site network since its implementation in 2003:

- In September 2009, monitoring of the Mangapouri Stream at Rahui Road[2] (site RS01) was discontinued because previous monitoring results (eg, Perrie 2009) showed that this site did not represent the 'best available' condition, that it was originally chosen for; and
- In July 2011, the monitoring site located on the Waiwhetu Stream at Wainuiomata Hill Bridge (site RS27) was relocated approximately 0.9 km upstream above the point of tidal influence (which was found to occasionally influence water quality at this site[3]). The new site (RS57) aligns with a Greater Wellington flow recorder at Whites Line East.

2.4 Monitoring variables

2.4.1 Water quality variables

Across the 55 RSoE sites, water quality is assessed at monthly intervals by measuring a range of physico-chemical and microbiological variables. These include dissolved oxygen, temperature, pH, conductivity, visual clarity, turbidity, suspended solids, faecal indicator bacteria, total organic carbon, and dissolved and total nutrients. The full list of variables monitored, together with the rationale for monitoring and details of field and analytical methods, is provided in Appendix 3.

Since September 2003, the core suite of water quality variables has largely remained stable, the exception being water colour (measured on the Munsell scale), which ceased being measured after June 2011. In January 2009, total suspended solids (TSS) and – at a selection of sites[4] – dissolved copper, lead and zinc, were added to the RSoE programme. The addition of these variables followed a 12-month period where the core suite of analyses was extended to include TSS, anions, cations, and a suite of heavy metals (see Perrie 2009).

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2 The monitoring record for this site falls largely outside of the 'state' reporting period used in this report and as such this site is not assessed. However, summaries of data collected from this site are available in annual reports up until monitoring ceased (eg, Perrie 2009).

3 The shift in site was also prompted by the possibility that recent flood protection works undertaken on the lower reaches of the stream might increase the frequency of tidal influence (through a change in the tidal prism as a result of channel deepening and widening). For a period of six months between July and December 2011, water quality sampling was undertaken at both Wainuiomata Hill Road and Whites Line East to assess the comparability of the two sites and facilitate future temporal trend assessments using data from both sites.

4 The selected sites are located in urban catchments that are considered at risk from heavy metal contamination and/or discharge into sensitive downstream receiving environments (eg, harbours and estuaries).

2.4.2 Biological variables

(a) Periphyton and macroinvertebrates

Ecosystem health is also assessed at each of the 55 RSoE sites through annual biological monitoring, incorporating semi-quantitative assessments of periphyton biomass and macroinvertebrate communities during stable/low flows in summer/autumn. Periphyton assessments are only undertaken at sites with hard substrates such as cobbles and large gravel (46 in total, see Appendix 1). Periphyton cover is also assessed monthly at these sites at the time of water sample collection. Details of current biological monitoring field and analytical methods are summarised in Appendix 3.

Biological assessment methods have remained largely unchanged since September 2003, the exception being that since 2010, the number of invertebrate samples collected from each site reduced from three to one.

(b) Macrophytes

Formal monitoring of aquatic macrophyte cover commenced at selected RSoE sites in July 2011 using methods outlined in Collier et al. (2007). Prior to this time, only general observations of the presence of nuisance macrophyte growths were recorded during monthly water sampling.

(c) Fish

In the last few years, Greater Wellington has trialled recently developed standardised fish sampling protocols (David et al. 2010) at several RSoE sites. Overall, however, most fish surveys to date have been undertaken at other locations in the region to gather further information on the spatial distribution of freshwater fish and/or to assist with targeted investigations. The location of many RSoE sites on large rivers and streams precludes them from being assessed using currently available standardised methodologies.

2.4.3 Supporting variables

(a) Flow

Flow is a fundamental supporting variable for monitoring river and stream health. Many water quality variables, notably turbidity, vary with flow and measurements need to be flow-adjusted for temporal trend assessment purposes (Davies-Colley et al. 2011). Flow measurements are also needed to calculate nutrient and contaminant loads, and to determine accrual periods for the interpretation of biological data.

Continuous flow recorders are located at, or very near to, 15 RSoE sites. For the other 40 sites, flows are estimated using Greater Wellington's extensive network of continuous and spot flow measurement records, in combination with flow records from NIWA's site network (Thompson & Gordon 2010a). The level of confidence in the accuracy of flow estimates varies across these sites due to the proximity of each RSoE site to a flow recorder (eg, whether or not the flow recorder is located in the same river catchment or another river catchment) and also the number of 'spot gaugings' available at each site to enable correlations with continuous flow records. At 11 of the current sites, Thompson and Gordon (2010a) considered that there was not enough information currently available to estimate flows with any level of confidence. Details on which sites have flow or flow estimates, including the associated 'level of confidence' in these estimates, can be found in Appendix 4.

(b) Continuous temperature and dissolved oxygen measurements

It is widely recognised that monthly spot measurements of variables such as water temperature and dissolved oxygen, which vary diurnally, are not able to capture the extremes in measurement that can impact on aquatic life. As a result, in recent years, Greater Wellington has deployed continuous water temperature and dissolved oxygen loggers at selected RSoE sites for a few weeks each summer. Some of the results of this monitoring are drawn on in later sections of this report.

(c) Stream habitat assessments

Alongside water quality and stream flow, riparian and instream habitat are strong drivers of river and stream ecological health. Detailed habitat assessments, using method P2 of the national protocols (Harding et al. 2009) only commenced at some RSoE sites in late 2011 (ie, outside of the reporting period). However, one-off habitat assessments were undertaken in 2008 following methods in Rowe et al. (2006) and assessments of substrate size classes are undertaken annually. Further details on these assessment methods can be found in Appendix 3.

3. Rivers and streams in the Wellington region

This section presents a brief overview of the natural diversity of river and stream types/environments in the Wellington region, providing context for some of the natural differences in water quality and ecological health observed across the region's rivers and streams. Although Greater Wellington's RSoE network focuses on permanently flowing water bodies, both permanently and intermittently flowing streams are outlined. This is consistent with the RMA (1991) definition of a river or stream as *"a continually or intermittently flowing body of fresh water"* that includes streams and modified watercourses. Some of the key anthropogenic activities that can affect stream water quality and ecological health are also outlined, with a particular focus on land use and significant consented activities in the Wellington region.

3.1 Permanently flowing rivers and streams

There are approximately 12,360 km of permanently flowing rivers and streams in the Wellington region. These rivers and streams range from the small-sized first order streams, found in headwaters and springheads, through to the larger lower reaches of major rivers such as the Otaki, Hutt and Pahaoa rivers (sixth order) and the Ruamahanga River (seventh order). First and second order streams make up approximately 75% of the entire length of rivers and streams in the region while rivers belonging to orders 5, 6 and 7 make up only 5% of total river and stream length (Table 3.1).

Table 3.1: Approximate lengths of rivers and streams belonging to each order in the Wellington region. Data obtained from REC (Snelder et al. 2004)

Order	Approximate length (km)	River/stream length in the region (%)
1	6,037	49
2	3,130	25
3	1,575	13
4	928	8
5	427	3
6	174	1
7	89	1
Total	12,360	100

Differences in geophysical characteristics of river and stream catchments, such as climate, topography and geology, result in natural differences in river and stream characteristics (Snelder at al. 2004), including differences in flow, slope, temperature and substrate. This, together with downstream factors, such as distance from the coast, affect the composition of biological communities including instream plants, macroinvertebrates and fish (Leathwick et al. 2008).

Rivers and streams in the Wellington region can be broadly grouped into three types based on their catchment geophysical characteristics:

- Steep gradients and hard sedimentary geology (Figure 3.1a and 3.1b) – these rivers and streams are found in the Tararua, Aorangi and Rimutaka ranges as well as in moderately elevated areas around the Wellington coast and eastern Wairarapa. They have naturally high water clarity and low concentrations of nutrients although some rivers (eg, the Waikanae and Wainuiomata rivers) appear to have naturally elevated concentrations of phosphorus (Ausseil 2011).

- Moderate/low gradients with soft sedimentary geology (Figure 3.1c and 3.1d) – these rivers and streams are generally associated with the soft sedimentary geology of northern and eastern Wairarapa. They have naturally higher concentrations of suspended sediment and in some cases may have naturally soft substrate. Infrequent rainfall in northern and eastern Wairarapa means that river flows are generally lower and flushing flows occur less frequently than in other parts of the region.
- Low gradients with alluvial floodplain geology (Figure 3.1e and 3.1f) – these rivers and streams generally occur in the central Wairarapa Valley (eg, Parkvale Stream near Carterton) and along the Kapiti Coast. High connectivity with groundwater is common and, in some cases, these streams drain wetlands or peat soils. Flows are often very stable and flushing flows can be infrequent.

Figure 3.1: Examples of natural variation in rivers and streams in the Wellington region, including rivers and streams with: steep, hard sedimentary catchments (a=Ruamahanga River at McLays, b=Beef Creek at headwaters), moderate/low gradient soft sedimentary catchments (c=Taueru River at Castlehill, d=Whareama River) and low gradient, alluvial floodplain catchments (e=Parkvale Stream, f=Ngarara Stream)

As mentioned in Section 2.3, the River Environment Classification (REC) has been used to characterise natural variability (and that due to land use) in rivers and streams represented in the RSoE programme (see Appendix 2 for details on the REC environmental factors).

3.2 Intermittently flowing rivers and streams

The extent of ephemeral and intermittent[5] streams in the Wellington region is unknown. However, an assessment undertaken in the Auckland region estimated the extent of ephemeral and intermittent streams to be 11,590 km or 75% over and above the estimated perennial stream length (Storey & Wadwha 2009). A similar proportion could be expected in the Wellington region.

Ephemeral and intermittent streams typically occur in headwater catchments and form the most upstream extent of rivers and streams. Intermittent streams can also be found in the lower reaches of some rivers and streams where flow runs beneath the surface of deep gravel substrates for part of the year. Larger rivers or streams in the Wellington region with intermittently flowing reaches include the Waipoua River and the Mangatarere Stream.

Although ephemeral and intermittent streams are not regularly monitored in the Wellington region, a recent study conducted in the wet sediment and intermittently flowing reaches of six forested Wellington streams found that these habitats supported diverse macroinvertebrate communities (Figure 3.2). Pollution sensitive Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa, including a number of rare or geographically restricted taxa, were found in both habitat types (Storey 2010). Similarly diverse macroinvertebrate communities have been found in ephemeral and intermittent streams in other parts of New Zealand (eg, Parkyn et al. 2006).

Figure 3.2: Intermittent (a) and wet sediment (b) reaches of a small stream in York Bay, Eastbourne (sampled in 2010)

[5] Ephemeral streams flow only for a short time during and, for a short time after, storm events while intermittent streams cease flowing for part of the year, generally during dry periods (Hansen 2001).

3.3 Regionally significant rivers and streams

Rivers and streams in the Wellington region have a range of values including aquatic ecosystem, tangata whenua, recreational, amenity, trout fishery and water supply values. Some reaches of rivers and streams in the region have been identified as regionally significant for one or more values and are listed in regional policies and plans. For example, Greater Wellington's Regional Freshwater Plan (RFP, WRC 1999) lists river and stream reaches that have a high degree of natural character, support nationally threatened native species of fish or aquatic plants, and have important trout habitat, recreational and/or amenity values. The proposed Regional Policy Statement (RPS, GWRC 2010) includes a revised list of rivers and streams with significant amenity, recreational and aquatic ecosystem values and it is expected that as part of the current review of the existing RFP, similar lists for other river and stream values will also be identified.

3.4 Key anthropogenic pressures on river and stream health

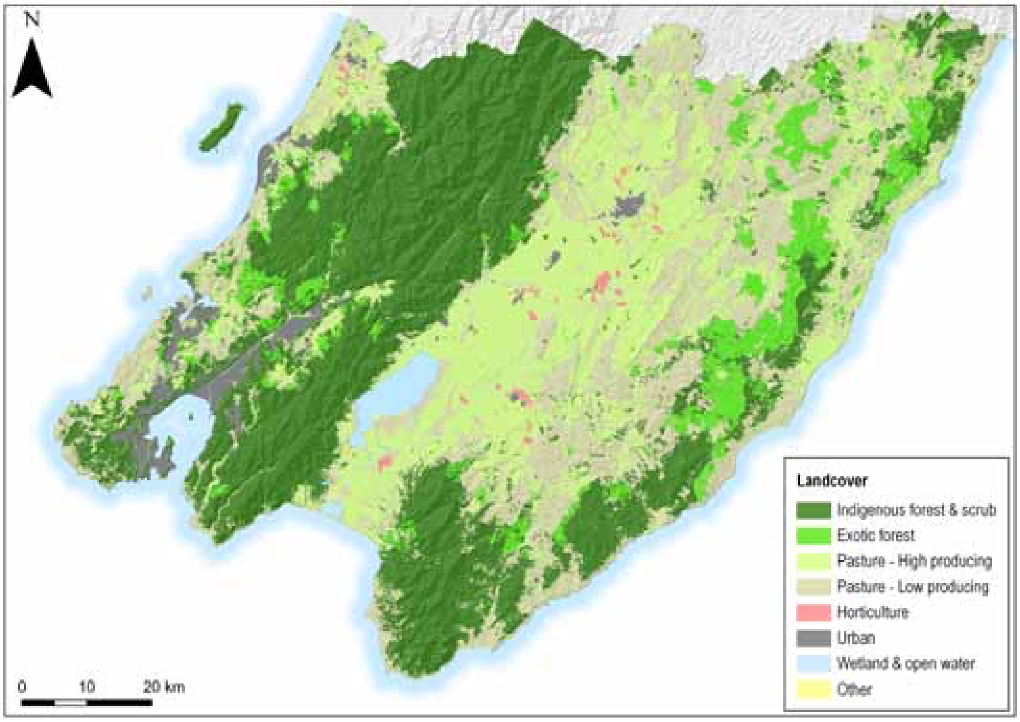
Alongside natural influences such as climate and geology, catchment land use can significantly affect river and stream health. This section provides an overview of land use in the Wellington region and summarises some of the significant consented activities that can impact on river and stream water quality and ecosystems. It is recognised that there are other factors that can also impact on river and stream health, including introduced invertebrate, plant and fish species.

3.4.1 Landcover and land use

General land use can be inferred from landcover information. The most up-to-date landcover information for the Wellington region is based on aerial photographs taken in 2008 by the Ministry for the Environment (MfE 2010) (Figure 3.3). According to this source of information, close to half of the 812,000 ha area of the Wellington region is in pasture, with 21.6% high producing pasture and 28.0% low producing pasture[6]. The majority of high producing pasture is located within the Wairarapa Valley and near Otaki, while the low producing pasture is predominantly located in the eastern hill country of the Wairarapa, and also the hill country of Wellington and Porirua.

Over 290,000 ha (37.0%) of the region's land area is under indigenous forest or scrub cover, with a large proportion of this found in the Tararua Forest Park. Exotic forest is found throughout the hill country on the western and eastern sides of the region, but makes up a smaller proportion of the land area (8.6%). There are just over 4,000 ha (0.5%) of horticulture (including cropping) in the region, located mainly around Otaki, Te Horo, Greytown and Martinborough. Urban areas occupy 2.4% of the region, and are concentrated mainly in the western side of the region around Wellington city, Porirua and the Hutt Valley.

[6] High producing pasture is defined as 'sown pasture'– pasture with a medium to high dry matter production, including rye grass and clover. In contrast, low producing pasture is defined as 'adventive grassland' and includes native grasses and browntop and other pasture species with low dry matter production (Ministry of Works and Development 1979).



(Source: LUCAS – MfE 2010)

Figure 3.3: Landcover of the Wellington region, derived from aerial photographs taken in 2008

Sorensen (2012) summarises recent land use change across the region, based on aerial photographs taken in 2002[7] and 2010, interpreted from soil intactness surveys reported by Crippen and Hicks (2004; 2011). According to these surveys, the largest land use change between 2002 and 2010 was a reduction in drystock farming (2.6% or over 21,000 ha of the region's land area), with over half of this reduction attributed to the conversion of pasture land to exotic forest. The majority of land converted into exotic forest over this time is located in the eastern hill country of the Wairarapa which is highly susceptible to erosion (Sorensen 2012). Between 2002 and 2010 small increases were also evident for dairying (0.7% of region's land area or approximately 5,600 ha[8]) and the 'other' category (0.7%), which includes urban areas. Some of the highest urban growth has occurred in the northern suburbs of Wellington city where there has been significant re-zoning and clearance of low producing pasture and bushland for residential subdivision and development. According to the Wellington City Council (2003), average growth in the number of new dwellings in the northern suburbs between 1996 and 2001 was 7.8% compared with 5.2% in Wellington city overall.

With approximately half of the region covered in pasture, agriculture is an important industry for the region. Sorensen (2012) notes that while there are still significantly more sheep than all other livestock in the region, sheep numbers have reduced consistently since 1990 (from around 2,600,000 to just over 1,600,000). In contrast, beef cattle and deer numbers remained reasonably

[7] The aerial photographs which were interpreted were taken from 2001 to 2003 across the region. For the purposes of this report the period is reported as 2002.
[8] Sorensen (2012) notes that this is in contrast to data reported by Dairy NZ (2010), which indicates an 11% decrease in effective farming area for dairying (See Table 3.2).

consistent and dairy cattle increased significantly, from 62,521 in 1990 to 92,375 in 2010.

In addition to an increase in dairy cows in the region, based on Dairy NZ (2010) data presented in Sorensen (2012), there has been a reduction in effective farming area; collectively this has resulted in a 33% increase in average herd size for the region – from 299 in 2002 to 399 in 2009 (Table 3.2). This also translates to an increase in the average stocking rate from, on average, 2.54 cows per hectare of dairy farm land in 2002/03 to 2.80 cows per hectare in 2009/10. While the decrease in effective farming area bucks the national trend, the increases in both average herd size and stocking rates in the Wellington region are very similar to the overall trends at the national level (Table 3.2).

Table 3.2: Dairy farming area, herd size and stocking rates for both the Wellington region and all of New Zealand (Source: DairyNZ 2010)

Milking season	Effective farming area (ha)		Average herd size		Average stocking rate (cows per hectare)	
	Wellington	New Zealand	Wellington	New Zealand	Wellington	New Zealand
2002/03	29,235	1,463,281	299	285	2.54	2.57
2003/04	27,855	1,421,147	311	302	2.66	2.72
2004/05	26,964	1,411,594	332	315	2.71	2.74
2005/06	26,307	1,398,966	347	322	2.66	2.73
2006/07	25,778	1,412,925	352	337	2.69	2.79
2007/08	25,629	1,436,549	371	351	2.70	2.79
2008/09	26,181	1,519,117	390	366	2.74	2.79
2009/10	25,898	1,563,495	399	376	2.80	2.81
% change 2002–2010	-11	7	33	32	10	9

Looking at the region's dairy farming on a district basis, South Wairarapa contains nearly half of all the dairy cattle in the Wellington region. It is also the district with the most growth in dairy cattle numbers, increasing from 35,466 in 2002/03 to 37,577 in 2009/10 (Figure 3.4). The second largest dairying district in the region is Carterton, with the combined dairy cattle numbers from the districts of Kapiti Coast and Upper Hutt, along with dairy cattle numbers in Masterton, making up smaller proportions of the total dairy cattle numbers for the region.

Although South Wairarapa and Carterton contain the majority of dairy cattle in the region, Masterton has until recently contained the highest stocking rate, peaking at 2.96 cows per hectare in 2006/07 (Figure 3.5); this decreased to 2.83 in 2009/10 but is still above the national average stocking rate (Table 3.2). Stocking rates in both South Wairarapa and Carterton have steadily increased since 2002/03, peaking at 2.89 and 2.78 cows/ha, respectively, in 2009/10.

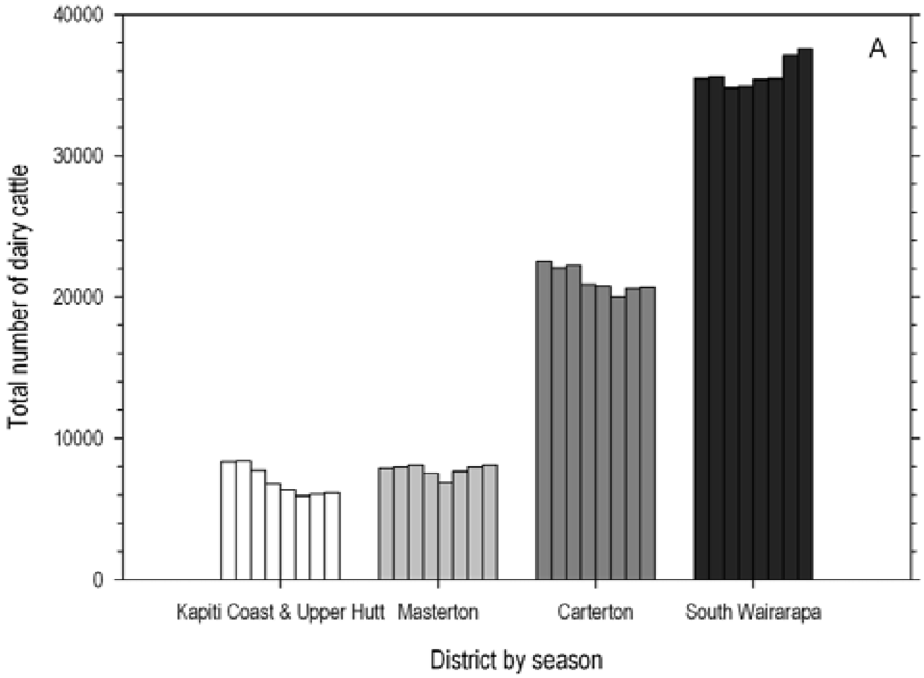
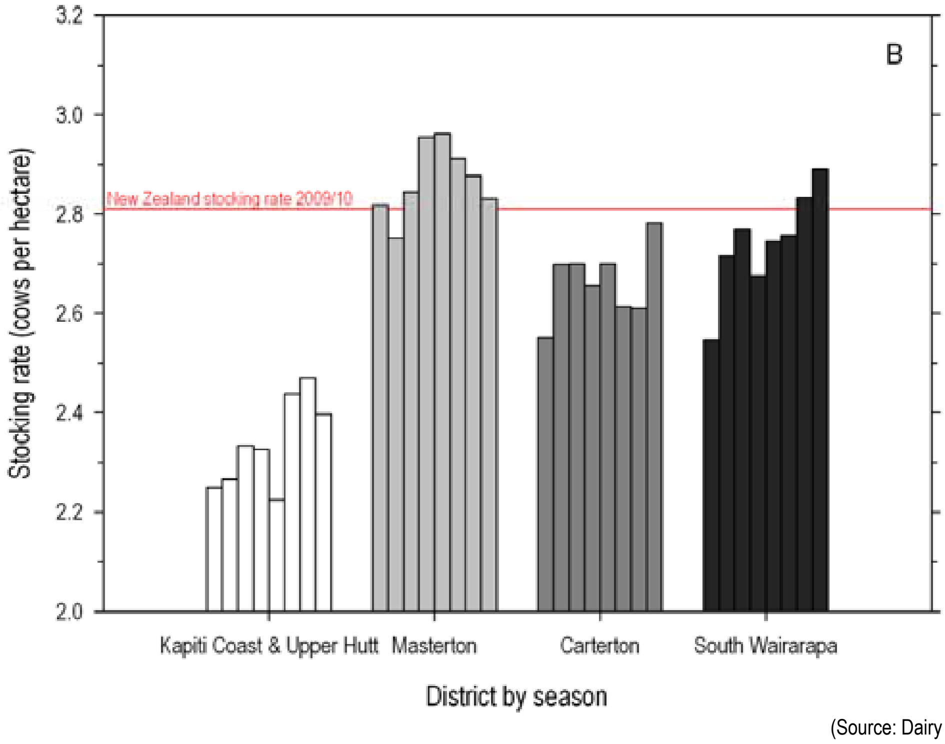


Figure 3.4: Total number of dairy cattle for each district in the Wellington region with dairy cattle, 2002/03 to 2009/10. Each bar represents a milking season, with the left-most bar for each district representing 2002/03 and the right-most bar representing 2009/10



(Source: Dairy NZ 2010)

Figure 3.5: Dairy cattle stocking rates (cows per hectare) for each district with dairy cattle in the Wellington region, 2002/03 to 2009/10. Each bar represents a milking season, with the left-most bar for each district representing 2002/03 and the right-most bar representing 2009/10

3.4.2 Significant consented activities

This section briefly outlines some of the specific consented land use activities with the potential to impact on river and stream health. These include discharges of municipal, agricultural and industrial wastewater, stormwater discharges, river and stream works, and water abstraction. The resource consent information presented in this section was drawn from Greater Wellington's 'Ozone' database and was current as at 30 June 2010.

(a) Discharges to surface water

(i) Municipal wastewater discharges

The principal discharges to surface water likely to have the greatest impact on water quality and ecosystem health in the Wellington region are discharges of treated municipal sewage (wastewater). There are six such discharges to water; these include wastewater from all five of the Wairarapa's main townships and the combined wastewater from Paraparaumu, Raumati and Waikanae on the Kapiti Coast (Table 3.3).

Table 3.3: Principal municipal wastewater discharges to rivers and streams in the Wellington region as at June 2010

Township	City/district	Estimated serviced population[1]	Receiving waterbody & location
Paraparaumu, Raumati & Waikanae	Kapiti Coast	30,000	Mazengarb Drain, a tributary of the Waikanae River.
Masterton	Masterton	17,700	Makoura Stream, approximately 0.8 km above its confluence with the Ruamahanga River near Homebush / Wardell's Bridge.
Carterton	Carterton	4,100	Mangatarere Stream during April to December (land-based discharge during summer except where high inflows prevent this), approximately 1.5 km from its confluence with the Waiohine River at SH 2.
Greytown	South Wairarapa	2,000	Papawai Stream, approximately 1.5 km from its confluence with the Ruamahanga River upstream of Morrisons Bush.
Featherston	South Wairarapa	2,330	Donald's Creek, a tributary of Abbotts Creek and Lake Wairarapa.
Martinborough	South Wairarapa	1,330	Ruamahanga River, approximately 2.5 km downstream of Waihenga Bridge.

[1] Estimated from recent resource consent application information.

In 2009, Masterton District Council's resource consent to discharge treated wastewater from Masterton was renewed with the requirement that from 2013 onwards, wastewater must be progressively discharged to land. Furthermore, from December 2014, no wastewater can be discharged to the Ruamahanga River during periods of less than median river flow during summer (1 November to 30 April) and less than half median flow during winter (1 May to 31 October).

Although no new consent requirements are in place as yet, the current river based discharges from the Carterton, Greytown and Martinborough Wastewater Treatment Plants (WWTPs) are all in the process of being assessed by the relevant territorial authorities for their long-term viability. Similar approaches to that of Masterton are being explored, the aim being to ensure wastewater is only discharged to land when river/stream flows are low.

In addition to the municipal WWTP discharges, there are several other wastewater discharges to water in the Wellington region. For example, Rathkeale College has consent to discharge treated wastewater to a tributary of the Ruamahanga River north of Masterton township and Castlepoint township discharges treated wastewater to Castlepoint Stream during the winter months when land disposal is not possible.

(ii) Industrial wastewater discharges

There are only a small number of industrial wastewater discharges to water in the Wellington region, the majority of which are associated with quarries, cleanfills/ landfills or sawmill yards. Treated wastewater associated with an animal research facility in Whitemans Valley is discharged to a tributary of the Mangaroa River and several municipal water treatment plants intermittently discharge waste products into rivers and streams (typically suspended sediment and aluminium-based coagulants associated with filter backwash water). Receiving waters for these backwash water discharges include the Waikanae, Hutt, Wainuiomata and Waingawa rivers, and the Waitohu and Kaipaitangata streams.

(iii) Stormwater and wet weather wastewater discharges

Generally defined as rainwater collected from roofs, driveways, roads, carparks and other sealed surfaces, stormwater in the Wellington region is piped directly into rivers and streams, generally without any treatment. During its travels, this stormwater picks up sediment, rubbish and a variety of other contaminants, including metals, hydrocarbons, herbicides, pesticides, nutrients and pathogens.

Although general stormwater discharges are a permitted activity under Greater Wellington's existing RFP (WRC 1999) and so do not require a resource consent[9], Kapiti Coast District Council and Carterton District Council both hold 'global network' resource consents to discharge stormwater to surface waters in their respective districts. Several territorial authorities also hold consents authorising the discharge of diluted untreated or partially treated wastewater to rivers and streams during times of very heavy or sustained rainfall. During these conditions, stormwater can directly infiltrate the sewer network, resulting in overflows at selected stormwater or 'emergency sewer' outfalls (eg, to the lower reaches of the Hutt and Wainuiomata rivers and the Waiwhetu Stream). High volumes of 'diluted' wastewater also arrive at the WWTPs in wet weather conditions where, on occasion when storage at the plants is exceeded, a portion of these 'wet weather flows' bypass treatment and are discharged directly to streams (or the coast) in close vicinity of the treatment plant (eg, the lower Waiwhetu Stream and Karori Stream in the cases

[9] Stormwater discharges must meet certain criteria to be permitted, a key one being that the discharges do not adversely affect aquatic life.

of the Seaview and Western WWTPs, respectively). Greater Wellington's resource consent monitoring records indicate that, on average, wet weather wastewater overflow discharges typically occur at least two to three times a year.

(b) Discharges to land

Although the land plays a significant role in attenuating contaminants from wastewater and stormwater discharges, such discharges often influence the quality of the underlying groundwater, especially in shallow and unconfined aquifers. Where there is strong hydraulic connectivity between the surface waters and unconfined aquifers, contaminated groundwater can impact on rivers and streams. Tidswell et al. (2012) provide a summary of consented discharges to land in the Wellington region. These largely relate to discharges associated with municipal and domestic wastewater from community treatment facilities in small settlements (eg, Tinui, Castlepoint and Lake Ferry) and recently developed rural subdivisions, agricultural discharges, industry discharges (eg, winery and slaughterhouse wastewater, paua processing water, timber treatment, fertiliser/compost production), and landfill discharges (solid waste, leachate and stormwater).

Numerically, agricultural discharges make up the largest number of consented wastewater discharges to land. As at 30 June 2010, there were approximately 200 operative permits for discharges of agricultural wastewater to land across the region (Figure 3.6)[10]. The majority (over 95%) of these permits are for dairyshed effluent discharges, mainly in the Wairarapa. Other agricultural discharges to land include piggery effluent (in the Mangatarere Stream catchment near Carterton, in south Featherston and near Greytown) and poultry effluent (near Otaki).

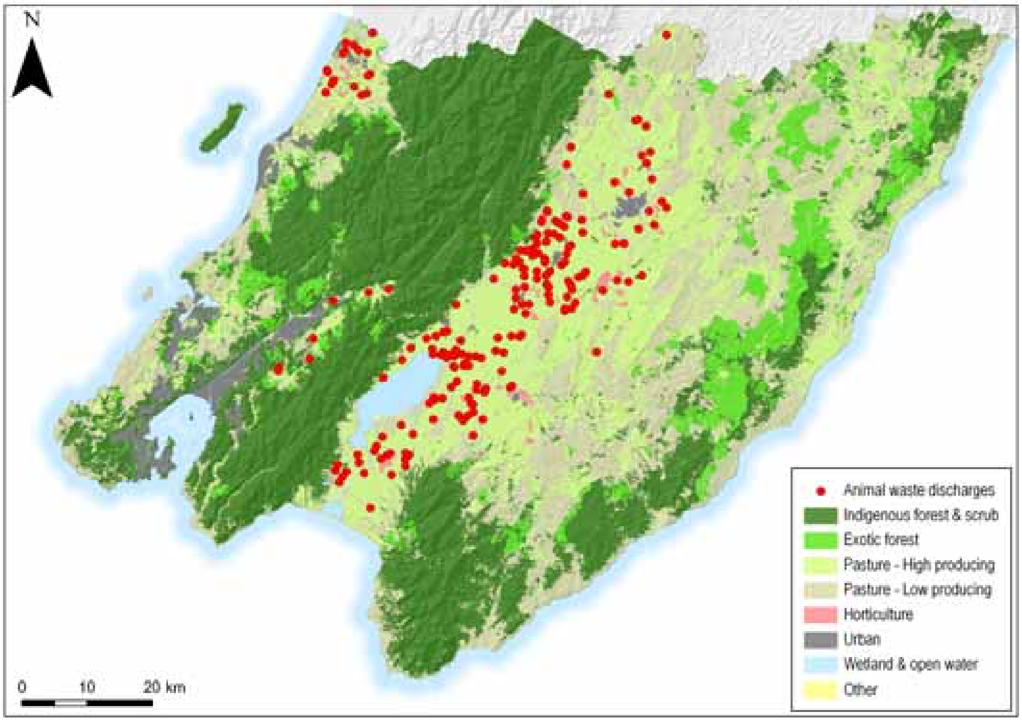


Figure 3.6: Consented agricultural wastewater discharges to land in the Wellington region as at June 2010

10 The exercise of consents for the discharge of agricultural wastewater to surface water in the Wellington region ceased around 2005.

(c) River and stream works

A range of riverbed and riverbank works are undertaken in the Wellington region for flood protection and erosion control purposes such as channel re-alignment, bed contouring and gravel extraction. Greater Wellington holds several resource consents to undertake such works in rivers across the region (eg, Otaki, Waikanae, Hutt, Ruamahanga, Waiohine and Tauherenikau rivers).

Other consented activities in the beds of streams in the Wellington region include diversions (temporary and permanent), installation of instream structures (eg, weirs) and piping and reclamation. A considerable amount of stream piping and reclamation in recent years has been associated with residential and roading development in urban areas of Wellington, Porirua and Hutt cities.[11]

(d) Water abstraction

Surface water is abstracted for a variety of uses throughout the region, including irrigation, public water supply, water race water supply and industrial uses. Water abstraction places pressure on rivers and streams by reducing the amount of water available for aquatic habitat, physical, chemical and biological processes, recreational activities, and other instream uses and values. Large scale abstraction of groundwater that is hydraulically connected to surface water also has the potential to impact on rivers and streams. The demand for water is often greatest during dry periods in summer when river and stream flows are at their lowest and temperatures are warm, further exacerbating the pressures placed on these ecosystems.

According to Keenan et al. (2012), as at the end of 2010, consented water abstraction in the Wellington region equated to approximately 414 million m^3/year; this represents a 54% increase on the 269 million m^3/year of water allocated in 1990. Surface water (ie, lakes, rivers and streams) makes up around two-thirds of the allocated water resource, of which community water supply has the greatest annual allocation (41%). Other major uses of surface water resources are irrigation (with 24% of the annual allocation), Wairarapa water races (19%) and hydroelectricity generation (14%). In contrast, the main uses of groundwater allocation are irrigation (60%) and public or community water supply (36%), although overall – from all groundwater and surface water sources – water supply and irrigation are allocated similar amounts of water on an annual basis (Keenan et al. 2012).

Most (77%) of the increase in water allocation between 1990 and 2010 was for irrigation; a further 20% was for public water supply. Further, most (83%) of the region's increase in water allocation occurred in the Wairarapa, mainly for dairying (Keenan et. al 2012). Under the current allocation policies of Greater Wellington's existing RFP (WRC 1999), the only rivers with significant (>30 L/s) remaining allocation available during normal to low flows are Tauherenikau, Hutt (lower reach), Wainuiomata (lower reach) and Otaki rivers (see Keenan et al. 2012 for further discussion).

[11] Based on Greater Wellington's consent records (excluding consents for culverts less than 20 m in length), it is estimated that between 2003 and 2005 a total of 14.9 km of stream length was lost due to piping or reclamation in the Wellington region.

4. Physico-chemical and microbiological water quality – state and trends

This section assesses river and stream water quality in the Wellington region, utilising monthly physico-chemical and microbiological water quality data collected at 55 RSoE sites. The current state of water quality (covering the period July 2008 to June 2011) is presented first, supported by the use of two indices to summarise overall water quality. Temporal trends in water quality data are then examined for the five-year period ending 30 June 2011. The trend section includes an assessment of data from NIWA's five national river water quality monitoring sites in the Wellington region.

4.1 Current state

4.1.1 Approach to analysis

Water quality data collected monthly from each of the 55 RSoE sites over the period July 2008 to June 2011 (inclusive) were used to assess the current state of river and stream water quality in the Wellington region. For the majority of the 55 RSoE sites, this provides 36 sample results for each water quality variable of interest (some sites were sampled on fewer occasions due to access being restricted at times, such as for lambing or safety reasons).

Monitoring data for key physico-chemical and microbiological variables were summarised and compared, where available, against appropriate national water quality guidelines to provide an overview of the state of water quality at each site (Table 4.1). In most instances the guideline values used were the Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) 'default' trigger values (TVs) for lowland aquatic ecosystems (herewith denoted as ANZECC 2000)[12]. There were some exceptions, as outlined in Table 4.1. In terms of microbiological water quality, the main *E. coli* TV relates to livestock drinking water, not contact recreation because Greater Wellington has a separate monitoring programme to assess the suitability of popular river sites for contact recreation (see Greenfield et al. 2012). However, the ANZECC (2000) stock water TV is considered conservative and so a second threshold (equivalent to Ministry for the Environment/Ministry of Health (2003) 'action' guideline for freshwater recreational areas) has also been used; this value serves as a convenient midpoint between the current (2000) and former (1992) ANZECC stock water TVs (100 and 1,000 cfu/100mL, respectively).

The ANZECC (2000) TVs for lowland aquatic ecosystems and stock water are intended to be compared against the *median* values from independent samples at a site. These TVs are not legal standards and breaches do not necessarily mean an adverse environmental effect would result (ie, they are not effects-based). Rather, they can be considered 'nominal thresholds' (Ballantine et al. 2010), where a breach is an 'early warning' mechanism to alert resource managers to a potential problem or emerging change that *may* warrant site-specific investigation or remedial action (ANZECC 2000).

12 The ANZECC (2000) guidelines provide different trigger values for New Zealand upland (>150 m altitude) and lowland ecosystems. While Greater Wellington's RSoE monitoring programme encompasses both upland and lowland sites, for simplicity in comparing water quality between sites, only the lowland trigger values were used. This is appropriate because the guidelines are considered to be conservative.

Table 4.1: 'Guidelines' and trigger values (TV) used to assess the current state of water quality in rivers and streams in the Wellington region. Variables and guidelines used in Greater Wellington's Water Quality Index (GW WQI) and the CCME (2001) WQI presented later in this section are also indicated. See Appendix 3 for an explanation of the different variables in this table

Variable	'Guideline' value	Reference	GW WQI	CCME WQI
Water temperature[1] (ºC)	≤19[1]	Quinn and Hickey (1990) and Hay et al. (2007)	—	✓
	≤25	Regional Freshwater Plan (RFP) for Wellington (WRC 1999) – trout fishery & spawning	—	—
Dissolved oxygen (% saturation)	≥80	RMA 1991 Third Schedule and WRC (1999) RFP 'bottom line'[2]	✓	✓
pH	6.5–9.0	ANZECC (1992)[2]	—	—
Visual clarity (m)	≥1.6	MfE (1994) – guideline for recreation[3]	✓	✓
Turbidity (NTU)	≤5.6	ANZECC (2000) lowland TV	—	—
Nitrite-nitrate nitrogen (mg/L)	≤0.444	ANZECC (2000) lowland TV	✓	—
Nitrate nitrogen (mg/L)	≤1.7	Hickey and Martin (2009) – recommended freshwater toxicity TV (95% protection level)	—	✓
Ammoniacal nitrogen (mg/L)	≤0.021	ANZECC (2000) – lowland TV	✓	—
	Varies[4]	ANZECC (2000) – freshwater toxicity TV (95% protection level) and USEPA (2009)	—	—
Dissolved inorganic nitrogen (mg/L)	≤0.465	ANZECC (2000) – by addition of the nitrite-nitrate nitrogen and ammoniacal nitrogen TVs	—	✓
Total nitrogen (mg/L)	≤0.614	ANZECC (2000) – lowland TV	—	—
Dissolved reactive phosphorus (mg/L)	≤0.010	ANZECC (2000) – lowland TV	✓	✓
Total phosphorus (mg/L)	≤0.033	ANZECC (2000) – lowland TV	—	—
E. coli (cfu/100mL)	≤100	ANZECC (2000) – stock water TV	✓	—
	≤550	MfE/MoH (2003) – action level for recreation (used as a less conservative proxy for stock water)	—	✓

[1] There are no formal guidelines for water temperature, but temperatures above 19ºC are known to cause behavioural disturbance in trout (Hay et al. 2007) and exclude sensitive macroinvertebrate species such as stoneflies (Quinn & Hickey 1990).

[2] The ANZECC (2000) default lowland TVs are considered overly stringent (see Milne & Perrie 2005).

[3] The ANZECC (2000) default lowland TV is considered erroneous (see Milne & Perrie 2005) and MfE (1994) is used by default.

[4] Ammonia toxicity varies with pH and temperature. Chronic toxicity was assessed on a sample by sample basis, taking into account pH and water temperature at the time of sampling and using the calculations in the ANZECC (2000) guidelines. Acute toxicity was examined in a similar way, except that toxicity was only assessed using pH at the time of sample collection, as per recommendations and equations in USEPA (2009).

For the 10 RSoE sites where water samples were also analysed for selected heavy metals and metalloids, median dissolved concentrations were compared against site-specific, hardness-modified TVs for chronic toxicity (95% level of protection) in accordance with ANZECC (2000). Acute toxicity was examined by comparing individual concentrations against site-specific, hardness-modified TVs based on recommendations and equations in USEPA (2009). Because water hardness is not part of the existing suite of variables analysed in the RSoE programme, the median water hardness determined from monthly monitoring over January 2008 to December 2008 was used as a proxy for water hardness conditions at the time of sample collection (see Appendix 1 for median hardness values).

As well as a comparison against the guideline values listed in Table 4.1, the River Environment Classification (REC) was also used to help interpret water quality across the 55 RSoE sites. The main REC class used was landcover (see Appendix 2). Information on the proportion of different landcover types in each catchment was derived from MfE (2010).

(a) Water quality indices

Two water quality indices are presented in Section 4.1.13 to summarise overall water quality and facilitate inter-site comparisons. First, to provide a measure of consistency and allow comparisons with earlier technical reports on river water quality in the Wellington region, Greater Wellington's water quality index (GW-WQI) developed by Milne and Perrie (2005) – and adapted by Perrie (2007) – was applied to median results from the 55 RSoE sites. The second index uses the methodology defined in the Canadian Water Quality Index (CCME 2001). CCME-type indices have already been trialled in several regions (eg, Auckland and Southland); more recently, this index has been recommended for further investigation in relation to national reporting of river water quality (Hudson et al. 2011). Further background and information on the application of the two water quality indices are provided in Appendix 5. The water quality variables and associated threshold values used in each index are listed in Table 4.1.

(b) General data processing, analysis and presentation

Data were initially screened for outliers and where there was cause for concern around the quality of a data value (eg, the field meter performance had been questioned by the field staff undertaking the sampling), these values were removed. During data processing, any water quality variables reported as less than or greater than detection limits (ie, censored data) were replaced by values one half of the detection limit or the detection limit respectively (eg, a value of <2 became 1, while a value of >400 became 400).

Considerable use of scatter plots and box-and-whisker plots (box plots) is made in this section to graphically summarise the median and range of measurements for various water quality variables and compare these between sampling sites and/or major REC landcover classes. All plots were generated in SigmaPlot (version 11.0). In terms of interpretation of the box plots:

- the lower and upper boundaries of the box represent the 25th percentile and 75th percentile of the data set, respectively (a minimum of three data points are needed to generate the box);
- the horizontal line within the box represents the median value;
- the 'whiskers' (error bars) extending above and below the box (interquartile range) represent the 90th and 10th percentile values, respectively; and
- the black dots represent outliers.

4.1.2 Summary statistics and compliance with guideline values – overview

Summary statistics for selected 'core' water quality variables over the three-year period examined are presented for each RSoE site in Table 4.2. Compliance with

Table 4.2: Summary of physico-chemical and microbiological water quality data and compliance with guideline/trigger values for 55 RSoE sites sampled monthly between July 2008 and June 2011. Median values that do not comply with a guideline value are shown in bold font

		Water temperature (°C)					Dissolved oxygen (% saturation)					pH					Visual clarity (m)					Turbidity (NTU)					Total suspended solids (mg/L)				Conductivity (µS/cm)				Total organic carbon (mg/L)			
Site No.	Site Name	Median	Min	Max	*n*	% Results >19 °C	Median	Min	Max	*n*	% Results <80%	Median	Min	Max	*n*	% Results <6.5 or >9	Median	Min	Max	*n*	% Results <1.6 m	Median	Min	Max	*n*	% Results >5.6 NTU	Median	Min	Max	*n*	Median	Min	Max	*n*	Median	Min	Max	*n*
RS02	Mangapouri S at Bennetts Rd	13.3	7.0	19.2	36	2.78	**70.6**	30.9	100.0	35	77.1	6.8	6.1	7.9	36	11.1	**0.43**	0.15	1.80	36	97.2	4.9	2.0	18.0	36	38.9	3.0	<2.0	32	36	210	184	246	36	5.2	2.9	15.2	36
RS03	Waitohu S at Forest Park	10.5	4.6	16.4	35	0.00	100.0	86.3	129.0	34	0.0	7.1	6.4	8.3	35	5.7	2.55	0.26	5.61	35	22.9	0.8	0.4	15.0	35	2.9	1.0	<2.0	18	35	85	65	98	35	1.9	1.0	4.5	35
RS04	Waitohu S at Norfolk Cres.	13.5	6.0	19.4	36	2.78	83.8	66.6	121.0	35	34.3	6.7	6.0	9.2	36	16.7	**0.46**	0.16	2.10	36	97.2	4.7	2.0	27.0	36	36.1	5.9	<2.0	47	36	151.5	94	205	36	4.1	2.5	7.1	36
RS05	Otaki R at Pukehinau	10.0	3.9	17.8	36	0.00	99.9	87.4	119.0	35	0.0	7.1	5.8	8.1	36	8.3	3.20	0.12	9.50	36	25.0	0.8	0.3	48.0	36	13.9	1.0	<2.0	60	36	66	37	80	36	1.2	<0.5	3.9	36
RS06	Otaki R at Mouth	11.4	5.3	19.0	36	2.78	101.0	85.2	119.0	35	0.0	7.2	6.3	8.4	36	5.6	2.39	0.10	9.07	36	33.3	0.9	0.4	61.0	36	19.4	1.0	<2.0	69	36	68	37	80	36	1.1	<0.5	4.6	36
RS07	Mangaone S at Sims Rd Br	12.7	7.5	18.2	36	0.00	**73.8**	46.1	92.7	35	65.7	6.7	5.7	8.3	36	19.4	**0.35**	0.15	1.42	35	100.0	**5.9**	2.7	20.0	36	52.8	5.1	<2.0	33	36	200	129	231	36	4.8	2.0	8.3	36
RS08	Ngarara S at Field Way	14.3	7.1	21.0	36	5.56	**54.5**	9.0	72.4	35	100.0	6.7	6.4	7.8	36	11.1	**0.39**	0.06	0.81	36	100.0	**8.6**	0.3	54.0	36	86.1	6.4	<2.0	86	36	298.5	226	1738	36	16.8	0.7	30.0	36
RS09	Waikanae R at Mangaone Walkway	11.2	5.4	16.5	36	0.00	98.4	83.0	112.0	35	0.0	7.2	6.6	8.2	36	0.0	3.15	1.40	5.66	36	2.8	0.6	0.2	5.4	36	0.0	1.0	<2.0	6	36	84.5	59	92	36	1.3	0.5	5.9	36
RS10	Waikanae R at Greenaway Rd	14.4	7.9	22.2	36	13.89	101.0	87.4	117.0	35	0.0	7.0	6.2	8.3	36	2.8	2.30	0.34	8.89	36	25.0	0.8	0.3	16.9	36	11.1	1.0	<2.0	26	36	103	75	158	36	1.4	0.5	12.0	36
RS11	Whareroa S at Waterfall Rd	11.2	5.6	16.7	36	0.00	96.0	76.8	110.0	35	5.7	7.3	6.5	8.6	36	2.8	**0.52**	0.03	1.46	36	100.0	**8.3**	2.9	190.0	36	61.1	4.7	<2.0	110	36	235	146	267	36	3.8	2.5	10.4	36
RS12	Whareroa S at QE Park	13.0	6.9	19.5	36	2.78	**73.9**	36.5	89.4	35	77.1	6.6	6.0	7.8	36	27.8	**0.45**	0.09	0.88	36	100.0	**8.7**	5.0	132.0	36	88.9	5.2	<2.0	173	36	260	163	299	36	13.9	6.8	24.0	36
RS13	Horokiri S at Snodgrass	12.8	6.2	18.8	36	0.00	104.0	89.3	119.0	35	0.0	7.2	6.0	8.6	36	2.8	**1.58**	0.23	4.48	36	50.0	1.4	0.4	20.0	36	11.1	1.0	<2.0	69	36	182.5	133	201	36	2.0	1.2	5.2	36
RS14	Pauatahanui S at Elmwood Br	12.4	5.3	20.1	36	2.78	98.2	77.6	117.0	35	5.7	7.2	6.0	8.4	36	2.8	**1.36**	0.05	2.59	36	69.4	2.6	0.9	46.0	36	19.4	1.0	<2.0	76	36	171.5	134	195	36	3.9	1.9	9.1	36
RS15	Porirua S at Glenside	12.7	8.0	18.7	36	0.00	110.0	78.8	134.0	35	2.9	7.6	6.6	8.9	35	0.0	**1.54**	0.05	3.17	36	50.0	2.0	0.5	250.0	36	22.2	1.5	<2.0	550	36	250	75	285	35	3.3	<0.5	9.1	36
RS16	Porirua S at Wall Park	12.4	8.1	17.3	36	0.00	107.0	12.7	144.0	35	5.7	7.5	6.7	8.9	35	0.0	**1.44**	0.05	4.35	36	61.1	2.8	1.1	100.0	36	22.2	1.0	<2.0	145	36	257	123	279	35	3.2	0.5	9.0	36
RS17	Makara S at Kennels	13.4	7.6	20.7	36	11.11	106.0	77.5	130.0	35	2.9	7.4	5.9	8.7	35	2.9	**1.13**	0.04	1.97	36	86.1	3.4	1.4	155.0	36	19.4	3.0	<2.0	320	36	268	188	330	35	4.5	1.3	13.6	36
RS18	Karori S at Makara Peak MBP	12.7	8.6	17.4	36	0.00	106.0	78.3	127.0	35	5.7	7.2	6.0	8.6	34	2.9	2.41	0.13	4.50	36	36.1	1.2	0.6	36.0	36	22.2	1.0	<2.0	45	36	223	81	232	35	2.1	1.0	7.6	36
RS19	Kaiwharawhara S at Ngaio Gorge	13.3	7.7	19.3	36	5.56	108.0	78.8	132.0	35	2.9	7.6	7.0	9.1	34	8.8	1.87	0.20	4.46	36	44.4	1.5	0.5	28.0	36	16.7	1.0	<2.0	47	36	286	157	333	35	3.0	0.5	7.7	36
RS20	Hutt R at Te Marua Intake Site	10.2	5.8	17.4	36	0.00	103.0	89.0	110.0	35	0.0	7.1	6.4	7.6	35	8.6	2.63	0.28	6.64	36	22.2	1.0	0.3	18.0	36	13.9	1.0	<2.0	23	36	66	46	85	35	2.2	0.9	8.7	36
RS21	Hutt R opp. Manor Park Golf Club	13.7	8.7	21.4	36	13.89	105.0	75.2	127.0	35	2.9	7.2	6.4	8.5	35	2.9	1.60	0.11	5.47	36	50.0	2.1	0.3	48.0	36	25.0	1.0	<2.0	61	36	102	72	136	35	2.8	1.4	10.6	36
RS22	Hutt R at Boulcott	13.6	8.2	21.5	36	13.89	102.0	73.5	126.0	35	2.9	7.0	6.4	8.0	35	2.9	**1.41**	0.11	6.31	36	61.1	2.3	0.3	57.0	36	30.6	1.0	<2.0	65	36	86	67	114	35	2.3	1.1	9.8	36
RS23	Pakuratahi R 50m Below Farm Ck	10.9	5.8	17.4	36	0.00	98.2	89.1	116.0	35	0.0	6.6	6.2	7.5	35	37.1	2.79	0.11	6.72	36	19.4	0.8	0.3	47.0	36	11.1	1.0	<2.0	58	36	82	56	89	35	2.1	0.8	9.2	36
RS24	Mangaroa R at Te Marua	12.0	6.8	18.2	36	0.00	102.0	88.7	116.0	34	0.0	6.9	6.1	7.5	35	11.4	**1.06**	0.06	3.16	36	72.2	1.8	0.4	56.0	36	16.7	1.0	<2.0	76	36	102	78	121	35	5.0	1.8	13.9	36
RS25	Akatarawa R at Hutt R confluence	11.1	5.8	17.5	36	0.00	103.0	90.8	114.0	35	0.0	7.1	6.6	8.2	35	0.0	3.07	0.42	6.77	36	16.7	0.6	0.2	7.6	36	5.6	1.0	<2.0	10	36	82	59	93	35	1.7	1.0	9.1	36
RS26	Whakatikei R at Riverstone	11.2	5.7	17.4	36	0.00	102.0	89.9	114.0	35	0.0	7.4	6.8	8.0	35	0.0	2.12	0.34	5.63	36	16.7	0.9	0.3	12.0	36	8.3	1.0	<2.0	16	36	110	76	123	35	1.7	0.8	5.1	36
RS27	Waiwhetu S at Wainuiomata Hill Br	14.1	9.6	19.8	36	8.33	**78.6**	45.8	146.0	35	51.4	6.8	6.3	9.2	35	17.1	**0.69**	0.15	1.61	36	94.4	5.1	1.9	36.0	36	44.4	4.0	<2.0	81	36	237	155	2713	34	3.8	2.1	9.8	36
RS28	Wainuiomata R at Manuka Track	9.5	5.7	15.1	35	0.00	99.3	91.5	110.0	34	0.0	7.0	6.2	7.4	34	8.8	2.48	0.35	4.70	35	8.6	0.9	0.5	14.1	35	2.9	1.0	<2.0	19	35	105.5	76	117	34	1.9	0.9	10.4	35
RS29	Wainuiomata R u/s of White Br	12.6	8.1	19.6	36	5.56	101.0	85.0	140.0	35	0.0	7.1	6.6	8.7	35	0.0	**1.31**	0.13	2.32	36	72.2	2.3	0.7	38.0	36	13.9	2.0	<2.0	86	36	138	111	155	35	1.8	1.2	3.1	36
RS30	Orongorongo R at Orongorongo Stn	14.0	8.6	21.9	36	16.67	102.0	72.9	112.0	35	2.9	7.5	6.9	8.1	35	0.0	**0.89**	0.03	5.25	36	61.1	**6.6**	0.6	1600.0	36	50.0	3.8	<2.0	1,390	36	132	102	164	35	1.9	<0.5	6.7	36
RS31	Ruamahanga R at McLays	9.8	3.4	16.4	36	0.00	98.1	79.0	130.0	35	5.7	6.9	5.8	7.9	35	17.1	2.15	0.25	7.65	36	33.3	1.2	0.2	30.0	36	11.1	1.0	<2.0	43	36	45	28	61	36	1.7	0.6	4.3	36
RS32	Ruamahanga R at Te Ore Ore	13.0	7.5	21.7	36	11.11	98.3	74.2	118.0	35	2.9	7.5	6.9	9.2	36	2.8	**0.75**	0.05	5.70	36	75.0	**5.7**	0.4	210.0	36	50.0	6.2	<2.0	210	36	122	51	180	35	3.1	<0.5	8.0	36
RS33	Ruamahanga R at Gladstone Br	13.4	8.3	22.2	36	16.67	99.0	72.9	156.0	35	5.7	7.4	6.5	9.2	36	8.3	**0.75**	0.04	3.55	36	72.2	4.3	0.4	180.0	36	41.7	4.0	<2.0	230	36	109	59	145	35	3.0	1.2	7.3	36
RS34	Ruamahanga R at Pukio	12.4	8.0	23.3	36	13.89	97.0	67.5	113.0	35	8.6	7.4	6.3	8.4	36	2.8	**0.27**	0.03	3.59	36	88.9	**15.5**	0.7	420.0	36	61.1	18.0	<2.0	480	36	130	51	203	35	3.8	<0.5	9.3	36
RS35	Mataikona trib. at Sugar Loaf Rd	10.4	6.2	19.1	36	2.78	99.8	82.4	114.0	35	0.0	7.9	7.2	8.9	36	0.0	**1.52**	0.12	>4.00	36	55.6	1.5	0.4	490.0	36	19.4	2.2	<2.0	1,320	36	398.5	276	536	36	3.1	1.8	16.4	36
RS36	Taueru R at Castlehill	10.3	5.6	20.9	36	5.56	96.4	82.1	117.0	35	0.0	7.6	6.8	8.5	36	0.0	**0.91**	0.10	2.88	36	80.6	3.9	1.6	370.0	36	41.7	2.9	<2.0	700	36	217.5	125	303	36	5.7	3.2	10.8	36
RS37	Taueru R at Gladstone	13.8	7.4	20.7	36	11.11	94.7	72.8	163.0	35	11.4	7.8	7.1	9.0	36	2.8	**0.50**	0.05	3.61	36	88.9	5.3	0.8	92.0	36	47.2	6.0	<2.0	94	36	428	268	510	36	6.5	1.5	13.0	36
RS38	Kopuaranga R at Stewarts	13.3	6.3	18.0	36	0.00	94.0	62.9	148.0	35	14.3	7.6	7.0	8.5	36	0.0	**0.67**	0.05	3.70	36	77.8	**5.7**	0.6	210.0	36	50.0	5.0	<2.0	300	36	264.5	135	386	36	4.5	0.5	13.7	36
RS39	Whangaehu R at 250m from confl.	14.3	6.6	20.6	36	11.11	86.8	42.9	133.0	35	31.4	7.3	6.9	8.2	36	0.0	**0.69**	0.04	2.91	36	86.1	**6.7**	0.9	470.0	36	55.6	4.8	<2.0	530	36	286	185	383	35	8.1	2.8	18.0	36
RS40	Waipoua R at Colombo Rd Br	14.6	8.5	25.0	36	13.89	106.0	72.6	130.0	35	2.9	7.4	6.3	8.3	35	2.9	2.59	0.15	5.40	36	22.2	0.7	0.2	41.0	36	8.3	1.0	<2.0	55	36	103.5	70	130	36	1.9	<0.5	7.2	36
RS41	Waingawa R at South Rd	13.4	7.1	21.4	36	13.89	99.6	79.0	123.0	35	5.7	7.2	6.2	8.3	36	5.6	2.60	0.07	9.33	36	33.3	1.1	0.3	65.0	36	19.4	1.0	<2.0	94	36	59	39	73	36	1.2	<0.5	3.9	36
RS42	Whareama R at Gauge	12.9	6.4	22.9	36	22.22	96.3	68.5	115.0	35	8.6	7.8	6.6	9.0	35	2.9	**0.51**	0.03	1.70	33	93.9	**6.9**	0.9	1100.0	36	58.3	6.5	<2.0	1,200	36	555.5	278	721	36	6.7	3.8	19.0	36
RS43	Motuwaireka S at Headwaters	10.5	6.4	18.6	35	0.00	98.3	68.2	113.0	34	2.9	7.4	7.0	8.5	35	0.0	2.54	0.52	>3.80	35	22.9	0.8	0.2	7.2	35	5.7	1.0	<2.0	10	35	296	188	429	35	2.2	<0.5	5.5	35
RS44	Totara S at Stronvar	13.8	6.6	24.1	35	28.57	100.5	61.2	137.0	34	8.8	7.5	6.5	8.6	35	2.9	2.50	0.04	5.10	35	25.7	0.8	0.1	320.0	35	5.7	1.0	<2.0	460	35	314	144	450	35	3.0	<0.5	13.0	35
RS45	Parkvale trib. at Lowes Reserve	13.6	10.5	15.9	28	0.00	**72.6**	60.6	102.0	28	85.7	**6.4**	6.0	7.0	28	78.6	2.40	1.21	4.00	27	22.2	1.0	0.2	2.6	28	0.0	2.0	<2.0	6.7	27	184.5	154	217	28	4.2	1.2	8.3	28
RS46	Parkvale S at Weir	15.6	8.4	23.2	36	22.22	103.0	76.1	131.0	35	2.9	7.4	6.6	8.7	36	0.0	**0.53**	0.12	1.98	36	88.9	4.8	1.3	49.0	36	41.7	7.2	<2.0	95	35	149.5	112	220	36	6.2	3.3	12.6	36
RS47	Waiohine R at Gorge	9.8	5.0	15.7	36	0.00	102.0	76.4	119.0	35	2.9	7.0	6.0	7.7	36	5.6	2.59	0.05	8.72	36	30.6	0.9	0.2	83.0	36	16.7	1.0	<2.0	59	35	54	29	89	36	1.3	0.5	5.1	36
RS48	Waiohine R at Bicknells	12.4	7.0	18.0	36	0.00	96.8	73.3	121.0	35	2.9	6.6	6.1	8.2	36	22.2	1.76	0.03	4.52	36	44.4	2.1	0.9	65.0	36	25.0	2.0	<2.0	150	35	72.5	37	106	36	1.5	0.8	3.5	36
RS49	Beef Ck at Headwaters	10.4	6.1	15.6	36	0.00	100.0	76.5	119.0	35	5.7	7.2	6.4	7.9	36	5.6	1.98	0.49	3.92	36	33.3	1.3	0.3	5.7	36	2.8	1.0	<2.0	11	35	88	62	131	36	1.9	1.0	5.1	36
RS50	Mangatarere S at SH 2	13.6	7.1	20.1	36	8.33	95.5	73.3	143.0	35	11.4	6.7	6.3	9.0	36	19.4	**1.52**	0.18	4.32	33	51.5	2.1	0.5	260.0	36	19.4	2.6	<2.0	120	35	112	83.8	175	36	2.3	1.5	4.7	36
RS51	Huangarua R at Ponatahi Br	14.3	7.6	23.5	36	25.00	108.0	83.0	163.0	35	0.0	8.0	6.0	8.7	35	2.9	**1.30**	0.04	4.33	36	55.6	2.0	0.4	290.0	36	41.7	2.8	<2.0	430	35	393	204	468	35	3.9	1.7	10.1	36
RS52	Tauanui R at Whakatomotomo Rd	11.2	6.2	17.0	35	0.00	99.6	77.8	113.0	34	2.9	7.3	5.6	7.8	34	2.9	3.51	0.06	5.83	35	28.6	1.0	0.2	51.0	35	14.3	1.0	<2.0	59	34	144.5	104	184	34	2.9	0.9	6.3	35
RS53	Awhea R at Tora Rd	16.6	7.2	24.3	36	33.33	106.0	76.8	146.0	35	2.9	8.0	6.0	8.7	35	2.9	**0.78**	0.02	4.66	36	75.0	**5.8**	0.4	850.0	36	50.0	4.9	<2.0	950	35	419	248	502	35	4.4	0.7	10.7	36
RS54	Coles Ck trib. at Lagoon Hill Rd	13.1	5.1	18.9	28	0.00	96.4	66.8	112.0	27	11.1	7.9	7.3	8.2	28	0.0	**0.88**	0.15	1.74	28	85.7	3.5	0.7	27.0	28	39.3	3.5	<2.0	18	27	640	245	1491	28	5.4	2.9	8.9	28
RS55	Tauherenikau R at Websters	11.6	5.3	20.0	36	8.33	97.7	70.8	113.0	35	2.9	7.1	6.4	9.4	36	8.3	**1.55**	0.09	7.19	36	50.0	3.1	0.5	78.0	36	30.6	2.3	<2.0	114	36	68	47	82	36	1.7	0.7	5.5	36
RS56	Waiorongomai R at Forest Park	12.1	7.1	18.1	36	0.00	101.0	70.4	117.0	35	2.9	7.1	5.7	7.7	35	5.7	2.19	0.22	>8.00	36	33.3	1.4	0.2	11.1	36	11.1	1.0	<2.0	9	36	114	80	143	35	2.5	1.3	8.4	36

Table 4.2 *cont.*: Summary of physico-chemical and microbiological water quality data and compliance with guideline/trigger values for 55 RSoE sites sampled monthly between July 2008 and June 2011. Median values that do not comply with a guideline value are shown in bold font (bolded and underlined median *E. coli* counts exceed both ANZECC (2000) and GWRC's proxy stock water guideline values)

		Nitrite + nitrate nitrogen (mg/L)					Ammoniacal nitrogen (mg/L)					Total nitrogen (mg/L)					Dissolved reactive phosphorus (mg/L)					Total phosphorus (mg/L)					*E. coli* (cfu/100 mL)					
Site No.	Site name	Median	Min	Max	*n*	% Results >0.444 mg/L	Median	Min	Max	*n*	% Results >0.021 mg/L	Median	Min	Max	*n*	% Results >0.614 mg/L	Median	Min	Max	*n*	% Results >0.010 mg/L	Median	Min	Max	*n*	% Results >0.033 mg/L	Median	Min	Max	*n*	% Results >100 cfu/100mL	% Results >550 cfu/100mL
RS02	Mangapouri S at Bennetts Rd	**2.500**	0.610	3.900	36	100.0	**0.031**	<0.010	0.096	36	80.6	**3.10**	1.22	4.70	36	100.0	**0.032**	0.020	0.096	36	100.0	**0.061**	0.042	0.172	36	100.0	**610**	130	5,400	36	100.0	52.8
RS03	Waitohu S at Forest Park	0.025	<0.002	0.068	35	0.0	0.005	<0.010	0.013	35	0.0	0.06	<0.11	0.46	35	0.0	0.008	<0.004	0.014	35	14.3	0.010	0.004	0.056	35	2.9	4	<1	2,200	35	5.7	2.9
RS04	Waitohu S at Norfolk Cres.	**0.505**	0.066	1.300	36	63.9	**0.041**	<0.010	0.110	36	80.6	**0.84**	0.37	1.70	36	86.1	**0.020**	0.008	0.037	36	94.4	**0.045**	0.030	0.102	36	88.9	**300**	97	4,200	36	94.4	27.8
RS05	Otaki R at Pukehinau	0.034	<0.002	2.800	36	2.8	0.005	<0.010	0.028	36	5.6	0.06	0.10	2.80	36	2.8	0.005	<0.004	0.011	36	2.8	0.005	<0.004	0.054	36	5.6	6	<1	22	36	0.0	0.0
RS06	Otaki R at Mouth	0.048	<0.002	0.140	36	0.0	0.005	<0.010	0.029	36	2.8	0.08	0.10	0.20	36	0.0	0.004	<0.004	0.009	36	0.0	0.006	<0.004	0.061	36	2.8	28	4	570	36	19.4	2.8
RS07	Mangaone S at Sims Rd Br	**1.930**	0.540	3.900	36	100.0	**0.080**	<0.010	0.143	36	91.7	**2.45**	0.99	4.50	36	100.0	**0.025**	0.014	0.054	36	100.0	**0.056**	0.024	0.104	36	91.7	**430**	95	4,800	36	97.2	36.1
RS08	Ngarara S at Field Way	0.111	<0.002	8.800	36	13.9	0.020	<0.010	0.080	36	47.2	**0.97**	0.41	9.90	36	80.6	**0.045**	0.008	0.113	36	97.2	**0.110**	0.007	0.610	36	97.2	**110**	22	2,200	36	52.8	2.8
RS09	Waikanae R at Mangaone Walkway	0.100	0.031	0.173	36	0.0	0.005	<0.010	0.012	36	0.0	0.15	0.10	0.31	36	0.0	**0.012**	0.006	0.016	36	83.3	0.013	0.009	0.032	36	0.0	8	<1	110	36	5.6	0.0
RS10	Waikanae R at Greenaway Rd	0.210	0.031	0.860	36	5.6	0.005	<0.010	0.050	36	2.8	0.27	<0.11	1.20	36	5.6	0.007	<0.004	0.043	36	22.2	0.009	0.004	0.140	36	5.6	21	4	500	36	8.3	0.0
RS11	Whareroa S at Waterfall Rd	0.335	0.130	0.850	36	27.8	0.005	<0.010	0.023	36	2.8	0.51	0.29	1.23	36	41.7	**0.028**	0.014	0.048	36	100.0	**0.044**	0.026	0.187	36	83.3	95	8	12,000	36	50.0	8.3
RS12	Whareroa S at QE Park	0.380	0.059	1.600	36	44.4	**0.087**	<0.010	0.220	36	94.4	**1.07**	0.47	2.40	36	86.1	**0.042**	0.021	0.061	36	100.0	**0.080**	0.054	0.360	36	100.0	**200**	44	18,000	36	83.3	13.9
RS13	Horokiri S at Snodgrass	0.370	0.007	1.100	36	47.2	0.005	<0.010	0.030	36	2.8	0.52	0.14	1.30	36	44.4	0.009	<0.004	0.022	36	47.2	0.016	0.008	0.056	36	13.9	**220**	10	2,800	36	91.7	11.1
RS14	Pauatahanui S at Elmwood Br	0.215	<0.002	0.900	36	25.0	0.014	<0.010	0.060	36	16.7	0.58	0.18	1.10	36	41.7	**0.014**	0.004	0.024	36	86.1	0.027	0.018	0.110	36	25.0	**265**	21	7,600	36	91.7	19.4
RS15	Porirua S at Glenside	**0.970**	0.300	2.200	36	97.2	0.005	<0.010	0.057	36	5.6	**1.20**	0.60	2.40	36	97.2	**0.019**	0.005	0.031	36	83.3	0.024	0.009	0.480	36	22.2	**210**	80	2,900	36	91.7	22.2
RS16	Porirua S at Wall Park	**0.955**	0.330	4.400	36	88.9	0.012	<0.010	0.160	36	33.3	**1.30**	0.56	4.60	36	94.4	**0.020**	0.004	0.058	36	91.7	**0.035**	0.016	0.220	36	58.3	**825**	160	11,000	36	100.0	63.9
RS17	Makara S at Kennels	0.285	0.004	1.400	36	44.4	0.012	<0.010	0.032	36	11.1	0.54	0.24	2.40	36	44.4	**0.027**	0.010	0.075	36	100.0	**0.046**	0.024	0.330	36	86.1	**230**	60	2,600	36	88.9	13.9
RS18	Karori S at Makara Peak MB Pk	**1.300**	0.350	4.300	36	91.7	0.013	<0.010	0.047	36	22.2	**1.50**	0.73	4.50	36	100.0	**0.038**	0.007	0.060	36	94.4	**0.049**	0.024	0.120	36	80.6	**1,100**	150	11,000	36	100.0	69.4
RS19	Kaiwharawhara S at Ngaio Gorge	**1.100**	<0.002	2.300	36	97.2	0.005	<0.010	0.148	36	27.8	**1.40**	0.26	2.50	36	97.2	**0.032**	0.005	0.085	36	94.4	**0.044**	0.024	0.120	36	80.6	**260**	28	22,000	36	88.9	36.1
RS20	Hutt R at Te Marua Intake Site	0.082	0.026	0.155	36	0.0	0.005	<0.010	0.014	36	0.0	0.16	<0.11	0.28	36	0.0	0.005	<0.004	0.008	36	0.0	0.006	<0.004	0.026	36	0.0	27	8	300	36	11.1	0.0
RS21	Hutt R opp. Manor Park Golf Club	0.215	0.050	0.890	36	5.6	0.005	<0.010	0.034	36	13.9	0.35	0.14	0.98	36	19.4	0.006	<0.004	0.014	36	13.9	0.011	<0.004	0.068	36	13.9	100	19	3,700	36	55.6	11.1
RS22	Hutt R at Boulcott	0.176	0.044	1.500	36	5.6	0.005	<0.010	0.011	36	0.0	0.28	0.12	1.50	36	5.6	0.004	<0.004	0.011	36	5.6	0.009	<0.004	0.076	36	13.9	73	10	1,800	36	38.9	8.3
RS23	Pakuratahi R 50m Below Farm Ck	0.225	0.077	0.410	36	0.0	0.005	<0.010	0.016	36	0.0	0.34	0.17	0.58	36	0.0	0.006	<0.004	0.013	36	11.1	0.009	<0.004	0.056	36	2.8	83	12	950	36	44.4	5.6
RS24	Mangaroa R at Te Marua	**0.470**	0.260	0.800	36	55.6	0.005	<0.010	0.034	36	5.6	**0.68**	0.43	1.30	36	63.9	**0.012**	0.004	0.026	36	69.4	0.019	0.010	0.131	36	16.7	**180**	34	2,800	36	77.8	13.9
RS25	Akatarawa R at Hutt R confluence	0.091	0.003	0.480	36	2.8	0.005	<0.010	0.087	36	5.6	0.14	0.10	0.51	36	0.0	0.002	<0.004	0.008	36	0.0	0.006	<0.004	0.017	36	0.0	43	11	120	36	8.3	0.0
RS26	Whakatikei R at Riverstone	0.077	0.017	0.310	36	0.0	0.005	<0.010	0.098	36	5.6	0.17	0.10	0.48	36	0.0	0.007	<0.004	0.012	36	19.4	0.010	0.005	0.025	36	0.0	20	3	130	36	2.8	0.0
RS27	Waiwhetu S at Wainuiomata Hill Br	**0.475**	0.081	1.100	36	52.8	**0.062**	<0.010	0.500	36	77.8	**0.76**	0.34	1.50	36	66.7	**0.026**	0.008	0.086	36	91.7	**0.056**	0.017	0.370	36	86.1	**310**	56	8,000	36	91.7	27.8
RS28	Wainuiomata R at Manuka Track	0.070	0.008	0.230	35	0.0	0.005	<0.010	0.014	35	0.0	0.14	0.10	0.49	35	0.0	0.010	0.005	0.018	35	62.9	0.013	0.009	0.940	35	5.7	4	<1	140	35	2.9	0.0
RS29	Wainuiomata R u/s of White Br	0.205	0.002	0.610	36	8.3	0.008	<0.010	0.046	36	22.2	0.31	0.10	1.40	36	11.1	**0.012**	0.004	0.020	36	69.4	0.020	0.012	0.110	36	5.6	89	24	7,400	36	44.4	5.6
RS30	Orongorongo R at Orongorongo Stn	0.037	<0.002	0.082	36	0.0	0.005	<0.010	0.030	36	2.8	0.06	0.10	1.46	36	2.8	0.005	<0.004	0.010	36	2.8	0.008	<0.004	1.610	36	19.4	26	<1	1,300	36	25.0	2.8
RS31	Ruamahanga R at McLays	0.023	0.002	0.046	36	0.0	0.005	<0.010	0.024	36	2.8	0.06	0.10	0.20	36	0.0	0.002	<0.004	0.007	36	0.0	0.005	<0.004	0.085	36	5.6	5	<1	260	36	5.6	0.0
RS32	Ruamahanga R at Te Ore Ore	0.355	0.014	0.940	36	30.6	0.005	<0.010	0.034	36	5.6	0.52	0.18	1.20	36	38.9	0.009	<0.004	0.059	35	45.7	0.019	0.004	0.230	36	27.8	100	12	2,900	36	52.8	25.0
RS33	Ruamahanga R at Gladstone Br	0.390	0.023	0.970	36	38.9	0.017	<0.010	0.066	36	38.9	**0.63**	0.15	1.30	36	50.0	**0.021**	0.007	0.032	36	97.2	**0.035**	0.016	0.260	36	52.8	82	6	9,300	36	47.2	19.4
RS34	Ruamahanga R at Pukio	0.345	<0.002	0.930	36	27.8	0.005	<0.010	0.038	36	13.9	0.57	0.11	2.10	36	41.7	**0.015**	<0.004	0.042	36	75.0	**0.049**	0.007	0.420	36	61.1	**160**	6	3,700	36	69.4	30.6
RS35	Mataikona trib. at Sugar Loaf Rd	0.015	<0.002	0.180	36	0.0	0.005	<0.010	0.022	36	2.8	0.16	<0.11	2.00	36	2.8	0.004	<0.004	0.009	36	0.0	0.008	<0.004	0.510	36	8.3	41	2	3,600	36	33.3	5.6
RS36	Taueru R at Castlehill	0.074	<0.002	0.440	36	0.0	0.005	<0.010	0.032	36	5.6	0.39	0.13	2.80	36	27.8	0.008	<0.004	0.014	36	38.9	0.025	0.007	0.650	36	25.0	100	24	13,000	36	52.8	8.3
RS37	Taueru R at Gladstone	**0.605**	0.190	1.900	36	86.1	0.005	<0.010	0.100	36	22.2	**1.20**	0.72	2.20	36	100.0	**0.012**	<0.004	0.040	36	58.3	**0.047**	0.006	0.140	36	63.9	**105**	29	1,800	36	52.8	16.7
RS38	Kopuaranga R at Stewarts	**0.955**	0.460	1.370	36	100.0	0.012	<0.010	0.034	36	19.4	**1.38**	0.89	2.30	36	100.0	**0.017**	0.005	0.035	36	86.1	**0.035**	0.013	0.330	36	55.6	**315**	60	11,000	36	94.4	36.1
RS39	Whangaehu R at 250m from confl.	**0.805**	0.220	2.900	36	88.9	0.005	<0.010	0.043	36	22.2	**1.55**	0.66	3.40	36	100.0	**0.038**	0.017	0.093	36	100.0	**0.074**	0.026	0.630	36	91.7	**375**	90	22,000	36	97.2	38.9
RS40	Waipoua R at Colombo Rd Br	**0.910**	0.210	2.600	36	94.4	0.005	<0.010	0.023	36	2.8	**1.06**	0.41	3.00	36	86.1	0.004	<0.004	0.009	36	0.0	0.008	<0.004	0.110	36	8.3	41	7	3,100	36	27.8	5.6
RS41	Waingawa R at South Rd	0.054	0.014	0.400	36	0.0	0.005	<0.010	0.016	36	0.0	0.13	<0.11	0.44	36	0.0	0.002	<0.004	0.008	36	0.0	0.005	<0.004	0.100	36	8.3	22	3	210	35	25.7	0.0
RS42	Whareama R at Gauge	0.005	<0.002	0.690	36	2.8	0.005	<0.010	0.110	36	16.7	0.41	0.25	2.30	36	27.8	0.004	<0.004	0.026	36	22.2	0.026	0.007	0.940	36	38.9	95	10	12,000	36	50.0	22.2
RS43	Motuwaireka S at Headwaters	0.026	0.003	0.420	35	0.0	0.005	<0.010	0.015	35	0.0	0.12	0.10	0.48	35	0.0	0.002	<0.004	0.008	35	0.0	0.004	<0.004	0.240	35	2.9	4	<1	160	34	2.9	0.0
RS44	Totara S at Stronvar	0.010	<0.002	0.200	35	0.0	0.005	<0.010	0.037	35	2.9	0.12	0.10	1.00	35	2.9	0.002	<0.004	0.006	35	0.0	0.005	<0.004	0.520	35	11.4	7	<1	170	34	8.8	0.0
RS45	Parkvale trib. at Lowes Reserve	**4.350**	2.400	6.800	28	100.0	0.005	<0.010	0.034	28	3.6	**4.80**	2.80	7.20	28	100.0	**0.017**	0.005	0.036	28	78.6	0.022	0.010	0.047	28	7.1	26	3	120	28	3.6	0.0
RS46	Parkvale S at Weir	**1.255**	<0.002	4.300	36	80.6	0.016	<0.010	0.122	36	25.0	**1.95**	0.39	5.40	36	91.7	**0.045**	0.016	0.140	36	100.0	**0.077**	0.033	0.390	36	97.2	**570**	<1	6,100	36	97.2	52.8
RS47	Waiohine R at Gorge	0.031	<0.002	0.097	36	0.0	0.005	<0.010	0.024	36	2.8	0.06	<0.11	0.30	36	0.0	0.002	<0.004	0.007	36	0.0	0.005	<0.004	0.120	36	11.1	7	<1	400	36	2.8	0.0
RS48	Waiohine R at Bicknells	0.295	0.010	1.100	36	30.6	0.013	<0.010	0.042	36	25.0	0.43	0.16	1.20	36	30.6	**0.016**	0.004	0.030	36	86.1	0.022	0.014	0.110	36	19.4	68	8	1,900	36	36.1	5.6
RS49	Beef Ck at Headwaters	0.020	<0.002	0.059	36	0.0	0.005	<0.010	0.012	36	0.0	0.06	0.10	0.30	36	0.0	0.007	<0.004	0.012	36	13.9	0.010	0.006	0.020	36	0.0	4	<1	650	36	8.3	2.8
RS50	Mangatarere S at SH 2	**1.200**	0.500	2.200	36	100.0	**0.100**	<0.010	0.520	36	88.9	**1.51**	0.79	2.80	36	100.0	**0.077**	0.024	0.710	36	100.0	**0.096**	0.043	0.810	36	100.0	**120**	13	2,300	36	63.9	16.7
RS51	Huangarua R at Ponatahi Br	0.235	0.002	0.730	36	11.1	0.005	<0.010	0.030	36	13.9	0.54	0.11	1.30	36	41.7	0.005	<0.004	0.085	36	36.1	0.011	<0.004	0.320	36	33.3	75	9	2,500	36	47.2	19.4
RS52	Tauanui R at Whakatomotomo Rd	0.010	<0.002	0.047	35	0.0	0.005	<0.010	0.027	35	2.9	0.06	0.10	0.28	35	0.0	0.007	<0.004	0.010	35	5.7	0.009	<0.004	0.073	35	2.9	4	<1	520	35	2.9	0.0
RS53	Awhea R at Tora Rd	0.029	<0.002	0.350	36	0.0	0.005	<0.010	0.024	36	8.3	0.24	<0.11	1.13	36	27.8	0.007	<0.004	0.030	36	36.1	0.022	<0.004	0.600	36	38.9	95	4	2,900	36	50.0	19.4
RS54	Coles Ck trib. at Lagoon Hill Rd	0.007	<0.002	0.052	28	0.0	0.005	<0.010	0.018	28	0.0	0.22	0.13	0.31	28	0.0	0.007	<0.004	0.013	28	17.9	0.016	0.006	0.033	28	0.0	46	4	350	28	42.9	0.0
RS55	Tauherenikau R at Websters	0.029	0.003	0.330	36	0.0	0.005	<0.010	0.014	36	0.0	0.11	0.10	0.44	36	0.0	0.002	<0.004	0.007	36	0.0	0.006	<0.004	0.097	36	11.1	20	<1	120	36	8.3	0.0
RS56	Waiorongomai R at Forest Park	0.013	<0.002	0.071	36	0.0	0.005	<0.010	0.005	36	0.0	0.06	<0.11	0.52	36	0.0	0.002	<0.004	0.009	36	0.0	0.006	<0.004	0.025	36	0.0	10	<1	1,400	36	2.8	2.8

the various guidelines across the 55 RSoE sites is summarised in Table 4.3. Overall, median values for each water quality variable met their corresponding guideline values at around two-thirds or more of sites. Visual clarity and dissolved reactive phosphorus (DRP) were the two exceptions; median values only met guidelines at 44% and 55% of sites, respectively.

Table 4.3: Summary of compliance with selected water quality guidelines/TVs, based on median values for data collected monthly from 55 RSoE sites over July 2008 to June 2011

Variable	Guideline/TV	Number (and percentage) of sites complying with guideline values
Water temperature (ºC)	≤19	55 (100%)
Dissolved oxygen (% saturation)	≥80	49 (89.1%)
pH	6.5–9.0	54 (98.2%)
Visual clarity (m)	≥1.6	24 (43.6%)
Turbidity (NTU)	≤5.6	44 (80.0%)
Nitrite-nitrate nitrogen (mg/L)	≤0.444	39 (70.9%)
Ammoniacal nitrogen (mg/L)	≤0.021	49 (89.1%)
Nitrate nitrogen – toxicity (mg/L)	≤1.7	52 (94.5%)
Total nitrogen (mg/L)	≤0.614	36 (65.5%)
Dissolved reactive phosphorus (mg/L)	≤0.010	30 (54.5%)
Total phosphorus (mg/L)	≤0.033	37 (67.3%)
E. coli (cfu/100mL)	≤100	35 (63.6%)
	≤550	51 (92.7%)

4.1.3 Water temperature

None of the 55 RSoE sites recorded a median water temperature value greater than the 19°C guideline. However, 30 sites exceeded this guideline on at least one sampling occasion and 17 sites exceeded it on more than 10% of sampling occasions (Table 4.2). Awhea River at Tora Road and Totara Stream at Stronvar exceeded the guideline on 33% and 27% of sampling occasions, respectively.

The highest maximum water temperature recorded was 25°C at Waipoua River at Colombo Road, just on Greater Wellington's RFP critical threshold. The next highest maximum temperatures were recorded at Awhea River at Tora Road and Totara Stream at Stronvar (24.3°C and 24.1°C, respectively).

RSoE sites located on the lower reaches of the region's larger rivers (eg, Ruamahanga River at Pukio), sites associated with the eastern Wairarapa hill country (eg, Awhea River at Tora Road), and sites on rivers and streams that experience long periods of low flows (eg, Waipoua River at Colombo Road) generally recorded the highest median water temperatures. Rivers and streams with limited streamside vegetation and shading (eg, Parkvale Stream at Weir) also tended to have higher median water temperatures (Figure 4.1). In contrast, sites located in catchments dominated by indigenous forest with hill elevation source of flows typically recorded the lowest median water temperatures over the reporting period (Figure 4.1).

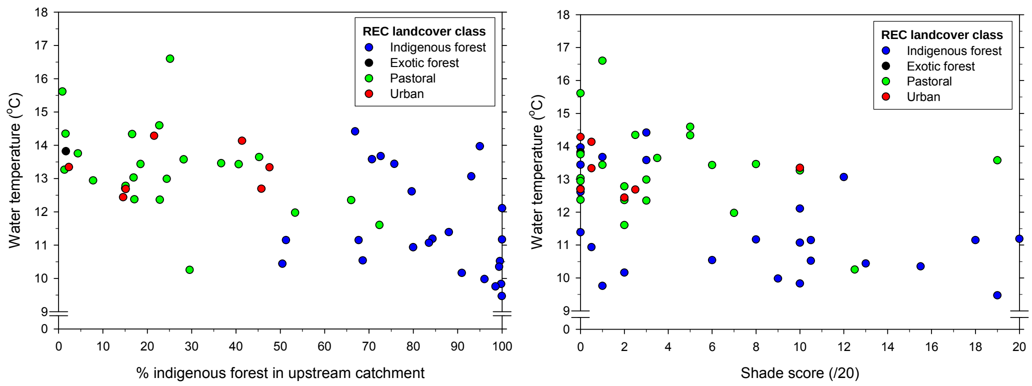


Figure 4.1: Scatter plots of indigenous forest cover in the upstream catchment (left) and estimated shade levels (right) against median water temperature for each RSoE site, based on monthly measurements between July 2008 and June 2011

As noted in Section 2.4.3, diurnal variation in water temperature means that the maximum values from monthly 'spot' measurements presented in Table 4.2 are unlikely to represent the maximum water temperatures experienced at a particular river or stream site. This is particularly the case at sites sampled in the early morning. For example, over the reporting period the Whareroa Stream at Queen Elizabeth Park was typically sampled before midday and only recorded a maximum temperature of 19.6°C (which was the only occasion when this site exceeded the 19°C threshold). However, measurements obtained from a short period of continuous water temperature monitoring during February and March 2011 clearly demonstrate that this site can (after midday) regularly exceed the 19°C threshold (Figure 4.2). This suggests that summer-time water temperatures have the potential to impact on aquatic fauna at this site.

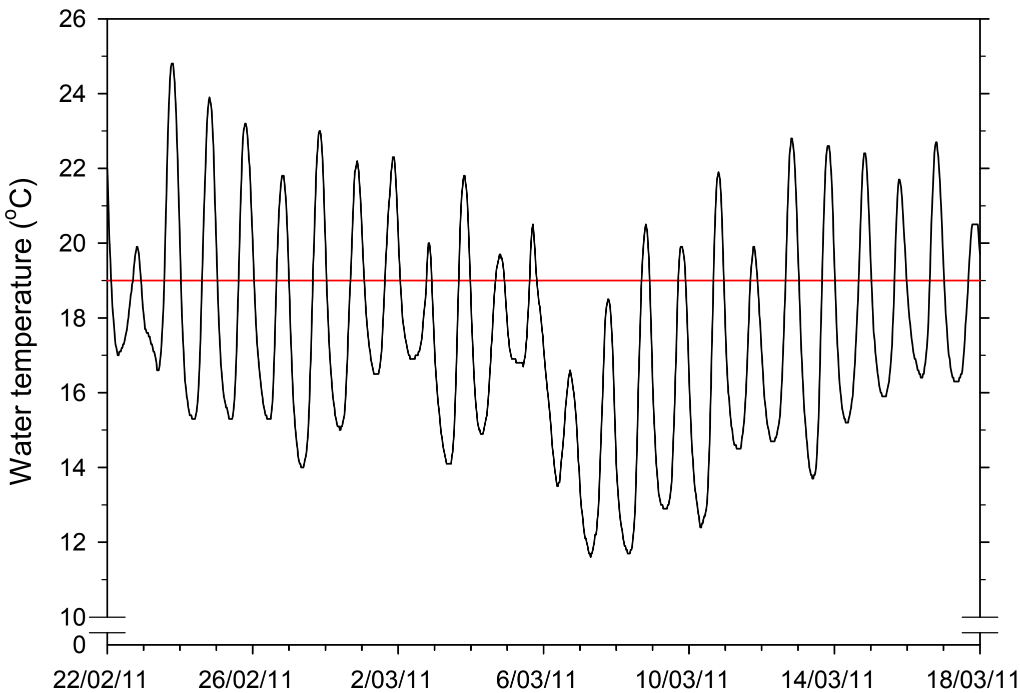


Figure 4.2: Continuous water temperature logging record for the Whareroa Stream at Queen Elizabeth Park between late February and mid March 2011. The 19°C threshold is indicated by the red line

4.1.4 Dissolved oxygen (% saturation)

Median dissolved oxygen (DO) values for the majority (49) of the 55 RSoE sites complied with the RMA and RFP critical minimum threshold of 80% (Tables 4.2 and 4.3), although most sites (50) did fall below 80% saturation on at least one sampling occasion during the reporting period. The six sites that recorded a median value below the 80% threshold were Ngarara Stream at Field Way, Mangapouri Stream at Bennetts Road, Parkvale tributary at Lowes Reserve, Mangaone Stream at Sims Road, Whareroa Stream at Queen Elizabeth Park and Waiwhetu Stream at Wainuiomata Hill Bridge. Minimum DO values were as low as 30–40% saturation at most of these sites, and even lower for Ngarara Stream at Field Way (minimum and median DO values of 9% and 55% saturation, respectively). Actual DO concentrations (see Appendix 6) at this site were less than 3 mg/L on eight occasions and likely placed significant stress on some aquatic life, particularly fish.

While dominant landcover does not seem to be a strong driver of DO saturation (Figure 4.3), all six of the sites that failed to comply with the 80% minimum threshold are located in catchments dominated by pastoral or urban landcover. However, these sites are also located on typically small, slow flowing and low elevation coastal streams which might naturally have lower DO levels (refer Section 3.1).

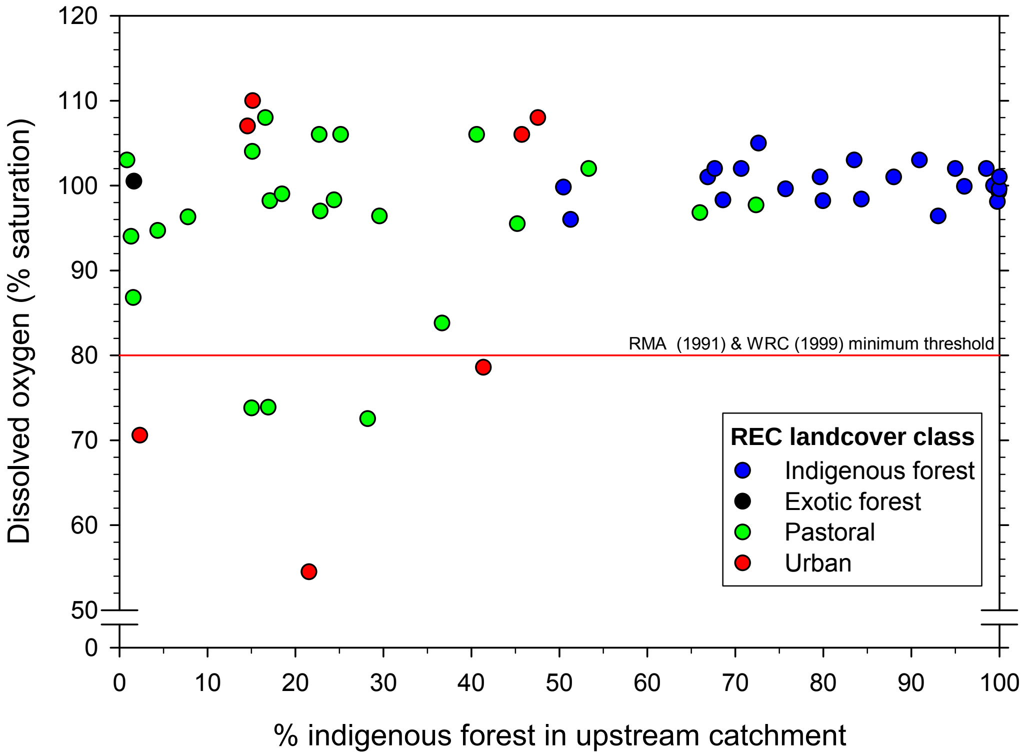


Figure 4.3: Scatterplot of median dissolved oxygen values (% saturation) for each RSoE site against indigenous forest cover (%) in the upstream catchment, based on monthly measurements between July 2008 and June 2011

Supersaturation was commonly recorded at most of the 55 RSoE sites at some stage (Table 4.2). Very high saturation values observed at some sites during stable flows in the summer months are a likely indication of high rates of photosynthesis by periphyton and/or aquatic macrophytes. For example, a saturation of 163% was recorded at Huangarua River at Ponatahi Bridge in March 2010, a time when extensive growths of periphyton were also observed at and upstream of the sampling site (Figure 4.4).

Figure 4.4: Prolific benthic periphyton cover just upstream of the RSoE sampling site located on the Huangarua River (March 2010)

Like water temperature, DO levels fluctuate diurnally and are therefore best measured continuously. Figure 4.5 provides part of a continuous record for Whareroa Stream at Queen Elizabeth Park. The record shows that DO saturation remained below the minimum 80% threshold for the majority of the time (frequently as low as 50–55%), adding support to the monthly spot measurements from this site that indicate DO levels are below optimum for extended periods during summer.

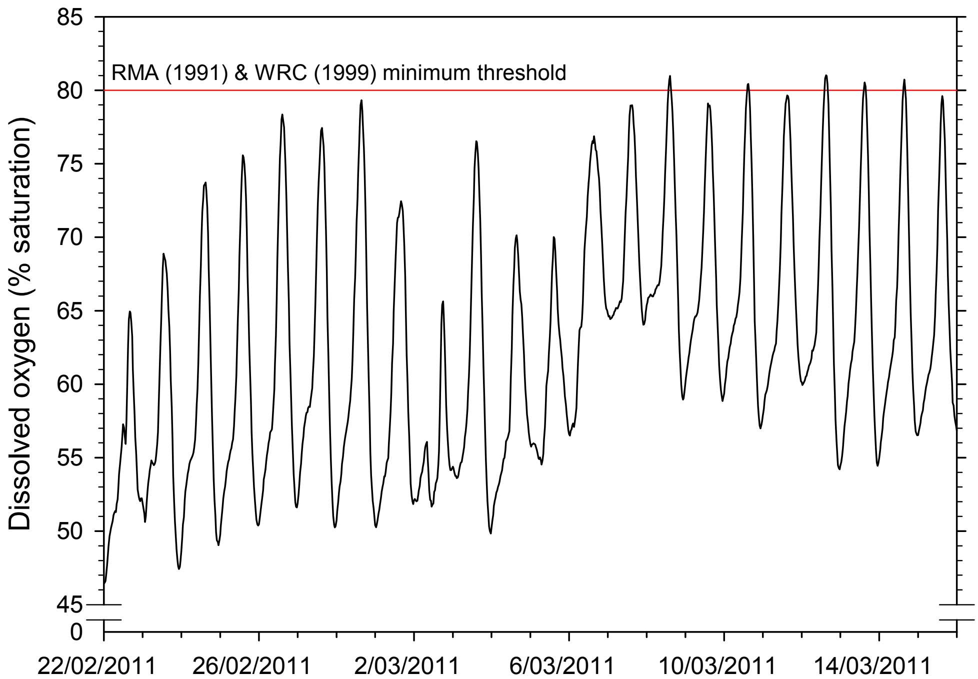


Figure 4.5: Continuous dissolved oxygen logging record for the Whareroa Stream at Queen Elizabeth Park between late February and mid March 2011

4.1.5 pH

Median pH values recorded across the 55 RSoE sites ranged from 6.4 (Parkvale Stream tributary at Lowes Reserve) to 8.0 (Huangarua River at Ponatahi Bridge and Awhea River at Tora Road) (Table 4.2). Sites located in catchments that drain the eastern Wairarapa hill country tended to have higher median pH values than sites located elsewhere (Figure 4.6), probably reflecting the carbonate-rich Miocene-Pliocene rocks/geology of marine origin present in this part of the region (Daughney 2010).

Only Parkvale tributary at Lowes Reserve recorded a median pH value outside of the ANZECC (1992) range of 6.5 to 9. The slightly acidic pH is likely to be a natural feature of this waterway; the majority of the flow in this stream is considered to be sourced from groundwater (Daughney 2010) with springs originating from within a remnant area of kahikatea swamp forest.

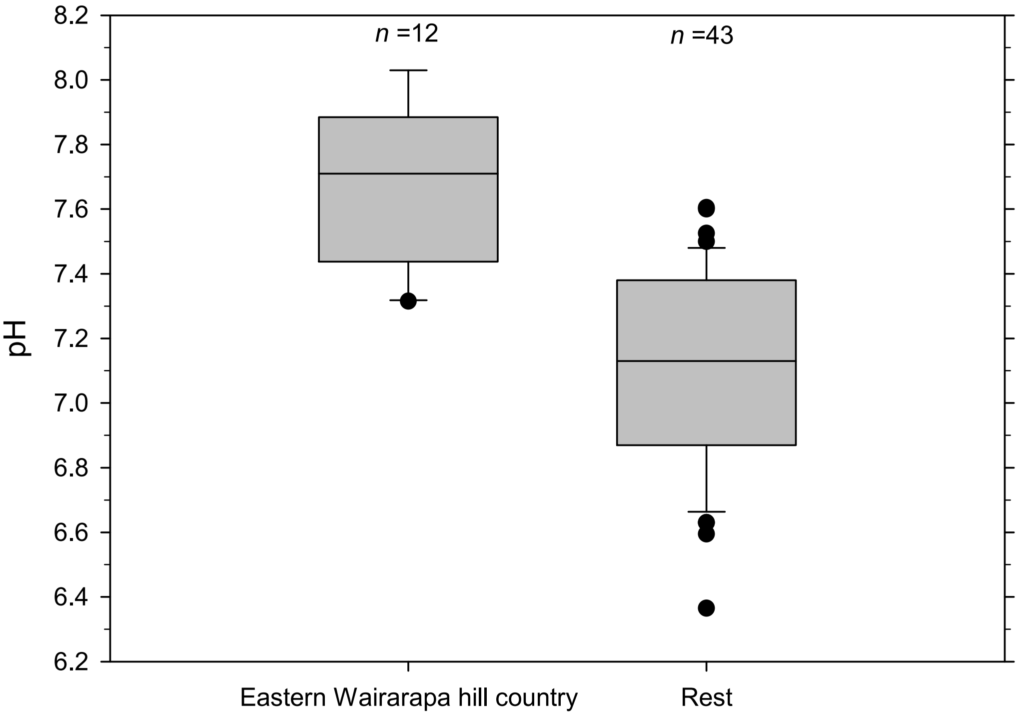


Figure 4.6: Box plots showing the range of median pH values measured at RSoE sites draining the eastern Wairarapa hill country compared with elsewhere, based on monthly sampling between July 2008 and June 2011. The difference between medians was statistically significant (Mann-Whitney Rank Sum Test, $p<0.001$)

Several sites recorded relatively large ranges in pH over the reporting period (Table 4.2). At some sites elevated pH maxima (ie, around 9) may be the result of intense photosynthesis occurring during summer months. For example, Parkvale Stream at Weir, a site characterised by nuisance periphyton and macrophyte growth (see Section 5.1), tended to record higher pH values (up to 8.7) in summer than in winter.

4.1.6 Visual clarity, turbidity and total suspended solids

Visual clarity (black disc) measurements tended to be highest at RSoE sites located on river and stream reaches that drain catchments with predominantly indigenous forest landcover and lower at low elevation sites with a pastoral or urban REC landcover class; the opposite pattern was observed for turbidity and total suspended solids (TSS) (Figure 4.7). Median visual clarity values at 31 sites failed to comply with the MfE (1994) guideline over the reporting period and median turbidity values at 11 of these sites were also above the ANZECC (2000) lowland TV of 5.6 NTU (Table 4.2).

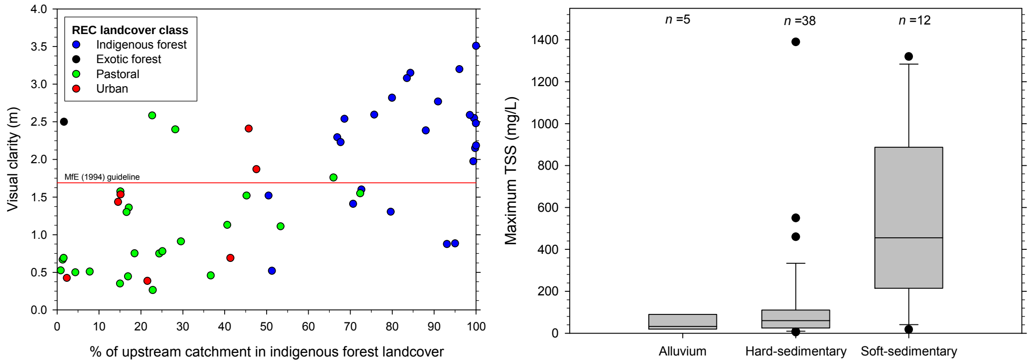


Figure 4.7: Scatter plot (left) of indigenous forest cover in the upstream catchment against median visual clarity values for each RSoE site, and box plot (right) summarising maximum TSS concentrations recorded at RSoE sites grouped by REC geology class. Both plots are based on the results of monthly sampling between July 2008 and June 2011

The highest median TSS concentration was recorded at Ruamahanga River at Pukio (18 mg/L). The next highest median TSS concentrations were recorded at Parkvale Stream at Weir (7.2 mg/L), Whareama River at Gauge (6.5 mg/L), Ruamahanga River at Te Ore Ore (6.4 mg/L) and Taueru River at Gladstone (6 mg/L). As expected, the highest maximum TSS concentrations were recorded during or following wet weather, and typically at RSoE sites with highly erodible soft-sedimentary soils/geology (Figure 4.7). These are generally sites draining the eastern Wairarapa (eg, Awhea River at Tora Road (950 mg/L), Whareama River at Gauge (1,200 mg/L), and Mataikona tributary at Sugar Loaf Road (1,320 mg/L)). However, the site that recorded the highest TSS concentration over the reporting period was Orongorongo River at Orongorongo Station (1,390 mg/L); this river has its headwaters in the Rimutaka Range (ie, hard-sedimentary geology).

While lower visual clarity values (and higher TSS concentrations and turbidity values) recorded at individual sites were generally associated with higher flows, there were some exceptions when activities such as instream works, stock access (eg, Parkvale Stream at Weir – see Section 4.1.11) or pollution events impacted on water clarity during dry weather/stable flow conditions. For example, a visual clarity value of just 0.30 m was recorded at Waingawa River at South Road during dry weather/stable flow conditions on 27 January 2009. This low result coincided with flood protection works being undertaken upstream of the site. A similarly poor visual clarity value (0.38 m) recorded during dry conditions at Hutt River at Boulcott on 7 October 2010 also coincided with instream flood protection works (visual clarity measured on the same day at Hutt River at Manor Park upstream of the works was 2.03 m).

4.1.7 Conductivity

Median conductivity concentrations ranged from 45 µS/cm (Ruamahanga River at McLays) to 640 µS/cm (Coles Creek tributary at Lagoon Hill Road) (Table 4.2). RSoE sites with hill elevation source of flow and predominantly indigenous forest in their upstream catchment tended to record the lowest conductivity values (Figure 4.8). However, there was significant natural variation across the region; sites in catchments draining the eastern Wairarapa hill country generally recorded much higher median conductivity values than sites elsewhere (Figure 4.8). As noted in Section 4.1.5, this likely reflects the more recent marine geology associated with this part of the region (Daughney 2010).

Three RSoE sites recorded maximum conductivity values greater than 1,000 µS/cm. In the case of one of these sites, Coles Creek tributary at Lagoon Hill Road (a site located in a catchment dominated by indigenous forest), the highest values occurred during summer low flows, reflecting a concentrating effect of the naturally occurring marine salts present in this part of the region. At the two other sites (Ngarara Stream at Field Way and Waiwhetu Stream at Wainuiomata Hill Bridge), the periodic recording of elevated conductivity values indicates that saline inputs (associated with tidal backflow) sometimes influence water quality at these sites[13].

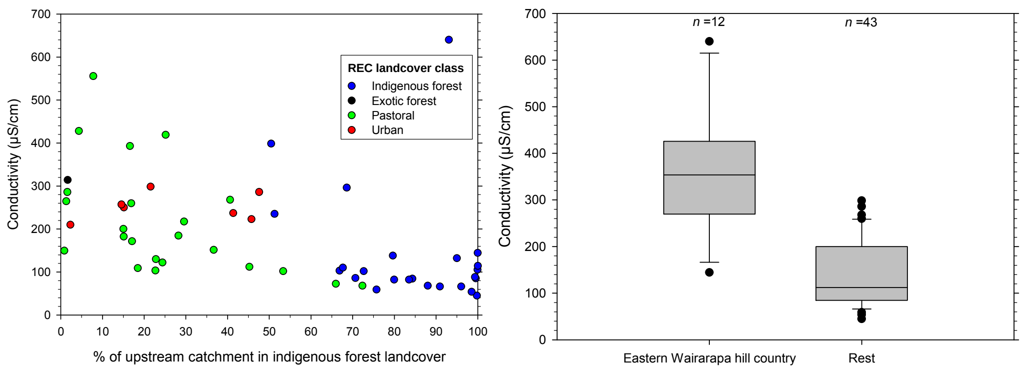


Figure 4.8: Scatter plot (left) of indigenous forest cover in the upstream catchment against median conductivity concentrations for each RSoE site, and box plot (right) summarising the range of median conductivity concentrations recorded across eastern Wairarapa RSoE sites compared with sites elsewhere (the difference between medians was statistically significant, Mann-Whitney Rank Sum Test, *p*<0.001). Both plots are based on data collected monthly between July 2008 and June 2011

4.1.8 Total organic carbon

Median total organic carbon (TOC) concentrations ranged from 1.1 to 8.1 mg/L at most sites (Table 4.2). The two exceptions were Ngarara Stream at Field Way and Whareroa Stream at Queen Elizabeth Park, with median concentrations of 16.8 mg/L and 13.9 mg/L, respectively. Higher concentrations at these sites likely represent naturally elevated concentrations from nearby wetland areas (both streams are characterised by humic-stained water). Other sites that

[13] The Waiwhetu Stream at Wainuiomata Road Bridge site was relocated to Whites Line East, approximately 0.9 km upstream, in July 2011 (see Section 2.3).

recorded median TOC concentrations at the higher end of the range included Whangaehu River 250 m from confluence (8.1 mg/L), Whareama River at Gauge (6.7 mg/L) and Parkvale Stream at Weir (6.2 mg/L).

4.1.9 Nitrogen

Median nitrite-nitrate nitrogen (NNN) concentrations ranged from 0.005 mg/L (Whareama River at Gauge) to 4.35 mg/L (Parkvale tributary at Lowes Reserve) over the reporting period[14], with 16 sites recording median concentrations above the ANZECC (2000) lowland TV (Table 4.2). All of these sites, along with a further three other sites, also exceeded the ANZECC (2000) lowland TV for total nitrogen (TN). Higher concentrations of both NNN and TN tended to be associated with lowland sites draining predominantly pastoral and/or urban catchments (Figure 4.9).

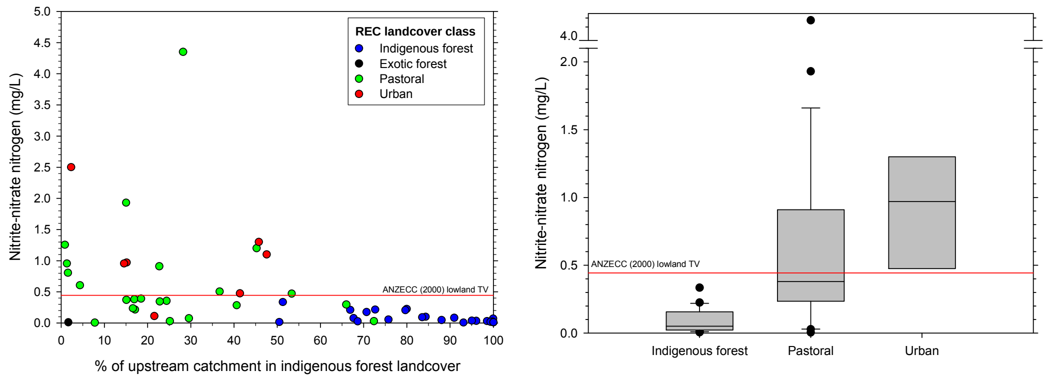


Figure 4.9: Scatter plot (left) of indigenous forest cover in the upstream catchment against median NNN concentrations for each RSoE site, and box plot (right) summarising the range of median NNN concentrations across the three main REC landcover classes represented in the RSoE network. Both plots are based on the results of monthly sampling between July 2008 and June 2011

Mangapouri Stream at Bennetts Road, Mangaone Stream at Sims Road and Parkvale tributary at Lowes Reserve all recorded median nitrate nitrogen concentrations above Hickey and Martin's (2009) chronic toxicity TV of 1.7 mg/L (see Appendix 6). Four other sites exceeded this TV on more than 10% of sampling occasions during the reporting period, including Parkvale Stream at Weir (42% of sampling occasions), Mangatarere Stream at SH 2 (14%), Porirua Stream at Wall Park (11%) and Waipoua River at Colombo Road (11%).

At most sites, the highest NNN concentrations were recorded during the winter months (Figure 4.10) when rainfall tends to be greater, the soils are more saturated, and groundwater levels are higher. While this 'winter flushing' pattern was generally present across sites in all landcover types, it was particularly marked at pastoral sites (Figure 4.10). Tidswell et al. (2012) found elevated winter nitrate concentrations in a number of shallow groundwater wells in the region, confirming the increased 'flushing' of nitrate from soils to groundwater during these months. Much of this shallow groundwater then enters nearby rivers and streams. Analysis of groundwater SoE and RSoE water

[14] It is worth noting that Mangapouri Stream at Rahui Road (Site RS01), where monitoring ceased in August 2009 (see Section 2.3), recorded the highest median NNN concentrations of all sites (7.05 mg/L for the period July 2008 to August 2009).

chemistry data undertaken by Daughney (2010) further shows that some RSoE sites have similar chemical signatures to groundwater, suggesting that groundwater potentially influences water quality at these sites for much of the year. Certainly a number of sites that recorded higher concentrations of NNN have been shown by Daughney (2010) to have hydraulic linkages with adjacent groundwater: Waitohu Stream at Norfolk Crescent, Mangapouri Stream at Bennetts Road, Mangaone Stream at Sims Road Bridge, Ngarara Stream at Field Way, Parkvale tributary at Lowes Reserve, Parkvale Stream at Weir, and Mangatarere Stream at SH 2.

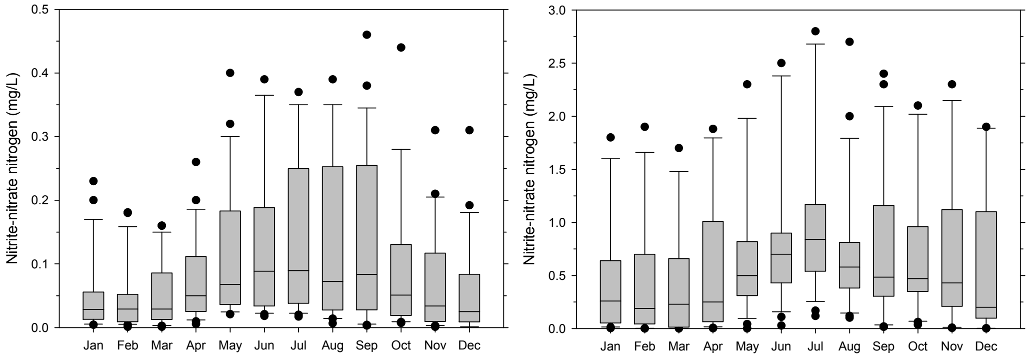


Figure 4.10: Box plots of median NNN concentrations at RSoE sites classed by REC as indigenous forest (left, *n*=24) and pasture (right, *n*=23), grouped by month of sample collection. Both plots are based on data collected monthly between July 2008 and June 2011 (note the different scales on the *y*-axes)

In terms of ammoniacal nitrogen (Amm N), the majority of monitoring sites recorded median concentrations below the ANZECC (2000) lowland TV (Table 4.2) and none exceeded ANZECC (2000) or USEPA (2009) toxicity TVs on any sampling occasion. All six of the sites that exceeded the lowland TV are located in catchments dominated by pastoral and/or urban land use, with five of these sites being small low elevation coastal streams (Mangapouri Stream at Bennetts Road, Mangaone Stream at Sims Road Bridge, Waiwhetu Stream at Wainuiomata Hill Bridge, Waitohu Stream at Norfolk Crescent and Whareroa Stream at Queen Elizabeth Park). The other site to exceed the TV was Mangatarere Stream at SH 2. This site is located approximately 1.2 km downstream of the Carterton WWTP discharge and recorded the highest median value of any site over the reporting period (0.10 mg/L).

4.1.10 Phosphorus

Median dissolved reactive phosphorus (DRP) concentrations at the 55 RSoE sites ranged from less than the analytical detection limit (ie, <0.004 mg/L, recorded at eight sites) to 0.077 mg/L for Mangatarere Stream at SH 2 (Table 4.2). Twenty five sites (45%) exceeded the ANZECC (2000) lowland TV of 0.01 mg/L, most of which tended to be sites with low elevation source of flows draining catchments dominated by pastoral or urban land uses (Figure 4.11). A notable exception was Waikanae River at Mangaone Walkway, a ‘best available’ reference site located in a catchment dominated by indigenous forest cover. The narrow exceedance of the DRP TV at this site is likely due to naturally elevated concentrations caused by underlying catchment geology. Some RSoE reference sites, such as Wainuiomata River at Manuka Track and

Beef Creek at Headwaters, are also thought to have naturally 'elevated' DRP concentrations (Perrie 2007; Ausseil 2011).

Based on median concentrations across the three major landcover types, urban sites recorded the highest concentrations of DRP, followed by pastoral sites (Figure 4.11). Although Mangatarere Stream at SH 2 is classified as a pastoral site, the very high median concentration at this site is attributed to the input of treated wastewater from Carterton township to the stream a short distance upstream (eg, Milne et al. 2010).

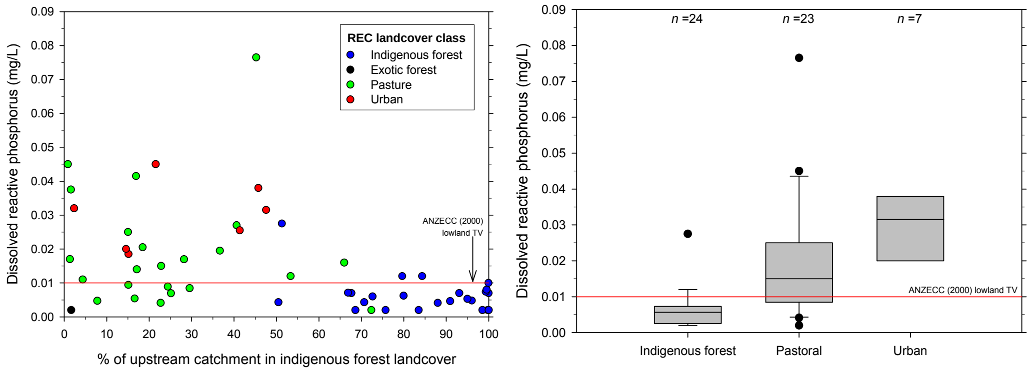


Figure 4.11: Scatter plot (left) of indigenous forest cover in the upstream catchment against median DRP concentrations for each RSoE site, and box plot (right) summarising the range of median DRP concentrations across the three main REC landcover classes represented by the RSoE network. Both plots are based on data collected monthly between July 2008 and June 2011

In contrast with NNN, there was no seasonal pattern in DRP concentrations common to the majority of sites. While some sites recorded higher DRP concentrations during the winter months, other sites showed the opposite pattern and at some sites no clear pattern was evident. Higher DRP concentrations recorded at some sites during low flows are generally consistent with some sort of point source discharge (eg, a WWTP discharge) or nutrient-rich groundwater input (Ausseil 2011). This pattern appeared strongest at some of the urban sites, such as Karori Stream at Makara Peak (Figure 4.12).

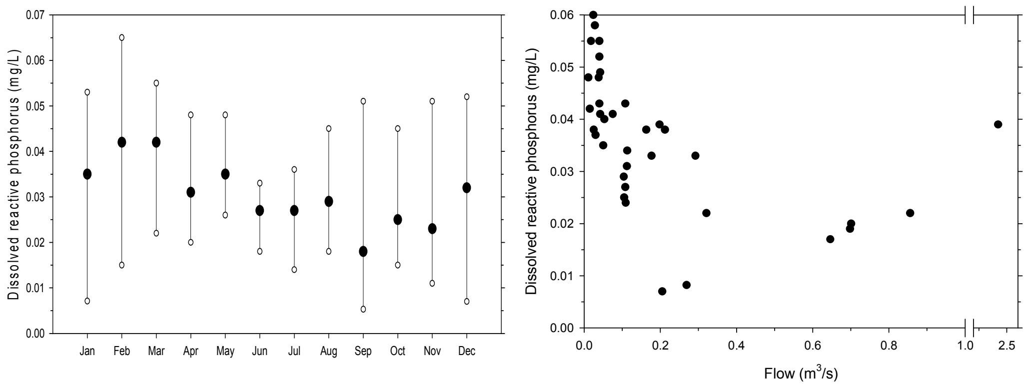


Figure 4.12: Median (and range) of DRP concentrations recorded at RSoE sites classed as urban (left, *n*=7) and scatter plot of flow and DRP concentrations recorded at Karori Stream at Makara Peak (right). Both plots data are based on data collected monthly between July 2008 and June 2011

At one site, Ngarara Stream at Field Way, release of DRP from streambed sediments may be occurring during times when dissolved oxygen concentrations are very low (Figure 4.13). This phenomenon is particularly common in eutrophic lakes in summer and is linked with the breakdown of organic matter in the bottom sediment under oxygen-poor conditions.

Median concentrations of total phosphorus (TP) ranged from 0.004 mg/L (Motuwaireka Stream at Headwaters) to 0.110 mg/L (Ngarara Stream at Field Way). Eighteen sites (33%) recorded a median concentration above the ANZECC (2000) lowland TV of 0.033 mg/L, all of which also exceeded the ANZECC (2000) DRP lowland TV.

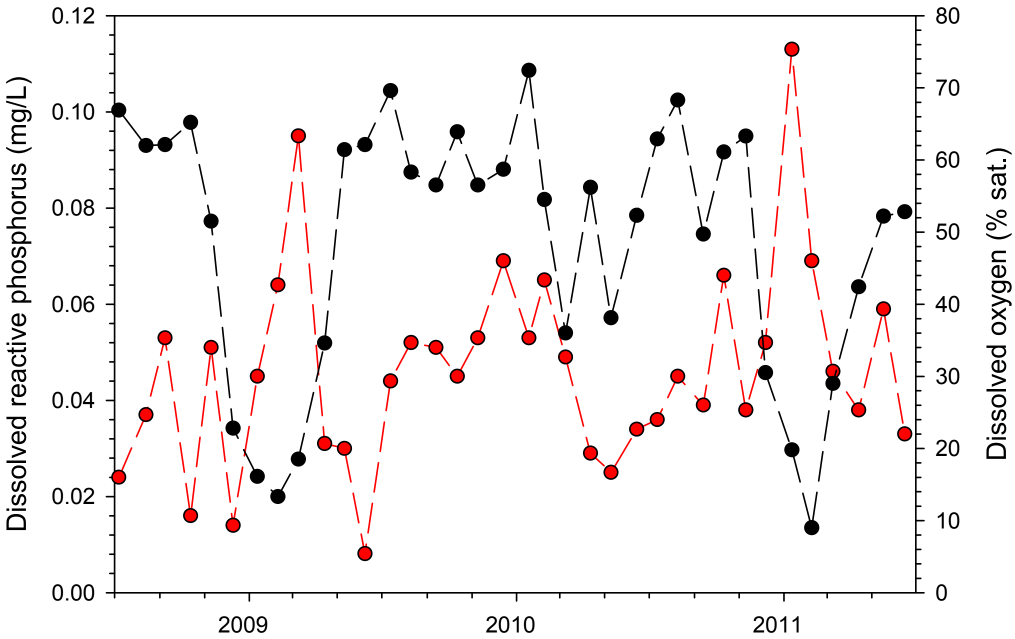


Figure 4.13: Relationship between concentrations of DRP (red line) and dissolved oxygen (% saturation, black line), based on data collected monthly between July 2008 and June 2011

4.1.11 E. coli

All RSoE sites located in catchments dominated by indigenous forest cover complied with the ANZECC (2000) stock water TV of 100 cfu/100mL. The 20 RSoE sites that exceeded this TV all have low elevation sources of flow and drain catchments assigned to either pastoral or urban landcover classes. At four of these 20 sites the median *E. coli* count also exceeded the less conservative proxy stock water TV adopted for use in this report (550 cfu/100mL): Parkvale Stream at Weir, Mangapouri Stream at Bennetts Road, Porirua Stream at Walk Park, and Karori Stream at Makara Peak (Table 4.2, Figure 4.14).

Around two thirds of the 55 sites recorded *E. coli* counts in excess of 1,000 cfu/100mL on at least one sampling occasion over the reporting period. Nine of these sites recorded values over 10,000 cfu/100mL, these typically being sites located in urban catchments (Karori Stream at Makara Peak, Kaiwharawhara Stream at Ngaio Gorge and Porirua Stream at Wall Park) or pastoral catchments that drain the eastern Wairarapa hill country (eg, Whareama River at Gauge, Kopuaranga River at Stewarts and Whangaehu

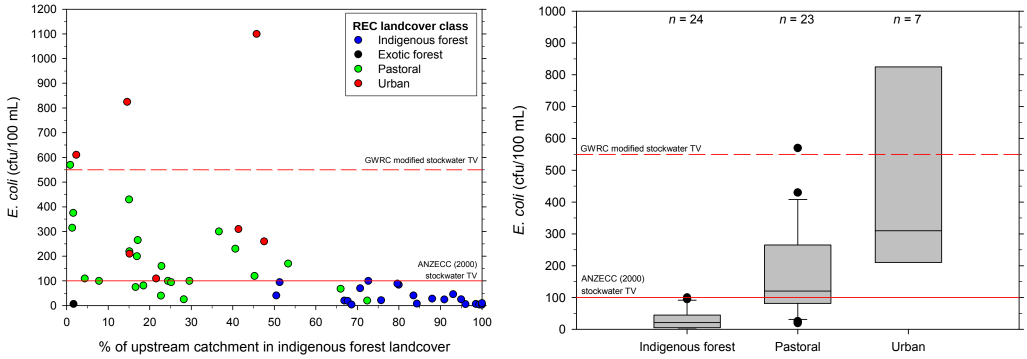


Figure 4.14: Scatter plot (left) of indigenous forest cover in the upstream catchment against median *E. coli* counts for each RSoE site, and box plot (right) summarising the range of median *E. coli* counts across the three main REC landcover classes represented in the RSoE network. Both plots are based on data collected monthly between July 2008 and June 2011

River 250 m from confluence). As noted below, some of the highest *E. coli* counts recorded at urban sites were associated with dry weather; this suggests, along with the presence of elevated nutrient concentrations in dry weather flows, the presence of a point source wastewater input(s) upstream. In contrast, high counts at the eastern Wairarapa sites were associated with wet weather, when the soft erosion-prone soils in the area are readily washed into the rivers – carrying with them faecal matter deposited by stock on unstable farmland and riparian margins/stream banks. Re-suspension of streambed sediments may also be a factor at these sites, as well as at other pastoral sites that recorded high *E. coli* counts in wet weather (eg, Whareroa Stream at Queen Elizabeth Park).

While elevated *E. coli* counts were typically associated with increased river and stream flow, a number of sites recorded elevated counts (ie, >550 cfu/100mL) at times when flows were relatively stable and there had been no recent rainfall. This was most commonly observed at urban sites, such as Karori Stream at Makara Peak where, for example, on 8 December 2009, a result of 11,000 cfu/100mL was recorded in the absence of any recent rainfall during clear and stable flow conditions. Some elevated *E. coli* counts were also recorded in rural areas in the absence of rainfall, most likely arising from stock access/crossings. For example, a herd of dairy cows crossing Parkvale Stream approximately 100 m upstream of the RSoE site (Parkvale at Weir) coincided with an *E. coli* count of 3,600 cfu/100mL on one occasion.

4.1.12 Heavy metals

Table 4.4 summarises dissolved copper, lead and zinc concentrations recorded at the 10 RSoE sites at which these metals were monitored over July 2008 to June 2011[15]. Median concentrations of dissolved lead were below the ANZECC (2000) toxicity TV at all sites. In contrast, median concentrations of dissolved copper and zinc exceeded their respective ANZECC (2000) toxicity TVs at two sites (Porirua Stream at Wall Park and Kaiwharawhara Stream at Ngaio Gorge) and four sites (Porirua Stream at Wall Park, Karori Stream at

[15] Dissolved concentrations of arsenic, cadmium, chromium and nickel were also measured at one site, Waiwhetu Stream at Wainuiomata Hill Road Bridge. The median concentrations for each of these metals were all well below their respective ANZECC (2000) toxicity TVs.

Makara Peak, Kaiwharawhara Stream at Ngaio Gorge and Waiwhetu Stream at Wainuiomata Hill Bridge), respectively. With the exception of dissolved copper and zinc at the Kaiwharawhara Stream site, all of these same sites also exceeded their site-specific, hardness-modified TVs.

Maximum concentrations of dissolved copper recorded at two sites exceeded the hardness-modified USEPA (2009) guideline for acute toxicity on one occasion: the Porirua Stream at Glenside and the Porirua Stream at Wall Park (Table 4.4). Maximum concentrations of dissolved zinc also exceeded hardness-modified USEPA (2009) acute toxicity thresholds at four sites: Karori Stream at Makara Peak (on four occasions), Porirua Stream at Wall Park (two occasions), Waiwhetu Stream at Wainuiomata Hill Bridge (two occasions), and Mangapouri Stream at Bennetts Road (one occasion).

Table 4.4: Summary of dissolved copper, lead and zinc concentrations (mg/L) measured at ten RSoE sites, based on monthly sampling between July 2008 and June 2011 (*n*=36). Median values in bold exceeded ANZECC (2000) chronic toxicity (95% level of protection) TVs and underlined median values exceeded site-specific, hardness-modified TVs. Maximum concentrations that exceeded USEPA (2009) hardness-modified acute toxicity guidelines are also in bold font

Site	Dissolved copper				Dissolved lead				Dissolved zinc			
	Med	Min	Max	*n* <D.L	Med	Min	Max	*n* <D.L.	Med	Min	Max	*n* <D.L.
Mangapouri S at Bennetts Rd (RS02)	0.00081	0.00025	0.0022	2	0.00019	0.00005	0.00027	1	0.0035	0.0005	**0.1960**	1
Ngarara S at Field Way (RS08)	0.00025	0.00025	0.0030	20	0.00005	0.00005	0.00061	31	0.0024	0.0005	0.0082	5
Waikanae R at Greenaway Rd (RS10)	0.00025	0.00025	0.0013	31	0.00005	0.00005	0.00054	32	0.0016	0.0005	0.0140	10
Porirua S at Glenside (RS15)	0.00095	0.00060	**0.0087**	0	0.00005	0.00005	0.00024	23	0.0052	0.0005	0.0197	3
Porirua S at Wall Park (RS16)	**0.00200**	0.00091	**0.0112**	0	0.00028	0.00005	0.00200	6	**0.0255**	0.0028	**0.0600**	0
Karori S at Makara Peak (RS18)	0.00134	0.00080	0.0047	0	0.00012	0.00005	0.00070	14	**0.0179**	0.0040	**0.0680**	0
Kaiwharawhara S at Ngaio Gorge (RS19)	**0.00155**	0.00088	0.0049	0	0.00008	0.00005	0.00071	18	**0.0091**	0.0005	0.0390	1
Hutt R opp. Manor Park GC (RS21)	0.00025	0.00025	0.0028	19	0.00011	0.00005	0.00085	12	0.0028	0.0005	0.0115	5
Hutt R at Boulcott (RS22)	0.00025	0.00025	0.0028	25	0.00005	0.00005	0.00137	29	0.0018	0.0005	0.0055	7
Waiwhetu S at Wainui Hill Br (RS27)	0.0011	0.0005	0.0037	2[1]	0.00037	0.00015	0.00084	0	**0.0200**	0.0041	**0.1410**	0

[1]The detection limit achieved by the analytical laboratory for samples from this site varied over the reporting period.

4.1.13 Water Quality Index

In this section the overall quality of rivers and streams in the Wellington region is summarised by the use of two different water quality indices. The first is Greater Wellington's WQI, detailed in Perrie (2007), and involves comparing the *median* values of six key water quality variables outlined in Table 4.1 against relevant guidelines and then allocating water quality grades as follows:

- Excellent: median values for all 6 variables comply with guideline values
- Good: median values for 5 of the 6 variables comply with guideline values, of which dissolved oxygen (DO) is one variable that must comply[16]
- Fair: median values for 3 or 4 of the 6 variables comply with guideline values, of which DO is one variable that must comply[16]
- Poor: median values for <3 of the 6 variables comply with guideline values and/or if the median DO concentration does not comply with the guideline value.

Sites were also ranked within each of the four water quality grades above according to the sum of the percent compliance across all six guidelines (see Appendix 5).

The second WQI uses the methodology defined in the Canadian Water Quality Index (CCME 2001) and incorporates a wider and slightly different range of variables and guidelines to Greater Wellington's WQI, including the addition of water temperature and nitrate toxicity (see Table 4.1). The Canadian WQI has three elements:

- *Scope*: the number of variables that do not meet the assigned compliance thresholds (known as the *objectives*) on at least one sampling occasion.
- *Frequency*: the frequency with which individual sample results fail to meet the assigned compliance thresholds.
- *Magnitude*: the amount by which individual sample results fail to meet the assigned compliance thresholds.

The three elements are combined to produce a single WQI value between 0 and 100 where the higher the value, the better the water quality (see Appendix 5 for calculation details). Once the WQI value has been determined, water quality can then be assigned to varying water quality categories (eg, scores over 80 typically represent 'excellent' water quality). However, given that the 'categorisation' process is subjective (CCME 2001) and the use of the CCME WQI in this report was a trial to assess its potential use in future SoE reporting, WQI scores have only been placed into quartile classes and compared against the outputs of Greater Wellington's WQI.

(a) Greater Wellington's WQI

Based on monthly monitoring results over the period July 2008 to June 2011, 18 of the 55 RSoE sites had a WQI grade of 'excellent' (Table 4.5, Figure 4.15).

Table 4.5: Water Quality Index grades for RSoE sites sampled at monthly intervals over June 2008 to July 2011 inclusive, based on compliance of median values with guideline values for six key variables (see Table 4.1)

Rank	Site No.	Site name	Water Quality Index (median values)						REC landcover
			DO%	Clarity	*E. coli*	NNN	Ammonia N	DRP	
Excellent									
1	RS43	Motuwaireka S at headwaters	✓	✓	✓	✓	✓	✓	Ind. forest
2	RS05	Otaki R at Pukehinau	✓	✓	✓	✓	✓	✓	Ind. forest
3	RS03	Waitohu S at Forest Park	✓	✓	✓	✓	✓	✓	Ind. forest
4	RS52	Tauanui R at Whakatomotomo Rd	✓	✓	✓	✓	✓	✓	Ind. forest
5	RS47	Waiohine R at Gorge	✓	✓	✓	✓	✓	✓	Ind. forest
6	RS56	Waiorongomai R at Forest Park	✓	✓	✓	✓	✓	✓	Ind. forest
7	RS31	Ruamahanga R at McLays	✓	✓	✓	✓	✓	✓	Ind. forest
8	RS49	Beef Ck at Headwaters	✓	✓	✓	✓	✓	✓	Ind. forest
9	RS28	Wainuiomata R at Manuka Track	✓	✓	✓	✓	✓	✓	Ind. forest
10	RS20	Hutt R at Te Marua Intake Site	✓	✓	✓	✓	✓	✓	Ind. forest
11	RS26	Whakatikei R at Riverstone	✓	✓	✓	✓	✓	✓	Ind. forest
12	RS44	Totara S at Stronvar	✓	✓	✓	✓	✓	✓	Ex. forest
13	RS25	Akatarawa R at Hutt confl.	✓	✓	✓	✓	✓	✓	Ind. forest
14	RS06	Otaki R at Mouth	✓	✓	✓	✓	✓	✓	Ind. forest
15	RS41	Waingawa R at South Rd	✓	✓	✓	✓	✓	✓	Ind. forest
16	RS10	Waikanae R at Greenaway Rd	✓	✓	✓	✓	✓	✓	Ind. forest
17	RS23	Pakuratahi R 50m Below Farm Ck	✓	✓	✓	✓	✓	✓	Ind. forest
18	RS21	Hutt R Opp Manor Park Golf Club	✓	✓	✓	✓	✓	✓	Ind. forest
Good									
19	RS09	Waikanae R at Mangaone Walkway	✓	✓	✓	✓	✓	x	Ind. forest
20	RS55	Tauherenikau R at Websters	✓	x	✓	✓	✓	✓	Pasture
21	RS35	Mataikona trib at Sugar Loaf Rd	✓	x	✓	✓	✓	✓	Ind. forest
22	RS30	Orongorongo R at Orongorongo St.	✓	x	✓	✓	✓	✓	Ind. forest
23	RS22	Hutt R at Boulcott	✓	x	✓	✓	✓	✓	Ind. forest
24	RS54	Coles Ck trib at Lagoon Hill Rd	✓	x	✓	✓	✓	✓	Ind. forest
25	RS40	Waipoua R at Colombo Rd Bridge	✓	✓	✓	x	✓	✓	Pasture
26	RS51	Huangarua Ri at Ponatahi Bridge	✓	x	✓	✓	✓	✓	Pasture
27	RS36	Taueru R at Castlehill	✓	x	✓	✓	✓	✓	Pasture
28	RS53	Awhea R at Tora Rd	✓	x	✓	✓	✓	✓	Pasture
29	RS42	Whareama R at Gauge	✓	x	✓	✓	✓	✓	Pasture
30	RS32	Ruamahanga R at Te Ore Ore	✓	x	✓	✓	✓	✓	Pasture
31	RS48	Waiohine R at Bicknells	✓	✓	✓	✓	✓	x	Pasture
Fair									
32	RS13	Horokiri S at Snodgrass	✓	x	x	✓	✓	✓	Pasture
33	RS29	Wainuiomata R u/s of White Br	✓	x	✓	✓	✓	x	Ind. forest
34	RS11	Whareroa S at Waterfall Rd	✓	x	✓	✓	✓	x	Ind. forest
35	RS33	Ruamahanga R at Gladstone Br	✓	x	✓	✓	✓	x	Pasture
36	RS14	Pauatahanui S at Elmwood Bridge	✓	x	x	✓	✓	x	Pasture
37	RS34	Ruamahanga R at Pukio	✓	x	x	✓	✓	x	Pasture
38	RS18	Karori S at Makara Peak MBP	✓	✓	x	x	✓	x	Urban
39	RS17	Makara S at Kennels	✓	x	x	✓	✓	x	Pasture
40	RS19	Kaiwharawhara S at Ngaio Gorge	✓	✓	x	x	✓	x	Urban
Poor									
41	RS45	Parkvale trib at Lowes Reserve	x	✓	✓	x	✓	x	Pasture
42	RS24	Mangaroa R at Te Marua	✓	x	x	x	✓	x	Pasture
43	RS15	Porirua S at Glenside O.C.	✓	x	x	x	✓	x	Urban
44	RS37	Taueru R at Gladstone	✓	x	x	x	✓	x	Pasture
45	RS16	Porirua S at Wall Park (Milk Depot)	✓	x	x	x	✓	x	Urban
46	RS38	Kopuaranga R at Stewarts	✓	x	x	x	✓	x	Pasture
47	RS46	Parkvale S at Weir	✓	x	x	x	✓	x	Pasture
48	RS39	Whangaehu R at 250m from conf.	✓	x	x	x	✓	x	Pasture
49	RS50	Mangatarere S at SH 2	✓	x	x	x	x	x	Pasture
50	RS04	Waitohu S at Norfolk Crescent	✓	x	x	x	x	x	Pasture
51	RS08	Ngarara S at Field Way	x	x	x	x	✓	x	Urban
52	RS12	Whareroa S at QE Park	x	x	x	x	x	x	Pasture
53	RS27	Waiwhetu S at Wainuiomata Hill Br	x	x	x	x	x	x	Urban
54	RS07	Mangaone S at Sims Road Bridge	x	x	x	x	x	x	Pasture
55	RS02	Mangapouri S at Bennetts Rd	x	x	x	x	x	x	Urban

[16] If the median DO concentration does not comply with the guideline value, then the WQI grade automatically drops to 'poor'.

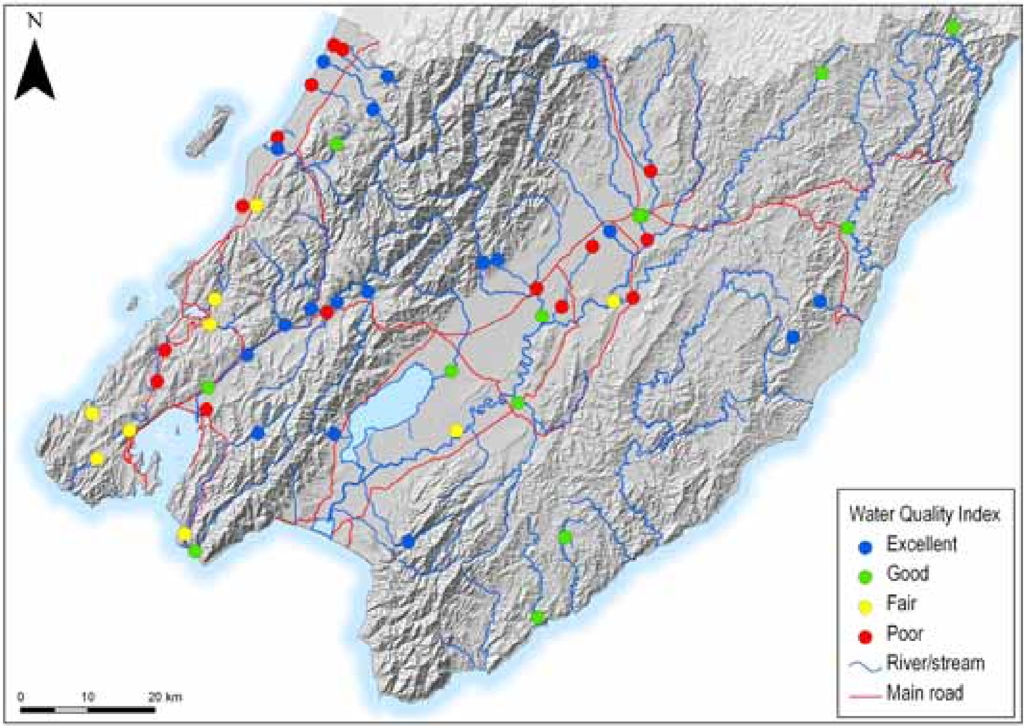


Figure 4.15: Map of Greater Wellington's WQI grades for RSoE sites sampled at monthly intervals over June 2008 to July 2011 inclusive, based on compliance of median values with guideline values for six key variables (see Table 4.1)

Sites that were assigned this grade are all located in catchments dominated by indigenous forest (68–100% cover) and, in one case, exotic forest (Totara Stream at Stronvar). These sites are typically located on the upper reaches of the region's rivers and streams that are flowing out of the Aorangi, Tararua, Rimutaka ranges. They generally have hill elevation sources of flow and hard-sedimentary geology.

Thirteen sites draining a mixture of both indigenous forest and pastoral landcover received a water quality grade of 'good', indicating that median values for five of the six water quality variables in the WQI complied with their respective guideline values. Visual clarity was the variable 'good' sites most commonly failed to meet (Table 4.5).

Nine sites were assigned a 'fair' water quality grade. These sites all have low elevation sources of flow and are located across a range of landcover types: indigenous forest (two sites), pasture (five) and urban (two). These sites are generally located on smaller streams or the lower reaches of larger rivers (eg, the Wainuiomata and Ruamahanga rivers).

Fifteen sites received a water quality grade of 'poor' because median values for less than half of the six water quality variables in the WQI complied with their respective guidelines (Table 4.5) or, as in the case of the Parkvale tributary at Lowes Reserve, the median DO value did not comply with the guideline. All poor sites failed to comply with the DRP guideline and, except for the Parkvale tributary at Lowes Reserve, the guidelines for water clarity and *E. coli*. Sites graded poor are located on the lower reaches of rivers and streams draining predominantly pastoral (10 sites) or urban catchments (5 sites) and are considered to have low elevation source of flows.

(b) CCME WQI

Water quality classified according to the CCME WQI is summarised for each RSoE site in Table 4.6. Across the 55 RSoE sites scores ranged from 20.5 (poorest score) for Mangapouri Stream at Bennetts Road to 90.6 (best score) for Hutt River at Te Marua. Similar to the Greater Wellington WQI classifications, RSoE sites located in catchments dominated by indigenous forest tended to have the highest CCME WQI scores (ie, assigned to the upper quartile of scores). In contrast, all sites with CCME WQI scores in the lower quartile range were located in either pastoral or urban catchments; all but one of the seven urban sites, Porirua Stream at Glenside, scored within the lower quartile.

A comparison of the CCME and Greater Wellington's WQI outputs shows that both indices generally rank sites in a similar fashion (Figure 4.16), despite some differences in the water quality variables, guidelines and calculations. For example, 13 of the 14 sites that received CCME WQI scores in the upper quartile range were allocated grades of 'excellent' by Greater Wellington's WQI. Similarly, all but two of the 14 sites that received CCME WQI scores in the lower quartile range were graded as 'poor' by Greater Wellington's WQI. On closer examination, while the overall ranking pattern is similar between the two WQIs, there is wide variation between individual ranks for some sites; 11 sites changed rank by at least 10 positions depending on the WQI used. The largest difference was for Mangaroa River at Te Marua – this site was ranked 44th using Greater Wellington's WQI but 24th by the CCME WQI.

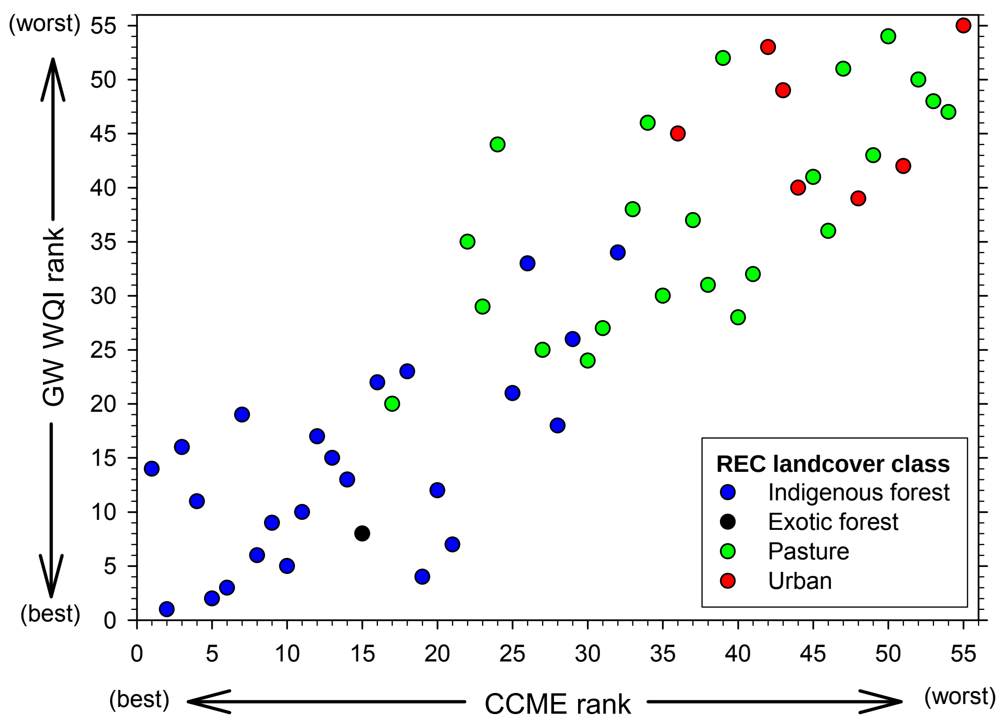


Figure 4.16: Scatter plot of individual water quality 'ranks' assigned to the 55 RSoE sites from the CCME WQI versus Greater Wellington's WQI. The REC landcover class for each site is also indicated

Table 4.6: CCME WQI rankings for RSoE sites sampled at monthly intervals over June 2008 to July 2011 inclusive, based on an assessment of seven water quality variables against guideline values (see Table 4.1 and Appendix 5)

Site no.	Site name	Scope	Frequency	Magnitude	Overall score	Rank	Quartile
RS20	Hutt R at Te Marua Intake Site	14.3	3.2	7.0	90.6	1	UQ
RS43	Motuwaireka S at Headwaters	28.6	3.9	1.9	83.3	2	UQ
RS25	Akatarawa R at Hutt confl.	28.6	2.8	4.1	83.3	3	UQ
RS26	Whakatikei R at Riverstone	28.6	3.6	4.5	83.2	4	UQ
RS31	Ruamahanga R at McLays	28.6	5.6	5.9	82.8	5	UQ
RS28	Wainuiomata R at Manuka Track	28.6	7.4	3.5	82.8	6	UQ
RS09	Waikanae R at Mangaone Walkway	28.6	11.3	3.2	82.2	7	UQ
RS52	Tauanui R at Whakatomotomo Rd	28.6	4.6	15.9	81.0	8	UQ
RS47	Waiohine R at Gorge	28.6	4.8	24.4	78.1	9	UQ
RS03	Waitohu S at Forest Pk	42.9	5.3	6.1	74.8	10	UQ
RS56	Waiorongomai R at Forest Pk	42.9	5.6	7.8	74.6	11	UQ
RS23	Pakuratahi R 50m d/s Farm Ck	42.9	4.0	12.7	74.1	12	UQ
RS06	Otaki R at Mouth	42.9	5.6	12.8	74.0	13	UQ
RS41	Waingawa R at South Rd	42.9	7.6	16.7	73.1	14	UQ
RS44	Totara S at Stronvar	42.9	9.3	16.5	73.0	15	Med to UQ
RS35	Mataikona Trib at Sugar Loaf Rd	42.9	9.3	20.1	72.1	16	Med to UQ
RS55	Tauherenikau R at Websters	42.9	8.8	22.3	71.7	17	Med to UQ
RS54	Coles Ck Trib at Lagoon Hill Rd	42.9	16.0	23.2	70.4	18	Med to UQ
RS49	Beef Ck at Headwaters	57.1	7.3	3.0	66.7	19	Med to UQ
RS10	Waikanae R at Greenaway Rd	57.1	8.8	5.7	66.5	20	Med to UQ
RS05	Otaki R at Pukehinau	57.1	4.8	10.8	66.3	21	Med to UQ
RS13	Horokiri S at Snodgrass	57.1	21.5	15.1	63.7	22	Med to UQ
RS36	Taueru R at Castlehill	57.1	17.5	28.5	61.8	23	Med to UQ
RS24	Mangaroa R at Te Marua	57.1	29.2	29.5	59.2	24	Med to UQ
RS30	Orongorongo R at Orongorongo Stn	57.1	12.0	48.3	56.3	25	Med to UQ
RS29	Wainuiomata R u/s of White Br	71.4	23.1	20.7	55.0	26	Med to UQ
RS48	Waiohine R at Bicknells	71.4	24.3	37.5	51.3	27	Med to UQ
RS21	Hutt R opp. Manor Park G.C.	85.7	12.7	20.8	48.5	28	LQ to Med.
RS22	Hutt R at Boulcott	85.7	13.5	25.6	47.8	29	LQ to Med.
RS40	Waipoua R at Colombo Rd Br	85.7	21.1	22.2	47.4	30	LQ to Med.
RS51	Huangarua R at Ponatahi Br	71.4	21.5	52.9	47.2	31	LQ to Med.
RS11	Whareroa S at Waterfall Rd	71.4	34.7	53.2	44.8	32	LQ to Med.
RS14	Pauatahanui S at Elmwood Br	85.7	29.5	31.9	44.5	33	LQ to Med.
RS38	Kopuaranga R at Stewarts	71.4	44.2	54.3	42.2	34	LQ to Med.
RS32	Ruamahanga R at Te Ore Ore	85.7	25.2	45.0	42.2	35	LQ to Med.
RS15	Porirua S at Glenside	85.7	37.8	37.5	41.7	36	LQ to Med.
RS17	Makara S at Kennels	85.7	36.3	39.5	41.6	37	LQ to Med.
RS53	Awhea R at Tora Rd	71.4	22.8	69.7	40.9	38	LQ to Med.
RS04	Waitohu S at Norfolk Cres	85.7	45.8	39.6	39.4	39	LQ to Med.
RS42	Whareama R at Gauge	85.7	23.4	58.0	38.7	40	LQ to Med.
RS33	Ruamahanga R at Gladstone Br	85.7	35.1	51.9	38.7	41	LQ to Med.
RS27	Waiwhetu S at Wainui Hill Br	85.7	46.2	43.9	38.3	42	LQ
RS16	Porirua S at Wall Park (Milk Depot)	85.7	45.4	49.7	37.1	43	LQ
RS18	Karori S at Makara Peak	85.7	43.4	52.8	36.7	44	LQ
RS45	Parkvale Trib at Lowes Reserve	71.4	56.9	61.6	36.4	45	LQ
RS34	Ruamahanga R at Pukio	85.7	35.1	60.7	36.1	46	LQ
RS12	Whareroa S at QE Park	85.7	49.4	55.9	34.4	47	LQ
RS19	Kaiwharawhara S at Ngaio Gorge	100.0	40.6	47.3	31.9	48	LQ
RS37	Taueru R at Gladstone	100.0	39.0	49.1	31.8	49	LQ
RS07	Mangaone S at Sims Rd Br	85.7	66.8	56.5	29.3	50	LQ
RS08	Ngarara S at Field Way	100.0	45.8	61.0	27.4	51	LQ
RS50	Mangatarere S at SH 2	100.0	43.1	66.3	26.4	52	LQ
RS46	Parkvale S at Weir	100.0	55.4	59.6	25.6	53	LQ
RS39	Whangaehu R 250m u/s confl.	100.0	51.8	66.1	24.6	54	LQ
RS02	Mangapouri S at Bennetts Rd	100.0	71.3	62.2	20.5	55	LQ

4.2 Temporal trends

4.2.1 Approach to analysis

A selection of 14 water quality variables were analysed for temporal trends, utilising RSoE monitoring data collected monthly over the period July 2006 to June 2011. An initial assessment examined trends between September 2003 and June 2010 (see Ballantine & Booker 2011); the September 2003 start date represented a logical follow-on from the 1997 to 2003 trend period used by Milne and Perrie (2005) in the last river and stream SoE technical report. However, a change in Greater Wellington's analytical laboratory (including detection limits for some variables) in July 2006 was deemed to have produced 'step changes' in some water quality variables (Ballantine & Booker 2011)[17], confounding trend assessments. As a result, the data record for the five years ending June 2011 was used for temporal trend analysis in this report.

Following methodology outlined in Ballantine and Booker (2011), temporal trends were analysed using the Seasonal Kendall trend test in NIWA's Time Trends software (Version 3.20). Trend analysis was undertaken on both raw data and – for the 44 sites where flow values or estimates were available (see Appendix 4) – flow-adjusted data. Seasonal Kendall trend tests were undertaken using 12 'seasons' (ie, reflecting monthly water quality sampling) and flow-adjustment was performed in the Time Trends software using LOWESS (Locally Weighted Scatterplot Smoothing) with a 30% span.

Prior to analysis, the nutrient data sets, which often contain a high proportion of censored values (ie, concentrations reported as below the analytical detection limit), were processed as follows:

- If a data set contained less than 10% censored data, the censored values were halved;
- For data sets containing between 10% and 80% censored data, censored values were estimated using Regression on Order Statistics (ROS); and
- For data sets with greater than 80% censored data, trend analysis was not undertaken due to the high level of uncertainty present in the dataset.

For the remaining variables (eg, TOC and *E. coli*) censored values typically comprised well below 10% of the values in the data set for each site (in all cases they were below 17%) and the censored data were simply halved before undertaking trend analysis.

While estimation of censored data using ROS is considered the best approach for dealing with censored data when undertaking water quality trend analysis (Ballantine & Booker 2011), it is important to note that as the proportion of censored data increases so too does any associated error. Ballantine and Booker (2011) advise that professional judgement is exercised when interpreting trend results that contain higher proportions of censored values. For this reason, only results for data sets that contained no more than 30% censored values are

[17] This is despite analytical methods remaining constant for many variables.

summarised and presented in this section (see Appendix 7 for the complete set of trend analysis results).

A trend was deemed statistically significant if the *p*-value was less than 0.05. In addition to statistical significance, the relative rate of change was assessed by dividing the Median Annual Sen Slope (MASS) value by the raw data median. As per Scarsbrook (2006), a relative rate of change threshold of 1% per annum was set to denote a trend that may be 'meaningful' (although Scarsbrook (2006) noted that a 1% threshold is totally arbitrary and rates of change above 1% may still not be environmentally significant (and vice versa)). Trend analysis results were then categorised as outlined below:

- No trend (ie, $p>0.05$);
- Significant increasing or decreasing trend but not 'meaningful' (ie, $p<0.05$ but the rate of change was less than 1% per year); or
- 'Meaningful' increasing or decreasing trend (ie, $p<0.05$ and the rate of change was greater than 1% per year).

(a) National River Water Quality Network

Trends in selected water quality variables (visual clarity, NNN, Amm N, TN, DRP and TP) were also analysed using data from NIWA's National River Water Quality Network (NRWQN). The NRWQN network has five sites in the Wellington region; two located on the Hutt River and three on the Ruamahanga River (Figure 4.17). The analysis followed the methodology outlined above and spanned the same five-year time period.

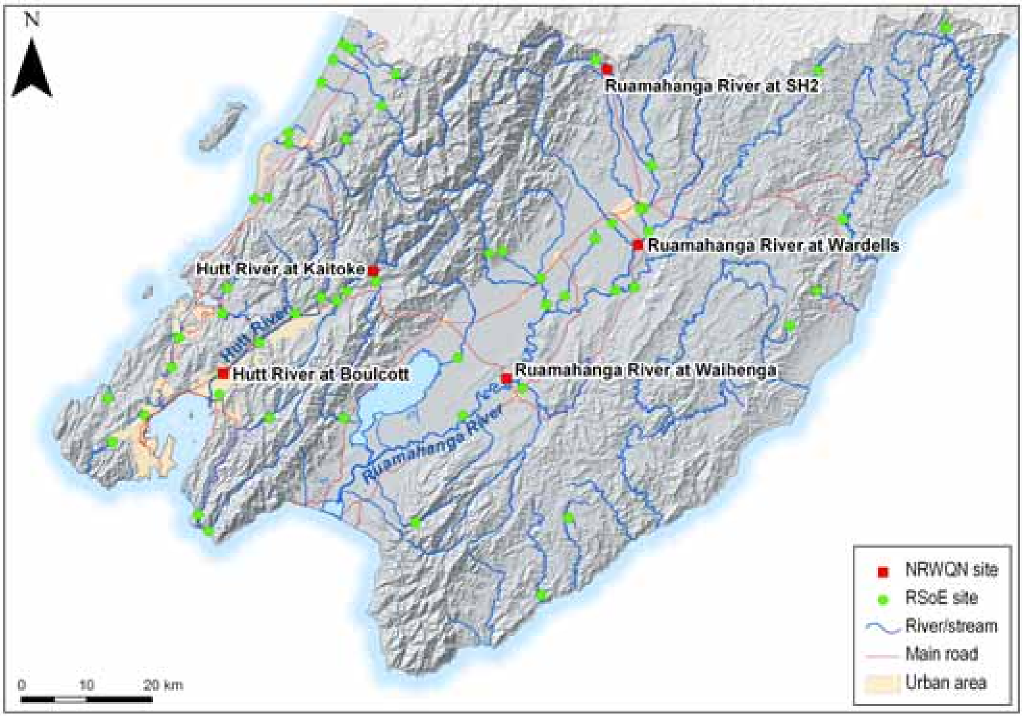


Figure 4.17: Location of NIWA's five national river water quality monitoring sites in the Wellington region, together with Greater Wellington's RSoE sites on the same rivers

4.2.2 Results

An overview of the temporal trend analysis outputs, for both raw and flow-adjusted data sets that contained 30% or less censored values, is presented in Table 4.7. Full details of all other trend analysis results can be found in Appendix 7.

The majority of RSoE sites were typically stable across the five-year period, based on both raw and flow-adjusted data for the 14 variables assessed. However, pH was an exception, with around half of the sites exhibiting decreasing trends over the reporting period. The reason for the declining pH trends is unclear but it should be noted that there were some changes in sampling personnel (and field meters) during the early part of the reporting period.[18] Further, along with water temperature and DO which also exhibit significant diurnal variation, changes in site sampling time during the reporting period confound interpretation of the trend results. The focus of the following sections is therefore placed on describing the meaningful trends (ie, statistically significant and with a rate of change >1% per annum) observed in water clarity, turbidity, nutrient concentrations, TOC concentrations, and *E. coli* bacteria counts. A total of 78 meaningful trends were identified in the raw data sets across these nine variables (equating to 14.1% out of a total of 411 possible trends), with half of these trends associated with just three variables: TP (15 sites), NNN (13 sites) and TN (11 sites).

(a) Visual clarity (black disc) and turbidity

Eight RSoE sites exhibited meaningful declining trends in raw black disc (visual clarity) values, three of which also exhibited these trends in flow-adjusted data (Table 4.8). Rates of decline ranged from 0.06 m/year (Ngarara Stream at Field Way) to 0.31 m/year (Beef Creek at Headwaters). These eight sites comprised a mixture of hard and soft-bottomed sites and all have low-elevation sources of flow. Two of these sites are classed as reference sites (Wainuiomata River at Manuka Track and Beef Creek at Headwaters), while the remaining six sites are located in catchments dominated by pastoral (five sites) or urban landcover (one site).

Only two RSoE sites (Taueru River at Castlehill and Whangaehu River 250 m from confluence) that recorded deteriorating trends in visual clarity recorded corresponding deteriorating (ie, increasing) trends in turbidity (raw data) (Table 4.9). Five sites recorded meaningful decreasing trends in turbidity which were typically only evident in flow-adjusted data (Table 4.9).

[18] From July 2005 up until January 2007, monthly water sampling was undertaken by external contractors. Issues were identified with the quality of some field measurements reported during this time.

Table 4.7: Summary of temporal trends in selected water quality variables for 55 RSoE sites sampled monthly between July 2006 and June 2011. Trend results are provided for both raw and flow-adjusted datasets that comprised no more than 30% of censored values

Variable	RAW DATA							FLOW-ADJUSTED DATA						
	Significant increase (*n*)	Meaningful increase (*n*)	No trend (*n*)	Significant decrease (*n*)	Meaningful decrease (*n*)	Total no. sites assessed	Censored sites (*n*)	Significant increase (*n*)	Meaningful increase (*n*)	No trend (*n*)	Significant decrease (*n*)	Meaningful decrease (*n*)	Total no. sites assessed	Censored sites (*n*)
Water temperature	0	2	41	0	12	55	0	0	2	32	0	10	44	0
Dissolved oxygen (% sat)	0	7	47	0	1	55	0	0	8	35	0	1	44	0
Dissolved oxygen (mg/L)	0	7	47	0	1	55	0	0	7	37	0	0	44	0
pH	0	0	26	4	25	55	0	0	0	20	5	19	44	0
Conductivity	0	2	52	0	1	55	0	0	4	38	0	2	44	0
Visual clarity	0	0	47	0	8	55	0	0	0	41	0	3	44	0
Turbidity	0	2	52	0	1	55	0	0	0	39	0	5	44	0
Total organic carbon	0	6	49	0	0	55	0	0	4	43	0	1	44	0
Nitrite-nitrate nitrogen	0	0	41	0	13	54	1	0	0	34	0	9	43	1
Ammoniacal nitrogen	0	0	7	0	2	9	46	0	0	7	0	0	7	37
Total nitrogen	0	0	32	0	11	43	12	0	0	26	0	7	33	11
Dissolved reactive phosphorus	0	4	24	0	6	34	21	0	4	26	0	2	28	16
Total phosphorus	0	1	36	0	14	51	4	0	0	27	0	13	40	4
E. coli	0	7	45	0	3	55	0	0	2	39	0	5	44	0
Total	**0**	**38**	**546**	**4**	**98**	**686**	**84**	**0**	**31**	**444**	**5**	**77**	**547**	**69**

Table 4.8: Summary of RSoE sites that recorded meaningful trends (ie, *p*<0.05 and a rate of change >1% per year) in visual clarity (m) measurements over July 2006 to June 2011. MASS=median annual Sen slope (m/year) calculated using the Seasonal Kendall test. The arrow indicates the direction of the trend

Site	Site name	Median	Raw data				Flow-adjusted data			
			n	MASS	Rate of change (%/year)	Trend	*n*	MASS	Rate of change (%/year)	Trend
RS04	Waitohu S at Norfolk Cres	0.61	60	-0.068	-11.2	↓	No trend			
RS08	Ngarara S at Field Way	0.42	60	-0.060	-14.4	↓	Not assessed (no flow data)			
RS11	Whareroa S at Waterfall Rd	0.62	60	-0.110	-17.8	↓	57	-0.064	-10.3	↓
RS13	Horokiri S at Snodgrass	1.88	60	-0.266	-14.1	↓	59	-0.174	-9.5	↓
RS28	Wainuiomata R at Manuka Track	2.60	56	-0.197	-7.6	↓	56	-0.273	-10.5	↓
RS36	Taueru R at Castlehill	1.11	60	-0.091	-8.2	↓	No trend			
RS39	Whangaehu R 250 u/s confl.	0.72	60	-0.131	-18.2	↓	Not assessed (no flow data)			
RS49	Beef Ck at Headwaters	2.30	58	-0.306	-13.4	↓	Not assessed (no flow data)			

Table 4.9: Summary of RSoE sites that recorded meaningful trends (ie, *p*<0.05 and a rate of change >1% per year) in turbidity (NTU) over July 2006 to June 2011. MASS=median annual Sen slope (NTU/year) calculated using the Seasonal Kendall test. The arrow indicates the direction of the trend

Site	Site name	Median	Raw data				Flow-adjusted data			
			n	MASS	Rate of change (%/year)	Trend	*n*	MASS	Rate of change (%/year)	Trend
RS15	Porirua S at Glenside	2.20	No trend				60	-0.343	-15.6	↓
RS27	Waiwhetu S at Wainui Hill Br	6.59	59	-1.025	-15.6	↓	59	-1.023	-15.5	↓
RS29	Wainuiomata R u/s of White Br	2.60	No trend				59	-0.285	-11.0	↓
RS32	Ruamahanga R at Te Ore Ore	4.35	No trend				60	-0.438	-10.1	↓
RS33	Ruamahanga R at Gladstone Br	3.20	No trend				60	-0.136	-4.3	↓
RS36	Taueru R at Castlehill	3.54	60	0.259	7.3	↑	No trend			
RS39	Whangaehu R 250 u/s confl.	4.78	60	0.921	19.3	↑	Not assessed (no flow data)			

The reasons for the observed trends in visual clarity and turbidity are not known. It is noted that of the eight sites that exhibited declining visual clarity trends, only the two reference sites (Wainuiomata River at Manuka Track and Beef Creek at Headwaters) returned median clarity values (for the three-year state period) above the MfE (1994) guideline of 1.6 m. It is possible that the declining trend in visual clarity reported for Beef Creek may be due to natural changes in the sampling reach morphology – during the latter part of the reporting period there were a number of occasions when visual clarity exceeded the sample reach available (ie, actual water clarity was greater than that recorded).

In the case of the Horokiri Stream at Snodgrass, while the five-year median listed in Table 4.9 met the MfE (1994) guideline, the more recent state analysis suggests visual clarity at this site has continued to decline (see Table 4.2). Soil/stream bank erosion and sediment runoff from forestry tracking activities are possible reasons for the decline; Oliver and Milne (2012) note steep and unstable soils are a feature of this catchment.

(b) TOC

Meaningful increasing trends in TOC concentration were exhibited in the raw data sets for six RSoE sites (Table 4.10), with rates of change ranging from 0.10 mg/L/year to 0.41 mg/L/year. Two sites (Mangaroa River at Te Marua and Waiorongomai River at Forest Park) also exhibited these trends after flow-adjustment. Both Otaki River sites also exhibited increasing trends in TOC concentration after flow-adjustment while a meaningful decreasing trend was reported for Mangaone Stream at Sims Road Bridge.

The reason for the observed trends is not clear. Given that increasing trends were found at several forested reference sites (eg, Otaki River at Pukehinau, Beef Creek at Headwaters), the trends may be natural (eg, climate-driven).

Table 4.10: Summary of RSoE sites that recorded meaningful trends (ie, *p*<0.05 and a rate of change >1% per year) in TOC concentrations (mg/L) over July 2006 to June 2011. MASS=median annual Sen slope (mg/L/year) calculated using the Seasonal Kendall test. The arrow indicates the direction of the trend

Site	Site name	Median	Raw data				Flow-adjusted data			
			n	MASS	Rate of change (%/yr)	Trend	*n*	MASS	Rate of change (%/yr)	Trend
RS05	Otaki R at Pukehinau	1.10	No trend				60	0.083	7.5	↑
RS06	Otaki R at Mouth	1.04	No trend				60	0.085	8.2	↑
RS07	Mangaone S at Sims Rd Br	4.90	No trend				60	-0.249	-5.1	↓
RS10	Waikanae R at Greenaway Rd	1.20	60	0.100	8.3	↑	Not assessed (no flow data)			
RS11	Whareroa S at Waterfall Rd	3.70	60	0.250	6.8	↑	No trend			
RS24	Mangaroa R at Te Marua	4.50	60	0.300	6.7	↑	59	0.256	5.7	↑
RS33	Ruamahanga R at Gladstone	2.55	60	0.412	16.2	↑	No trend			
RS49	Beef Ck at Headwaters	1.70	60	0.100	5.9	↑	Not assessed (no flow data)			
RS56	Waiorongomai R at Forest Pk	2.45	60	0.298	12.2	↑	54	0.281	11.5	↑

(c) Nitrogen

Meaningful trends were recorded in either raw and/or flow-adjusted data sets for 18, 2 and 15 RSoE sites for concentrations of nitrite-nitrate nitrogen (NNN), ammoniacal nitrogen (Amm N) and total nitrogen (TN), respectively (Table 4.11). All of these trends represented decreasing concentrations during the 2006 to 2011 reporting period and are indicative of potential 'improvements' in water quality. Seven sites exhibited decreasing trends in both NNN and TN concentrations, one of which (Ngarara Stream at Field Way), also recorded declining concentrations of Amm N.

The rates of change in nitrogen concentrations were highly variable across sites. Typically sites that had low median concentrations (eg, reference sites and other sites dominated by indigenous forest in their upstream catchment) had relatively small rates of change when compared to sites located in more developed or impacted catchments. For example, at Otaki River at Pukehinau (a reference site), concentrations of NNN decreased at a rate of 0.006 mg/L/year whereas at Whangaehu River 250 m from confluence (a site located in a pastoral catchment) concentrations of NNN decreased at a rate of 0.214 mg/L/year.

Table 4.11: Summary of meaningful trends (ie, $p<0.05$ and a rate of change >1% per year) in NNN, Amm N and TN concentrations (mg/L) recorded at RSoE sites over July 2006 to June 2011. MASS=median annual Sen slope (mg/L/yr) calculated using the Seasonal Kendall test. The arrow indicates the direction of the trend

Site	Site name	Median	Raw data				Flow-adjusted data			
			n	MASS	Rate of change (%/year)	Trend	*n*	MASS	Rate of change (%/year)	Trend
Nitrite-nitrate nitrogen (NNN)										
RS05	Otaki R at Pukehinau	0.038	60	-0.003	-8.7	↓	60	-0.004	-10.5	↓
RS08	Ngarara S at Field Way	0.255	60	-0.054	-21.0	↓	Not assessed (no flow data)			
RS15	Porirua S at Glenside	1.000	60	-0.058	-5.8	↓	No trend			
RS16	Porirua S at Wall Park	0.990	60	-0.044	-4.5	↓	No trend			
RS24	Mangaroa R at Te Marua	0.484	60	-0.029	-6.0	↓	No trend			
RS25	Akatarawa R at Hutt Confl.	No trend					60	-0.008	-8.0	↓
RS28	Wainuiomata R at Manuka Trk	0.075	58	-0.006	-8.3	↓	57	-0.006	-7.7	↓
RS30	Orongorongo R at Orongo. Stn	0.056	59	-0.014	-25.5	↓	53	-0.015	-28.7	↓
RS31	Ruamahanga R at McLays	0.025	60	-0.002	-6.9	↓	No trend			
RS32	Ruamahanga R at Te Ore Ore	0.397	60	-0.037	-9.4	↓	No trend			
RS33	Ruamahanga R at Gladstone Br	No trend					60	-0.038	-9.5	↓
RS36	Taueru R at Castlehill	No trend					60	-0.010	-14.5	↓
RS37	Taueru R at Gladstone	0.910	59	-0.120	-13.2	↓	Not assessed (no flow data)			
RS39	Whangaehu R 250 u/s confl.	0.965	60	-0.214	-22.2	↓	Not assessed (no flow data)			
RS46	Parkvale S at Weir	No trend					57	-0.130	-10.5	↓
RS49	Beef Ck at Headwaters	0.024	60	-0.003	-12.4	↓	Not assessed (no flow data)			
RS50	Mangatarere S at SH 2	No trend					59	-0.051	-4.1	↓
RS52	Tauanui R at Whakatomotomo	0.012	59	-0.001	-8.8	↓	59	-0.001	-12.3	↓
Ammoniacal nitrogen (Amm N)										
RS08	Ngarara St at Field Way	0.03	60	-0.007	-26.7	↓	Not assessed (no flow data)			
RS18	Karori S at Makara Peak	0.01	60	-0.001	-10.6	↓	No trend			
Total nitrogen (TN)										
RS07	Mangaone S at Sims Road Br	2.60	60	-0.188	-7.2	↓	60	-0.117	-4.5	↓
RS08	Ngarara S at Field Way	1.00	60	-0.100	-10.1	↓	Not assessed (no flow data)			
RS15	Porirua S at Glenside	No trend					60	-0.057	-4.4	↓
RS17	Makara S at Kennels	No trend					60	-0.034	-5.6	↓
RS27	Waiwhetu S at Wainui Hill Br	0.80	59	-0.049	-6.1	↓	59	-0.040	-4.9	↓
RS29	Wainuiomata R u/s of White Br	0.38	59	-0.036	-9.4	↓	No trend			
RS32	Ruamahanga R at Te Ore Ore	0.56	60	-0.049	-8.9	↓	No trend			
RS33	Ruamahanga R at Gladstone Br	No trend					60	-0.046	-6.8	↓
RS35	Mataikona trib at Sugar Loaf Rd	0.19	59	-0.025	-13.2	↓	Not assessed (no flow data)			
RS37	Taueru R at Gladstone	1.47	59	-0.151	-10.3	↓	Not assessed (no flow data)			
RS39	Whangaehu R 250 u/s confl.	1.70	60	-0.197	-11.6	↓	Not assessed (no flow data)			
RS44	Totara S at Stronvar	0.15	58	-0.026	-17.2	↓	58	-0.020	-13.1	↓
RS45	Parkvale trib at Lowes Res.	4.80	47	-0.298	-6.2	↓	No flow data			
RS46	Parkvale S at Weir	No trend					57	-0.116	-6.1	↓
RS54	Coles Ck trib at Lagoon Hill Rd	0.23	50	-0.012	-5.4	↓	Not assessed (no flow data)			

Despite a number of 'impacted' sites showing improvements, such as Ngarara Stream at Field Way (which now meets the ANZECC (2000) lowland TV for Amm N, Figure 4.18), in many cases the overall median values of NNN and TN are still elevated when compared against their respective ANZECC (2000) lowland TVs. For example, while the decreasing NNN trends of highest magnitude were observed at Taueru River at Gladstone and Whangaehu River 250 m from confluence (0.120 and 0.214 mg/L/year, respectively), the state analysis shows that median NNN concentrations are still well above the ANZECC (2000) lowland TV of 0.444 mg/L.

The reasons for the observed trends are not clear. In the case of NNN and TN concentrations, decreasing trends were present at sites located in catchments dominated by all of the major landcover types found in the region (eg, indigenous forest, exotic forest, pastoral and urban), including a number of reference sites (eg, Otaki River at Pukehinau) and also several sites that typically record very low median NNN and TN values (eg, Akatarawa River at Hutt confluence and Taueru River at Castlehill). This suggests that the declining trends may be related to natural factors such as climate.

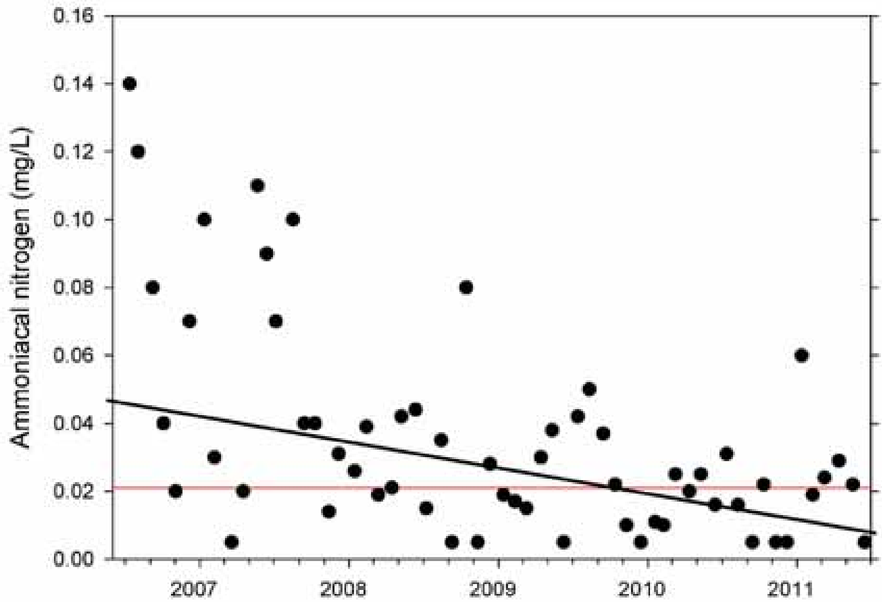


Figure 4.18: Ammoniacal nitrogen concentrations recorded in the Ngarara Stream at Field Way, based on monthly monitoring over July 2006 to June 2011. The red and black lines denote the ANZECC (2000) lowland TV and the direction of the trend in concentrations, respectively

(d) Phosphorus

Meaningful trends in concentrations of dissolved reactive phosphorus (DRP) and total phosphorus (TP) were detected in raw and/or flow-adjusted data sets from 11 and 17 RSoE sites, respectively (Table 4.12). The majority of the trends represented decreasing concentrations and are indicative of potential ‘improvements’ in water quality over the reporting period. Five sites exhibited trends in both DRP and TP concentrations: Porirua Stream at Glenside, Karori Stream at Makara Peak, Kaiwharawhara Stream at Ngaio Gorge, Wainuiomata River at Manuka Track and Whangaehu River at 250 m from confluence. With the exception of the Wainuiomata site, the direction of the trends in DRP and TP concentrations were in agreement.

Table 4.12: Summary of meaningful trends (ie, *p*<0.05 and a rate of change >1% per year) in DRP and TP concentrations (mg/L) recorded at RSoE sites over July 2006 to June 2011. MASS=median annual Sen slope (mg/L/yr) calculated using the Seasonal Kendall test. The arrow indicates the direction of the trend

Site	Site name	Median	Raw data				Flow-adjusted data			
			n	MASS	Rate of change (%/year)	Trend	*n*	MASS	Rate of change (%/year)	Trend
Dissolved reactive phosphorus (DRP)										
RS03	Waitohu S at Forest Pk	0.008	59	0.001	7.1	↑	57	0.001	8.6	↑
RS11	Whareroa S at Waterfall Rd	0.029	60	-0.002	-6.3	↓	No trend			
RS15	Porirua S at Glenside	0.019	60	-0.002	-8.0	↓	No trend			
RS17	Makara S at Kennels	0.029	60	-0.002	-5.5	↓	No trend			
RS18	Karori S at Makara Peak	0.039	60	-0.004	-9.6	↓	60	-0.002	-5.4	↓
RS19	Kaiwharawhara S at Ngaio Gorge	0.034	60	-0.006	-17.5	↓	60	-0.004	-12.3	↓
RS24	Mangaroa R at Te Marua	0.010	60	0.001	13.0	↑	59	0.001	12.9	↑
RS28	Wainuiomata R at Manuka Trk	0.010	58	0.001	6.1	↑	57	0.000	5.0	↑
RS33	Ruamahanga R at Gladstone Br	0.024	60	-0.002	-8.3	↓	No trend			
RS36	Taueru R at Castlehill	0.008	No trend				60	0.000	6.5	↑
RS39	Whangaehu R 250 u/s confl.	0.030	60	0.007	22.5	↑	Not assessed (no flow data)			
Total phosphorus (TP)										
RS05	Otaki R at Pukehinau	0.007	60	-0.001	-12.1	↓	60	-0.001	-10.8	↓
RS06	Otaki R at Mouth	0.007	60	-0.001	-15.0	↓	60	-0.001	-13.7	↓
RS09	Waikanae R at Mangaone Wk	0.015	60	-0.001	-10.3	↓	60	-0.001	-7.9	↓
RS12	Whareroa S at QE Park	0.082	No trend				57	-0.003	-4.1	↓
RS13	Horokiri S at Snodgrass	0.019	60	-0.002	-11.4	↓	59	-0.002	-12.0	↓
RS14	Pauatahanui S at Elmwood Br	0.031	60	-0.002	-7.2	↓	60	-0.003	-8.6	↓
RS15	Porirua S at Glenside	0.031	60	-0.004	-11.8	↓	60	-0.004	-14.4	↓
RS18	Karori S at Makara Peak	0.051	60	-0.004	-8.6	↓	60	-0.003	-5.8	↓
RS19	Kaiwharawhara S at Ngaio Gorge	0.049	60	-0.006	-11.5	↓	60	-0.005	-10.0	↓
RS20	Hutt R at Te Marua Intake Site	0.007	No trend				60	-0.001	-8.7	↓
RS27	Waiwhetu S at Wainui Hill Br	0.064	59	-0.008	-11.8	↓	No trend			
RS28	Wainuiomata R at Manuka Trk	0.015	58	-0.001	-6.7	↓	57	-0.001	-5.6	↓
RS29	Wainuiomata R u/s of White Br	0.023	59	-0.003	-13.1	↓	59	-0.002	-8.7	↓
RS39	Whangaehu R 250 u/s confl.	0.065	60	0.012	18.1	↑	Not assessed (no flow data)			
RS49	Beef Ck at Headwaters	0.011	60	-0.001	-6.5	↓	Not assessed (no flow data)			
RS50	Mangatarere S at SH 2	0.105	60	-0.009	-8.9	↓	No trend			
RS52	Tauanui R at Whakatomotomo	0.009	59	-0.001	-8.2	↓	59	-0.001	-8.9	↓

Overall, improving trends in DRP concentrations were demonstrated at six sites, five of which are classed as urban or pastoral (the forested Whareroa Stream at Waterfall Road was the exception). However, despite some relatively large rates of improvement exhibited at these sites (eg, DRP concentrations at Kaiwharawhara Stream at Ngaio Gorge decreased 0.006 mg/L/year (-17.5%/year), the state analysis (refer Table 4.2) indicates that median DRP concentrations at all six sites are typically well above the ANZECC (2000) lowland TV of 0.010 mg/L.

In contrast, at four of the five sites that exhibited a meaningful increase in DRP concentration, median concentrations for the state period are just below – or in the case of Mangaroa River at Te Marua (Figure 4.19), now just above – the ANZECC (2000) lowland TV. Of these five sites, two are reference sites

(Waitohu Stream at Forest Park and Wainuiomata River at Manuka Track) and the remaining three are located in catchments dominated by pastoral landcover. The largest rate of increase was observed at Whangaehu River 250 m from confluence (0.007 mg/L/year) (Table 4.12).

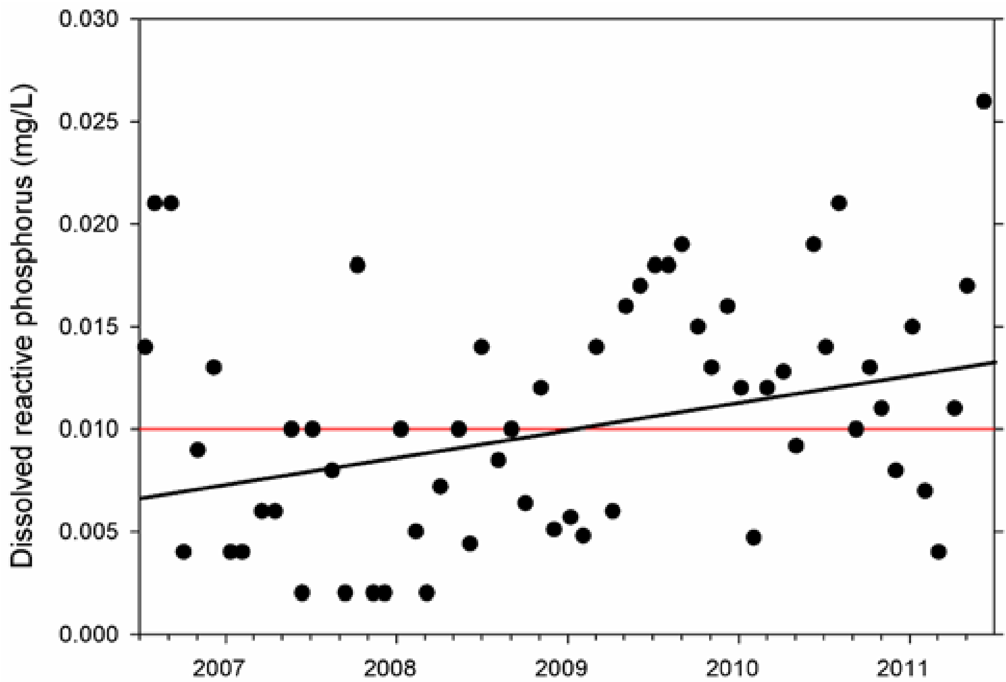


Figure 4.19: DRP concentrations recorded in the Mangaroa River at Te Marua, based on monthly monitoring over July 2006 to June 2011. The red and black lines denote the ANZECC (2000) lowland TV and the direction of the trend in concentrations, respectively

Whangaehu River 250 m from confluence was the only site to record a meaningful increase in TP concentration. As noted earlier in this section, this site drains a portion of the erosion-prone eastern Wairarapa hill country and the increase in TP concentration of 0.012 mg/L/year (Table 4.13) coincided with both a decrease in visual clarity (-0.13 cm/year) and an increase in turbidity of more than 0.9 NTU/year (refer Tables 4.8 and 4.9). While this suggests that increasing TP concentrations might be related to increased sediment entering the Whangaehu River, no flow-adjusted trend assessments were able to be performed for this site (ie, the observed trends may be flow-related).

Similar to the nitrogen trend results, a number (7) of the 16 sites that showed improving trends in concentrations of TP are either reference sites or sites with upstream catchments dominated by indigenous forest cover (eg, Otaki River at Mouth and Hutt River at Te Marua). This suggests that many of the improving trends may be related to natural factors (eg, climate variability). It is also noted that five of the other nine sites that exhibited improvements in TP concentrations still recorded elevated median concentrations (relative to the ANZECC (2000) lowland TV) in the state analysis, particularly Mangatarere Stream at SH 2 (see Table 4.2).

(e) *E. coli*

Thirteen RSoE sites exhibited meaningful trends in raw and/or flow-adjusted *E. coli* counts over the reporting period (Table 4.13). Increasing trends were observed in the raw data from seven sites, with sites on the Kopuaranga and Whangaehu rivers recording the largest rates of change (43 and 85 cfu/100 mL/year, respectively). However, the flow-adjusted analysis (which was limited to six of the seven sites) demonstrated that only two of these sites recorded a corresponding increasing trend in *E. coli* counts (ie, the increasing counts at most sites, although indicative of a deterioration in water quality, can be attributed to river flow conditions). Further, the two sites that did also display increasing trends in flow-adjusted *E. coli* counts (Totara Stream at Stronvar and Waiohine River at Gorge) had very low median values (5 cfu/100mL), indicating that the increasing trends are of little environmental consequence. In contrast, the magnitude of change was more notable for the two sites that exhibited decreasing trends in both raw and flow-adjusted *E. coli* counts (Akatarawa River at Hutt confluence and Waipoua River at Colombo Road); *E. coli* counts at these sites decreased in the order of 10 cfu/100mL/year between July 2005 and June 2011 (Table 4.13). The reason for the improvements is unclear; the median values were relatively low for the reporting period and meet the ANZECC (2000) stock water TV.

Table 4.13: Summary of meaningful trends (ie, *p*<0.05 and a rate of change >1% per year) in *E. coli* counts (cfu/100mL) recorded at RSoE sites over July 2006 to June 2011. Bolded median values exceed the relevant ANZECC (2000) lowland TV (refer Table 4.1). MASS=median annual Sen slope (cfu/100mL/yr) calculated using the Seasonal Kendall test. The arrow indicates the direction of the trend

Site	Site name	Median	Raw data				Flow-adjusted data			
			n	MASS	Rate of change (%/year)	Trend	*n*	MASS	Rate of change (%/year)	Trend
RS03	Waitohu S at Forest Park	6	No trend				57	-2.30	-38.3	↓
RS09	Waikanae R at Mangaone Wk	13	No trend				60	-2.31	-18.5	↓
RS14	Pauatahanui S at Elmwood Br	255	60	28.30	11.1	↑	No trend			
RS22	Hutt R at Boulcott	105	60	-14.47	-13.8	↓	No trend			
RS23	Pakuratahi R 50m d/s Farm Ck	66	60	14.84	22.3	↑	No trend			
RS25	Akatarawa R at Hutt R confl.	56	60	-10.84	-19.4	↓	60	-10.54	-18.8	↓
RS29	Wainuiomata R u/s of White Br	100	No trend				59	-26.14	-26.1	↓
RS34	Ruamahanga R at Pukio	105	60	25.22	24.0	↑	No trend			
RS38	Kopuaranga R at Stewarts	210	60	43.32	20.6	↑	No trend			
RS39	Whangaehu R 250 u/s confl.	285	60	84.71	29.7	↑	Not assessed (no flow data)			
RS40	Waipoua R at Colombo Rd Br	73	60	-11.49	-15.8	↓	52	-10.56	-19.2	↓
RS44	Totara S at Stronvar	5	57	1.44	28.8	↑	57	2.76	55.2	↑
RS47	Waiohine R at Gorge	5	60	0.99	22.0	↑	60	1.19	26.5	↑

(f) National River Water Quality Network (NRWQN) sites

Just three meaningful trends were observed across the five NRWQN sites for the six water quality variables examined (Table 4.14). Only the increase in DRP concentration of 0.0002 mg/L/year at Hutt River at Kaitoke (a reference site) was evident in both raw and flow-adjusted data sets. No such equivalent trend was observed at Greater Wellington's site further downstream at Te

Marua. The decreasing trend in TN concentrations observed for Ruamahanga River at Mt Bruce is broadly consistent with the RSoE network findings; eleven RSoE sites, including two sites on the Ruamahanga River (although not Ruamahanga River at McLays which is located closest to NIWA's Mt Bruce site), exhibited meaningful declining trends in TN concentrations between July 2005 and June 2011 (refer Table 4.11).

Table 4.14: Summary of meaningful trends (ie, p<0.05 and a rate of change >1% per year) in nutrient concentrations (mg/L) recorded at NRWQN sites over July 2006 to June 2011. MASS=median annual Sen slope (mg/L/yr) calculated using the Seasonal Kendall test. The arrow indicates the direction of the trend

Site name	Variable	Raw data					Flow-adjusted data				
		Median	*n*	MASS	Rate of change (%/year)	Trend	Median	*n*	MASS	Rate of change (%/year)	Trend
Ruamahanga R at Waihenga	Amm. N	0.009	60	-0.001	-14	↓	No trend				
Ruamahanga R at Mt Bruce	TN	No trend					0.090	60	-0.004	-4.2	↓
Hutt R at Kaitoke	DRP	0.003	60	0.0002	4.4	↑	0.003	60	0.0002	6.5	↑

4.3 Synthesis

Analysis of physico-chemical and microbiological water quality data collected at 55 RSoE sites over the three-year period July 2008 to June 2011 indicates that more than half of the river and stream sites monitored in the Wellington region currently have 'good' or 'excellent' water quality (according to Greater Wellington's WQI). Sites classified in this way tend to be located on the upper reaches of rivers and streams that drain the Tararua, Rimutaka and Aorangi ranges (ie, their catchments are dominated by indigenous forest cover).

Water quality is strongly linked with upstream catchment landcover and land use. Broadly speaking, as the proportion of pastoral and/or urban landcover increases within a site's upstream catchment, water quality tends to decline. Of the 15 sites graded 'poor' for water quality, five are located in urban areas and ten drain predominantly pastoral catchments (of which most support at least some intensive agriculture, typically dairying). One of the poorest sites, Mangatarere Stream at SH 2, also receives treated wastewater from Carterton township. Analysis of monitoring data from this site indicates that the WWTP discharge is having a notable impact on water quality, principally through increased DRP and Amm N concentrations. Although more 'subtle' in the monitoring record, Ruamahanga River at Gladstone also shows signs of impacts from municipal wastewater (from the Masterton WWTP discharge approximately 10 km upstream). This site exceeded the ANZECC (2000) lowland TVs for DRP and Amm N on 97% and 39% of sampling occasions, respectively. While diffuse source inputs likely account for the majority of the nutrient load at this site, analysis by Ausseil (2011) indicates that soluble nutrient concentrations are also elevated during lower river flows (ie, dry weather conditions).

Ausseil (2011) also demonstrated that nutrient concentrations remain consistently elevated at lower flows at other RSoE sites, including many urban streams (eg, Porirua Stream at Wall Park, Karori Stream at Makara Peak, Kaiwharawhara Stream at Ngaio Gorge and Waiwhetu Stream at Wainuiomata Hill Road Bridge), consistent with nutrient inputs from point source discharges (eg, wastewater) and/or nutrient-rich groundwater. As will be discussed further in Section 8, it is likely that both sources are applicable in the Wellington region. Certainly Daughney (2010) has demonstrated that water quality at many RSoE sites is influenced by groundwater inputs, including some of the highly impacted rural streams in the central Wairarapa (eg, Mangatarere and Parkvale streams).

The most common water quality variables to exceed guideline values over the three-year state analysis period were visual clarity and DRP; median values only met guidelines at 44% and 55% of sites, respectively. At some sites, the exceedances may reflect natural geology. This is considered to be the case for DRP at Waikanae River at Mangaone Walkway (a 'best available' reference site with a high proportion of indigenous forest cover) and highlights the limitations associated with region-wide application of the ANZECC (2000) TVs. This limitation has been documented previously for the Wellington region (eg, Milne & Perrie 2005) and is currently being addressed through the development of more specific trigger level guidance for Greater Wellington's new Regional Plan intended to better reflect the natural diversity of the region's river and stream types (eg, Ausseil in prep a–d; Greenfield in prep a & b).

Other water quality variables with median values that frequently exceeded guidelines included *E. coli* (36% of sites exceeded the ANZECC (2000) stock water TV) and NNN (30%). In terms of nitrate nitrogen, median concentrations at three sites (Mangapouri Stream at Bennetts Road, Mangaone Stream at Sims Road and Parkvale tributary at Lowes Reserve) exceeded the recommended trigger value for aquatic toxicity. Water temperature also appears to be an issue at some sites during the warmer months; 17 sites exceeded the 19°C guideline on more than 10% of sampling occasions, of which two (Awhea River at Tora Road and Totara Stream at Stronvar) exceeded this threshold on more than 25% of sampling occasions.

Metal toxicity also appears to be a concern for some of the region's urban streams. Three of the ten RSoE sites routinely monitored for heavy metals (Porirua Stream at Wall Park, Karori Stream at Makara Peak and Waiwhetu Stream at Wainuiomata Hill Bridge) consistently recorded median concentrations of dissolved copper and/or zinc above their respective ANZECC (2000) hardness-modified toxicity TVs. Metal concentrations at some of these sites also exceeded USEPA (2009) acute toxicity guidelines on a few sampling occasions. This is discussed further in Section 8.

The results of temporal trend analysis illustrated that the majority of RSoE sites were largely 'stable' across the July 2006 to June 2011 period assessed, based on both raw and flow-adjusted data for the 14 variables examined. Of the selected key variables of interest, most of the meaningful trends were observed across five variables: TP (15 sites), NNN (13 sites), TN (11 sites), DRP (10 sites) and *E. coli* (10 sites). In regards to nutrients, more sites exhibited improving trends than deteriorating trends (ie, decreasing concentrations), including all nitrogen-related trends. The reason for the improving trends is not clear but given that these trends were evident at RSoE sites located across all three main landcover types represented in the RSoE network (indigenous forest, pastoral and urban), including a number of reference sites, they likely reflect (at least in part) broader regional scale patterns, such as natural climate variation. For example, it is noted that Keenan et al. (2012) reported a slight drying trend over 2005/06 to 2010/11, where summer (defined as November to April) 'low flows' generally occurred more frequently and for a longer duration across the region. The influence of this, if any, on water quality at RSoE sites is unclear but climatic variability/patterns have been shown to exert a strong influence on water quality trends in New Zealand rivers. For example, Scarsbrook et al. (2003) reported trends in water quality for both baseline (reference) and impact river sites that were generally consistent with trends in the Southern Oscillation Index.

The results of trend analysis performed on monitoring data collected from the five NRWQN monitoring sites in the Wellington region support the general finding that, on a regional basis at least, water quality has largely remained stable in rivers and streams in the Wellington region. While this can be considered a positive finding (ie, water quality generally has not deteriorated), the RSoE state analysis has identified that a number of pastoral and urban sites have impaired water quality. The principal water quality issues and their implications for aquatic ecosystem health are discussed in Section 8.

Although not discussed further, a comparison of the water quality grades assigned by Greater Wellington's WQI with the CCME (2001) WQI showed that both indices generally produced comparable rankings. This was despite some differences in the water quality variables, guidelines and calculations applied. However, the CCME WQI is considered to be a superior index given its greater sophistication (in particular its consideration of the magnitude of guideline exceedances). As such, its use in reporting on the state of water quality in the Wellington region should be continued – especially given that it can readily accommodate site-specific guidelines.

5. Periphyton – state and trends

This section assesses state and trends in periphyton growth in river and streams across the Wellington region, based on monitoring results from the 46 RSoE sites which have gravel/cobble substrates suitable for periphyton growth. Assessment of the current state of periphyton growth is presented first, using cover and biomass measurements collected over the period July 2008 to June 2011. Brief comment is also provided on macrophyte cover present at the nine RSoE sites with beds dominated by soft sediment. Temporal trends in periphyton cover and biomass are then examined for the period September 2003 to June 2011.

5.1 State

5.1.1 Approach to analysis

The current state of periphyton growth was assessed at the 46 hard substrate RSoE sites using two data sets: monthly observations of percent periphyton streambed cover from July 2008 to June 2011 and periphyton biomass (represented by chlorophyll *a* concentration) from annual biological sampling during the 2009, 2010 and 2011 summer/autumn periods. These data sets were compared against the MfE (2000) New Zealand periphyton guideline values. The MfE (2000) guidelines identify periphyton cover and biomass thresholds to protect a number of different instream values (Table 5.1).

Table 5.1: MfE (2000) guidelines used to assess periphyton stream bed cover and biomass at 46 RSoE sites

Instream value	Periphyton cover (% cover)		Periphyton biomass (mg/m^2)
	Mat >0.3 cm thick	Filamentous >2 cm long	
Aesthetics/recreation	60%	30%	–
Benthic biodiversity	–	–	50
Trout habitat and angling	–	30%	120

To facilitate inter-site comparisons of overall periphyton growth and to help summarise where periphyton growth may be an issue, each RSoE site was categorised into one of four classes ranging from 'poor' to 'excellent'. The classes were identified by assessing the number or percentage of guideline exceedances using a combination of both monthly streambed cover and annual biomass data (Table 5.2). Mean periphyton cover and percent compliance with guideline values were calculated based on the total number of times a site was visited rather than the number of periphyton cover assessments able to be made. This is because the majority of instances in which periphyton cover could not be assessed coincided with high river or stream flows when periphyton cover was likely to be minimal/below guidelines.

Relationships between mean and maximum periphyton cover/biomass, upstream landcover and a range of environmental variables were also assessed using Spearman Rank correlations with a significance threshold of $p<0.05$. The environmental variables examined included selected water quality variables (as median values from the state analysis in Section 4.1 and Appendix 6), habitat

Table 5.2: Criteria and MfE (2000) thresholds used to assign each RSoE site to one of four periphyton classes. Note that a site only had to exceed one of the streambed cover or biomass thresholds to be categorised into a particular class

Quality class	Explanation	Guidelines/thresholds used to determine class			
		Streambed cover (%*n* exceedances)		Chlorophyll *a* (*n* exceedances)	
		Mat (60%)	Filamentous (30%)	50 mg/m²	120 mg/m²
Excellent	Minimal exceedance of streambed cover guidelines and full compliance with biomass guidelines	<3	<3	0	0
Good	Infrequent non-compliance with streambed cover and/or biomass guidelines	3–10	3–10	1	0
Fair	Intermittent non-compliance with streambed cover and/or biomass guidelines	10–20	10–20	2	1
Poor	Frequent non-compliance with streambed cover and/or biomass guidelines	>20	>20	3	≥ 2

quality and shade (one-off measures, see Appendix 8) substrate size (mean of three assessments), and estimates of mean annual maximum accrual derived by Thompson and Gordon (2010b).

(a) Cautionary notes

The number of observations of periphyton streambed cover made at each of the 46 RSoE sites varied significantly over the reporting period. On average, observations could not be made on seven sampling occasions at each site (range 0 to 20), due to either high turbidity, high flows or because the site could not be accessed (eg, road closure). As a result, several sites had less than 60% of the potential number of streambed cover assessments (max *n*=36).

The MfE (2000) cover and biomass thresholds for trout habitat and angling in Table 5.1 do not apply to all RSoE sites as not all rivers and streams in the Wellington region are valued for trout fishing or spawning. In addition, the periphyton biomass thresholds for the protection of aquatic biodiversity do not take into account natural variation in periphyton biomass that can occur in response to differences in catchment altitude, geology and other geophysical characteristics.

5.1.2 Periphyton cover

Twenty six RSoE sites exceeded MfE (2000) guidelines for periphyton streambed cover at least once (and typically more than once) during the reporting period (Table 5.3). The guideline for filamentous streambed cover was more frequently exceeded than the mat cover guideline (25 sites and 6 sites, respectively). Sites that exceeded the guideline for mat periphyton cover typically also exceeded the filamentous periphyton guideline at some time during the reporting period except at one site, Hutt River opposite Manor Park Golf Club.

Table 5.3: Summary of streambed periphyton cover (based on monthly assessments undertaken between July 2008 and June 2011)[1] and biomass (chlorophyll *a* based on annual assessments in 2009, 2010 and 2011) at 46 RSoE sites. An overall periphyton 'class' for each site is also presented based on compliance with the MfE (2000) periphyton guidelines (see Table 5.2)

Site no. and name		Periphyton streambed cover (%)							Chlorophyll *a* (mg/m²)				Quality class
		Mat			Filamentous			*n*					
		Mean	Max	% *n*>60	Mean	Max	% *n*>30		2009	2010	2011	Mean	
RS03	Waitohu S at Forest Pk	0.5	10	0	0.6	15	0	34	1.1	0.8	1.4	1.1	Excellent
RS05	Otaki R at Pukehinau	1.0	27	0	2.0	39	2.8	31	0.7	2.2	1.0	1.3	Excellent
RS06	Otaki R at Mouth	3.8	61	2.8	6.4	50	8.3	33	2.5	2.1	1.8	2.2	Good
RS09	Waikanae R at Mangaone Walk	0	0	0	0	0	0	36	0.2	0.9	0.3	0.5	Excellent
RS10	Waikanae R at Greenaway Rd	8.8	48	0	1.3	15	0	32	19.8	9.7	19.1	16.2	Excellent
RS11	Whareroa S at Waterfall Rd	0	0	0	0	0	0	32	29.7	0.6	1.1	10.4	Excellent
RS13	Horokiri S at Snodgrass	0.7	7	0	6.3	74	8.3	34	34.4	46.1	77.2	52.6	Good
RS14	Pauatahanui S at Elmwood Br	0	0	0	21.7	100	19.4	30	141.4	23.3	53.1	72.6	Fair
RS15	Porirua S at Glenside	1.3	20	0	23.6	91	25.0	30	43.3	76.7	30.3	50.1	Poor
RS16	Porirua S at Wall Park (Milk Depot)	2.7	29	0	24.7	84	30.6	30	38.5	55.3	20.0	37.9	Poor
RS17	Makara S at Kennels	0	0	0	1.6	28	0	29	5.7	15.4	0.1	7.1	Excellent
RS18	Karori S at Makara Peak	3.1	38	0	28.4	97	27.8	31	71.1	25.1	10.8	35.6	Poor
RS19	Kaiwharawhara S at Ngaio Gorge	4.0	43	0	29.9	100	36.1	33	61.5	34.2	37.8	44.5	Poor
RS20	Hutt R at Te Marua Intake Site	0	0	0	0	0	0	29	0.8	0.9	0.4	0.7	Excellent
RS21	Hutt R opp. Manor Park G.C.	15.8	88	5.6	3.5	20	0	29	18.1	59.8	1.6	26.5	Good
RS22	Hutt R at Boulcott	14.6	100	2.8	4.0	31	2.8	25	17.1	119.3	20.6	52.3	Good
RS23	Pakuratahi R 50m d/s Farm Ck	4.3	31	0	0.3	6	0	30	4.4	20.2	0.2	8.2	Excellent
RS24	Mangaroa R at Te Marua	11.3	54	0	8.5	79	5.6	30	59.8	72.6	83.9	72.1	Poor
RS25	Akatarawa R at Hutt R confl.	0.4	9	0	0	0	0	32	2.3	0.3	7.8	3.5	Excellent
RS26	Whakatikei R at Riverstone	2.8	30	0	2.5	46	2.8	32	13.6	5.0	6.8	8.4	Excellent
RS28	Wainuiomata R at Manuka Track	0	1	0	0	0	0	34	6.8	10.2	1.4	6.1	Excellent
RS29	Wainuiomata R u/s of White Br	7.5	43	0	2.8	19	0	28	40.2	236.3	78.6	118.4	Fair
RS30	Orongorongo R at Orongorongo Stn	1.3	11	0	15.5	100	19.4	22	19.9	3.3	3.0	8.8	Fair
RS31	Ruamahanga R at McLays	0.6	17	0	0.1	3	0	29	0.3	0.4	1.8	0.8	Excellent
RS32	Ruamahanga R at Te Ore Ore	0.7	12	0	1.7	20	0	19	27.7	34.8	90.5	51.0	Good
RS33	Ruamahanga R at Gladstone Br	3.5	60	0	5.0	42	2.8	22	47.0	65.0	58.3	56.8	Fair
RS34	Ruamahanga R at Pukio	0	0	0	13.0	100	5.6	16	22.0	91.5	49.0	54.1	Good
RS35	Mataikona Trib at Sugar Loaf Rd	0	0	0	0.2	5	0	34	7.3	11.7	4.0	7.7	Excellent
RS37	Taueru R at Gladstone	1.7	30	0	69.4	100	50.0	21	477.2	583.7	486.7	515.8	Poor
RS38	Kopuaranga R at Stewarts	6.8	26	0	44.4	100	34.3	20	690.0	515.2	350.5	518.6	Poor
RS40	Waipoua R at Colombo Rd Br	22.3	100	13.9	7.8	53	8.3	34	34.6	33.7	46.1	38.1	Fair
RS41	Waingawa R at South Rd	0.6	11	0	1.2	19	0	31	51.3	8.6	1.5	20.5	Good
RS43	Motuwaireka S at Headwaters	0	0	0	0	0	0	35	2.9	1.6	1.3	2.0	Excellent
RS44	Totara S at Stronvar	10.2	100	5.7	16.9	100	20.0	31	14.7	7.9	25.8	16.1	Fair
RS45	Parkvale Trib at Lowes Reserve	0	0	0	0	0	0	28	18.2	41.4	30.3	30.0	Excellent
RS46	Parkvale S at Weir	2.7	31	0	22.9	97	19.4	26	304.4	309.3	49.6	221.1	Poor
RS47	Waiohine R at Gorge	0.9	20	0	0.1	3	0	27	0.3	0.7	0.5	0.5	Excellent
RS48	Waiohine R at Bicknells	0.7	10	0	2.4	27	0	28	48.0	51.4	6.5	35.3	Good
RS49	Beef Ck at Headwaters	0.2	5	0	0	0	0	36	7.0	10.5	7.6	8.4	Excellent
RS50	Mangatarere S at SH 2	3.5	56	0	21.9	100	22.2	30	143.2	47.8	38.7	76.5	Poor
RS51	Huangarua R at Ponatahi Br	25.2	80	11.1	36.1	100	38.9	24	122.9	96.3	280.4	166.6	Poor
RS52	Tauanui R at Whakatomotomo Rd	0.3	9	0	1.3	21	0	28	0.8	30.6	1.7	11.1	Excellent
RS53	Awhea R at Tora Rd	1.7	36	0	55.3	100	38.9	21	35.8	29.3	60.8	42.0	Poor
RS54	Coles Ck Trib at Lagoon Hill Rd	0	0	0	16.3	80	17.2	27	41.6	21.5	59.6	40.9	Fair
RS55	Tauherenikau R at Websters	0	0	0	8.0	85	11.1	29	12.1	10.2	2.0	8.1	Fair
RS56	Waiorongomai R at Forest Pk	0	0	0	1.0	31	2.9	32	1.7	0.4	0.6	0.9	Excellent

[1] Mean and maximum values, and % compliance with guideline values were calculated based on the total number of times a site was visited, not the number of periphyton assessments able to be made at each site (this is because the majority of instances in which periphyton could not be assessed coincided with high river or stream flows when periphyton cover was likely to be minimal/below guidelines).

Eight sites exceeded the MfE (2000) filamentous periphyton streambed cover guideline (30% cover) on at least a quarter or more of sampling occasions during the reporting period (Table 5.3). Four of these sites are located on small streams draining predominantly urban catchments (Porirua Stream at Glenside, Porirua Stream at Wall Park, Karori Stream at Makara Peak and Kaiwharawhara Stream at Ngaio Gorge) and the other four sites are located in predominantly pastoral catchments that drain the eastern Wairarapa hill country (Taueru River at Gladstone, Kopuaranga River at Stewarts, Huangarua River at Ponatahi Bridge and Awhea River at Tora Road).

The sites that most regularly exceeded the MfE (2000) mat periphyton streambed cover guideline were Waipoua River at Colombo Road and Huangarua River at Ponatahi Bridge (14% and 11% of sampling occasions, respectively). Hutt River opposite Manor Park, Hutt River at Boulcott and Mangaroa River at Te Marua also recorded elevated mat periphyton cover on some occasions (Table 5.3).

5.1.3 Periphyton biomass

Twenty two of the 46 RSoE sites exceeded the MfE (2000) chlorophyll *a* guideline for benthic biodiversity (50 mg/m^2) on at least one of the annual sampling occasions over the three-year reporting period (Table 5.3). Four sites exceeded the guideline twice and three sites exceeded in all three years: Taueru River at Gladstone, Kopuaranga River at Stewarts and Huangarua River at Ponatahi Bridge (Table 5.3).

Two sites exceeded the MfE (2000) chlorophyll *a* guideline of 120 mg/m^2 for the protection of trout habitat and fisheries on one sampling occasion (Wainuiomata River upstream of White Bridge and Mangatarere Stream at SH 2). Two sites (Parkvale Stream at Weir and Huangarua River at Ponatahi Bridge) exceeded the threshold twice and two sites exceeded on all three sampling occasions (Taueru River at Gladstone and Kopuaranga River at Stewarts).

5.1.4 Periphyton classes and relationship with landcover

Overall, 19 RSoE sites were assigned a periphyton classification of ‘excellent’, indicative of a very high level of compliance with the MfE (2000) periphyton cover and biomass guidelines. Eight sites were classified as ‘good’ (17%), eight were ‘fair’ (17%) and 11 were ‘poor’ (24%). The majority (17) of sites classed as ‘excellent’ are located in catchments dominated by indigenous forest (Figure 5.1), with the remaining two sites (Makara Stream at Kennels and Parkvale Stream at Lowes Reserve) located in pasture dominated catchments. Sites classed as ‘poor’ have upstream catchments dominated by either pasture or urban landcover.

There was a strong negative correlation (r_s=-0.73, p<0.001) between mean periphyton biomass and the proportion of indigenous forest in the upstream catchment; periphyton biomass decreased with increasing indigenous forest cover. Conversely, within the 17 RSoE sites in the REC pastoral landcover class there was a moderate positive correlation (r_s=0.63, p=0.007) between periphyton biomass and the proportion of pastoral landcover; periphyton biomass increased with increasing pastoral landcover in the upstream catchment (Figure 5.2). There were insufficient data to assess the relationship between periphyton biomass and urban or exotic forest landcover. However, all four RSoE sites with a REC landcover class of 'urban' were classed as 'poor' based on compliance with MfE (2000) periphyton guidelines, while the single site representing exotic forest landcover was classed as 'fair'.

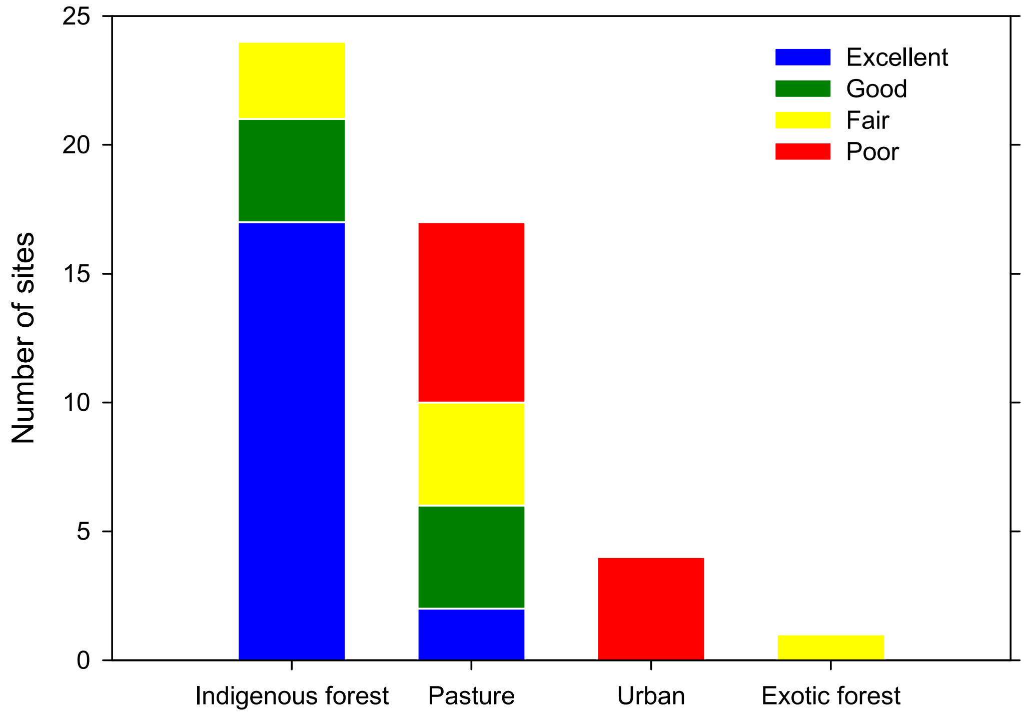


Figure 5.1: Periphyton classes assigned to each of 46 hard-bottomed RSoE sites, according to the degree of compliance with MfE (2000) guidelines for periphyton biomass and cover over the period July 2008 to June 2011. Sites are colour-coded according to their REC landcover class

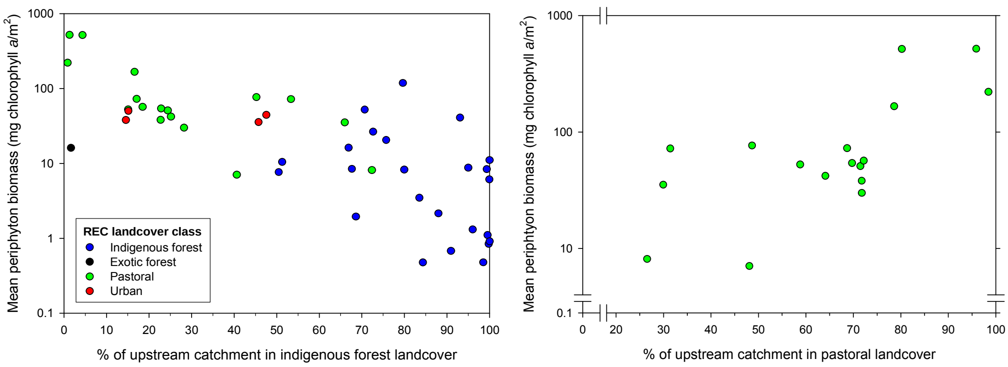


Figure 5.2: Scatter plots demonstrating the relationship between mean periphyton biomass (based on annual sampling in 2009, 2010 and 2011) and the proportion of indigenous forest (left) and pastoral landcover (right) in the catchment upstream of each RSoE site. Note that only sites classed as 'pastoral' (*n*=17) are included in the pastoral landcover plot

5.1.5 Relationships between periphyton growth and environmental variables

Spearman rank correlations between periphyton metrics and selected environmental variables showed that mean periphyton biomass tended to be more strongly correlated with environmental variables than periphyton cover. The environmental variables that demonstrated the strongest positive correlations with periphyton biomass were total nitrogen (TN), total Kjeldahl nitrogen (TKN), total phosphorus (TP) and water temperature (r_s=0.67–0.76). In contrast, water clarity and habitat score exhibited strong negative correlations (r_s=-0.69–-0.54) with periphyton biomass (Table 5.4, Figure 5.3).

Mean filamentous periphyton cover showed stronger correlations with environmental variables than maximum filamentous cover; it was most strongly positively correlated with water temperature (r_s=0.65), followed by TKN, TN and pH (r_s=0.54–0.55) and most strongly negatively correlated with habitat score, water clarity and shade score (r_s=-0.67–-0.54).

Table 5.4: Spearman rank correlations between selected periphyton metrics and environmental variables at 46 RSoE sites. Correlations are listed from highest to lowest (both positive and negative) based on periphyton biomass results. Environmental variables used in the analysis are medians unless stated otherwise. Correlations in bold are statistically significant (*p*<0.05)

Environmental variable	Mean biomass (mg chla/m²)	Mean mat (% cover)	Max. mat (% cover)	Mean filamentous (% cover)	Max. filamentous (% cover)
Total nitrogen (mg/L)	**0.76**	**0.32**	0.27	**0.54**	**0.44**
Total Kjeldahl nitrogen (mg/L)	**0.73**	0.13	0.10	**0.61**	**0.53**
Visual clarity (m)	**-0.69**	-0.10	-0.06	**-0.55**	**-0.52**
Total phosphorus (mg/L)	**0.67**	0.07	0.04	**0.49**	**0.42**
Water temperature (°C)	**0.67**	**0.50**	**0.50**	**0.65**	**0.61**
Dissolved inorganic N (mg/L)	**0.64**	**0.36**	**0.30**	**0.43**	**0.33**
Nitrite-nitrate N (mg/L)	**0.63**	**0.36**	**0.30**	**0.42**	**0.32**
Turbidity (NTU)	**0.61**	-0.03	-0.05	**0.52**	**0.50**
Total organic carbon (mg/L)	**0.60**	-0.02	-0.05	**0.47**	**0.44**
Temperature 95th–ile (°C)	**0.58**	**0.44**	**0.47**	**0.61**	**0.61**
Dissolved reactive P (mg/L)	**0.55**	0.06	0.02	**0.35**	0.28
Habitat score[1]	**-0.54**	**-0.31**	**-0.31**	**-0.67**	**-0.62**
Conductivity (µs/cm)	**0.49**	0.00	-0.04	**0.50**	**0.46**
Ammoniacal-N (mg/L)	**0.44**	0.13	0.14	**0.36**	**0.31**
Substrate score[2]	**-0.39**	0.10	0.05	**-0.33**	**-0.36**
Mean annual maximum accrual period (days)[3]	**0.38**	0.02	-0.04	0.27	0.22
Shade score[1]	**-0.36**	**-0.42**	**-0.45**	**-0.54**	**-0.51**
pH	**0.34**	0.08	0.08	**0.54**	**0.51**
Dissolved oxygen (% sat.)	-0.01	**0.40**	**0.40**	0.25	0.17

[1] One-off assessment in 2008 (see Appendix 8).
[2] Derived as a mean from assessments made during annual biological sampling in 2009, 2010 and 2011 (see Appendix 8).
[3] Estimates derived by Thompson and Gordon (2010b).

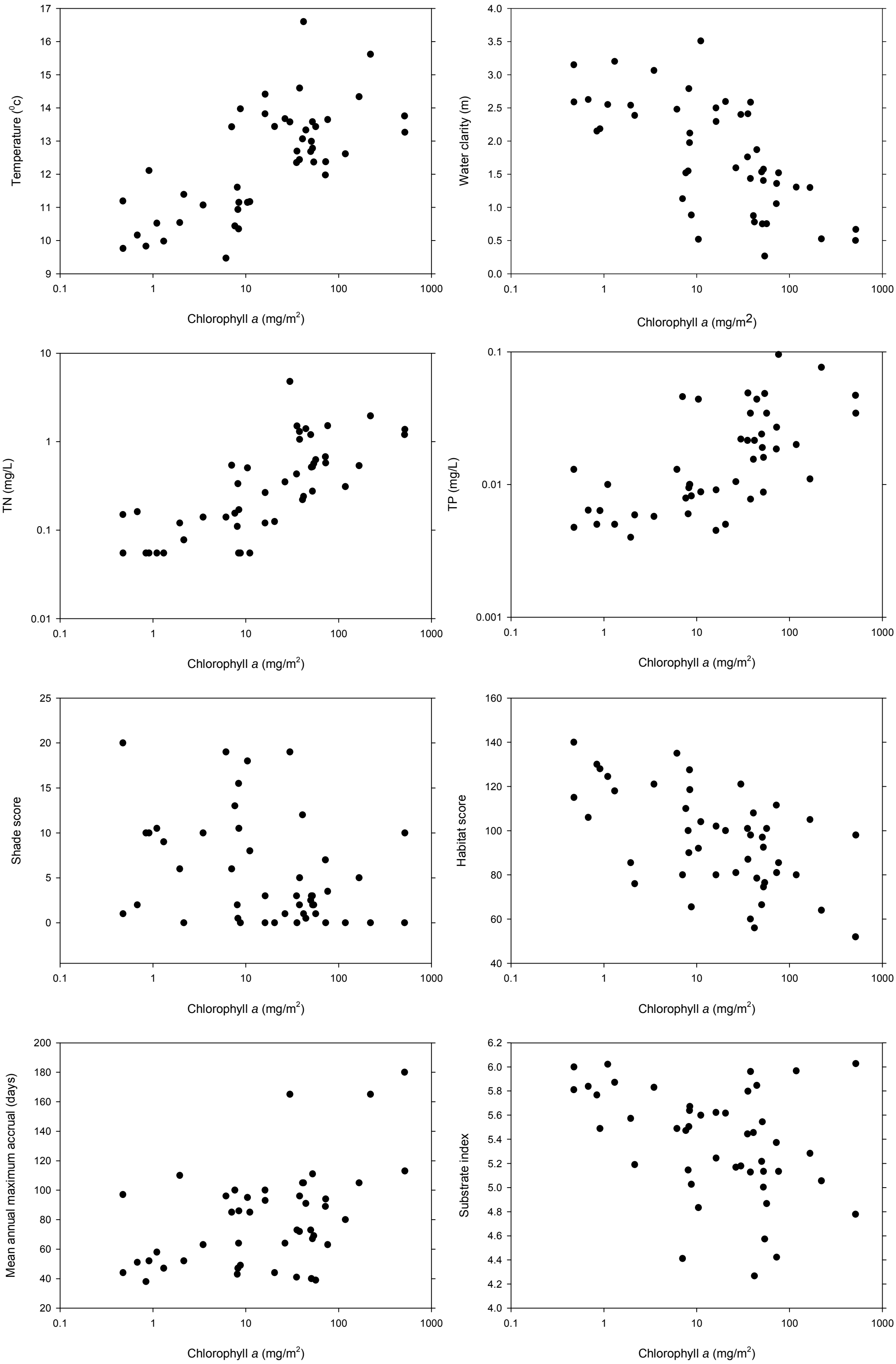


Figure 5.3: Scatter plots showing the relationships between mean periphyton biomass (as chlorophyll *a*) and selected environmental variables, based on data collected at 46 RSoE sites between July 2008 and June 2011. All environmental variables are medians apart from shade and habitat scores (one-off measures), substrate (mean of three assessments) and mean annual maximum accrual (determined by Thompson & Gordon (2010b)). Note the log (and different) scales on some axes

Mean and maximum mat periphyton cover demonstrated few statistically significant correlations apart from moderate to weak correlations with water temperature, shade, dissolved oxygen and dissolved inorganic nitrogen (Table 5.4). It is important to note that a strong correlation between periphyton growth and a particular environmental variable does not necessarily mean that there is a cause and effect relationship between the two. Although variables such as water temperature, shade and nutrient concentrations have been shown to directly affect periphyton growth (MfE 2000), other variables are unlikely to directly influence periphyton growth. For example, the moderate correlation between filamentous periphyton cover and pH is likely to be related to the four RSoE sites with the highest mean filamentous periphyton cover being located in eastern Wairarapa. These sites typically have high pH (median pH of 7.6–8.0) due to their catchment geology (see Section 4.1.5) but proliferation of filamentous periphyton is more likely to be a result of low summer-time flows and infrequent freshes that are also typical of these sites.

The strong negative correlation between periphyton biomass/filamentous cover and visual (water) clarity was unexpected because all other factors being equal, higher water clarity and the associated increase in light availability to the streambed should result in increased periphyton growth. It is likely that the strong negative correlation is due to high water clarity being associated with oligotrophic conditions present at some RSoE sites.

The relatively poor correlation between periphyton growth and average accrual period (r_s=0.38–0.02) was also surprising given that the frequency of flushing flows is widely recognised as one of the key factors determining periphyton growth (eg, MfE 2000). The poor correlation is likely to be related to the over-riding effect of land use related factors such as nutrient concentration and water temperature at some sites. For example, although sites such as Motuwaireka Stream at Headwaters and Waikanae River at Mangaone Walkway are characterised by long accrual periods (average annual maximum accrual of 110 and 97 days, respectively) they have low periphyton biomass as they are located in the headwaters of forested streams. Conversely, although Ruamahanga River at Gladstone Bridge has the second shortest average annual maximum accrual period (39 days) it has moderate periphyton growth – most likely due to moderate nutrient enrichment found at this site.

Most RSoE sites assigned to the ‘excellent’ periphyton class (refer Table 5.3) were characterised by very low median concentrations of TN and/or TP (<0.2 mg/L and <0.009 mg/L, respectively) and a median water temperature of less than 12^{o}C. Most of these sites also had high visual clarity (median of >2 m) and habitat scores (>100), reflecting their location in catchments dominated by indigenous forest (refer Figure 5.1). Two notable exceptions were Whareroa Stream at Waterfall Road (Figure 5.4) and Parkvale Stream at Lowes Reserve; these two sites recorded moderate to high median nutrient concentrations but are also characterised by a high degree of shade (shade scores of 19 and 18, respectively) which is likely to be the key factor controlling periphyton growth at these sites.

Figure 5.4: RSoE sites Whareroa Stream at Waterfall Road (left) and Awhea River at Tora Road (right)

Most of the RSoE sites assigned to the 'poor' periphyton class recorded very high median concentrations of TN (>1 mg/L) and/or TP (>0.04 mg/L). Awhea River at Tora Road (Figure 5.4) and Huangarua River at Ponatahi Bridge were two exceptions, recording only low or moderate median nutrient concentrations. However, these two sites are characterised by both high water temperatures (median values >14^{o}C) and long accrual periods (mean annual maximum accrual period is estimated to be 105 days at both), a reflection of their location in the eastern Wairarapa which typically experiences dry summers. Both sites also have minimal shade.

The other exception in the 'poor' class was Mangaroa River at Te Marua. This site recorded only moderate concentrations of TN and TP and a low median water temperature. The reason for high periphyton growth at this site is unclear but could be related to the relatively long accrual periods this site can experience (average annual maximum accrual period of 89 days).

5.1.6 Macrophytes

Nine RSoE sites have substrate dominated by soft sediment (eg, silt and sand) which makes them more suitable for growth of macrophytes than periphyton. Although monitoring of macrophyte cover was not undertaken during the July 2008 to June 2011 reporting period (monitoring only commenced in July 2011), general observations made at the time of routine monthly water quality sampling suggest that extensive macrophyte cover is frequently present at four soft-bottomed RSoE sites: Mangapouri Stream at Bennetts Road (Figure 5.5), Mangaone Stream at Sims Road Bridge, Whangaehu River 250 m from confluence and Whareama River at Gauge.

Extensive macrophyte growth has also been observed at some hard-bottomed RSoE sites, many of which have substrate at the lower size limit of that suitable for periphyton growth and/or experience long accrual periods. These sites include Pauatahanui Stream at Elmwood Bridge, Makara Stream at Kennels, Wainuiomata River upstream of White Bridge, Parkvale Stream at Weir and Taueru River at Gladstone Bridge. Most of these sites are located near the bottom of low lying catchments dominated by pastoral land use.

Figure 5.5: Extensive growth of *Lagarosiphon major* just downstream of the RSoE sampling site on the Mangapouri Stream at Bennetts Road (March 2009)

5.2 Temporal trends

5.2.1 Approach to analysis

Temporal trends in periphyton growth were assessed at each of 46 hard substrate RSoE sites using two data sets: monthly observations of percent periphyton streambed cover from September 2003 to June 2011 and periphyton biomass (chlorophyll *a* concentration) data from annual sampling between summer/autumn 2004 and 2011 (n=8)[19]. The 2003/04 to 2010/11 period was the longest available for trend assessment since major changes were made to the RSoE site network in 2003 (refer Section 2.1).

Trends in periphyton cover were assessed using annual mean and maximum cover data – a similar approach to that used by Quinn and Raaphorst (2009). In order to be consistent with the methods used in Quinn and Raaphorst (2009), annual mean cover results were calculated based on the number of periphyton cover assessments made at a site (ie, this is in contrast to the approach used in Section 5.1 where cover data were calculated based on the total number of visits to each site). Annual mean and maximum cover values were calculated for the period July to June for all years (except for 2003/04 which was limited to September to June because observations of mat and filamentous streambed cover only commenced in September 2003)[20].

Non-parametric Spearman Rank correlations were used to determine whether or not statistically significant temporal trends were present in periphyton cover

[19] n=7 for periphyton biomass at the three Hutt River sites (the 2011 biomass results were excluded due to the influence of a fresh).

[20] The absence of July and August data for the 2003/04 year is unlikely to significantly affect the results of trend analysis at many RSoE sites because periphyton cover is not regularly recorded during these months.

and biomass data. Three trend classes were defined. Trends were considered 'possible' when Spearman Rank correlation coefficient probabilities (*p*-values) were between 0.1 and 0.05, 'probable' when $p<0.05$, and 'clear' when they were deemed statistically significant ($p<0.05$) after adjustment for multiple comparisons using the False Discovery Rate (FDR). Spearman Rank correlations were performed in SigmaPlot (version 11.0) and FDR analysis in NIWA's TimeTrends software (version 3.20). While all trend classes are summarised, only 'probable' and 'clear' trends are presented and discussed. For sites where trends were present, a linear regression line was fitted and the slope of this line used to provide some context for the rate of change or the magnitude of the trend at each site. The relative rate of change was also calculated by dividing the slope by the mean periphyton metric value.

In order to assess the influence of flow variation on periphyton cover/biomass trends, estimates of the accrual period prior to each periphyton biomass sampling occasion and 25th percentile flows for each summer period were calculated. The accrual period (or time since the last flushing flow) determines the degree to which periphyton growth is able to accumulate while the extent of low flows during summer influences water temperature and periphyton growth rates. Accrual periods prior to each periphyton biomass sampling occasion were estimated using the methods outlined in Thompson and Gordon (2010b) while 25th percentile flow values for each summer over the reporting period were calculated from instantaneous flows recorded during the period 1 November to 30 April.

(a) Cautionary notes

There were several changes in sampling personnel undertaking periphyton cover assessments over the trend analysis period, including the use of external contractors that undertook periphyton cover assessments from July 2006 to December 2007. It is possible that these changes may have provided an additional source of variation in the results. It is also possible that slight changes in the location at which assessments were undertaken may have occurred at some sites over this period.

5.2.2 Results

At 22 of the 46 RSoE sites, no trends were present in any of the five periphyton metrics assessed. For the 24 sites where trends were present, four of these exhibited only 'possible' trends. Full trend analysis results, including sites with possible trends, can be found in Appendix 7.

Twenty one sites exhibited at least one 'probable' ($p<0.05$) or 'clear' ($p<0.05$ after FDR adjustment) trend in one of the five metrics assessed (Table 5.5). In all but one case, probable and clear trends were increasing rather than decreasing trends. Such trends were present in two or more of the five metrics assessed at ten sites and in three of the five metrics at two sites (Hutt River opposite Manor Park and Orongorongo River at Orongorongo Station). Trends were present at sites across all REC landcover classes represented in the RSoE network, including sites with upstream catchments dominated by indigenous forest.

Table 5.5: Number of sites assigned into different trend categories for the five periphyton metrics assessed at 46 RSoE sites with hard-bottomed substrate, based on annual mean and maximum streambed cover (filamentous and mat) values calculated from monthly assessments carried out over August 2003 to June 2011, and annual assessments of biomass (chlorophyll *a*) for the period 2004 to 2011

Periphyton metric	Increasing trend				No trend	Decreasing trend			
	Possible	Probable	Clear	Total		Possible	Probable	Clear	Total
Max. filamentous cover (%)	5	6	4	15	30	1	0	0	1
Mean filamentous cover (%)	5	7	3	15	31	0	0	0	0
Max. mat cover (%)	0	2	2	4	42	0	0	0	0
Mean mat cover (%)	1	5	2	8	37	1	0	0	1
Biomass (mg Chla/m^2)	4	0	3	7	38	0	0	1	1

At a number of sites the magnitude of trends in filamentous and mat streambed cover (as indicated by the slope of a linear regression line) were small. For example, Waiohine River at Bicknells recorded increases in annual mean and maximum mat periphyton cover of 0.2% and 1.2% per year, respectively (Table 5.6). However, larger magnitude trends were observed at some sites, with four sites (Porirua Stream at Wall Park, Kaiwharawhara Stream at Ngaio Gorge, Taueru River at Gladstone and Awhea River at Tora Road) exhibiting increases in mean filamentous streambed cover of around 4% per year or more (Figure 5.6). Based on the mean values, this equated to a relative rate of change of up to 35% per year at these sites. A number of sites recorded increases in maximum filamentous streambed cover of around 10% per year or greater. Two sites located on the Hutt River (at Manor Park Golf Club and Boulcott) exhibited similarly large increases in maximum mat cover (Table 5.6); both of these sites also exhibited clear increasing trends in mean mat periphyton streambed cover (Table 5.6, Figure 5.7).

It is unlikely that the trends of small magnitude at sites with low periphyton cover had a significant effect on recreational, ecological or other river values. However, at sites where periphyton cover increased from low to moderate (eg, Porirua Stream at Wall Park and Kaiwharawhara Stream at Ngaio Gorge) or from low to high levels (eg, Taueru River at Gladstone Bridge and Awhea River at Tora Road), it is likely that at least some stream values were degraded as a result.

Table 5.6: Summary of 'probable' (p<0.05) and 'clear' (p<0.05 after FDR adjustment) trends in mean and maximum annual filamentous and mat periphyton cover for the period 2003/04 to 2010/11. Slope=% cover/year and RRC=% relative rate of change. A single arrow indicates a 'probable' trend and a double arrow indicates a 'clear' trend

Site no.	Site name	Annual mean (%)					Annual maximum (%)				
		Trend	Mean	Max	Slope	RRC (%/yr)	Trend	Mean	Max	Slope	RRC (%/yr)
Filamentous periphyton streambed cover											
RS06	Otaki R at Mouth	↑	3.2	8.3	1.0	31.3	No trend				
RS14	Pauatahanui S at Elmwood Br	↑↑	10.9	37.3	3.8	34.9	↑↑	41.0	100.0	13.7	33.4
RS16	Porirua S at Wall Park	↑↑	11.7	30.5	4.0	34.2	↑↑	46.3	84.0	9.7	21.0
RS19	Kaiwharawhara S at Ngaio G.	↑	13.2	33.5	4.9	37.1	↑↑	46.9	100.0	14.0	29.9
RS21	Hutt R opp. Manor Park	↑	1.5	6.1	0.5	33.3	No trend				
RS30	Orongorongo R at Orongo. Stn	↑	7.0	22.6	2.4	34.3	↑	32.2	100.0	9.0	28.0
RS37	Taueru R at Gladstone	↑	47.9	76.0	7.1	14.8	↑	79.8	100.0	9.4	11.8
RS38	Kopuaranga R at Stewarts	No trend					↑	69.4	100.0	9.9	14.3
RS40	Waipoua R at Colombo Rd Br	↑	4.4	8.7	1.0	22.7	↑	24.0	53.0	5.5	22.9
RS44	Totara S at Stronvar	No trend					↑	61.6	100.0	10.8	17.5
RS51	Huangarua R at Ponatahi Br	No trend					↑	68.5	100.0	12.8	18.7
RS53	Awhea R at Tora Rd	↑↑	37.9	58.3	6.7	17.7	↑↑	92.3	100.0	3.6	3.9
RS55	Tauherenikau R Websters	↑	5.7	12.6	1.5	26.3	No trend				
Mat periphyton streambed cover											
RS21	Hutt R opp. Manor Park	↑↑	8.8	17.7	2.2	25.0	↑↑	37.9	88.0	11.6	30.6
RS22	Hutt R at Boulcott	↑↑	7.9	16.2	2.7	34.2	↑↑	39.3	100.0	12.9	32.8
RS23	Pakuratahi R d/s Farm Ck	↑	2.6	7.4	0.7	26.9	↑	15.5	30.5	3.3	21.3
RS24	Mangaroa R at Te Marua	↑	10.4	31.7	1.5	14.4	No trend				
RS30	Orongorongo R at Orongo. Stn	↑	0.6	2.1	0.3	50.0	No trend				
RS48	Waiohine R at Bicknells	↑	0.2	1.0	0.2	100.0	↑	2.0	10.0	1.2	60.0
RS51	Huangarua R at Ponatahi Br	↑	12.9	28.6	4.4	34.1	No trend				

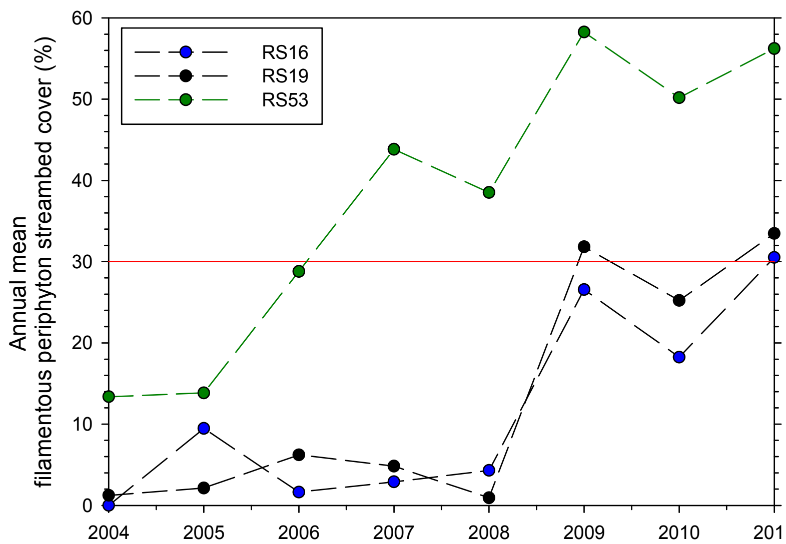


Figure 5.6: Annual mean filamentous streambed cover (%) at Porirua Stream at Wall Park (RS16), Kaiwharawhara Stream at Ngaio Gorge (RS19) and Awhea River at Tora Road (RS53), based on monthly assessments undertaken over 2003/04 to 2010/11 (based on a July to June year). The horizontal red line indicates the MfE (2000) streambed cover guideline for filamentous periphyton (30%)

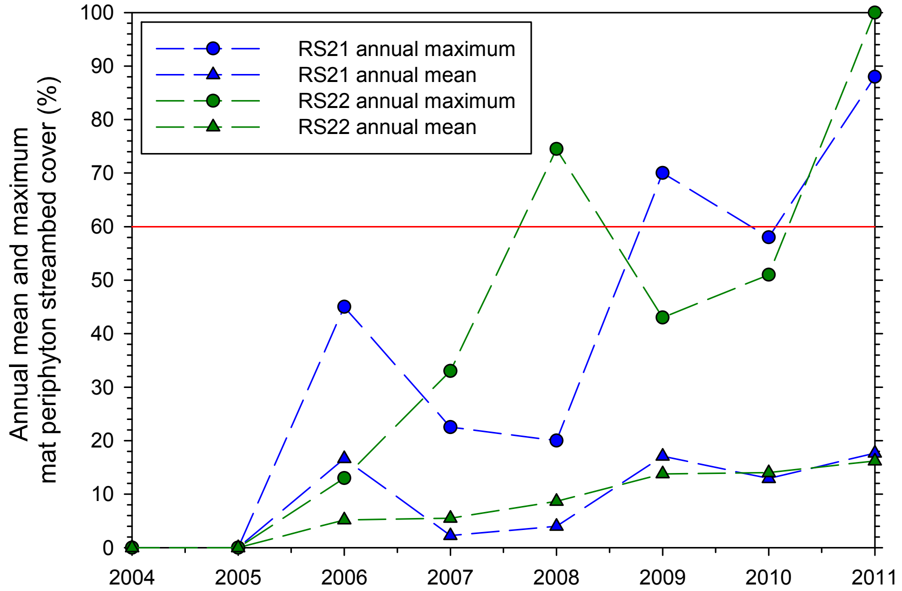


Figure 5.7: Annual mean and maximum mat periphyton streambed cover at Hutt River opposite Manor Park Golf Club (RS21) and Hutt River at Boulcott (RS22), based on monthly assessments undertaken over 2003/04 to 2010/11 (based on a July to June year). The horizontal red line indicates the MfE (2000) streambed cover guidelines for mat periphyton (60%)

Clear trends were evident in periphyton biomass at four sites (Table 5.7): a decreasing trend at Waitohu Stream at Forest Park and increasing trends at Mangaroa River at Te Marua, Wainuiomata River upstream of White Bridge and Ruamahanga River at Gladstone (Figure 5.8). The three increasing trends ranged in magnitude from 9 to 18 mg/m^2/yr, representing an increase of more than 20% per year relative to the mean periphyton biomass values. Exceedance of the MfE (2000) guideline for protection of aquatic biodiversity at all three sites and a corresponding decreasing trend in macroinvertebrate health at one site (Ruamahanga River at Gladstone, see Section 6.2.2) suggests that these increases in periphyton biomass may be ecologically significant. In contrast, the small magnitude of the decreasing trend at Waitohu Stream at Forest Park, a site with already low periphyton biomass, is unlikely to be ecologically significant.

Table 5.7: Summary of 'probable' (*p*<0.05) and 'clear' (*p*<0.05 after FDR adjustment) trends in periphyton biomass (chlorophyll *a* concentrations) for the period 2003/04 to 2010/11. A single arrow indicates a 'probable' trend and a double arrow indicates a 'clear' trend

Site no.	Site name	Trend	Mean	Min	Max	Slope (mg/m^2/yr)	Relative rate of change (%/yr)
RS03	Waitohu S at Forest Pk	↓↓	3.6	0.8	9.3	-1.2	33
RS24	Mangaroa R at Te Marua	↑↑	49.3	0.6	83.9	10.7	22
RS29	Wainuiomata R u/s of White Br	↑↑	59.7	6.1	236.3	18.1	30
RS33	Ruamahanga R at Gladstone	↑↑	38.1	4.1	65.0	8.6	23

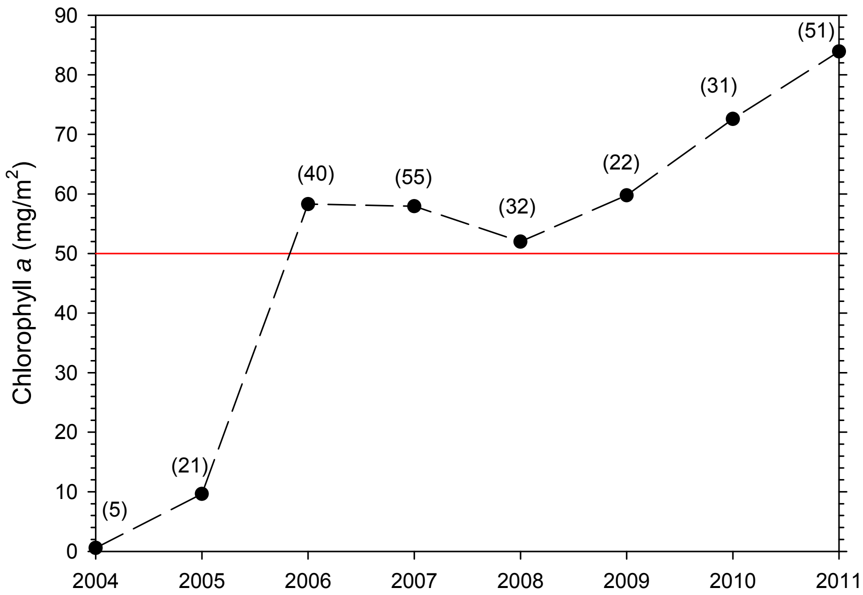


Figure 5.8: Chlorophyll *a* concentrations at Ruamahanga River at Gladstone, based on annual periphyton biomass sampling between 2004 and 2011. The numbers in brackets indicate the accrual period (days) prior to sampling and the red horizontal line indicates the MfE (2000) 50 mg/m² threshold

The reasons behind the increasing periphyton cover and/or biomass trends at such a large number of sites across a wide range of landcover types are unclear. At two sites changes in sampling location may be behind the apparent increase in periphyton growth. For example, the increase in both annual mean and annual maximum filamentous periphyton cover at Pauatahanui Stream at Elmwood Bridge is the likely result of shifting the site 40 m downstream in 2008 to enable easier access to the stream. Habitat at this downstream site is more suitable (gravel/cobble) for periphyton growth compared to the former silt-dominated upstream site. Similarly, trends in periphyton growth at Hutt River at Boulcott may be related to the sampling site being shifted to a shallower site 100 m upstream in 2009 when the previous sampling site became too deep to access safely.

There were no clear links between trends in periphyton growth and trends in water quality variables such as nutrient concentrations and water temperature that are known to be key drivers of periphyton growth. At most sites where clear increases in periphyton growth and/or biomass were detected there were no significant increases in nutrient concentrations; in fact, the temporal trend analysis presented in Section 4.2 indicates that significant decreases in TN and/or TP concentrations were recorded at some of these sites (although water quality trends were assessed over a shorter period). The exception was Mangaroa River at Te Marua which exhibited a significant increase in TP concentrations.

Variation in river flow over the 2003/04 to 2010/11 period may be a key factor behind the observed trends in periphyton growth. Due to the occurrence of frequent freshes during the summer months of 2003/04 and 2004/05, periphyton biomass samples taken from many RSoE sites during these years followed only a short accrual period and, in some cases, coincided with lower water temperatures due to samples being taken later in the season. These conditions are reflected in both periphyton biomass and periphyton cover measurements being at their lowest across all 46 sites in the first two years of the trend period (Figure 5.9). The low biomass values recorded in 2003/04 and 2004/05 are likely to have influenced the increasing trends detected at several sites (eg, Figure 5.8).

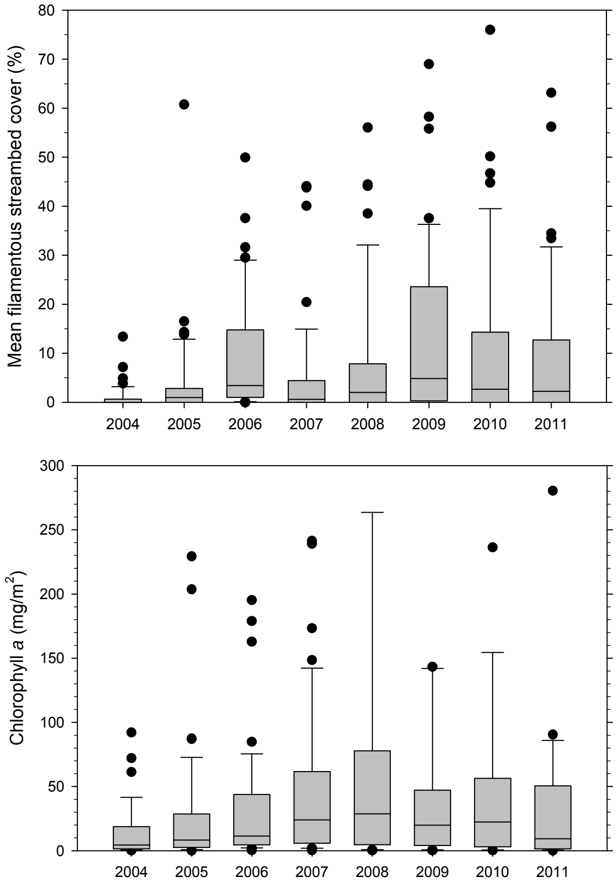


Figure 5.9: Box plots summarising the range of annual measurements of mean filamentous periphyton cover (top) and periphyton biomass (as represented by chlorophyll *a*, bottom), based on data collected from 46 RSoE sites with hard substrates between September 2003 and June 2011. Note that some outliers have been excluded from the periphyton biomass plots for clarity

Assessment of summer-time 25th percentile flows[21] at flow recorder sites at or near RSoE sites that exhibited increasing periphyton trends showed that across the region, flows during the 2003/04 and 2004/05 summers were considerably higher than the rest of the reporting period (Figure 5.10). At some rivers or streams (eg, the Ruakokoputuna River in eastern Wairarapa which is considered to have similar flow patterns to the Awhea River) there was a notable decline in 25th percentile summer-time flows across the period while at others (eg, Porirua Stream) summer-time low flows fluctuated following a peak in 2004 and 2005. In general, Keenan et al. (2012) noted that since 2005 there have been lower annual 7-day low flows and more low flow days per year compared to average.

[21] 25th percentile flow was used to indicate lowest summer-time flows when periphyton growth tends to be greatest. Other statistics such as median and minimum flow showed similar patterns.

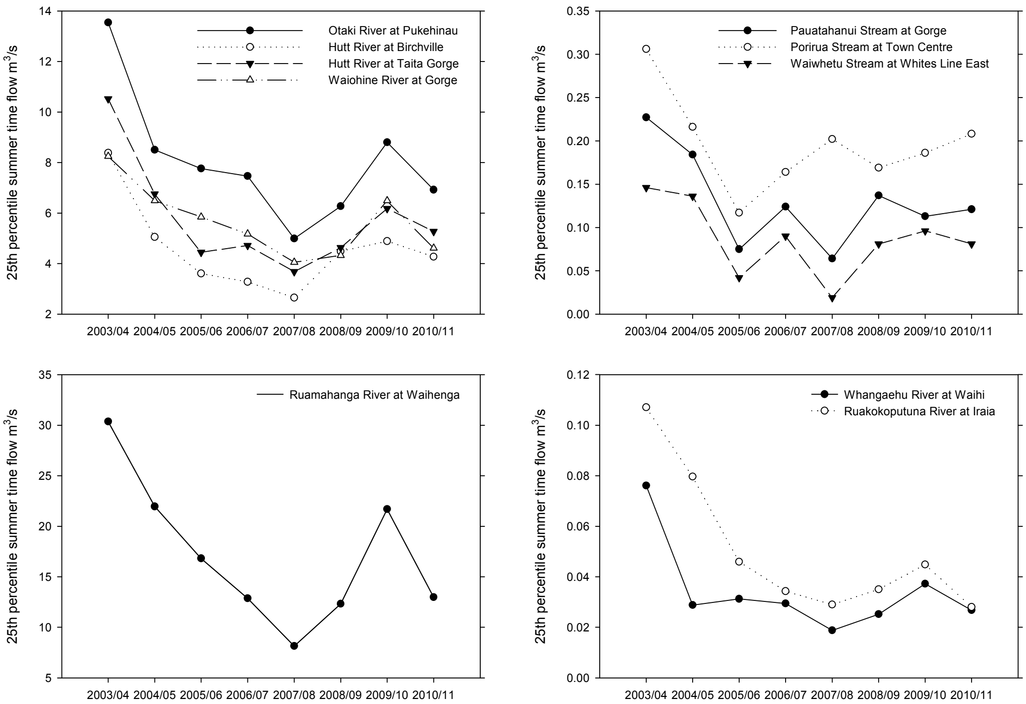


Figure 5.10: 25th percentile summer-time (November–April) flows between 2003/04 and 2010/11 at ten flow monitoring sites across the Wellington region. Data from the Whangaehu and Ruakokoputuna river sites provided courtesy of NIWA

5.3 Synthesis

Both periphyton cover and biomass were lowest at RSoE sites with catchments dominated by forested areas of the Tararua, Rimutaka and Aorangi ranges. These sites rarely exceeded the MfE (2000) guidelines for protection of instream values and, along with two highly shaded sites on streams with pastoral catchments, were assigned an overall periphyton class of ‘excellent’ (Figure 5.11).

Periphyton growth was greatest at urban sites in Wellington and Porirua, as well as at pastoral sites in central and eastern Wairarapa (Figure 5.11). These sites frequently exceeded guidelines for protection of recreational, aquatic biodiversity and trout fishery/spawning values and were classed as ‘poor’. Several of these sites, including Taueru River at Gladstone, Kopuaranga River at Stewarts, Mangatarere Stream at SH 2 and Huangarua River at Ponatahi Bridge, are listed in Greater Wellington’s existing Regional Freshwater Plan (WRC 1999) as supporting important trout habitat.

Environmental variables that exhibited the strongest correlations with periphyton biomass and/or cover were nutrient concentrations and water temperature. Many RSoE sites classified as having ‘poor’ compliance with the MfE (2000) periphyton guidelines recorded very high median concentrations of TN and/or TP, and high water temperatures. Some sites, such as those in eastern Wairarapa, recorded only low to moderate nutrient concentrations but high water temperatures. Rivers and streams in these areas are subject to periods of extended low flow during summer and can support high periphyton biomass despite relatively low nutrient concentrations. Conversely, at two sites

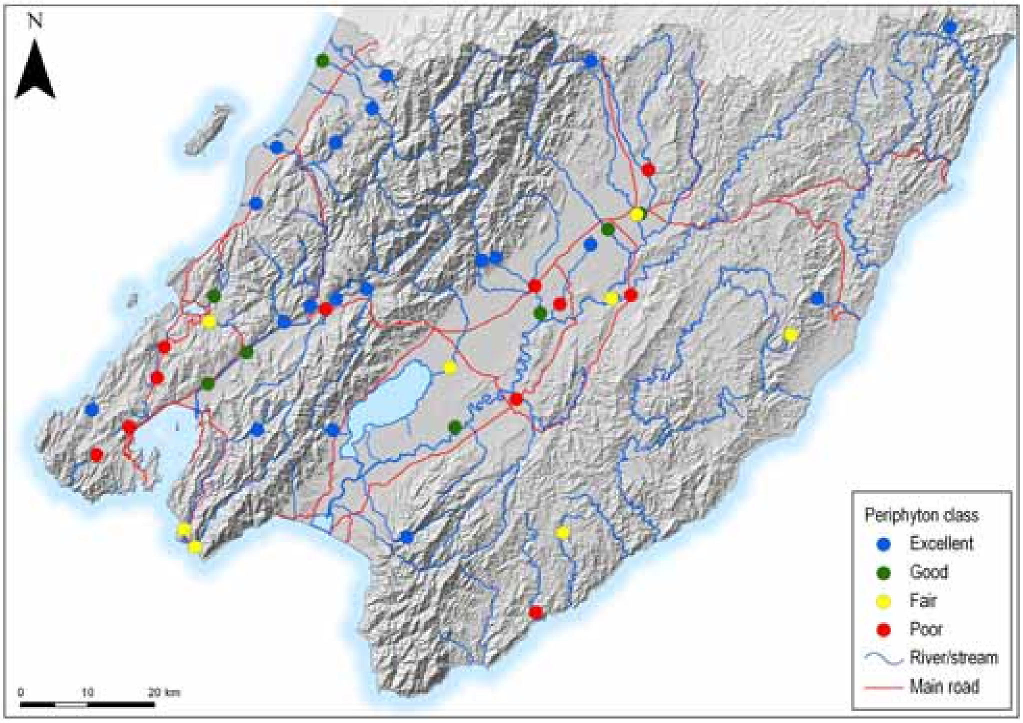


Figure 5.11: Periphyton quality classes for each of the 46 RSoE sites with hard substrate suitable for periphyton growth. Classes were assigned to each site according to compliance with MfE (2000) guidelines, based on both monthly assessments of periphyton cover and annual assessments of periphyton biomass made between July 2008 and June 2011

a high degree of stream shade resulted in low periphyton growth despite exposure to moderate to high nutrient concentrations.

Although formal monitoring of macrophyte cover was not undertaken during the reporting period at the nine RSoE sites dominated by soft substrate, observations recorded during other monitoring suggest that nuisance macrophyte growth regularly occurs at four of these sites. Nuisance macrophyte growth also occurs at a number of hard-bottomed sites characterised by small substrate and/or long accrual periods.

Significant increases in periphyton cover and/or biomass were detected at 19 RSoE sites while a significant decreasing trend was detected at one site. The magnitude of increasing trends was considerable at some sites – including many sites classified as 'poor' – and in some cases may have resulted in significant degradation of river and stream values. The reasons for these increasing trends are unclear. At many sites, the increasing trends have likely been influenced by unusually high river flows and short accrual periods at the start of the analysis period (summers of 2004 and 2005) which resulted in very low periphyton growth in these years. Further, at some sites, decreasing summer-time river flows over the duration of the trend period may also have influenced the observed trends.

6. Macroinvertebrates – state and trends

This section assesses state and trends in macroinvertebrate community health in river and streams across the Wellington region, based on the results of monitoring conducted annually at 55 RSoE sites in late summer/early autumn. The current state of macroinvertebrate health is presented first, using annual data from 2009, 2010 and 2011. Temporal trends are then examined for the period 2004 to 2011.

6.1 State

6.1.1 Approach to analysis

Macroinvertebrate samples collected annually in 2009, 2010 and 2011 were used to determine the current state of macroinvertebrate health at each of the 55 RSoE sites. Due to changes in the number of samples collected over the reporting period (from 2004 to 2009 three replicate samples were collected from each site, whereas in 2010 and 2011 just one sample was collected) and some inconsistencies in the resolution of taxonomic identification between years, an initial data screening and 'clean up' process was undertaken prior to data analysis.[22] As a result of this exercise, some of the metric scores presented here may differ slightly to those presented in earlier reports (eg, Perrie & Cockeram 2010).

Consistent with the SoE reporting recommendations in Stark and Maxted (2007), the current 'state' of macroinvertebrate community health was determined using the Macroinvertebrate Community Index (MCI). However, additional metrics – Quantitative MCI (QMCI), %Ephemeroptera-Plicoptera-Trichoptera (EPT) taxa[23] and %EPT individuals[23] – were also calculated and are discussed where relevant (see Appendix 3 for more information on the various macroinvertebrate metrics). Mean metric scores were calculated for each site across the three years and compared against the quality class thresholds in Stark and Maxted (2007) (Table 6.1). Stark and Maxted (2007) note that these thresholds should be interpreted as having 'fuzzy boundaries', with a margin of ±5 or ±0.2 units applied to the MCI or QMCI thresholds, respectively.

Table 6.1: Interpretation of MCI-type and QMCI scores (from Stark & Maxted 2007)

Quality class	MCI and MCIsb	QMCI
Excellent	≥ 120	≥ 6.00
Good	100−119	5.00−5.99
Fair	80−99	4.00−4.99
Poor	<80	<4.00

[22] This involved combining taxa from the three replicate samples collected at each site into one composite sample which was then used to generate each macroinvertebrate metric, and ensuring that the taxonomic resolution across all years was consistent with that outlined in Stark and Maxted (2007).

[23] Pollution tolerant EPT taxa (*Oxyethira* and *Paroxyethira*) were excluded from these calculations.

The MCI developed for hard-bottomed streams was applied to all 55 RSoE sites, including the nine sites with predominantly soft sedimentary substrate (see Appendix 1). While this approach differs from some earlier reports (eg, Perrie 2007; Perrie & Cockeram 2010) that used the MCI developed for soft-bottomed streams (MCIsb) to summarise data collected from these sites, it provides for easier inter-site comparisons and avoids some of the uncertainties and limitations associated with the use of the MCIsb. For example:

- Stark and Maxted (2007) note that MCIsb is most appropriate for use at sites that are known to be naturally soft-sedimentary rather than hard-bottomed sites that have been inundated with sediment. While the natural substrate characteristics of the nine RSoE sites that have predominantly soft sedimentary substrate are unknown, at least some of these sites are likely to have been hard sedimentary in their natural state.
- A number of taxa recorded at soft-bottomed RSoE sites have yet to be assigned MCIsb tolerance scores, meaning that the index can only be calculated from a subset of the total taxa present.

Relationships between macroinvertebrate metrics, landcover and selected environmental variables were assessed using Spearman rank correlations with a significance threshold of $p<0.05$. The environmental variables examined included selected water quality variables (as median values from the state analysis in Section 4.1), substrate (a mean score based on three annual assessments), and habitat quality and stream shade (from one-off assessments).

To identify patterns in macroinvertebrate community composition non-metric multi-dimensional scaling (NMDS) was performed on macroinvertebrate taxa abundance data from each of the 55 RSoE sites. Abundance data from each site were averaged across the three-year state period to give a mean abundance for each taxon at each site. Similar to Clapcott and Olsen (2010), BEST routines were then used to assess the rank correlation between multivariate patterns in the macroinvertebrate community composition data (based on Bray Curtis dissimilarity matrix) and those from environmental variables associated with each sample (based on Euclidian distance). BEST is a permutation based procedure to find the best match between all possible combinations (in this case the maximum number of variables was set at five) of environmental variables and macroinvertebrate community data. Biological data were $\log_{10}$ transformed prior to analysis while environmental variables were $\log_{10}$ transformed and normalised. NMDS and BEST routines were undertaken using PRIMER (version 6.1.13, Primer-E Ltd).

(a) Cautionary notes

The assessment relies heavily on the use of MCI (and to a lesser extent, QMCI) metrics which were originally developed to assess the effects of organic enrichment on macroinvertebrate communities. Although MCI and QMCI have since been shown to respond to a wide range of environmental stressors, it is possible that the effects of some stressors, such as those of heavy metal pollution, may not be adequately represented by these metrics (Boothroyd & Stark 2000).

It should also be noted that MCI and QMCI thresholds suggested by Stark and Maxted (2007) do not take into account the natural variation in macroinvertebrate community composition that can occur in response to differences in catchment altitude, geology and other geophysical characteristics.

6.1.2 Macroinvertebrate metrics

Summary statistics for the four metrics calculated (MCI, QMCI, %EPT taxa and %EPT individuals) calculated for each of the 55 RSoE sites are presented in Table 6.2. Mean MCI scores across the 55 RSoE sites ranged from a minimum of 67 (Waiwhetu Stream at Wainuiomata Hill Bridge) to a maximum of 146 (Ruamahanga River at McLays). As outlined in Section 2.3, the Waiwhetu Stream site is known to be occasionally influenced by tidal backflow and taxa indicative of estuarine conditions have been recorded at this site. Because the MCI was not designed to take into account estuarine influence its application at this site may not be appropriate. The next lowest mean MCI score recorded across the 55 sites was 75.9 (Parkvale Stream at Weir).

Based on mean MCI scores, 16 sites were classified as 'excellent', 20 sites as 'good', 16 sites as 'fair' and 3 sites as 'poor'. All sites classed as 'excellent' drain upstream catchments dominated by indigenous forest. The seven sites classed as 'poor' or within the 'fuzzy boundary' of the fair/poor threshold were found in catchments dominated by pastoral or urban landcover (Figure 6.1). All but one of these sites have substrate dominated by soft sediment – the exception being Parkvale Stream at Weir which has a relatively small catchment dominated by intensive agricultural land use.

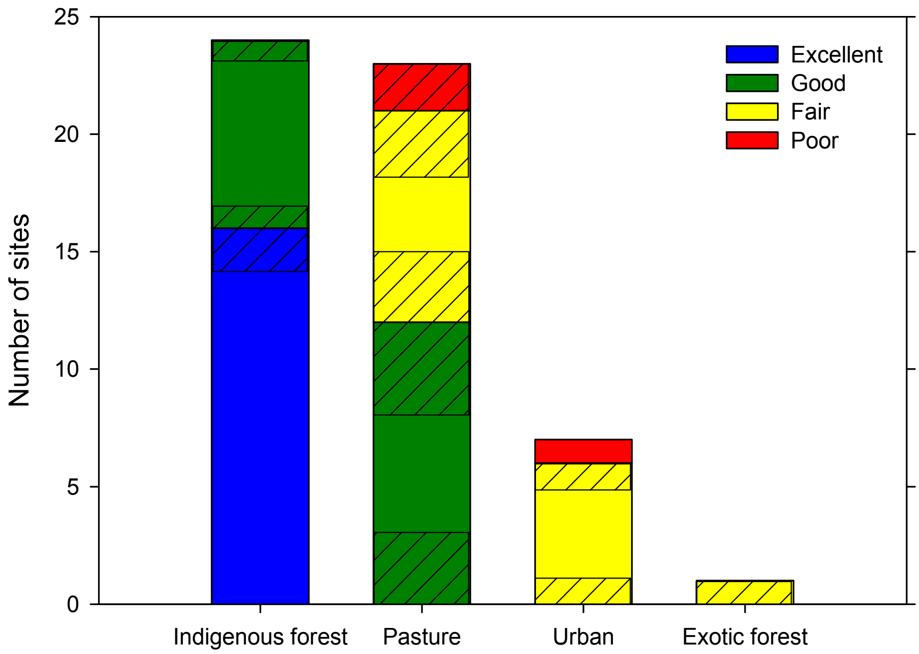


Figure 6.1: Macroinvertebrate quality classes assigned to each of the 55 RSoE sites, grouped according to REC landcover. Quality classes are based on the application of Stark and Maxted (2007) thresholds to mean MCI scores from annual sampling in 2009, 2010 and 2011. Hatched boxes represent sites within the ±5 MCI unit 'fuzzy boundary' between each class (note the result from the single exotic forestry site falls on the boundary of the fair/good threshold)

Table 6.2: Mean macroinvertebrate metric (MCI, QMCI, %EPT individuals and %EPT taxa) scores at the 55 RSoE sites, based on samples collected annually in 2009, 2010 and 2011. MCI quality classes (from Stark & Maxted 2007) are also indicated; blue='excellent', green='good', yellow='fair' and red='poor'

Site no.	Site name	MCI	QMCI	%EPT individuals	%EPT taxa
RS02	Mangapouri S at Bennetts Rd	91.5	4.46	1.2	12.7
RS03	Waitohu S at Forest Pk	145.9	8.17	90.7	71.1
RS04	Waitohu S at Norfolk Cres	94	4.63	4.7	33.5
RS05	Otaki R at Pukehinau	136.9	7.43	87.8	64.2
RS06	Otaki R at Mouth	112.6	7.3	85	42.9
RS07	Mangaone S at Sims Rd Br	82.5	4.27	0.1	6.4
RS08	Ngarara S at Field Way	80.5	4.57	0.4	7
RS09	Waikanae R at Mangaone Walkway	140.9	8.06	83	64
RS10	Waikanae R at Greenaway Rd	114.9	5.81	52.1	46.3
RS11	Whareroa S at Waterfall Rd	113.9	6.23	58.6	41.7
RS12	Whareroa S at QE Park	80.8	4.5	0.4	7.8
RS13	Horokiri S at Snodgrass	113.1	5.87	65.1	51
RS14	Pauatahanui S at Elmwood Br	106.9	5.13	48	44.9
RS15	Porirua S at Glenside	97.4	4.82	37.1	34.1
RS16	Porirua S at Wall Park (Milk Depot)	88.9	3.99	21.1	24.6
RS17	Makara S at Kennels	112.1	5.12	20.1	48
RS18	Karori S at Makara Peak	89.3	3.71	27.1	20.8
RS19	Kaiwharawhara S at Ngaio Gorge	89.8	3.44	27.9	28.7
RS20	Hutt R at Te Marua Intake Site[1]	137	8.39	91.63	62.6
RS21	Hutt R opp. Manor Park Golf Club[1]	124.7	6.56	70.17	62.9
RS22	Hutt R at Boulcott[1]	118.1	7.28	83.11	43.8
RS23	Pakuratahi R 50m d/s Farm Ck	125	7.45	80	52.4
RS24	Mangaroa R at Te Marua	117.9	6.14	64.6	46
RS25	Akatarawa R at Hutt R confl.	130.5	7.56	84.9	57.5
RS26	Whakatikei R at Riverstone	130.3	6.61	70.9	58.8
RS27	Waiwhetu S at Wainui Hill Br	67.2	4.15	0.2	5.2
RS28	Wainuiomata R at Manuka Track	135.5	7.2	71	60
RS29	Wainuiomata R u/s of White Br	101.8	4.33	45.2	38.1
RS30	Orongorongo R at Orongorongo Stn	105.8	6.44	65.7	37.6
RS31	Ruamahanga R at McLays	146	8.03	93.3	67.6
RS32	Ruamahanga R at Te Ore Ore	110.4	6.89	75.5	46.1
RS33	Ruamahanga R at Gladstone Br	103.1	7.11	78.3	38.6
RS34	Ruamahanga R at Pukio	102.1	7.44	89.5	37.6
RS35	Mataikona Trib at Sugar Loaf Rd	130.6	7.03	73.2	58
RS36	Taueru R at Castlehill	110.5	5.07	48.6	42.8
RS37	Taueru R at Gladstone	89.5	4.41	12.9	32.5
RS38	Kopuaranga R at Stewarts	95	3.95	37.4	34
RS39	Whangaehu R 250m u/s confl.	76.9	4.09	0.2	5
RS40	Waipoua R at Colombo Rd Br	103.6	4.23	48.3	40.4
RS41	Waingawa R at South Rd	113.3	6.82	76.3	49.3
RS42	Whareama R at Gauge	80.2	3.98	0.4	14.8
RS43	Motuwaireka S at Headwaters	130	6.79	60.4	58.3
RS44	Totara S at Stronvar	98.9	4.55	48.8	35.3
RS45	Parkvale Trib at Lowes Reserve	101	4.74	25.5	36.3
RS46	Parkvale S at Weir	75.9	3.39	6.2	19.5
RS47	Waiohine R at Gorge	139.2	7.88	92.4	69
RS48	Waiohine R at Bicknells	116.5	6.56	72.9	50
RS49	Beef Ck at Headwaters	133.3	7.28	75	58.4
RS50	Mangatarere S at SH 2	96.9	4.58	27	34.5
RS51	Huangarua R at Ponatahi Br	95.5	4.11	57.8	30
RS52	Tauanui R at Whakatomotomo Rd	129.8	6.74	75.3	59.7
RS53	Awhea R at Tora Rd	97.2	5.75	39.3	23.4
RS54	Coles Ck Trib at Lagoon Hill Rd	107.6	5.19	30.2	31.1
RS55	Tauherenikau R at Websters	118.7	7.15	86.9	47.5
RS56	Waiorongomai R at Forest Pk	124.8	7.14	81.9	54.4

[1] Scores presented for these sites are based only samples results from 2009 and 2010 only. The 2011 sample results were influenced by a small fresh at the time of sampling.

Although RSoE sites located on the region's larger rivers (eg, the Otaki, Hutt, Wainuiomata, Ruamahanga and Waiohine rivers) tended to be classed as 'excellent' or 'good', mean MCI scores at sites on the middle and lower reaches of these rivers were often considerably lower than at sites in the upper catchment reaches. For example, there was a difference in mean MCI score of 36 points between Ruamahanga River at McLays (a highly forested headwaters site) and Ruamahanga River at Te Ore Ore (approximately 25 km downstream at which point pastoral landcover makes up 72% of the upstream catchment).

6.1.3 Relationships between MCI, landcover and environmental variables

Strong relationships were found between mean MCI scores and landcover in the upstream catchment. In particular, there was a strong positive correlation (r_s=0.8, p<0.001) between mean MCI score and the proportion of indigenous forest in the upstream catchment and, within RSoE sites assigned to the pastoral REC landcover class, a strong negative correlation (r_s=-0.69, p<0.001) between mean MCI score and the proportion of pastoral landcover (Figure 6.2). There were insufficient sites in the 'urban' and 'exotic forest' landcover classes to adequately assess the relationship between these landcover types and mean MCI scores. However, based on mean MCI scores across the three major landcover types represented by the RSoE site network, sites located in urban catchments tended to record the lowest scores (mean MCI score of 86 cf. 99 at pastoral sites and 126 at indigenous forest sites). A mean MCI score of 99 was recorded at the single exotic forest site (Table 6.2).

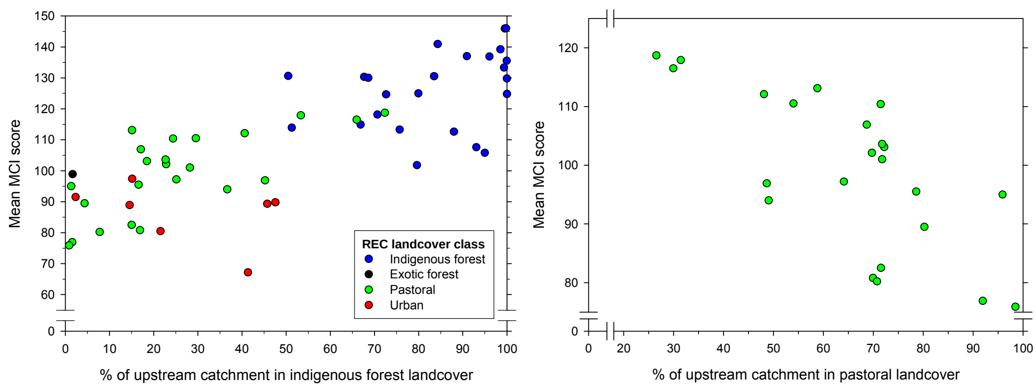


Figure 6.2: Scatter plots demonstrating the relationship between mean MCI score (based on annual sampling in 2009, 2010 and 2011) and the proportion of indigenous landcover (left) and pastoral landcover (right) in the catchment upstream of each RSoE site. Note that only RSoE sites classed as 'pastoral' forest' (*n*=23) are included in the pastoral landcover plot

Strong correlations were identified between mean MCI score and Greater Wellington's Water Quality Index (WQI) (r_s=-0.84, p<0.001), and between mean MCI score and habitat quality score (r_s=0.81, p<0.001) (Figure 6.3). The majority of sites that were classed as 'excellent' based on mean MCI scores were also ranked as excellent based on the WQI and, conversely, sites classed as having 'poor' or 'fair' macroinvertebrate health were generally also assigned a WQI grade of 'poor'. With regards to habitat, RSoE sites with higher habitat quality scores generally also recorded higher mean MCI scores and vice versa (Figure 6.3).

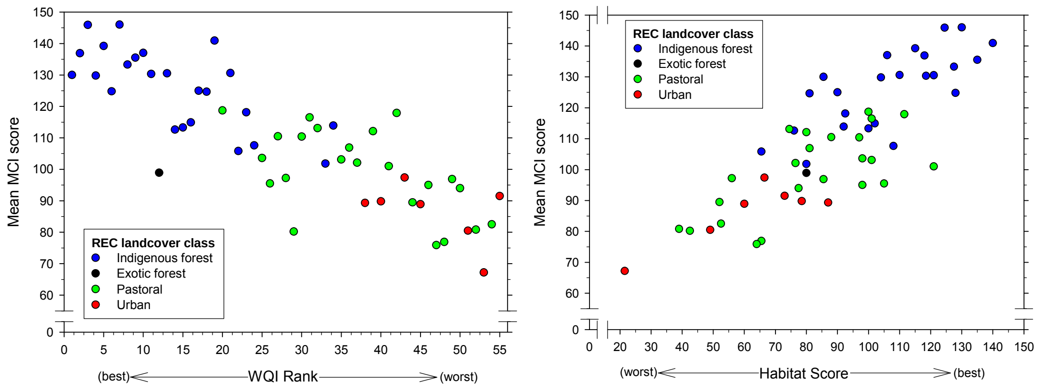


Figure 6.3: Scatter plots of mean MCI scores (based on annual sampling in 2009, 2010 and 2011) against WQI rank (left, see Section 4.1.14 for calculation details) and habitat score (right) for each RSoE site

There was also a strong correlation (r_s=-0.8, p<0.001) between mean MCI scores and mean periphyton biomass at the 46 RSoE sites dominated by hard substrate (Figure 6.4). Site classification based on macroinvertebrate health and compliance with MfE (2000) periphyton guidelines was generally aligned across the 55 RSoE sites. For example, 14 of the 16 sites classed as 'excellent' based on mean MCI score were also classed as 'excellent' based on compliance with periphyton guidelines (refer Section 5.1.4). Of the three sites classed as 'poor' for macroinvertebrate health, one (Parkvale Stream at Weir) was classed as 'poor' for periphyton (the other two sites are soft-bottomed and periphyton growth was not assessed).

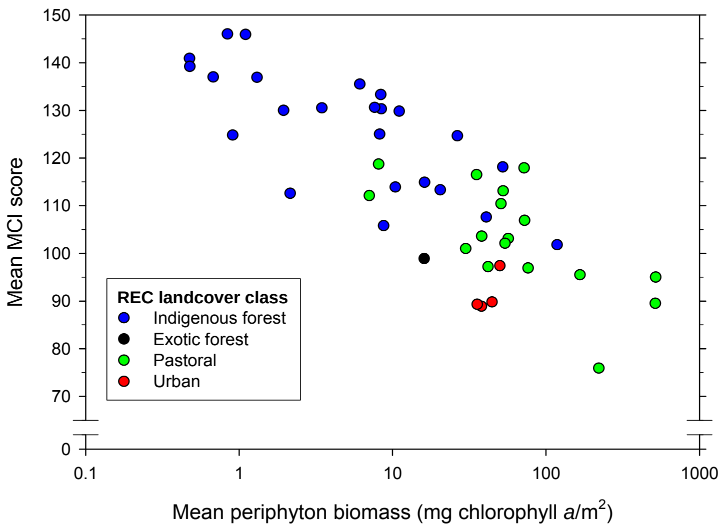


Figure 6.4: Scatter plot of mean MCI scores against mean periphyton biomass at the 46 RSoE sites dominated by hard substrate. MCI and periphyton values are based on annual sampling in 2009, 2010 and 2011. Note the logarithmic scale on the *x*-axis

BEST analysis found that the five-environmental variable solution with the highest correlation with macroinvertebrate community composition (r_s=0.84) included water temperature, total nitrogen, total Kjeldahl nitrogen (TKN), habitat score and substrate score (Figure 6.5). Substrate score occurred in all of the best 10 solutions while habitat score occurred in nine. The single variable

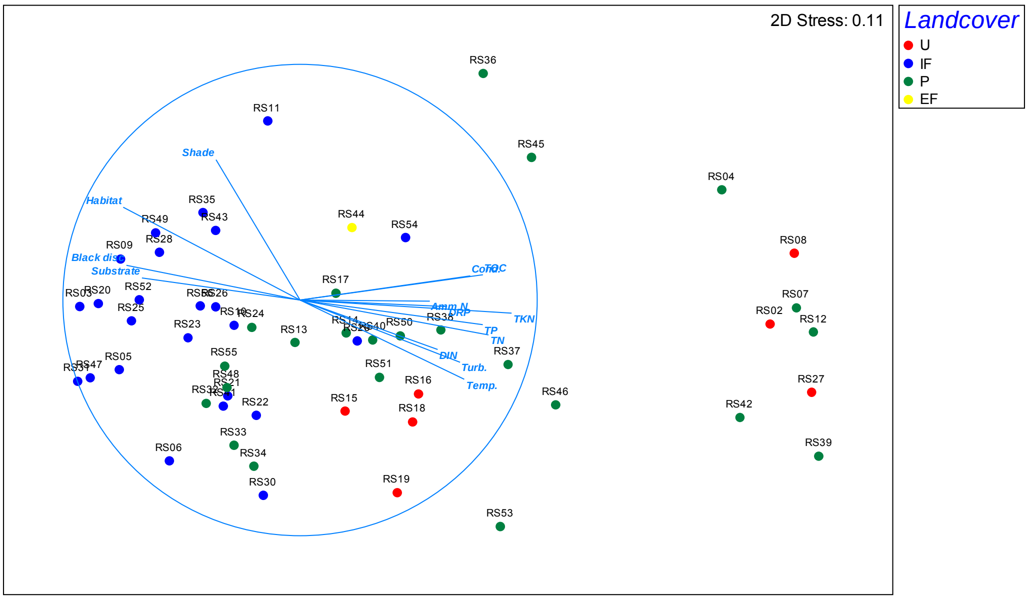


Figure 6.5: NMDS ordination of macroinvertebrate community composition based on mean taxon abundance at each of 55 RSoE sites determined from samples collected annually in 2009, 2010 and 2011. Environmental variables with a Spearman Rank correlation greater than r_S=0.6 are shown by the overlain vectors

most strongly correlated with macroinvertebrate community composition was TKN (r_s=0.68), while the strongest two variable solution included TKN and substrate size (r_s=0.81). This suggests that of the environmental variables measured, nitrogen enrichment and substrate size are most strongly linked with macroinvertebrate community composition.

6.2 Temporal trends

6.2.1 Approach to analysis

Temporal trends were analysed over the period 2004 to 2011 (*n*=8)[24]. The approach used was similar to that of Collier and Kelly (2006) who analysed trends in macroinvertebrate metrics in a dataset over a similar length of record. The 2004 to 2011 period was the longest available for trend assessment since major changes were made to the RSoE site network in 2003 (refer Section 2.1). The September 2003 start date also represented a logical follow-on from the 1999 to 2003 trend period used to report on macroinvertebrate health in the last river and stream SoE technical report (Milne & Perrie 2005).

Non-parametric Spearman Rank correlations (performed in SigmaPlot, version 11.0) were used to assess trends in four metrics: MCI (hard-bottomed), QMCI, %EPT taxa[25] and %EPT individuals[25]. As with the periphyton trend analysis (refer to Section 5.2), three trend classes were defined. Trends were considered 'possible' when Spearman Rank correlation coefficient probabilities (*p*) were between 0.1 and 0.05, 'probable' when *p*<0.05, and 'clear' where trends were still statistically significant (*p*<0.05) after adjustment for multiple comparisons using the False Discovery Rate (FDR) analysis in NIWA's TimeTrends

[24] The exceptions were Coles Creek tributary (at Lagoon Hill Road) which was not sampled in 2005 due to insufficient flow and the three Hutt River sites where the 2011 sample results were excluded due to being influenced by a recent fresh (*n*=7).
[25] Pollution tolerant EPT taxa (*Oxyethira* and *Paroxyethira*) were excluded from these calculations.

software (version 3.20). While all trend classes are summarised, only 'probable' and 'clear' trends are presented and discussed. For sites where trends were present, a linear regression line was fitted and the slope of this line used to provide some context for the rate of change or the magnitude of the trend at each site. The relative rate of change was also calculated by dividing the slope by the mean macroinvertebrate metric value.

While useful indicators of macroinvertebrate community health, trends in abundance-based metrics (eg, QMCI and %EPT individuals) should be interpreted with caution as these metrics are more likely to be influenced by changes in sampling intensity, micro-scale habitat variables and fluctuations in the numbers of tolerant taxa than other presence/absence based metrics (Collier et al. 1998; Scarsbrook et al. 2000).

6.2.2 Results

The trend analysis results are summarised in Table 6.3. Across all four of the metrics assessed, the majority of RSoE sites were typically stable over the seven-year reporting period (78% to 87% of sites depending on the metric). More trends were apparent in MCI than in the other metrics, although half of these were deemed 'possible' trends. The majority (83%) of all trends (possible, probable and clear) were indicative of deteriorating invertebrate community health. Only 'clear' and 'probable' trends (summarised in Table 6.4) are discussed further. The complete set of trend analysis results can be found in Appendix 7.

Table 6.3: Number of RSoE sites assigned into different trend categories for each of four macroinvertebrate metrics, determined by performing Spearman Rank correlations on macroinvertebrate results from annual sampling at 55 sites between 2004 and 2011

Metric	Deteriorating trend				No trend	Improving trend			
	Possible decline	Probable decline	Clear decline	Total		Possible increase	Probable increase	Clear increase	Total
MCI	5	1	4	10	43	1	1	0	2
QMCI	2	3	3	8	47	0	0	0	0
%EPT taxa	2	4	1	7	48	0	0	0	0
%EPT individuals	2	1	2	5	46	1	2	1	4

Sixteen sites (29%) demonstrated at least one 'clear' or 'probable' trend in one of the four metrics assessed (Table 6.4), with 23 trends detected in total. Three sites exhibited trends in two metrics (Mangapouri Stream at Bennetts Road, Waiwhetu Stream at Wainuiomata Hill Bridge and Waingawa River at South Road) and two sites exhibited trends in three metrics (Whareroa Stream at Waterfall Road and Kopuaranga River at Stewarts). Of the sites with trends in two or more metrics all but one of the trends detected were indicative of deterioration. The exception was Mangapouri Stream at Bennetts Road, where an improving trend in MCI coincided with a deteriorating trend in QMCI. This site, along with three other sites (Waitohu Stream at Forest Park, Ruamahanga River at Pukio and Waiohine River at Gorge) also exhibited an improving trend in %EPT individuals.

Table 6.4: Summary of 'probable' and 'clear' trends in MCI, QMCI, %EPT individuals[1] and %EPT taxa[1] metrics, based on annual means derived from macroinvertebrate samples collected at 55 RSoE sites between 2004 and 2011 (*n*=8). Arrows indicate the direction of the trend, with a single arrow indicating a 'probable' trend (*p*<0.05) and a double arrow a 'clear' trend (*p*<0.05 with FDR). The slope indicates the rate of change in metric/year

Site no.	Site name	Trend	Mean	Min	Max	Slope	Relative rate of change (%/yr)
MCI							
RS02	Mangapouri S at Bennetts Rd	↑	84.09	75.79	95.29	2.330	2.77
RS11	Whareroa S at Waterfall Rd	↓↓	118.66	105.6	128.57	-2.470	-2.08
RS27	Waiwhetu S at Wainuiomata Hill	↓	73.08	51.67	91.67	-3.500	-4.79
RS33	Ruamahanga R at Gladstone Br	↓↓	107.78	96	120	-2.800	-2.60
RS38	Kopuaranga R at Stewarts	↓↓	99.21	90.97	107.41	-1.710	-1.72
RS41	Waingawa R at South Rd	↓↓	119.56	110.67	140	-2.610	-2.19
QMCI							
RS02	Mangapouri S at Bennetts Rd	↓	4.55	4.3	4.9	-0.051	-1.12
RS37	Taueru R at Gladstone	↓	4.55	4.08	5	-0.101	-2.21
RS38	Kopuaranga R at Stewarts	↓↓	4.85	3.71	6.57	-0.331	-6.82
RS40	Waipoua R at Colombo Rd Br	↓↓	5.08	3.68	6.98	-0.379	-7.46
RS46	Parkvale S at Weir	↓	3.9	3.16	4.85	-0.146	-3.74
RS50	Mangatarere S at SH 2	↓↓	5.24	4.53	6.31	-0.207	-3.96
%EPT individuals[1]							
RS03	Waitohu S at Forest Pk	↑↑	87.9	81.89	93.33	1.130	1.29
RS11	Whareroa S at Waterfall Rd	↓↓	65.71	46.57	91.84	-4.300	-6.54
RS28	Wainuiomata R at Manuka Trk	↓↓	77.23	68.11	87.91	-2.490	-3.22
RS34	Ruamahanga R at Pukio	↑	58.8	25.97	96.17	9.540	16.23
RS47	Waiohine R at Gorge	↑	89.83	78.17	94.69	1.360	1.51
RS49	Beef Ck at Headwaters	↓	79.73	67.8	94.55	-2.040	-2.56
%EPT taxa[1]							
RS11	Whareroa S at Waterfall Rd	↓↓	46.24	37.04	61.9	-2.270	-4.90
RS27	Waiwhetu S at Wainuiomata Hill	↓	8.22	0	16.67	-1.330	-16.21
RS38	Kopuaranga R at Stewarts	↓	37.97	29.03	44.44	-1.360	-3.57
RS39	Whangaehu R 250m u/s confl.	↓	8.51	4.35	17.65	-1.330	-15.64
RS41	Waingawa R at South Rd	↓	54.34	46.67	72.73	-2.030	-3.74

[1] Pollution tolerant EPT taxa (*Oxyethira* and *Paroxyethira*) excluded.

Most of the sites that exhibited deteriorating trends have upstream catchments dominated by pastoral or urban landcover. Some sites, such as Waiwhetu Stream at Wainuiomata Hill Bridge and Parkvale Stream at Weir, are amongst the most impacted in the region; these sites are classified as 'poor' based not only on macroinvertebrate health but also water quality and periphyton metrics (see Sections 4.1.13 and 5.1.4, respectively). Declining trends were also observed at two reference sites (Wainuiomata River at Manuka Track and Beef Creek at Headwaters), although such trends were limited to one metric (%EPT individuals), with only the trend for Wainuiomata River at Manuka Track falling into the 'clear' category.

The ecological significance of these trends is unclear. However, at some sites where a deteriorating trend in MCI was identified (eg, Whareroa Stream at Waterfall Road and Waiwhetu Stream at Wainuiomata Hill Road), the magnitude of the deteriorating trend resulted in the site moving into a lower macroinvertebrate class during the reporting period (Figure 6.6). Application of two thresholds used in other regions to identify ecologically significant trends – a relative rate of change greater than 1% per year and an overall change greater than 20% (Stark 2010; Collier & Hamer 2012) – resulted in all 23 and 16 trends, respectively, being classed as ecologically significant. However, these thresholds are considered arbitrary and so should be used with caution. For future reporting of macroinvertebrate metric trends it is recommended that alternative methods for assessing ecological significance be explored, including the method used by Collier and Hamer (2012); this method bases the threshold for ecological significance on the degree of 'natural variation' at reference sites over time.

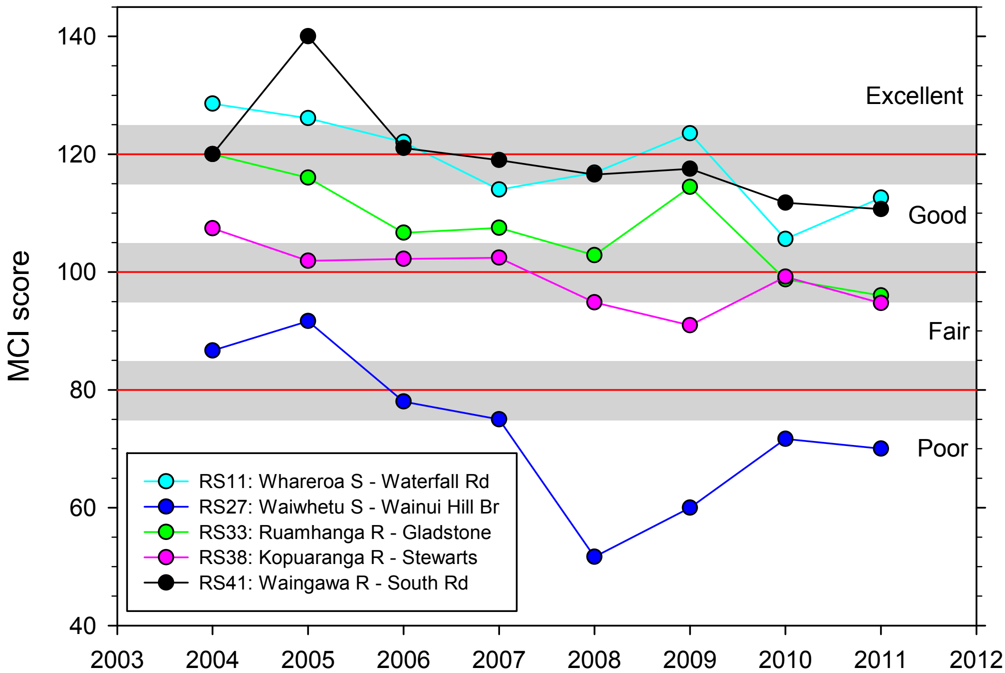


Figure 6.6: Mean Macroinvertebrate Community Index (MCI) scores for samples collected annually between 2004 and 2011 from five RSoE sites where significant declining trends were detected. Red lines and the grey bands represent Stark and Maxted (2007) thresholds and corresponding fuzzy boundaries, respectively

In general, no clear reasons could be found for the observed trends in macroinvertebrate metrics. However, corresponding trends in water quality or periphyton variables may have had a bearing on results at some sites. For example:

- The decline in %EPT taxa identified at Whangaehu River 250 m from confluence coincided with a deterioration in visual clarity and an increase in turbidity, dissolved reactive phosphorus and total phosphorus (based on non-flow adjusted data) (Section 4.2.2).

- The deteriorating trends observed in several macroinvertebrate metrics at Whareroa Stream at Waterfall Road corresponded with observations of increased sediment deposition (Figure 6.7). Although there were no formal sediment deposition assessments with which to confirm this, these observations are supported by a significant decline in visual clarity at this site (Section 4.2.2).

- At three sites (Ruamahanga River at Gladstone, Kopuaranga River at Stewarts and Waipoua River at Colombo Road) the deterioration in MCI scores coincided with a significant increase in periphyton biomass (Figure 6.8) and/or filamentous periphyton cover.

Figure 6.7: Sediment settled on the bed of the Whareroa Stream at Waterfall Road (January 2012)

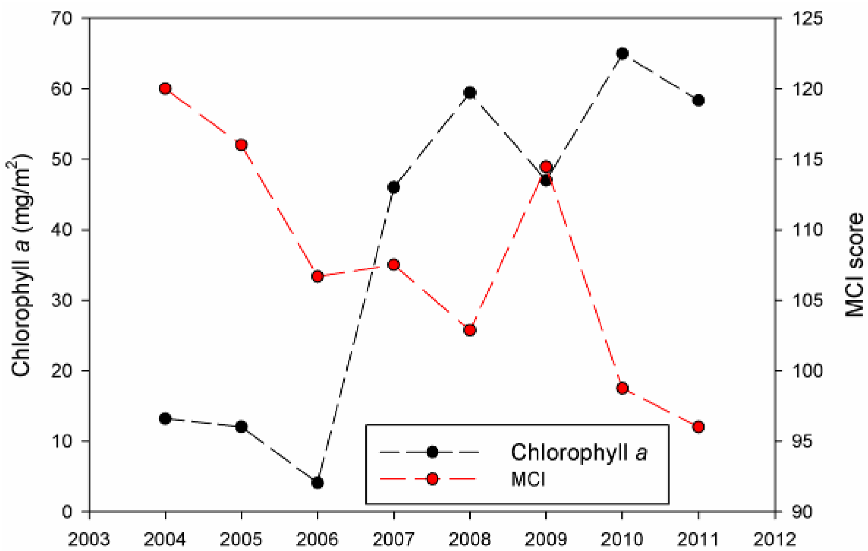


Figure 6.8: Periphyton biomass and corresponding (mean) MCI scores at Ruamahanga River at Gladstone between 2004 and 2011

Similar to the trends in periphyton growth, it is possible that declining trends in macroinvertebrate metrics at some sites are a result of unusual flow conditions affecting samples at the start of the trend analysis period. Many samples taken during 2004 and 2005 were subject to unusually high river flows, short accrual periods and in some cases low water temperatures due to samples being taken later in the season. These conditions generally resulted in higher macroinvertebrate metric scores in 2004 and 2005 than in later years, as illustrated by the overall patterns in macroinvertebrate metrics at the 55 RSoE sites across the trend analysis period (Figure 6.9).

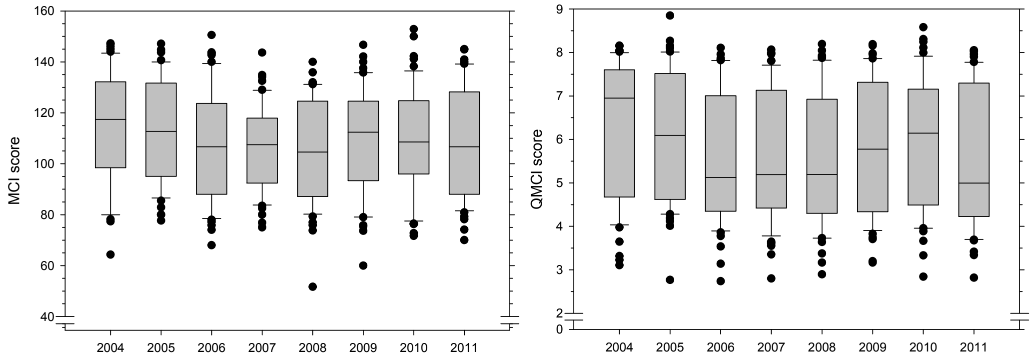


Figure 6.9: Box plots summarising the range of mean MCI (left) and QMCI (right) scores recorded across all 55 RSoE monitoring sites for each year from 2004 to 2011

6.3 Synthesis

Based on mean MCI scores for the 2009 to 2011 period, 16 sites are classified as having 'excellent' macroinvertebrate community health, 20 sites as 'good', 16 sites as 'fair', and 3 sites as 'poor' (Figure 6.10). All sites classed as 'excellent' have upstream catchments dominated by indigenous forest cover. In contrast, the majority of the sites classed as 'poor' or as being within the 'fuzzy boundary' of the fair/poor threshold were soft-bottomed sites in catchments dominated by pastoral or urban landcover. Although sites on the mid and lower reaches of the larger rivers in the region such as the Otaki, Hutt, Wainuiomata, Ruamahanga and Waiohine rivers tended to be classed as 'good', mean MCI scores at these sites were often considerably reduced compared to upper catchment sites.

Mean MCI scores were strongly positively correlated with indigenous forest cover and, for sites classed as 'pastoral', strongly negatively correlated with the proportion of pastoral landcover. Although there were insufficient sites to assess the relationship between MCI and urban landcover, RSoE sites classed as 'urban' recorded the lowest mean MCI scores of all three major landcover types. Further, comparison of macroinvertebrate data collected by Kingett Mitchell (2005a) from 67 urban stream sites across Hutt, Wellington and Porirua cities and the Kapiti Coast with the proportion of impervious cover in the upstream catchment (Greater Wellington unpublished data) indicates that stream health declines with increasing intensity of urban land use (Figure 6.11). These data suggest that as little as 10% impervious cover within a catchment can reduce stream health.

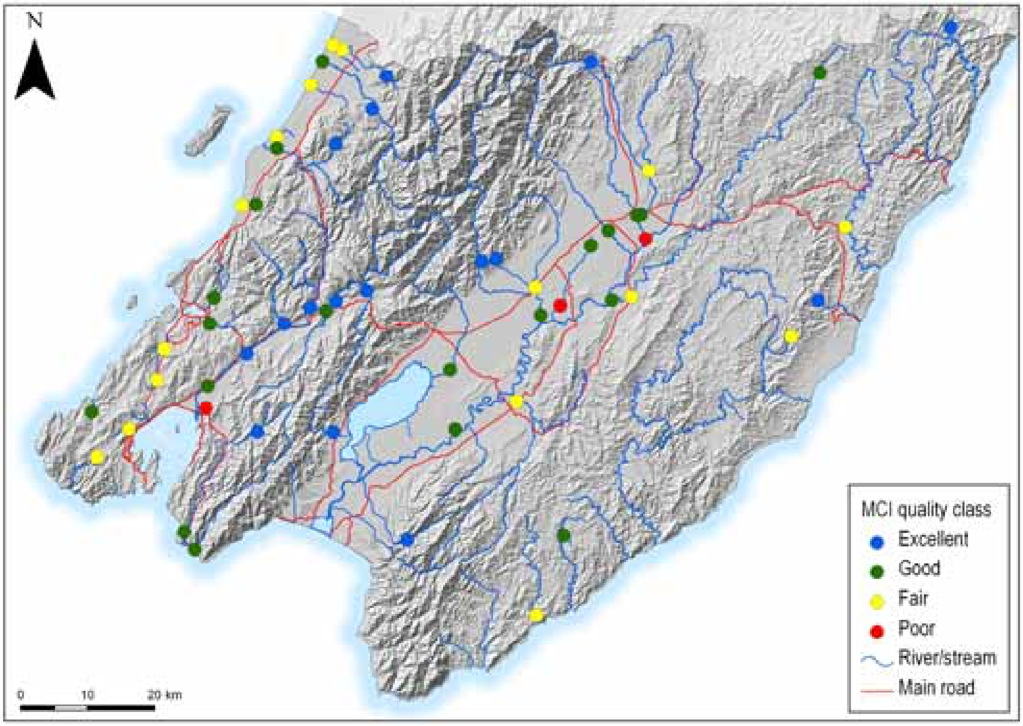


Figure 6.10: Macroinvertebrate quality classes for 55 RSoE sites in the Wellington region, based on mean MCI scores from annual samples collected during 2009, 2010 and 2011

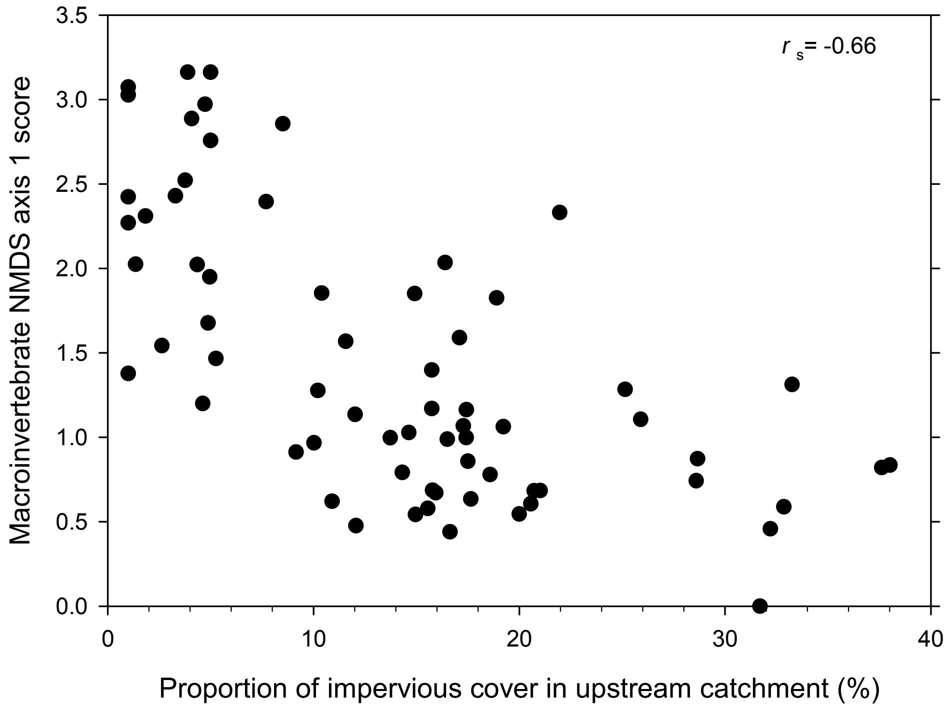


Figure 6.11: Scatter plot demonstrating the relationship between intensity of urban land use (represented by proportion of impervious cover in upstream catchment) and macroinvertebrate health (as represented by a score from multivariate analysis which summarises three macroinvertebrate metrics – MCI, QMCI and number of EPT taxa) at 67 sites within or near to urban areas of Hutt, Wellington and Porirua cities and the Kapiti Coast sampled by Kingett Mitchell (2005a) between 2002 and 2008

MCI scores at RSoE sites showed a strong positive correlation with both habitat quality and water quality, and a strong negative correlation with periphyton biomass. Multivariate analysis of macroinvertebrate community composition and environmental data suggested that TKN and substrate size were the environmental variables most strongly correlated with changes in macroinvertebrate community composition across the 55 RSoE sites.

Significant trends in one or more macroinvertebrate metrics were exhibited at 16 RSoE sites between 2004 and 2011. Most of these sites (13) exhibited trends of deteriorating macroinvertebrate health. In most cases the reasons for these trends were unclear although at some sites deteriorating trends coincided with deteriorating water quality (Whangaehu River 250 m from confluence), increasing periphyton biomass (Ruamahanga River at Gladstone) or a potential increase in streambed sedimentation (Whareroa Stream at Waterfall Road). Similar to the trends in periphyton growth reported in Section 5.2.2, high river flows, short accrual periods and corresponding high macroinvertebrate metric scores at the start of the trend analysis period (2004 and 2005) may have influenced some of the deteriorating trends.

7. Fish – state and trends

As outlined in Section 2.4.2, fish monitoring using a standardised survey approach has only been trialled at five of the 55 RSoE sites to date. This section summarises the results of this monitoring and compares these against RSoE water quality, periphyton and macroinvertebrate monitoring results. To help provide a more complete picture of the fish health in the Wellington region's rivers and streams, the second part of this section presents an analysis of state and trends in freshwater fish communities using data extracted from the New Zealand Freshwater Fish Database (NZFFD). Administered by NIWA, this database provides a large amount of information on the distribution of freshwater fish within the Wellington region and NZFFD data has previously been used successfully at both regional and national scales to analyse spatial and temporal trends in freshwater fish populations (Joy 2009; Joy 2011).

7.1 State

7.1.1 Approach to analysis

The Index of Biotic Integrity (IBI) was calculated for each site (using both RSoE and NZFDD fish data) to help facilitate inter-site comparisons and provide an indication of overall fish community condition. The IBI is a combination of six metrics that was developed specifically to assess the condition of New Zealand's fish fauna and takes into account the fact that many species exhibit diadromous life histories (ie, often migrate between the ocean and freshwater at some point in their lifecycle). The IBI compares the species found at a site with those expected to be at a site, while taking into account natural changes that occur with distance inland and elevation. For full details of the IBI see Joy and Death (2004) and Joy (2004).

IBI scores were generated for each site in a Microsoft Excel spreadsheet macro using a version of the IBI calibrated for the Wellington region (Joy 2004). IBI scores can range from 0 (no fish present) to 60, with a score of 60 indicating that all fish expected to be present were found. Interpretation of IBI scores was undertaken using the classes recommended in Joy (2004) and outlined in Table 7.1. See Section 4.1.1 for interpretation of the box plots presented in this section.

Table 7.1: Attributes and suggested thresholds for interpretation of IBI scores for the Wellington region from Joy (2004)

IBI score	Integrity class	Attributes
52–60	Excellent	Comparable to the best situations without human disturbance; all regionally expected species for the stream position are present. Site is above the 97th percentile of Wellington sites.
48–51	Very good	Site is above the 90th percentile of all Wellington sites; species richness is slightly less then best for the region.
38–47	Good	Site is above the 70th percentile of Wellington sites but species richness and habitat or migratory access reduced some signs of stress.
30–37	Fair	Score is just above average but species richness is significantly reduced habitat and or access impaired.
18–29	Poor	Site is less than average for Wellington region IBI scores, less than the 50th percentile, thus species richness and or habitat are severely impacted.
2–17	Very poor	Site is impacted or migratory access almost non-existent.
0	No native fish	Site is grossly impacted or access for fish is non-existent.

(a) RSoE sites

Over 2009 to 2011, four RSoE sites (Beef Creek at Headwaters, Kaiwharawhara Stream at Ngaio Gorge, Tauanui River at Whakatomotomo Road and Totara Stream at Stronvar) were surveyed following standardised fish monitoring protocols documented in David et al. (2010); in brief, this involved fishing 150 m of suitable stream reach using one-pass backpack electric fishing. Additionally, a 150 m reach of the Whareroa Stream at Queen Elizabeth Park was also surveyed in 2011 using 10 fyke nets and 20 minnow traps[26]. The use of nets and traps at this site follows 'best practice' recommendations for surveying freshwater fish communities in deep streams (typically >0.6 m) characterised by a soft-bottomed substrate, poor water clarity and low velocities (Joy & David in prep.).

(b) NZFFD records

Given the limited RSoE fish data available, the current state of freshwater fish communities in the Wellington region was assessed using NZFFD records for the period 1990 to 2010. This 20-year period was chosen to provide sufficient data for analysis. However, it must be recognised that, in some cases, NZFFD records from the earlier part of this period may no longer accurately represent the current state of the fish communities in the river or stream surveyed.

All fish survey records for the Wellington region were downloaded from the NZFFD in April 2011. The 'sampling locality' for each record was screened prior to any analyses being undertaken and all records with sampling localities that were clearly not river or stream type environments (eg, lakes, wetlands, etc.) were excluded from the dataset. NZFFD records were plotted on a map to provide a spatial representation of fish surveys across the region. A list of species, both indigenous and introduced, was compiled and the 'frequency of occurrence' of each species in the region was calculated (ie, the number of records for a species divided by the total number of records in the NZFFD).

IBI scores were calculated for all records and the range of scores compared between different catchments. Comparisons between catchments were limited to those that had sufficient records (in this case arbitrarily defined as $n \geq 15$). Given the large variation in the number of records between catchments, along with the significant range of catchment sizes assessed, no in-depth analysis was undertaken other than summarising the range of IBI scores for each catchment.

Relationships between IBI scores and landcover were examined following a similar approach to Joy (2011). Each NZFFD record was assigned a River Environment Classification (REC) landcover class (see Appendix 2) of indigenous forest, exotic forest, pasture or urban. Because the data were not normally distributed, differences between IBI scores for different landcover types were examined using a Kruskal-Wallis One Way Analysis of Variance on ranked data. These tests were performed in SigmaPlot (Version 11.0) with a statistically significant difference set at $p<0.05$.

[26] The Whareroa Stream data were provided courtesy of Dr Mike Joy (Massey University).

(c) Cautionary notes

Given that the state analysis period spans 20 years (1990 to 2010), it can be expected that in some cases the REC landcover class may not accurately reflect the dominant landcover at the time some of the earlier fish surveys were undertaken (the same is true for landcover classes used in the trend analysis carried out in Section in 7.2). In addition, there are several potential limitations in using fish data from the NZFFD that should be borne in mind when interpreting the results of the analyses undertaken:

- Not all catchments in the Wellington region have been surveyed equally (in terms of the number of records and also the type, methodology and effort of each individual survey).
- NZFFD data have been collected using a range of survey methods and while backpack electric fishing has been used to undertake the majority of surveys in the Wellington region (>70% of all records), other methods have also been used (eg, spotlighting and netting/trapping). Different fishing methods have different biases in terms of both the habitat they can be used effectively in and the range of species they are likely to catch (Joy & David in prep)[27]. For example, the predominance of backpack electric fishing – which is only suitable for use in wadeable rivers and streams – indicates that larger/deeper rivers are likely to be under-represented in NZFFD data. Furthermore, the 'catchability' of different species using this method is also widely variable, suggesting that the presence of some species (eg, large galaxiids and pelagic species) may be under-represented.
- Many surveys undertaken target specific species, such as those that are rare or considered threatened, and as such these species might be over-represented in the NZFFD records.

7.1.2 Results

(a) RSoE data

A summary of species caught, along with relevant site information, from the five RSoE sites fished between 2009 and 2011 is presented in Table 7.2. The five sites surveyed ranged from being located relatively close to the coast (Kaiwharawhara Stream at Ngaio Gorge and Whareroa Stream at Queen Elizabeth Park) to 90 km inland (Beef Creek at Headwaters) and are located across the four REC landcover types represented in the RSoE network (indigenous forest, exotic forest, pasture and urban).

Across these five sites, a total of 11 indigenous as well as one introduced (brown trout) species were caught. Indigenous species diversity at each site ranged from two (Tauanui River at Whakatomotomo Road and Beef Creek at Headwaters) to eight (Whareroa Stream at Queen Elizabeth Park) species and the total number of fish caught at each site ranged from 23 (Beef Creek at Headwaters) to 318 (Totara Stream at Stronvar). Longfin eels were the only species caught at all five sites. IBI scores ranged from 28 ('poor', two sites) to 48 ('very good') (Table 7.2).

[27] Different biases associated with different sampling methodologies should also be kept in mind when interpreting the RSoE site data presented in this section.

Table 7.2: Summary of fish community data and relevant site information for five RSoE sites, based on one-off fish surveys undertaken in a 150 m long stream reach between 2009 and 2011

	RS12	RS18	RS44	RS49	RS52
	Whareroa S at QE Park[1]	Kaiwharawhara S at Ngaio Gorge	Totara S at Stronvar	Beef Ck at Headwaters	Tauanui R at Whakatomotomo Rd
Year surveyed	2011	2011	2009	2009	2009
Elevation (m)	2	21	200	148	150
Distance inland (km)	1	2	31	90	29
Dominant landcover	Pasture	Urban	Exotic forest	Indigenous forest	Indigenous forest
IBI score	48	34	40	28	28
IBI class	Very good	Fair	Good	Poor	Poor
Species caught and abundance					
Longfin eel	19	15	78	3	4
Shortfin eel	11	14	–	–	–
Bluegill bully	–	10	–	–	–
Common bully	1	–	–	–	–
Cran's bully	–	–	156	–	–
Giant bully	9	–	–	–	–
Redfin bully	14	40	83	–	–
Upland bully	–	–	1	18	289
Inanga	5	–	–	–	–
Giant kokopu	15	–	–	–	–
Smelt	1	–	–	–	–
Brown trout	–	–	–	2	3
Species richness	8	4	4	3	3
Total fish caught	75	79	318	23	296

[1] Data provided courtesy of Dr Mike Joy (Massey University).

The lowest IBI scores (28) were recorded at two sites with upstream catchments dominated by indigenous forest (and are classed as 'reference' sites): Beef Creek at Headwaters and Tauanui River at Whakatomotomo Road. Both of these are tributaries of the Ruamahanga River, are located at moderately high elevations (~150 m) and range from 30 to 90 km inland from the coast. The low IBI scores at these two sites are in contrast to the excellent results for water quality, periphyton and monitoring indicators, as well as the excellent habitat present at both sites (Table 7.3). The reason for the poor IBI score at the Tauanui River site is not known. In the case of Beef Creek, an instream barrier downstream of the monitoring site may affect fish access to the site.

Whareroa Stream at Queen Elizabeth Park shows the opposite pattern to the Beef Creek and Tauanui River sites. This site is located on the lower reaches of a pastoral catchment and typically records amongst the poorest water quality and macroinvertebrate health of the 55 RSoE sites; despite this, its IBI score (48) places it in the top 10% of all NZFFD fish records for the Wellington region. This likely reflects the close proximity of this site to the coast, along with the absence of instream barriers to restrict access to diadromous species. Overall, the fact that habitat quality at the Whareroa Stream site was also classed

Table 7.3: IBI, Water Quality Index (WQI), periphyton and macroinvertebrate (MCI) classes (grades) for five RSoE sites, based on analyses presented in Tables 4.5, 5.3 and 6.2 of this report. Habitat quality classes from one-off assessments in 2008 (see Appendix 8) are also presented

Class	RS12	RS18	RS44	RS49	RS52
	Whareroa S at QE Park	Kaiwharawhara S at Ngaio Gorge	Totara S at Stronvar	Beef Ck at headwaters	Tauanui R at Whakatomotomo Rd
IBI	Very Good	Fair	Good	Poor	Poor
WQI	Poor	Fair	Excellent	Excellent	Excellent
Periphyton	N/A[1]	Poor	Fair	Excellent	Excellent
MCI	Fair	Fair	Fair	Excellent	Excellent
Habitat	Poor	Poor	Fair	Excellent	Excellent

[1] Periphyton is not assessed at this site because it has a soft substrate.

as 'poor' perhaps suggests that the limited assessments undertaken to date have not captured some of the habitat characteristics critical for fish communities. Further, the divergence of fish community condition from other indicators of stream health at some sites is a clear indication that fish monitoring is required to provide a more complete picture of aquatic ecosystem health.

(b) NZFFD data

All NZFFD records for fishing undertaken in river and streams in the Wellington region between 1990 and 2010 are plotted in Figure 7.1. It is clear that not all catchments have been surveyed equally, and in some cases, even relatively large catchments contain few or no records. For example, there are no NZFFD records for the Whangaehu River catchment, a relatively large tributary of the Ruamahanga River. When compared with the rest of the region, a significant proportion of the eastern Wairarapa is poorly represented in the NZFFD. This spatial limitation needs to be kept in mind when interpreting the results in this section.

Between 1990 and 2010, a total of 26 freshwater fish species were recorded in the NZFFD for river and stream environments across the Wellington region (Table 7.4). Of these 26 species, 20 are indigenous and six (brown and rainbow trout, perch, goldfish, tench and rudd) are introduced species that have naturalised in the region (ie, have formed self-supporting populations). Of the 20 indigenous species, 15 are diadromous and one, the yelloweye mullet, is considered a marine wanderer (McDowall 2000). Over half of the indigenous species listed in Table 7.4 are categorised as 'at risk' and populations of these species are considered to be declining across New Zealand (Allibone et al. 2010).

The fish species recorded most commonly in the NZFFD between 1990 and 2010 were longfin eel (62% of sites), redfin bully (35%), shortfin eel (33%) and brown trout (28%). Six species were found in than less than 1% of all records; two indigenous species (giant bully and black flounder) and four introduced species (goldfish, rudd, tench and rainbow trout) (Table 7.4).

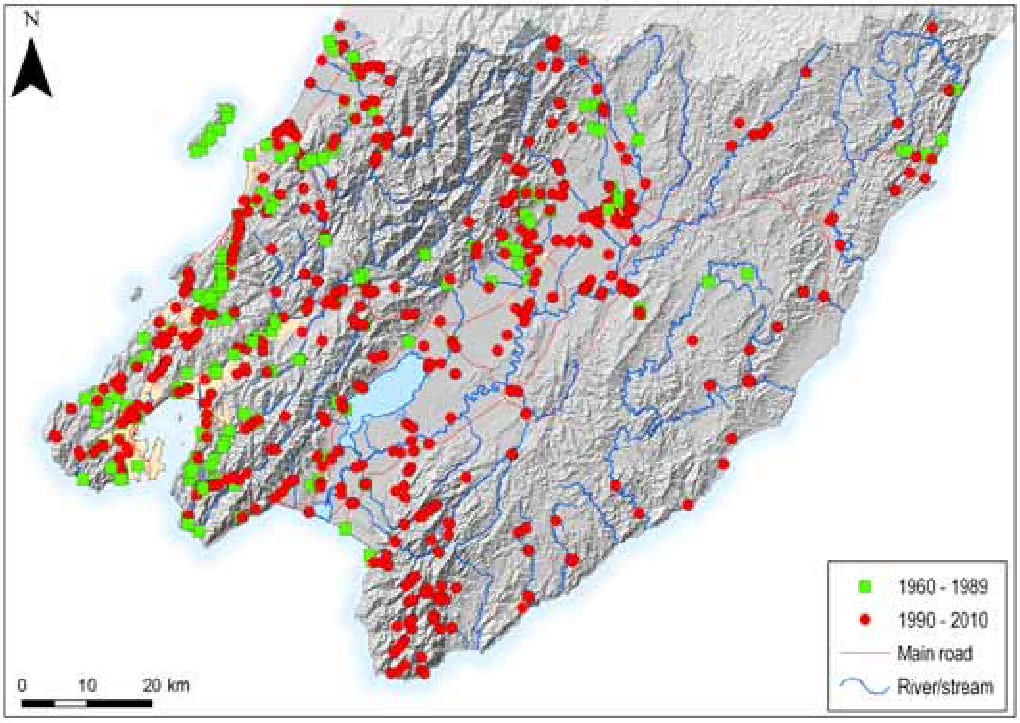


Figure 7.1: NZFFD records for rivers and streams in the Wellington region, based on data extracted from the NZFFD in April 2011

Table 7.4: Summary of fish species recorded in the Wellington region based on 583 river and stream records extracted from the NZFFD for the period 1990 to 2010. The threat categories from Allibone et al. (2010) are also listed. * and ** indicate diadromous species and 'marine wanderers', respectively

Common name	Scientific name	No. of records	Frequency of occurrence (% of sites)	Threat category
Longfin eel*	*Anguilla dieffenbachia*	359	61.6	At risk (declining)
Redfin bully*	*Gobiomorphus huttoni*	201	34.5	At risk (declining)
Shortfin eel*	*Anguilla australis*	190	32.6	Not threatened
Brown trout	*Salmo trutta*	160	27.4	Introduced & naturalised
Common bully*	*Gobiomorphus cotidianus*	123	21.1	Not threatened
Koaro*	*Galaxias brevipinnis*	123	21.1	At risk (declining)
Banded kokopu*	*Galaxias fasciatus*	78	13.4	Not threatened
Inanga*	*Galaxias maculatus*	73	12.5	At risk (declining)
Upland bully	*Gobiomorphus breviceps*	63	10.8	Not threatened
Torrentfish*	*Cheimarrichthys fosteri*	48	8.2	At risk (declining)
Giant kokopu*	*Galaxias argenteus*	41	7.0	At risk (declining)
Cran's bully	*Gobiomorphus basalis*	39	6.7	Not threatened
Brown mudfish	*Neochanna apoda*	34	5.8	At risk (declining)
Common smelt*	*Retropinna retropinna*	27	4.6	Not threatened
Dwarf galaxias	*Galaxias divergens*	27	4.6	At risk (declining)
Shortjaw kokopu*	*Galaxias postvectis*	23	3.9	At risk (declining)
Bluegill bully*	*Gobiomorphus hubbsi*	21	3.6	At risk (declining)
Lamprey*	*Geotria australis*	18	3.1	At risk (declining)
Perch	*Perca fluviatilis*	9	1.5	Introduced & naturalised

Table 7.4 *cont.*: Summary of fish species recorded in the Wellington region based on 583 river and stream records extracted from the NZFFD for the period 1990 to 2010. The threat categories from Allibone et al. (2010) are also listed. * and ** indicate diadromous species and 'marine wanderers', respectively

Common name	Scientific name	No. of records	Frequency of occurrence (% of sites)	Threat category
Yelloweye mullet**	*Aldrichetta forsteri*	6	1.0	Not threatened
Giant bully*	*Gobiomorphus gobioides*	5	<1	Not threatened
Rainbow trout	*Oncorhynchus mykiss*	5	<1	Introduced & naturalised
Black flounder*	*Rhombosolea retiaria*	4	<1	Not threatened
Goldfish	*Carassius auratus*	4	<1	Introduced & naturalised
Rudd	*Scardinius erythrophthalmus*	4	<1	Introduced & naturalised
Tench	*Tinca tinca*	1	<1	Introduced & naturalised

A comparison of the range of IBI scores for different river and stream catchments (with $n \geq 15$ NZFFD records) is presented in Figure 7.2. Considerable variation can be seen within each catchment; median IBI scores indicate that the Otaki and Waikanae rivers tend to have the highest community condition and the Parkvale and Porirua streams the poorest. However, in most catchments the range of IBI scores includes at least some sites that are classed as 'good' or better. This indicates that while overall fish community condition may be degraded in a catchment, in most catchments there are some reaches that remain in better condition.

A breakdown of fish community condition in the Wellington region, based on IBI scores and dominant landcover is presented in Table 7.5. Only a small number of sites were located in catchments dominated by exotic forest (n=8) and this precluded their inclusion in any further interpretation and analyses. Sites located in catchments dominated by indigenous forest had significantly higher IBI scores than sites located in pastoral or urban catchments (Kruskal-Wallis One Way Analysis of Variance on ranked data $p<0.05$). For example, within the indigenous forest landcover class, IBI scores for over half the sites were 'fair' or better, whereas for pastoral and urban sites, only a third or less of sites fell within these classes (Table 7.5). Urban sites generally had lower IBI scores than pastoral sites (Figure 7.3), although this difference was not statistically significant. IBI scores also tended to be poorer at low elevation (<150 m) NZFFD sites (Figure 7.4, Mann-Whitney Rank Sum Test $p<0.001$) which probably reflects a greater likelihood of low elevation sites being more impacted by pastoral and urban land use.

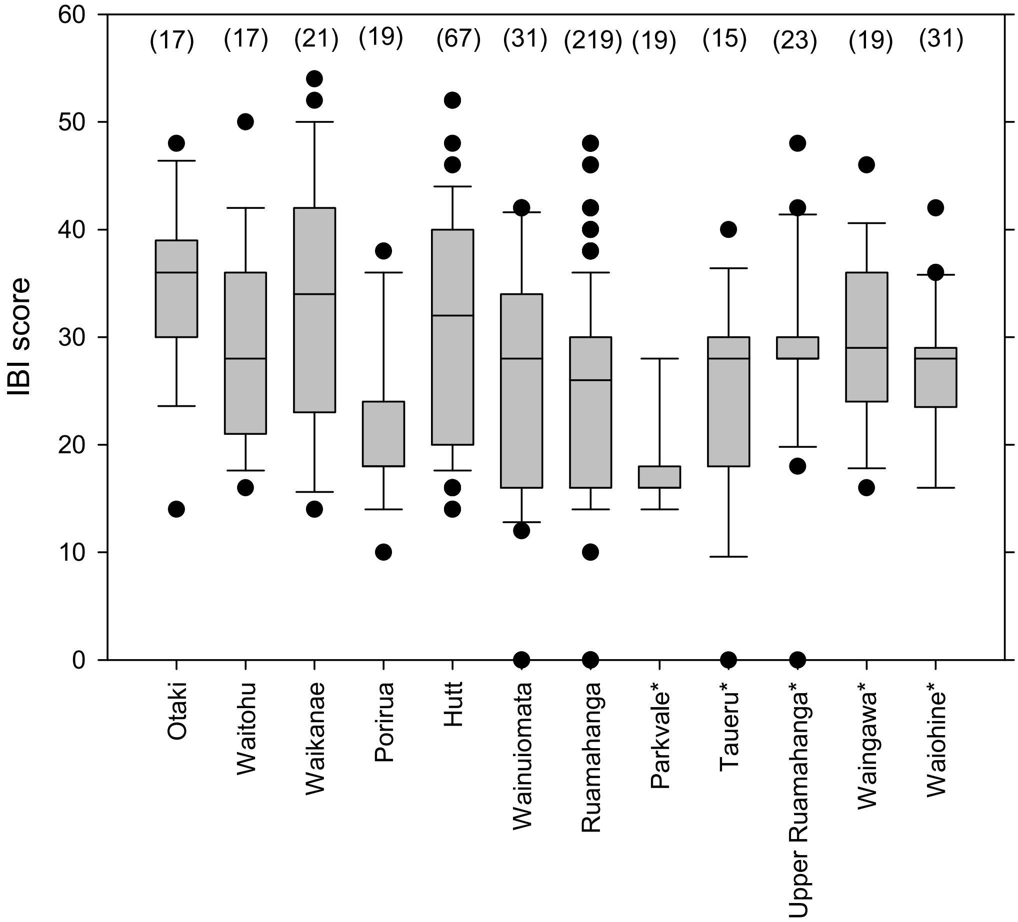


Figure 7.2: Box plot showing the range of IBI scores for selected catchments in the Wellington region (with *n* ≥15), calculated from NZFFD records for the period 1990 to 2010. Numbers in brackets indicate the number of records within each catchment and an * denotes 'sub-catchments' of the Ruamahanga River

Table 7.5: IBI classes assigned to 583 NZFFD records for rivers and streams in the Wellington region (1990 to 2010), summarised according to records within each REC landcover class

Landcover	IBI class														
	Excellent		Very good		Good		Fair		Poor		Very poor		No native fish		Total
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	
Indigenous forest	6	2	18	7	51	19	67	25	103	38	22	8	2	1	269
Exotic forest	0	0	1	13	0	0	4	50	3	38	0	0	0	0	8
Pasture	5	2	1	0.5	25	11	44	19	94	41	55	24	4	2	228
Urban	0	0	0	0	5	6	15	19	39	50	18	23	1	1	78
Overall (total)	11	2	20	3	81	14	130	22	239	41	95	16	7	1	583

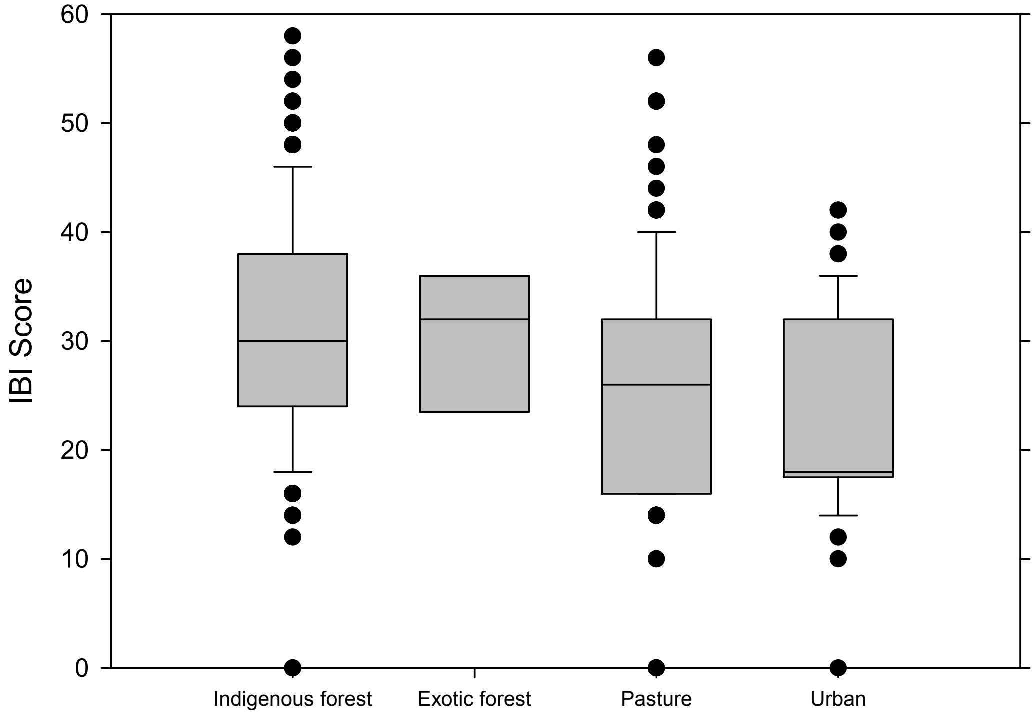


Figure 7.3: Box plot showing the range of IBI scores for different REC landcover classes (indigenous forest, *n*=269; exotic forest, *n*=8; pasture *n*=228; urban *n*=78), based on NZFFD records for rivers and streams fished in the Wellington region between 1990 and 2010

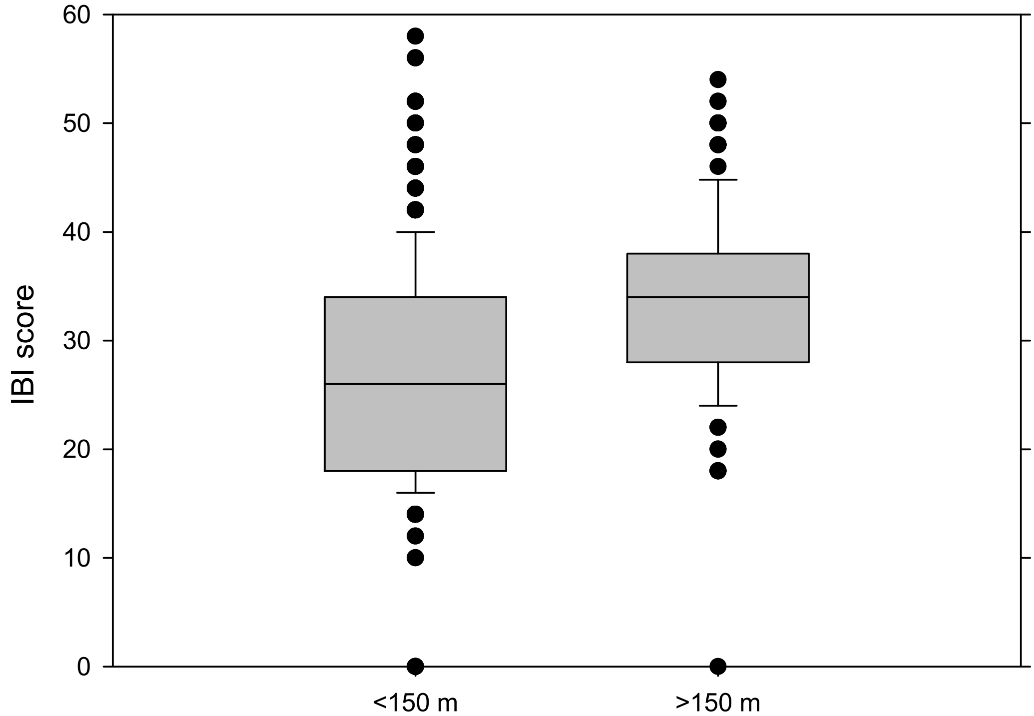


Figure 7.4: Box plot showing the range of IBI scores for sites fished below (*n*=441) and above (*n*=142) 150 m altitude, based on NZFFD records for rivers and streams in the Wellington region (1990 to 2010)

7.2 Temporal trends

7.2.1 Approach to analysis

Analysis of trends in freshwater fish community condition for river and stream environments in the Wellington region followed a similar approach to an assessment undertaken in the Southland region by Joy (2011). NZFFD records in the Wellington region were divided into three time periods to provide a roughly similar amount of records in each period: 1961 to 1990 (n=287), 1991 to 2000 (n=206) and 2001 to 2010 (n=363). IBI scores were generated for each NZFDD record (see Section 7.1.1) and differences between the IBI scores for each of the three time periods were assessed using a Kruskal-Wallis One Way Analysis of Variance on ranked data (carried out in SigmaPlot, Version 11.0). A statistically significant difference was considered where p<0.05. Trends were also examined within each of the three main landcover types represented by NZFFD records (indigenous forest, pastoral and urban – exotic forest was excluded given the small number of records within this landcover type) using the same three time periods.

7.2.2 Results

Median IBI scores for the three different time periods (1961–1990, 1991–2000 and 2001–2010) examined are presented in Table 7.6. While the overall median scores were similar for the three time periods, the difference between the range of scores for the 1961–1990 and 2001–2010 periods was statistically significant (p<0.05). This indicates that a decline in fish community condition occurred between the earliest and most recent periods examined.

Table 7.6: Median IBI scores (both overall and by REC landcover class) for the three time periods used to assess temporal trends in fish community condition (1961–1990, 1991–2000 and 2001–2010), based on NZFFD data for the Wellington region

Time period	Overall		Indigenous forest		Pasture		Urban	
	IBI score	*n*	IBI score	*n*	IBI score	*n*	IBI score	*n*
1961–1990	30	287	28	143	32	109	26	33
1991–2000	28	206	32	125	26	75	18	6
2001–2010	28	359	29	134	26	148	18	71

When analysed individually, no significant differences were present between the three time periods for sites located within indigenous forest; the median values in each period were fairly similar (Table 7.6). In contrast, median IBI scores for both pastoral and urban sites declined between the earliest time period (1960–1990) and the two more recent periods. However, statistically significant differences were only found for sites located in pastoral landcover, with the earliest time period being significantly different from both the 1991–2000 and 2001–2010 periods (p<0.001).

7.3 Synthesis

Based on IBI classes, fish community condition at the five RSoE sites surveyed ranged from ‘poor’ (Beef Creek at Headwaters and Tauanui River at

Whakatomotomo Road) to 'very good' (Whareroa Stream at Queen Elizabeth Park). Comparisons between fish community condition and other commonly reported measures of stream health (eg, water quality, periphyton growth and macroinvertebrate community composition) indicate that, at least at some RSoE sites, there can be significant discrepancies in the condition or 'health' reported for a site. These discrepancies most likely arise, at least in part, due to the fact that diadromous fish communities respond to whole catchment scale influences (eg, both upstream and downstream landcover/land use influences as well as local habitat), whereas other measures primarily respond to only local and upstream catchment influences (David et al. 2010). Regardless of the causes, it is clear that monitoring of fish communities is required to provide a more complete picture of ecosystem health.

Similar to landcover relationships reported for the whole of New Zealand (Joy 2009), analysis of IBI scores calculated from NZFFD data for the Wellington region has demonstrated that fish community condition is typically highest in rivers and streams located in catchments dominated by indigenous forest and poorer in catchments dominated by pastoral or urban landcover. Fish condition in urban streams appears to be poorest overall, although the difference between urban and pastoral landcover types was not statistically significant. However, this analysis has indicated that some reaches of urban and/or pastoral rivers and streams can still retain high freshwater fish values. For example, based on interpretation of water quality and macroinvertebrate community health, Whareroa Stream at Queen Elizabeth Park is ranked 52nd and 50th of the 55 RSoE sites, respectively. However based on its IBI score, this site is ranked in the top 10% of all NZFFD records for the Wellington region.

Analysis of IBI scores generated from NZFDD data indicated that there has been a decline in fish community condition in the Wellington region since the 1990s; this decline was statistically significant for rivers and streams under pastoral landcover. Similar declining trends in rivers and streams draining pastoral and urban landcover have been reported in a nationwide assessment of IBI scores (Joy 2009). Allibone et al. (2010) also reported a decline across New Zealand in populations of a number of diadromous species that occur in the Wellington region (inanga, koaro, shortjaw kokopu, torrentfish and redfin and bluegill bullies); the loss of shortjaw kokopu populations from the Wellington region was specifically mentioned.

8. Discussion

This section revisits the main findings from Sections 4 through 7. A regional overview of state and trends in river and stream health is presented first, with this information then considered in a national context. The principal issues affecting the region's rivers and streams are discussed and key management issues identified, with brief consideration also given to downstream receiving environments. Lastly, monitoring limitations and knowledge gaps are outlined.

8.1 Regional overview

8.1.1 State

Analysis of RSoE water quality, periphyton and macroinvertebrate data collected at 55 sites (46 in the case of periphyton) over the period July 2008 to June 2011 found that:

- 27 (49%) sites were assigned 'good' or 'excellent' water quality grades, indicating that median values for at least five of the six key indicator variables in Greater Wellington's Water Quality Index (WQI) met guideline values;
- 27 (59%) sites were classed as 'good' or 'excellent' in terms of compliance with MfE (2000) periphyton cover/biomass guidelines, indicating infrequent or nil occurrence of nuisance periphyton growth; and
- 36 (65%) sites were classed as having 'good' or 'excellent' macroinvertebrate community health, based on a comparison of mean MCI scores against the thresholds in national guidance provided by Stark and Maxted (2007).

The remaining sites (35–51% depending on the indicator) were classed as having 'fair' or 'poor' water quality or ecosystem health. While this report has not attempted to assess the suitability of rivers and streams for other, values[28] such as recreational use and trout fishery/spawning, these values are also likely to be impaired at some RSoE sites. For example, the two Ruamahanga River sites with a WQI grade of 'fair' (Gladstone and Pukio) are in close proximity to recreational water quality monitoring sites with Suitability for Recreation Grades of 'poor' (see Greenfield et al. 2012). Similarly, sites on a number of river and stream reaches listed in Greater Wellington's existing Regional Freshwater Plan (WRC 1999) as supporting trout habitat (eg, Taueru River at Gladstone, Kopuaranga River at Stewarts, Mangatarere Stream at SH 2 and Huangarua River at Ponatahi Bridge), frequently exceeded MfE (2000) periphyton guidelines for protection of trout habitat and angling values.

Water quality, periphyton cover/biomass and macroinvertebrate health all showed clear linkages with upstream catchment landcover (Figure 8.1). Sites classified as having 'good' or 'excellent' water quality and ecosystem health tend to be located on the upper reaches of rivers and streams that drain the

[28] The specific values that rivers and streams in the Wellington region are to be managed for are currently being considered as part of the review of Greater Wellington's existing Regional Freshwater Plan.

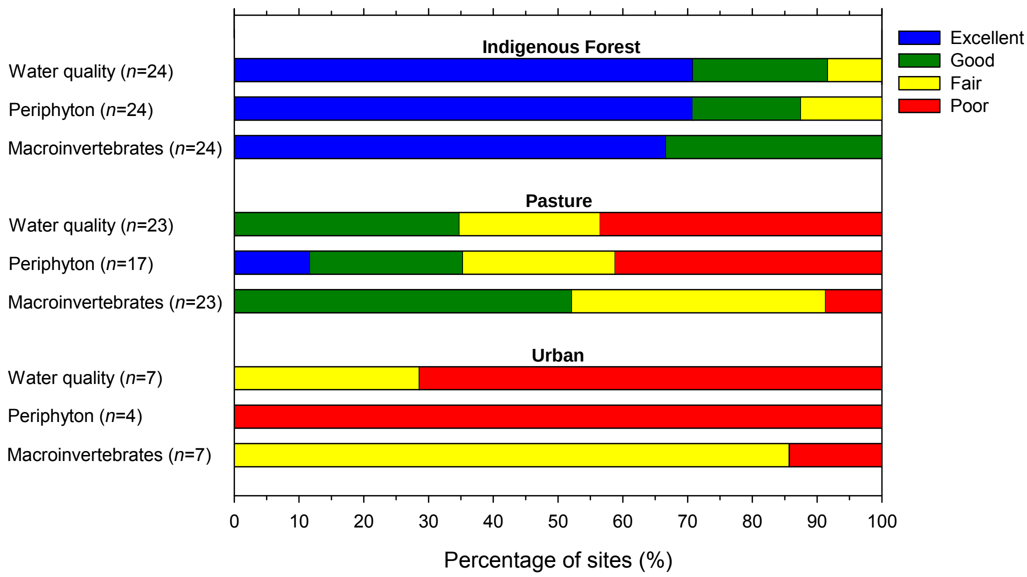


Figure 8.1: Breakdown of water quality, periphyton and macroinvertebrate health grades (classes) for 54 of the 55 RSoE sites, grouped according to their REC landcover class. Note that one site (RS44) belonging to the exotic forestry landcover class is not included in this summary

forested Tararua, Rimutaka and Aorangi ranges. However, as the proportion of pastoral and/or urban landcover increases within a site's upstream catchment, water quality and macroinvertebrate health tend to decline while nuisance periphyton and macrophyte growth increases. Of the 15 sites graded 'poor' for water quality, five are located in urban areas and ten drain predominantly pastoral catchments (of which most support at least some intensive agriculture, typically dairying). Most (12) of these sites are also located on relatively small (fourth order or less) river and streams, which suggests that these are more susceptible to degradation than larger rivers. Similar patterns were observed with periphyton growth and macroinvertebrate health, although geological and climatic influences mean that some sites assigned to 'fair' or 'poor' periphyton and/or macroinvertebrate classes (eg, those in the eastern Wairarapa hill country) are likely to naturally score lower for these indicators.

Application of the Index of Biotic Integrity (IBI) to fish data held within the New Zealand Freshwater Fish Database (NZFDD) also showed that a significant relationship exists between fish community condition and upstream catchment landcover in the Wellington region. Fish community condition is significantly higher at sites located on rivers and streams draining predominantly indigenous forest catchments than at those draining pastoral or urban catchments. However, in some cases, fish community condition contrasts significantly with the water quality, periphyton and macroinvertebrate indicators. For example, some urban and pastoral sites (eg, Whareroa Stream at Queen Elizabeth Park) can have high fish community condition while some indigenous forest sites (including RSoE 'reference' sites, such as Beef Creek at Headwaters) can have poor community condition. Contrasting results between fish and other indicators are not unexpected; the Wellington region's fish fauna are largely migratory and therefore respond to catchment scale influences as well as local habitat (cf. water quality, periphyton and macroinvertebrates which tend to respond to upstream or local influences), meaning that they can be significantly impacted by physical barriers (eg, culverts, weirs) that prevent upstream fish migration.

8.1.2 Temporal trends

Temporal trend analysis performed on both raw and flow-adjusted physico-chemical and microbiological water quality data found that water quality was typically stable at the majority of RSoE sites between July 2006 and June 2011. A total of 78 'meaningful' trends (ie, statistically significant and a relative rate of change >1%/year) were identified across nine core variables (equating to 14.1% out of a total of 411 possible trends), with half of these trends associated with just three variables: total phosphorus (TP, 15 sites), nitrite-nitrate nitrogen (NNN, 13 sites) and total nitrogen (TN, 11 sites). In almost all cases, the trends in nutrient concentrations were decreasing. Such trends were present at a number of sites, including both nutrient-rich (eg, Mangaone Stream at Sims Road Bridge) and nutrient-poor (eg, Hutt River at Te Marua) sites. The reasons for the improvements are not known, but given that reference sites were well represented, these 'improving' trends may be related more to natural factors (eg, climate variability) than changes in land use/management. More importantly, while a number of 'degraded' sites showed improvements, these sites – as well as many sites that did not exhibit any meaningful trends – still recorded median nutrient concentrations well above ANZECC (2000) TVs.

A few sites exhibited trends indicative of deteriorating water quality – such as an increase in DRP concentration (Mangaroa River at Te Marua and Whangaehu River 250 m from confluence) and a decline in visual clarity (eg, Horokiri Stream at Snodgrass and Whareroa Stream at Waterfall Road). In most cases, the causes for these trends are not known; as noted in Section 4.2.2 and discussed further in Section 8.3.2, declining water clarity in the Horokiri Stream may be associated with soil/stream bank erosion and sediment runoff from forestry activities.

The results of trend analysis conducted on water quality data from NIWA's monitoring sites located on the Ruamahanga (three sites) and Hutt (two sites) rivers for the same five-year period were not too dissimilar from the findings for RSoE sites located on these rivers. In fact, analysis over a longer time period (1989 to 2007) by Ballantine and Davies-Colley (2010) suggests that water quality in both of these rivers has remained relatively stable for some time. Where trends were identified, these were typically of a very small magnitude (eg, an increase in flow-adjusted NNN concentration of 0.006 mg/L/year was observed for the site Ruamahanga River at Wardells).

Periphyton cover/biomass and macroinvertebrate community health were also stable at the majority of RSoE sites. However, and in contrast with water quality, where trends were present in one or more periphyton or macroinvertebrate metrics (19 and 15 sites, respectively, for the period 2004 to 2011), these were overwhelmingly indicative of deteriorating ecosystem health and tended to occur mainly at 'impacted' sites (ie, sites located in pastoral and urban catchments). The majority of the observed trends in these metrics did not coincide with one another, nor with any trends in water quality. It is likely that variation in climatic factors – in particular the frequency of flushing flows –

influenced the deteriorating trends reported for many sites. The 2004 and 2005 summers at the start of the trend analysis period were characterised by high river flows and frequent freshes, contributing to low periphyton biomass and high macroinvertebrate scores.

Analysis of NZFFD records identified a statistically significant decline in indigenous fish community condition in the Wellington region (particularly evident at pastoral sites) between the earliest time period (1960–1990) and the two more recent periods (1991–2000 and 2001–2010) examined. As will be discussed next, this observation is also present in the national record.

8.2 National context

The strong relationship between river/stream health and landcover/land use in this report is consistent with patterns observed in other regions (eg, Collier & Hamer 2010; Neale 2010) and across New Zealand (eg, Quinn & Raaphorst 2009; Ballantine et al. 2010; Ballantine & Davies-Colley 2010); rivers and streams located in catchments dominated by indigenous forest typically have better water quality, healthier macroinvertebrate communities and less periphyton growth than those located in pastoral and urban catchments. Fish communities generally exhibit a similar pattern (Joy 2009).

8.2.1 Water quality

Making direct comparisons between the data presented in this reported with similar data reported by other regional councils or nationally is problematic given differences in monitoring site networks (eg, number and location of sites), sampling frequency, and sampling and analytical methods between some regions. However, the recent analysis of regional water quality data sets undertaken as part of the Land and Water New Zealand (LAWNZ)[29] initiative provides an indication of how water quality in the Wellington region currently compares with the rest of New Zealand. According to this analysis (summarised in Table 8.1), for the period January 2004 to December 2011:

- RSoE sites classed as upland (>150 m altitude) forest were generally in a similar or better condition than the national average (median), although three of the seven RSoE sites in this class recorded median DRP concentrations above the national median.
- Regional median values for most variables in the lowland (<150 m altitude) forest class were fairly similar to their respective national median values. The exceptions were TP and *E. coli* where the majority of RSoE sites in this class recorded median concentrations less than their respective national medians.

  RSoE sites classed as lowland rural (ie, pastoral) generally had lower median concentrations of *E. coli* and ammoniacal nitrogen, but higher median concentrations of NNN, DRP and TP compared with their respective national medians. For both DRP and NNN, median concentrations at six sites were at least two times their respective national

[29] LAWNZ is a recent regional council initiative for sharing environmental monitoring information across New Zealand's regional and unitary authorities. See www.landandwater.org.nz

median values (this was the case for both DRP and NNN at Whangaehu River 250 m from confluence, Parkvale Stream at Weir, and Mangatarere Stream at SH 2). At one site (Mangatarere Stream at SH 2), the median DRP concentration was six times the national median (and over three times the national upper quartile of 0.023 mg/L).

- Six of the seven lowland urban RSoE sites recorded median DRP concentrations above the national median, and five sites recorded median NNN and *E. coli* concentrations above their respective national medians. In contrast, median water clarity was better at five of the seven sites.

Table 8.1: Regional (RSoE sites) and national median values for selected water quality variables grouped according to their altitude (upland/lowland) and dominant landcover (forest/rural/urban), based on LAWNZ state analysis for the period 2004 to 2011. The number of RSoE sites above and below (or equal to) the national median value are also presented

	Regional median	National median (*n*)	No. of RSoE sites above national median (and range of median values)	No. of RSoE sites below/equal to national median (and range of median values)
Upland forest (RSoE *n*=7)				
Visual clarity (m)	2.71	2.68 (47)	5 (2.71–3.24)	2 (2.37–2.68)
Ammoniacal nitrogen (mg/L)	0.005	0.005 (51)	0	7 (0.005)
Nitrite-nitrate nitrogen (mg/L)	0.030	0.079 (50)	1 (0.112)	6 (0.012–0.077)
Total nitrogen (mg/L)	0.080	0.153 (48)	2 (0.165–0.200)	5 (0.055–0.140)
Dissolved reactive phosphorus (mg/L)	0.008	0.009 (51)	3 (0.010–0.013)	4 (0.002–0.008)
Total phosphorus (mg/L)	0.012	0.016 (48)	0	7 (0.006–0.016)
E. coli (cfu/100mL)	5	14 (45)	0	7 (4–14)
Lowland forest (RSoE *n*=17)				
Visual clarity (m)	2.37	2.13 (89)	10 (2.24–3.19)	7 (0.94–1.92)
Ammoniacal nitrogen (mg/L)	0.005	0.005 (117)	1 (0.013)	16 (0.005)
Nitrite-nitrate nitrogen (mg/L)	0.075	0.074 (108)	9 (0.075–0.260)	8 (0.009–0.051)
Total nitrogen (mg/L)	0.152	0.195 (79)	6 (0.220–0.361)	11 (0.055–0.195)
Dissolved reactive phosphorus (mg/L)	0.007	0.007 (117)	9 (0.007–0.010)	8 (0.002–0.007)
Total phosphorus (mg/L)	0.010	0.013 (73)	2 (0.017–0.024)	15 (0.006–0.013)
E. coli (cfu/100mL)	29	63 (97)	4 (63–105)	13 (5–53)
Lowland rural (RSoE *n*=23)				
Visual clarity (m)	1.16	1.13 (344)	12 (1.16–2.52)	11 (0.46–0.96)
Ammoniacal nitrogen (mg/L)	0.010	0.012 (499)	8 (0.014–0.096)	15 (0.005–0.0105)
Nitrite-nitrate nitrogen (mg/L)	0.426	0.382 (479)	13 (0.392–4.500)	10 (0.007–0.374)
Total nitrogen (mg/L)	0.653	0.717 (454)	11 (0.720–4.95)	12 (0.190–0.653)
Dissolved reactive phosphorus (mg/L)	0.016	0.013 (490)	16 (0.014– 0.080)	7 (0.005–0.011)
Total phosphorus (mg/L)	0.039	0.034 (443)	13 (0.035–0.105)	10 (0.010–0.032)
E. coli (cfu/100mL)	135	175 (475)	9 (215–545)	14 (25–175)
Lowland urban (RSoE *n*=7)				
Visual clarity (m)	1.26	0.63 (27)	5 (1.26–2.34)	2 (0.42–0.63)
Ammoniacal nitrogen (mg/L)	0.017	0.034 (32)	3 (0.039–0.074)	4 (0.005–0.017)
Nitrite-nitrate nitrogen (mg/L)	1.080	0.762 (31)	5 (0.988–2.120)	2 (0.314–0.478)
Total nitrogen (mg/L)	1.335	1.173 (26)	5 (1.305–2.700)	2 (0.800–1.060)
Dissolved reactive phosphorus (mg/L)	0.030	0.020 (32)	6 (0.021–0.045)	1 (0.020)
Total phosphorus (mg/L)	0.052	0.049 (17)	4 (0.052–0.114)	3 (0.033–0.049)
E. coli (cfu/100mL)	500	475 (30)	5 (500–1,100)	2 (160–300)

Placement of the temporal trends in water quality presented in this report in a national context is difficult. The most recent national trend analysis was undertaken by Ballantine and Davies-Colley (2010) and spanned a significantly longer time period (1989 to 2007). Based on the collective trends across the 75 NRWQN sites examined, Ballantine and Davies-Colley (2010) concluded that concentrations of NNN, TN, DRP and TP had increased. These overall increasing trends indicate deteriorating water quality at the national level that the authors considered were mainly attributable to expansion and intensification of pastoral agriculture.

8.2.2 Ecological health

There are no readily available current national-scale assessments of periphyton growth or macroinvertebrate health against which to compare RSoE periphyton and macroinvertebrate data. In terms of indigenous freshwater fish, a nationwide assessment of IBI scores by Joy (2009) found similar declining trends at river and stream sites under pastoral landcover as those identified for the Wellington region in this report (as well as significant declining trends at sites under urban landcover). Allibone et al. (2010) also reported a decline across New Zealand in populations of a number of diadromous species that occur in the Wellington region (inanga, koaro, shortjaw kokopu, torrentfish and redfin and bluegill bullies); the loss of shortjaw kokopu populations from the Wellington region was specifically mentioned.

8.3 Key issues affecting river and stream health

The RSoE sites in poorest condition – in particular those with small catchments dominated by urban or intensive agricultural land use – share in common one or more of the following issues or ‘stressors’: nutrient enrichment, poor clarity, toxicity, microbiological contamination, and/or habitat degradation. Overall aquatic ecological health measured at each RSoE site is a reflection of the cumulative impact of the stressors present. In the case of indigenous fish condition, these stressors may be present upstream or downstream of a given site.

8.3.1 Nutrient enrichment

The occurrence of elevated nutrient concentrations in rivers and streams is recognised nationally and internationally as a key contributor to the occurrence of nuisance periphyton and/or macrophyte growth (eg, MfE 2000) that can degrade aquatic ecosystem health and other river and stream values (eg, trout spawning and contact recreation). Analysis of RSoE data here confirms an earlier assessment by Ausseil (2011) that periphyton issues are relatively widespread in the Wellington region (nuisance macrophyte growth may also be relatively widespread), with periphyton cover/biomass at RSoE sites strongly correlated with nutrient concentrations – in particular nitrogen. All 15 RSoE sites graded ‘poor’ for water quality recorded median NNN and DRP concentrations above ANZECC (2000) lowland trigger values (TVs). While these TVs are not effects-based and only serve as a general ‘bench marking’ assessment tool, it was demonstrated from the analysis in Section 6 that many of the RSoE sites with elevated median nutrient concentrations also frequently recorded nuisance periphyton cover and/or biomass.

Seven RSoE sites recorded a median NNN concentration over the 2008–2011 state period that was at least an order of magnitude greater than that recorded at the other sites. Three of these sites, Parkvale tributary at Lowes Reserve (median 4.35 mg/L), Parkvale Stream at Weir (1.26 mg/L) and Mangatarere Stream at SH 2 (1.2 mg/L) drain intensive agricultural catchments in the central Wairarapa Valley and are known to be influenced by shallow groundwater (eg, Daughney 2010; Milne et al. 2010). Dairying is prominent in these catchments, as well as in several other catchments in which RSoE sites recorded elevated NNN concentrations (eg, Mangaone – also in the top seven with a median of 1.93 mg/L at Sims Road Bridge, Kopuaranga and Whangaehu catchments).[30] In the case of the Mangatarere Stream catchment, a large piggery that discharges effluent to land in the mid catchment reaches and, to a lesser extent, the discharge of treated municipal wastewater from Carterton township, are also considered to be major contributors to instream NNN (Milne et al. 2010).

The other three RSoE sites that recorded the highest median NNN concentrations are classed as urban: Mangapouri Stream at Bennetts Road (median 2.5 mg/L), Karori Stream at Makara Peak (1.3 mg/L) and Kaiwharawhara Stream at Ngaio Gorge (1.1 mg/L). While groundwater nutrient inputs can not be ruled out at some sites, notably the Mangapouri Stream[31], Greater Wellington's pollution incident records and monitoring undertaken by the respective territorial authorities indicate that sections of two of these streams, along with sections of other urban streams that recorded elevated concentrations of NNN or DRP (eg, Porirua Stream at Glenside, Porirua Stream at Wall Park and Waiwhetu Stream at Wainuiomata Hill Road) are impacted, at least periodically, by sewer/stormwater discharges and/or faults (eg, cross connections). For example, sewer leaks were reported in the Karori Stream at Karori Park (approximately 1 km upstream of the Makara Peak monitoring site) in late December 2011 (O. Vorwerk[32], pers. comm. 2012). Infrastructure-sourced inputs may also be significant at higher flows, particularly during heavy or prolonged rainfall when stormwater can directly infiltrate and overload the sewer network, resulting in pump station overflows to nearby streams (refer to Section 3.4.2).

In a detailed analysis of the region's RSoE nutrient concentration data, Ausseil (2011) identified a pattern of increasing median nutrient concentrations under low flow conditions at many urban sites, as well as some pastoral sites, including Mangatarere Stream at SH 2 and Ruamahanga River at Gladstone. This pattern was particularly strong for DRP, which Ausseil (2011) considered to be generally consistent with some sort of point source discharge, such as a WWTP discharge, or nutrient-rich groundwater inputs. In the case of Mangatarere Stream at SH 2 and Ruamahanga River at Gladstone, increased DRP concentrations at low flows are attributed to these sites being located

30 Fonterra records supplied to Greater Wellington in September 2011 indicate that these catchments all support more than 2,000 dairy cows. The Mangatarere Stream catchment has in the order of 7,000 dairy cows and is also home to a large piggery that, in recent years has supported in the order of 9,000 to 10,000 pigs/month (Shivas & Hosken 2012).

31 Daughney (2010) identified a chemical signature for the Bennetts Road site similar to that of groundwater in the area, suggesting that some of the nutrient enrichment may be related to inputs of nutrient-rich shallow groundwater (although the site is classified as urban, pastoral landcover makes up over half of the upstream catchment and the former RSoE site at Rahui Road (located further upstream) was characterised by very high concentrations of NNN).

32 Olivia Vorwerk, Environmental Protection Officer, Greater Wellington.

downstream of the Carterton and Masterton WWTP discharges, respectively. This is well established for the Carterton WWTP discharge which Milne et al. (2010) estimated contributed as much as 90% of the total DRP load to the Mangatarere Stream during low flow conditions. The influence of the Carterton WWTP discharge appears to extend well beyond the Mangatarere Stream; the Waiohine River at Bicknells (located approximately 4 km downstream of the Mangatarere Stream confluence), also recorded a median DRP concentration above the ANZECC (2000) lowland TV. Ausseil (2011) noted that DRP concentrations at this site remain elevated under low flow conditions, confirming that the WWTP discharge is the likely reason for this.

In an assessment of nutrient ratios (DIN to DRP) across the 55 RSoE sites, which provide a general indication of which nutrient may limit periphyton growth, Ausseil (2011) estimated that 41% of RSoE sites are nitrogen-limited or co-limited (where the limiting nutrient switches regularly from nitrogen to phosphorus). Of the remaining sites, 38% are phosphorus-limited (principally pastoral sites as a result of nitrogen inputs) and 21% have concentrations of both nitrogen and phosphorus that are high enough for neither nutrient to be limiting periphyton growth. This suggests that management of point and non-point source nutrient inputs to rivers and streams across the region should focus on control of both nitrogen and phosphorus; a similar conclusion to that reached by Wilcock et al. (2007) when considering nutrient management in the Manawatu-Wanganui region.

8.3.2 Poor clarity and sedimentation

Median visual clarity values at all but one of the 15 RSoE sites graded ‘poor’ and seven of the nine sites graded ‘fair’ for water quality failed to meet the MfE (1994) minimum of 1.6 m. In fact, failure to meet the 1.6 m threshold was also the principal difference separating ‘good’ and ‘excellent’ sites. Reduced water clarity can affect the sight range for humans and aquatic animals as well as the availability of light for aquatic plant growth (Davies-Colley et al. 2003), resulting in degradation of recreational and ecological values.

The occurrence of poor water clarity and high concentrations of total suspended solids (TSS) at many sites indicates the potential for increased sediment deposition on the streambed. Increased sedimentation is recognised as a key impact of land use change which results in degradation of aquatic habitat for macroinvertebrates and fish in particular (Clapcott et al. 2011). Although streambed sedimentation is not currently assessed under the RSoE programme, the occurrence of soft substrate at a number of sites gives a clear indication of where sediment deposition rates are highest.

All but one of the nine RSoE sites with substrates dominated by soft sediment are located on small lowland streams along the Kapiti Coast or in the eastern Wairarapa hill country (the exception being Waiwhetu Stream at Wainuiomata Hill Road). Although some of these sites may be naturally inclined toward being soft sedimentary due to catchment geology (eg, Taueru River at Castlehill), others are likely to be hard-bottomed sites which have been inundated with fine sediment (eg, Waiwhetu Stream at Wainuiomata Hill Road) as a result of upstream land use. Assessment of macroinvertebrate community composition at RSoE sites showed that the occurrence of soft sedimentary substrate was highly correlated with the occurrence of pollution-tolerant macroinvertebrate taxa and all but one of the soft-bottomed sites were assigned to a macroinvertebrate class of 'fair' or 'poor'. Unsurprisingly these sites also had poor water clarity.

In addition to being poor at soft-bottomed sites, water clarity was also poor at a number of hard-bottomed sites with highly erodible and/or soft sedimentary geology catchments, such as Awhea River at Tora Road and Mataikona tributary at Sugar Loaf Road. Greater Wellington (and its predecessor the Wairarapa Catchment Board) has been working with landowners in the eastern Wairarapa hill country for a number of decades to develop farm or sustainability plans and retire and re-vegetate erosion-prone land. In 2009 the Wellington Regional Erosion Control Initiative (WRECI) was launched, leading to the development of more comprehensive farm management plans to address soil erosion in targeted catchments. While this has resulted in significant soil conservation gains for landowners, visual clarity and total suspended sediment monitoring results indicate that stream sediment loads remain high (as do sedimentation rates in the Whareama Estuary – see Oliver and Milne (2012)), suggesting that additional monitoring and management approaches are needed to identify and protect erosion 'hot spots' within the catchment. Although no work has been done to date to quantify such hot spots, it is likely that stream bank collapse and erosion are key sources of instream sediment (A. Stewart[33], pers. comm. 2012). Addressing this will require extending beyond planting on farms to the retiring, fencing and re-vegetating of riparian margins of affected rivers.

The Horokiri Stream catchment, which drains to the Pauatahanui Arm of Porirua Harbour, is also characterised by steep and unstable soils. Soil/stream bank erosion and sediment runoff from forestry tracking activities may explain the significant decline in visual clarity (0.27 m/year and 0.17 m/year in raw and flow-adjusted data, respectively) recorded at Horokiri Stream at Snodgrass over the period July 2006 to June 2011. According to Oliver and Milne (2012), in the order of 200 ha of forestry clearance is expected in this catchment over the next five years, highlighting the need for effective sediment control measures to reduce sediment runoff to the Horokiri Stream.

In stable, hard sedimentary catchments poor water clarity or high TSS concentrations recorded on some occasions during dry weather were associated with stock crossings (eg, Parkvale Stream at Weir), instream flood protection or gravel extraction works (eg, Hutt River at Boulcott and Ruamahanga River at Te Ore Ore), and specific pollution incidents. As noted in Section 3.4.1, there has been significant urban development in parts of the Wellington region over the last decade, particularly in the northern suburbs of Wellington city. Greater Wellington pollution incident records, along with compliance assessments of consented earthworks sites, confirm a number of instances where sediment control mechanisms (eg, silt ponds) have failed (Figure 8.2), resulting in large volumes of sediment entering nearby streams. A number of the incidents have been reported in the Porirua Harbour catchment, where there

[33] Andrew Stewart, Land Management Project Co-ordinator, Greater Wellington.

has been a particularly large amount of earthworks associated with urban subdivision or roading projects in recent years.[34]

(Source: Environmental Regulation Department, Greater Wellington)

Figure 8.2: Sediment runoff to Stebbings Stream (a tributary of Porirua Stream) in December 2009, resulting from a failure in sediment control measures in place on an earthworks site

8.3.3 Toxicity

Ongoing (ie, chronic) exposure to toxic concentrations of nitrate and heavy metals may be impacting on ecosystem health at some RSoE sites. Mangapouri Stream at Bennetts Road, Mangaone Stream at Sims Road and Parkvale tributary at Lowes Reserve all recorded median concentrations of nitrate nitrogen above Hickey and Martin's (2009) chronic toxicity TV of 1.7 mg/L. A further four sites exceeded this TV on at least 10% of sampling occasions during the three-year state reporting period: Parkvale Stream at Weir (42% of sampling occasions), Mangatarere Stream at SH 2 (14%), Porirua Stream at Wall Park (11%), and Waipoua River at Colombo Road (11%).

Several urban stream sites recorded median concentrations of dissolved copper and/or zinc above their respective hardness-modified ANZECC (2000) toxicity TVs, indicating chronic exposure to elevated metal concentrations. These sites were Porirua Stream at Wall Park, Karori Stream at Makara Peak and Waiwhetu Stream at Wainuiomata Hill Bridge. Acute toxicity may also be an issue at times; concentrations of dissolved copper and zinc exceeded their

[34] Greater Wellington's consenting records indicate that approximately 105 hectares of earthworks were consented in 2011 alone – much of this area lies within the Porirua Stream catchment. This estimate only applies to earthworks for land >0.3 ha in area (smaller areas of earthworks are regulated by Porirua and Wellington city councils).

respective hardness-modified USEPA (2009) guidelines for acute toxicity on at least one occasion at two and four sites, respectively.

Examination of macroinvertebrate data from the RSoE sites that regularly exceeded chronic nitrate, copper and/or zinc toxicity guidelines during the reporting period shows an impacted invertebrate fauna; the more pollution-sensitive Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa typically make up less than 25% of the fauna present (the Parkvale tributary is higher at 36%) and MCI quality is only classed as ‘fair’. While the influence of other water quality and habitat-related factors, notably substrate and flow heterogeneity, must also be considered, elevated concentrations of toxicants are likely to be contributing to the impacted invertebrate communities at these sites.

In terms of copper and zinc, the impacts are not likely to be limited to exposure to elevated dissolved concentrations in the water column. Several investigations of contaminants in streambed sediments in the Wellington region have identified elevated concentrations of a range of contaminants, including zinc, polycyclic aromatic hydrocarbons (PAHs) and pesticides (principally DDT) (eg, Milne & Watts 2008; Sorensen & Milne 2009). One-off sampling of streambed biofilms at selected RSoE sites in 2010 also revealed very high concentrations of some heavy metals, particularly copper, at sites draining predominantly urban catchments (Figure 8.3). Similar contamination has been reported in urban areas elsewhere (eg, Stansfield et al. 2010) and linked with adverse effects on instream invertebrate communities. For example, Suren (unpublished data, in Suren & Elliott 2004) demonstrated using an *in-situ* cage experiment in three urban streams in Christchurch that metal-contaminated biofilms and sediments, together with high sedimentation levels, were likely to be largely responsible for the absence of sensitive invertebrates such as *Deleatidium* mayflies.

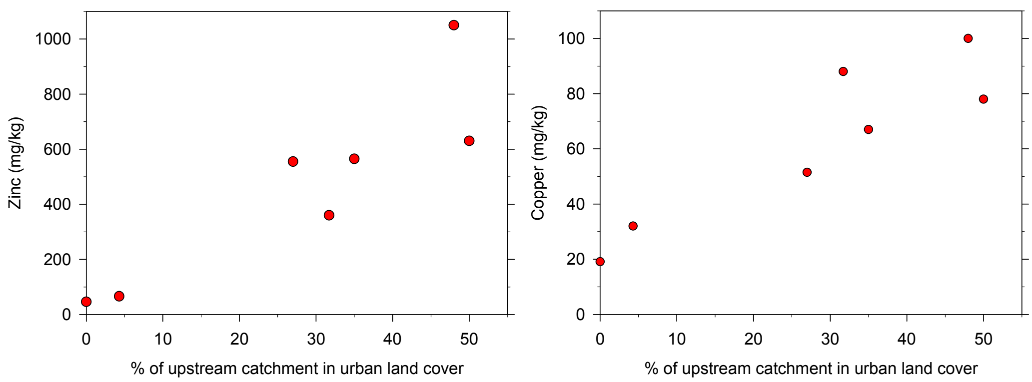


Figure 8.3: Total recoverable zinc (left) and copper (right) concentrations recorded in streambed biofilm samples collected from eight RSoE sites in early 2010. Although the number of data points is limited, there is a clear relationship between metal concentrations and the percentage of upstream urban land use

Copper and zinc are widely recognised as contaminants associated with urban stormwater discharges in the Wellington region (eg, Kingett Mitchell Ltd 2005b) and elsewhere. It is therefore not surprising that these metals are present at elevated concentrations in many of the region’s urban streams during wet weather conditions, a finding reported by Milne and Watts (2008). However, the persistent presence of dissolved copper and zinc at concentrations above chronic toxicity guidelines at some sites during 'base flows' presents a more difficult challenge for improving ecosystem health in urban streams. For example, despite extensive riparian rehabilitation being carried out along the Karori Stream at Makara Peak in the early 2000s, subsequent ecological monitoring has not identified any improvements in stream health. Perrie (2008) attributed this to the overriding impact of stormwater contaminants and habitat degradation associated with the urban land use that dominates the upstream catchment.

8.3.4 Microbiological contamination

Microbiological water quality data for the three-year state period examined highlight that significant faecal contamination exists at some urban and pastoral sites. The highest median *E. coli* counts were recorded at Karori Stream at Makara Peak (1,100 cfu/100mL), Porirua Stream at Wall Park (910 cfu/100mL), Mangapouri Stream at Bennetts Road (610 cfu/100mL), and Parkvale Stream at Weir (570 cfu/100mL). Three of these stream sites are located in urban areas where, as outlined in Section 8.3.1, sewer/stormwater infrastructure-related issues have been identified in the past – both in dry and wet weather. In the case of Parkvale Stream at Weir, the elevated median *E. coli* count – as well as a similar median count at Mangaone Stream at Sims Road Bridge (430 cfu/100mL) – is in part attributed to cattle having direct access to the stream margins and channel.

Nine RSoE sites recorded maximum *E. coli* counts over 10,000 cfu/100mL, these typically being sites located in urban (Karori Stream at Makara Peak, Kaiwharawhara Stream at Ngaio Gorge and Porirua Stream at Wall Park) or pastoral catchments that drain the eastern Wairarapa hill country (eg, Whareama River at Gauge, Kopuaranga River at Stewarts and Whangaehu River 250 m from confluence). As noted above, sewer/stormwater infrastructure-related issues likely explain elevated *E. coli* counts at the urban sites. In contrast, high counts at the eastern Wairarapa sites were associated with wet weather and are attributed to faecal matter deposited from stock on unstable farmland and riparian margins/stream banks being washed into the rivers.[35] Remobilisation of faecal deposits in streambed sediments may also occur at these and other pastoral sites that recorded high *E. coli* counts in wet weather (eg, Whareroa Stream at Queen Elizabeth Park). Overall, the widespread occurrence of elevated *E. coli* counts during wet weather highlights the need to address sewer/stormwater infrastructure issues in urban areas and, in rural areas, the importance of establishing vegetated riparian margins and excluding stock from streams. The benefits of riparian rehabilitation and stock exclusion for stream water quality and ecological health are discussed next.

[35] Faecal inputs from effluent runoff in wet weather are also expected in catchments that support dairying. As at the end of 2010, only around 40% of the 175-odd dairy farms in the Wairarapa Valley had some capacity for wet weather storage (see Perrie & Milne 2012). This indicates that dairyshed effluent is at times applied to land when soils are fully saturated, increasing the potential for surface runoff to streams.

8.3.5 Habitat degradation

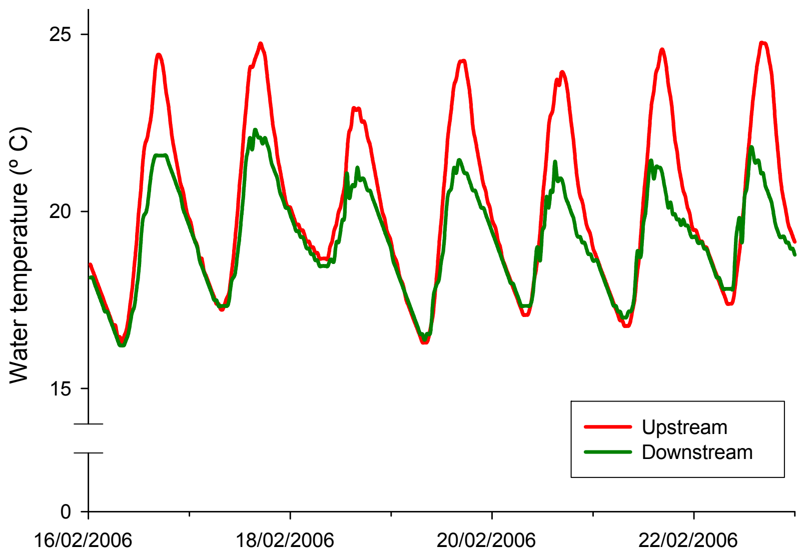
Along with water quality, habitat quality is a strong driver of ecological health in rivers and streams. Generally speaking, ecological health is highest when there is a diversity of stream substrate, flow (runs, riffles and pools) and good riparian vegetation to stabilise stream banks and provide instream shade/cover (Parkyn 2004). While habitat assessments have not been routinely included in RSoE monitoring to date, from recent habitat assessments in 2011, along with a one-off qualitative assessment undertaken in 2008, it is clear that degraded ecological health at many RSoE sites is linked with degraded instream and/or riparian habitat. The streams that were graded poorest for macroinvertebrate health all showed one or more common attributes of poor aquatic habitat such as a highly modified stream channel with uniform flow (eg, Porirua Stream at Wall Park, Figure 8.4), silted and homogenous substrates (eg, Waiwhetu Stream at Wainuiomata Hill Road Bridge), and an absence of riparian shade (eg, Parkvale Stream at Weir, Figure 8.4).

Figure 8.4: Porirua Stream at Wall Park (left) is an example of one of many channelised urban streams in the Wellington region. Parkvale Stream at Weir (right) lacks riparian shade and is characterised by nuisance periphyton and macrophyte growth

A common feature across RSoE sites with poor ecological health is a general lack of riparian shade, resulting in elevated summer-time water temperatures. For example, Parkvale Stream at Weir has no riparian shade and almost a quarter of all (spot) water temperature measurements made at this site over the 2008 to 2011 state period were above the 19^{o}C threshold where impacts on sensitive macroinvertebrate and fish taxa are possible. Further, continuous monitoring over the summer months at this site has identified that water temperatures can exceed the critical threshold of 25^{o}C. Similar measurements have been recorded at other sites in the region, such as Whareroa Stream at Queen Elizabeth Park (refer Section 4.1.3).

At many of the RSoE sites characterised by elevated summer-time water temperatures nuisance growths of periphyton were also recorded. This is despite some sites, such as those in eastern Wairarapa (eg, Awhea River at Tora Road), recording only low to moderate nutrient concentrations. Rivers and streams in this area are subject to extended periods of low flow during summer and can support high periphyton growth despite relatively low nutrient concentrations. While reduced flows in these rivers largely reflects the less frequent summer rainfall and naturally lower groundwater inputs associated with the eastern Wairarapa hill country, in some other streams, water abstraction may be a contributing factor. As noted in Section 3.4.2, there has been a considerable increase in consented water abstraction in the Wellington region in recent years, for both urban water supply and irrigation in rural areas (principally for dairying in the Wairarapa). Despite a cap being in place on new surface water takes from some small streams in the central Wairarapa Valley, such as the Parkvale and Mangatarere streams, Hughes and Gyopari (2011) demonstrated that the flow in these streams is depleted by the abstraction of hydraulically connected groundwater. Further much of this groundwater has not to date been considered as part of the consented surface water allocation. A new framework for conjunctive management of surface and groundwater in the Wairarapa Valley has recently been recommended to address this issue (see Keenan et al. 2012).

The benefits of riparian vegetation for stream health by way of increasing stream shade and reducing water temperatures and periphyton growth are well known (eg, Parkyn 2004) and have been demonstrated to be particularly effective in small rivers and streams. For example, Perrie (2008) reported a reduction in maximum water temperatures of several degrees for the Enaki Stream in the Mangatarere catchment near Carterton (Figure 8.5), despite the presence of relatively young riparian plantings. Monitoring at RSoE sites has shown that high levels of shade can limit periphyton growth even at sites with elevated nutrient concentrations (eg, Parkvale Stream tributary at Lowes Reserve and Whareroa Stream at Waterfall Road), thereby potentially mitigating some of the effects of nutrient enrichment associated with upstream land use activities. There are also a number of other potential benefits from riparian vegetation, including interception and attenuation of nutrients, sediment and pathogens, improved bank stability, and improved habitat diversity and complexity through leaf litter and woody debris inputs (eg, Parkyn 2004).



(Source: After Perrie 2008)

Figure 8.5: Daily variation in water temperatures upstream and downstream of a planted reach of the Enaki Stream (near Carterton) for a week during February 2006

While riparian vegetation can provide a variety of benefits to river and stream habitat (and water quality), Perrie (2008) noted that in some cases the benefits of riparian vegetation may be limited due to the overriding influence of land use in the upstream catchment. For example, as noted in Section 8.3.3, riparian rehabilitation along a reach of the Karori Stream in the vicinity of the RSoE site at Makara Peak that is subjected to significant urban stormwater contamination (and soluble nutrient inputs) resulted in no improvement to aquatic ecosystem health. Similarly, despite improvements in some variables such as water temperature and bank stability, the lack of any significant improvement in periphyton or macroinvertebrate metrics associated with riparian rehabilitation undertaken on reaches of the Enaki Stream was in part attributed to poor upstream farming practices (including stock access to stream beds and unauthorised dairy effluent run-off). This highlights that although the benefits of riparian rehabilitation are well established, it may not be sufficient to mitigate the detrimental effects of other factors such as urban stormwater discharges and poor land management practices.

To improve indigenous fish community condition, the removal of physical barriers that prevent or impede fish migration is also required. Limited monitoring to date indicates that fish communities at some RSoE sites at least are affected by instream barriers (eg, Beef Creek at Headwaters has poorer than expected fish community condition). Further, in an assessment of 28 barriers across 13 river/streams in the Wellington region, Atkinson (2008) concluded that they were all, to some degree, negatively impacting on the ability of native fish to migrate upstream. This indicates that barriers to fish passage are a potentially widespread problem. Greater Wellington has recognised this and developed a specific strategy to address native fish passage issues in the Wellington region (GWRC 2011).

8.4 Downstream receiving environments

Although beyond the scope of this report, it is important to recognise that the state of some of the region's rivers and streams can have flow-on effects for downstream receiving environments. For example, Greenfield et al. (2012) identified that poor microbiological water quality in the lower reaches of the Mangaone Stream at times negatively impacts on water quality at Te Horo Beach. Similarly, Oliver and Milne (2012) identified sedimentation, nutrient enrichment, and toxicant and microbiological contamination as some of the main issues affecting estuaries in the Wellington region. All of these issues are particularly pertinent for Porirua Harbour, with sedimentation and nutrient enrichment the main concerns for Lake Onoke. Nutrient enrichment is also a key issue for Lake Wairarapa (Perrie & Milne 2012). With further land use change expected in their upstream catchments (forestry clearance, and residential and roading development in the case of Porirua Harbour, and rural land use intensification in the cases of Lakes Wairarapa and Onoke), it is important that measures introduced to manage the effects of this change on river and stream health are implemented with consideration of the need to also manage potential 'downstream' effects.

8.5 Monitoring limitations and knowledge gaps

Greater Wellington's RSoE monitoring programme has provided a significant amount of knowledge about the health of rivers and streams in the Wellington region. However, there are some limitations associated with the monitoring to date, as well as some more general knowledge gaps. The main limitations and knowledge gaps are outlined below.

- While the RSoE programme has remained relatively stable in terms of monitoring sites and variables in recent years, there have been several changes in analytical laboratory over the last ten years, the most recent change being in July 2006 (for both water quality analyses and periphyton and macroinvertebrate identification). There have also been some changes in sampling personnel, most notably the use of external contractors between July 2006 and December 2007. Despite a number of checks being put in place to maintain consistency in sampling and analytical methods, a review of the RSoE data collected during the preparation of this report does indicate that there have been some effects on data quality, particularly for some water quality variables. For this reason the length of the temporal trend assessment period was restricted to the five most recent years. While a five-year period is considered appropriate for analysing recent trends in water quality data collected at monthly intervals (eg, Ballantine et al. 2010), assessment over a longer period would also have been desirable. Potentially the five-year period assessed here prevented the detection of some significant changes in water quality (Ballantine et al. 2010).

- In addition to the change from external to in-house water quality sampling personnel during the five-year trend period, changes in some of the RSoE sampling runs meant that sampling times at some RSoE sites varied across the reporting period. As noted in Section 4.2, these changes impeded robust trend analysis for field measurements, particularly water temperature, dissolved oxygen and pH which all exhibit diurnal variation. The need for standardisation of field data collection, ideally to within +/- 1 hour, has been emphasised by Davies-Colley et al. (2011) in a recent report setting out recommended variables and protocols to support the establishment of a national river water quality monitoring programme. This same report also recommended continuous monitoring of diurnally fluctuating variables where possible.

- While flow-adjusted trend analyses were possible for water quality data from a much greater number of monitoring sites than in the last assessment of trends in river and stream water quality (Milne & Perrie 2005), there are still 11 sites where it has not yet been possible to derive an estimate of flow robust enough to enable flow-adjusted trend analysis. This is a significant limitation given that flow is known to influence some aspects of water quality, particularly optical properties and total phosphorus and *E. coli* concentrations (eg, three RSoE sites exhibited declining trends in visual clarity based on 'raw' measurements but the lack of flow data means that it is not known whether the trends are simply a result of changes in flow). Further efforts are required to obtain robust flow estimates for the affected sites; this may require manual flow gaugings at the time of sample collection or, even, relocation of monitoring sites to reaches where flow can be measured or better estimated.

- A number of important aspects of stream health have not been monitored routinely to date, or have only recently been incorporated into the RSoE programme. These include fish community condition, macrophyte cover, instream sedimentation and stream habitat quality. The lack of information on these components has limited the scope of the overall conclusions made in this report about the health of the region's rivers and streams. For example, as noted in Section 7.3, some RSoE sites considered 'degraded' by traditional measures (eg, water quality and macroinvertebrate community metrics) can have significant indigenous fish values. The recent development of standardised protocols for assessing freshwater fish populations (David et al. 2010; Joy & David in prep) should be utilised to implement a formal fish monitoring programme for the Wellington region. Similarly, national protocols have recently been finalised that provide guidance on monitoring of instream sedimentation (Clapcott et al. 2011) and stream habitat (Harding et al. 2009).

- The most significant limitation in terms of RSoE reporting is the lack of region-specific guidelines for water quality and ecological health that cover the range of natural characteristics and values (eg, ecosystem health, swimming, trout spawning, etc.) associated with the region's rivers and streams. As outlined in Section 3.1, natural catchment characteristics, such as geology and elevation, result in variation in water quality, stream habitat and aquatic communities. Evidence that region-wide application of 'one size fits all' national guidelines is not appropriate is provided by the presence of DRP at concentrations above the ANZECC (2000) lowland trigger value at some reference sites in the region. Work is currently underway to develop region-specific guidelines for Greater Wellington's next Regional Plan that better reflect not only the natural diversity of river and stream types in the Wellington region but also the range of values these rivers and streams are managed for (eg, Ausseil in prep a–d; Greenfield in prep a & b).

- There are some significant knowledge gaps around the effects of specific activities on river and stream health in the Wellington region (eg, exotic forestry harvest and instream works such as gravel extraction and river channel realignment/contouring), and the sources of high nutrient or sediment inputs to some streams. The use of targeted, catchment-based monitoring and investigations is recommended to address these knowledge gaps.

9. Conclusions

Analysis of water quality, periphyton and macroinvertebrate data collected at 55 RSoE sites over the period July 2008 to June 2011 has found clear linkages between river and stream health and catchment land use. Sites classified as having 'good' or 'excellent' water quality (27 sites) and ecosystem health (27 and 36 sites for periphyton and macroinvertebrate indicators, respectively) tend to be located on the upper reaches of rivers and streams that drain the forested Tararua, Rimutaka and Aorangi ranges. As the proportion of pastoral and/or urban landcover increases within a site's upstream catchment, water quality and macroinvertebrate health tend to decline while nuisance periphyton and macrophyte growth increases. Of the 15 sites graded 'poor' for water quality, five are located in urban areas and ten drain predominantly pastoral catchments – of which most support at least some intensive agriculture. Similar patterns were observed with periphyton growth and macroinvertebrate health, although geological and climatic factors in part account for some sites (particularly those in the eastern Wairarapa hill country) being assigned to 'fair' or 'poor' classes for these indicators.

Analysis of New Zealand Freshwater Fish Database records also showed that a significant relationship exists between fish community condition and upstream catchment landcover in the Wellington region. Fish community condition is significantly higher at sites located on rivers and streams draining predominantly indigenous forest catchments than at those draining pastoral or urban catchments. Based on limited monitoring, fish community condition at some RSoE sites contrasts significantly with the water quality, periphyton and macroinvertebrate indicators measured at these sites.

The majority of RSoE sites exhibited relatively stable water quality and ecological health over the time periods examined (2006 to 2011 and 2004 to 2011, respectively). Generally speaking, the majority of statistically significant trends tended to be indicative of improving water quality (predominantly declining nutrient concentrations) but deteriorating ecological condition (increasing periphyton cover/biomass and declining macroinvertebrate community health). In most cases the reasons for the observed trends were unclear. The presence of improving nutrient concentrations across a wide spectrum of sites, including several reference sites, suggests that the improvements are more likely related to natural factors such as climate variability than changes in land use or land management practices. Similarly, variation in river and stream flow probably influenced many of the trends identified in periphyton and macroinvertebrate metrics.

Overall, while the absence of wide scale deteriorating trends in water quality and ecological health is positive, many of the RSoE sites are considered 'degraded', with some very degraded when considered in the national context. For example, most urban sites and several lowland pastoral sites recorded nutrient concentrations well above their respective national median values for similar urban and rural streams. The RSoE sites in poorest condition – in particular those with small catchments dominated by urban or intensive agricultural land uses – share in common one or more of the following 'stressors': nutrient enrichment, poor water clarity, nitrate or heavy metal toxicity, microbiological contamination and instream habitat degradation. Management of these stressors requires a whole of catchment approach that addresses municipal wastewater discharges to water (in the Wairarapa Valley in particular), nutrient loss (from both overland runoff and leaching via shallow groundwater) in intensively farmed rural catchments, sediment runoff associated with erosion-prone farmland, exotic forestry and urban development, sewer infrastructure leaks/faults, urban stormwater discharges, water abstraction, and direct stock access to streams and riparian margins.

9.1 Recommendations

1. Review Greater Wellington's existing River SoE monitoring programme, giving priority consideration to:

   - Standardising the timeframe of water sample collection to within ±1 hour where possible;
   - Revisiting existing QA/QC practices in place for both field sampling and analytical laboratory components of the programme;
   - Implementing a formal regional fish monitoring programme;
   - Introducing regular assessments of instream sedimentation and habitat quality; and
   - Establishing greater linkages with SoE hydrological, groundwater quality and downstream (estuary and lake) monitoring networks.

2. Continue work to establish estimates of flow at all RSoE monitoring sites, and improve existing estimates at sites where direct flow measurements are not regularly taken.

3. Consider, in the next assessment of state and trends in RSoE monitoring results:

   - Further exploration of the use of indices, such as the Canadian Water Quality Index (CCME 2001), to summarise river and stream health, including the potential for a single index that integrates water quality, ecological indicators (periphyton, macroinvertebrates and fish) and habitat quality;
   - Identifying, and reporting against, selected indicators of river and stream health applicable to different management purposes (eg, aquatic ecosystem health and trout habitat/angling), using thresholds that take into account the natural diversity of river and stream types in the Wellington region;
   - Analysing temporal trends in physico-chemical water quality over both five and ten-year timeframes; and
   - Exploring alternative methods to assess the ecological significance of trends in periphyton and macroinvertebrate indicators.

4. Continue to address existing knowledge gaps around the effects of specific activities on river and stream health in the Wellington region (eg, instream works) and the sources of high nutrient or sediment inputs to some streams using targeted, catchment-based monitoring and investigations.

5. Continue Greater Wellington's existing soil conservation programmes to reduce soil erosion across the region's erosion-prone hill country.

6. Promote further riparian rehabilitation in small degraded or 'at risk' stream catchments most likely to benefit from riparian revegetation and continue with existing initiatives to remove physical barriers to native fish migration.

7. Take into account the findings of this report in the review of Greater Wellington's existing regional plans, particularly the need to address:

    - Nutrient losses (both nitrogen and phosphorus) from intensive rural land uses, such as dairying and horticulture;
    - Microbiological and nutrient contamination from municipal wastewater discharges, stock access to streams and, in urban areas, sewer/stormwater cross connections, leaks and overflows;
    - Land use practices and activities that contribute significant sediment inputs to rivers and streams, particularly stock access to waterways and riparian margins, forestry, and bulk earthworks associated with urban and roading developments;
    - The effects of urban stormwater discharges on the region's rivers and streams; and
    - Activities in urban and rural areas that degrade instream habitat, such as stream realignment, water abstraction and removal of riparian vegetation.

References

Allibone R, David B, Hitchmough R, Jellyman D, Ling N, Ravenscroft P and Waters J. 2010. Conservation status of New Zealand freshwater fish, 2009. *New Zealand Journal of Marine and Freshwater Research,* 44: 1–17.

Atkinson N. 2008. *Rites of passage: Biotic and abiotic influences on freshwater fish migration*. MSc thesis. Massey University, Palmerston North.

Ausseil O. 2011. Nutrient status of rivers and streams in the Wellington region: An *analysis of state of the environment monitoring data*. Report prepared for Greater Wellington Regional Council by Aquanet Consulting Ltd, Palmerston North.

Ausseil A. In prep. (a). *Recommended biological and water quality limits for trout fishery and trout spawning waters in the Wellington region*. Report prepared by Aquanet Consulting Ltd for Greater Wellington Regional Council.

Ausseil A. In prep. (b). *Recommended biological and water quality limits for rivers and streams managed for contact recreation, amenity and stock drinking water in the Wellington region*. Report prepared by Aquanet Consulting Ltd for Greater Wellington Regional Council.

Ausseil A. In prep. (c). *Recommended water quality limits for rivers and streams managed for Aquatic Ecosystem Health in the Wellington region*. Report prepared by Aquanet Consulting Ltd for Greater Wellington Regional Council.

Ausseil A. In prep. (d). *Recommended in-stream nutrient limits for rivers and streams in the Wellington region*. Report prepared by Aquanet Consulting Ltd for Greater Wellington Regional Council.

Australian and New Zealand Environment and Conservation Council (ANZECC). 1992. *Australian water quality guidelines for fresh and marine waters. National Water Quality Management Strategy Paper No. 4,* Australian and New Zealand Environment and Conservation Council, Canberra.

Australian and New Zealand Environment and Conservation Council (ANZECC). 2000. *Australian and New Zealand guidelines for fresh and marine water quality, volume 1, the guidelines*. Agriculture and Resource Management Councils of Australia and New Zealand, Canberrra.

Ballantine D and Booker D. 2011. *Greater Wellington State of Environment river water quality data assessment and trend analysis* (2003-2010). Report No. HAM2011-126 prepared for Greater Wellington Regional Council by NIWA, Hamilton.

Ballantine D, Booker D, Unwin M and Snelder T. 2010. Analysis of national river water quality data for the period 1998–2007. Report No. CHC2010-038 prepared for the Ministry for the Environment by NIWA, Christchurch.

Ballantine D and Davies-Colley R. 2010. *Water quality trends at NRWQN sites for the period 1989–2007*. Report No. HAM2009-026 prepared for the Ministry of the Environment by NIWA, Hamilton.

Biggs B and Kilroy C. 2000. *Stream periphyton monitoring manual*. National Institute for Water and Atmosphere, Christchurch.

Boothroyd I and Stark J. 2000. Use of invertebrates in monitoring. In: Collier KJ, Winterbourne MJ (eds), *New Zealand stream invertebrates: Ecology and implications for management.* New Zealand Limnological Society, pp.313–343.

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

Clapcott J and Olsen D. 2010. *Macroinvertebrate community characteristics in the Wellington region – towards indicators and objectives for the next Regional Plan.* Report No. 1799 prepared for Greater Wellington Regional Council by the Cawthron Institute, Nelson.

Clapcott J, Young R, Harding J, Matthaei C, Quinn J and Death R. 2011. *Sediment assessment methods: Protocols and guidelines for assessing the effects of deposited fine sediment on in-stream values*. Report prepared for the Ministry for the Environment by the Cawthron Institute, Nelson.

Collier K and Hamer M. 2012. *The ecological condition of Waikato wadeable streams based on the Regional Monitoring of Streams (REMS) programme*. Waikato Regional Council Technical Report 2012/27, Hamilton.

Collier K and Kelly J. 2006. *Patterns and trends in the ecological condition of Waikato streams based on monitoring of aquatic invertebrates from 1994 to 2005*. Environment Waikato Technical Report 2006/04. Environment Waikato, Hamilton.

Collier K, Kelly J and Champion, P. 2007. *Regional guidelines for ecological assessments of freshwater environments: Aquatic plant cover in wadeable streams*. Environment Waikato, Document 1106963, Hamilton.

Collier K, Wilcock R and Meredith A. 1998. Influence of substrate type and physiochemical conditions on macroinvertebrate faunas and biotic metrics of some lowland Waikato streams. *New Zealand Journal of Marine and Freshwater Research*, 32: 1–19.

Crippen T and Hicks DL. 2004. *Soil intactness assessment of the Wellington region 2004.* Report prepared for Greater Wellington Regional Council by T. Crippen and D. Hicks, Wellington.

Crippen T and Hicks DL. 2011. *Changes in the state of the soil in the Wellington region 2002 to 2010.* Report prepared for Greater Wellington Regional Council by T. Crippen and D. Hicks, Wellington.

Daughney CJ. 2010. *Hydrochemical classification of groundwater and river state of the environment monitoring sites in the greater Wellington region.* GNS Science Report 2009/68 prepared for Greater Wellington Regional Council.

David B, Hamer M, Collier K, Lake M, Surrey G, McArthur K, Nicholson C, Perrie A and Dale M. 2010. A standardised sampling protocol for robust assessment of reach-scale fish community diversity in wadeable New Zealand streams. *New Zealand Journal of Marine and Freshwater Research,* 44: 177–187.

Davies-Colley R, Larned S, Unwin M, Verburg P, Hughes A, Storey R, McBridge G, Ballantine D, Hudson N, Daughney C and Hamill K. 2011. *Dependable monitoring of fresh waters for national-scale environmental reporting.* Report No. HAM2011-055, prepared for the Ministry for the Environment by NIWA, Hamilton.

Davies-Colley R, Vant W and Smith D. 2003. *Colour and clarity of natural waters*. Science and management of optical water quality. Blackburn Press, New Jersey, USA.

Greater Wellington Regional Council. 2005. *Measuring up: State of the environment report for the Wellington region 2005.* Greater Wellington Regional Council, Publication No. GW/ENV-G-05/278, Wellington.

Greater Wellington Regional Council. 2010. *Proposed Regional Policy Statement for the Wellington region, May 2010.* Publication No. GW/EP-G-08/200, Wellington.

Greater Wellington Regional Council. 2011. *A strategy for providing passage for native freshwater fish in the Wellington region.* Unpublished report (Greater Wellington Regional Council Document #960408), prepared by Haydn Butler, Flatfish Environmental, Wellington.

Greenfield S. In prep. (a). *River and stream periphyton and macrophyte limits for the protection of aquatic ecosystem values*. Unpublished internal report, Document #808707, Greater Wellington Regional Council, Wellington.

Greenfield S. In prep. (b). *River and stream macroinvertebrate limits for the protection of aquatic ecosystem values*. Unpublished internal report, Document #816827, Greater Wellington Regional Council, Wellington.

Greenfield S, Ryan A and Milne J. 2012. *Recreational water quality in the Wellington region: State and trends.* Greater Wellington Regional Council, GW/EMI-T-12/142, Wellington.

Hansen W. 2001. *Identifying stream types and management implications*. Forest Ecology and Management 143: 39-46.

Harding J, Clapcott J, Quinn J, Hayes J, Joy M, Storey R, Greig H, Hay J, James T, Beech M, Ozanne R, Meredith A and Boothroyd I. 2009. *Stream habitat assessment protocols for wadeable rivers and streams of New Zealand*. University of Canterbury, Christchurch.

Hay J, Hayes J and Young R. 2007. *Water quality guidelines to protect trout fisheries values.* Report No. 1205 prepared for Horizons Regional Council by the Cawthron Institute, Nelson.

Hickey C and Martin M. 2009. *A review of nitrate toxicity to freshwater aquatic species.* Report R09/57 prepared for Environment Canterbury, Christchurch.

Hudson N, Ballantine D, Gibbs M, de Winton M, Storey R, Verburg P and Hamill K. 2011. *Investigation of single indicators for water quality assessment and reporting.* Report No. HAM2011-066 prepared for the Ministry for the Environment by NIWA, Hamilton.

Hughes B and Gyopari M. 2011. *Wairarapa Valley groundwater resource investigation: Proposed framework for conjunctive water management.* Greater Wellington Regional Council, Publication No. GW/EMI-T-11/53, Wellington.

Joy M. 2004. A *fish index of biotic integrity for the Wellington region*. Report prepared for Greater Wellington Regional Council.

Joy M. 2009. *Temporal and land-cover trends in freshwater fish communities in New Zealand's rivers: An analysis of data from the New Zealand Freshwater Fish Database* (1970–2007). Report prepared for the Ministry for the Environment

Joy M. 2011. *Freshwater fish in the Southland region: Spatial distribution in relation to landcover and temporal trends*. Report prepared for Southland Regional Council by Wairesearch Limited.

Joy M and David B. In prep. *New Zealand Freshwater fish monitoring protocols: Part one, wadeable rivers and streams.*

Joy M and Death R. 2004. Application of the index of biotic integrity methodology to New Zealand freshwater fish communities. *Environmental Management*, 34: 415–428.

Keenan L, Thompson M and Mzila D. 2012. *Freshwater allocation and availability in the Wellington region: State and trends.* Greater Wellington Regional Council, Publication No. GW/EMI-T-12/141, Wellington.

Kingett Mitchell Ltd. 2005a. *Aquatic ecology and stream management groups for urban streams in the Wellington region.* Report prepared for Greater Wellington Regional Council by Kingett Mitchell Limited.

Kingett Mitchell Ltd. 2005b. *Assessment of urban stormwater quality in the greater Wellington region.* Report prepared for Greater Wellington Regional Council by Kingett Mitchell Limited.

Leathwick J, Julian K, Elith J, Chadderton L, Ferrier S and Snelder T. 2008. *A biologically optimised environmental classification of New Zealand rivers and streams; reanalysis excluding human impact variables.* Report No. HAM2008-027 prepared for the Department of Conservation by NIWA, Hamilton.

McDowall R. 2000. *The Reed field guide to New Zealand freshwater fishes*. Reed publishing, Auckland.

Meyer J, Kaplan L, Newbold D, Strayer D, Woltemade C, Zedler J, Beilfuss R, Carpenter Q, Semlitsch, Watzin M and Zedler P. 2003. *Where rivers are born: The scientific imperative for defending small streams and wetlands*. American Rivers and Sierra Club, United States.

Milne JR and Perrie A. 2005. *Freshwater quality monitoring technical report.* Greater Wellington Regional Council, Publication No. GW/RINV-T-05/87, Wellington.

Milne JR, Tidswell S, Perrie A and Sorensen P. 2010. *Mangatarere Stream catchment water quality investigation.* Greater Wellington Regional Council, Publication No. GW/EMI-T-10/72, Wellington.

Milne JR and Watts L. 2008. *Stormwater contaminants in urban streams in the Wellington region.* Greater Wellington Regional Council, Publication No. GW/EMI-T-08/82, Wellington.

Ministry for the Environment. 1994. *Water quality guidelines No. 2: Guidelines for the management of water colour and clarity.* Ministry for the Environment, Wellington.

Ministry for the Environment. 2000. *New Zealand periphyton guideline: detecting, monitoring and managing enrichment of streams*. Ministry for the Environment, Wellington.

Ministry for the Environment. 2010. *Measuring carbon emissions from land-use change and forestry: The New Zealand land-use and carbon analysis system.* Ministry for the Environment, Wellington.

Ministry for the Environment and Ministry of Health. 2003. *Microbiological water quality guidelines for marine and freshwater recreational areas*. Ministry for the Environment, Wellington.

Neale M. 2010. *State of environment monitoring: River water quality annual report 2008*. Auckland Regional Council Technical Report No 016, Auckland.

Oliver MD and Milne JR. 2012. *Coastal water quality and ecology in the Wellington region: State and trends.* Greater Wellington Regional Council, Publication No. GW/EMI-T-12/144, Wellington.

Parkyn S. 2004. *Review of riparian buffer zone effectiveness.* MAF Technical Paper No: 2004/05.

Parkyn S, Wilding T and Croker G. 2006. *Small headwater streams of the Auckland region Volume 4: Natural values*. Auckland Regional Council, Technical Publication No. 310, Auckland.

Perrie A. 2007. *The state of water quality in selected rivers and streams in the Wellington region, 2003–2006.* Greater Wellington Regional Council, Publication No. GW/EMI-T-07/218, Wellington.

Perrie A. 2008. *Riparian rehabilitation to improve aquatic environments in the Wellington region: Results from the riparian management pilot programme, 2002–07.* Greater Wellington Regional Council, Publication No. GW/EMI-T-08/80, Wellington.

Perrie A. 2009. *Rivers state of envionment monitoring programme: Results of additional physico-chemical water quality variables monitored during 2008.* Greater Wellington Regional Council, unpublished internal report (Document #638660), Wellington.

Perrie A and Cockeram B. 2010. *Annual freshwater quality monitoring report for the Wellington region, 2009/10.* Greater Wellington Regional Council, Publication No. GW/EMI-G-10/163, Wellington.

Perrie A and Milne J. 2012. *Lake water quality and ecology in the Wellington region: States and trends.* Greater Wellington Regional Council, Publication No. GW/EMI-T-12/139, Wellington.

Quinn J and Hickey, C. 1990. Characterisation and classification of benthic invertebrate communities in 88 New Zealand rivers in relation to environmental factors. *New Zealand Journal of Marine and Freshwater Research*, 24: 387–409.

Quinn J and Raaphorst E. 2009. *Trends in nuisance periphyton cover at New Zealand National River Water Quality Network sites 1990–2006*. Report No. HAM2008-194 prepared for Ministry for the Environment by NIWA, Hamilton.

Rowe D, Quinn J, Parkyn S, Collier K, Hatton C, Joy M, Maxted J and Moore S. 2006. *Stream ecological valuation (SEV): A method for scoring the ecological performance of Auckland streams and quantifying mitigation*. Auckland Regional Council, Technical Publication 302, Auckland.

Scarsbrook M. 2006. *State and trends in the National River Water Quality Network (1989–2005).* Ministry for the Environment, Report ME 778, Wellington.

Scarsbrook MR, Boothroyd IK and Quinn J. 2000. *New Zealand's National River Water Quality Network: Long-term trends in macroinvertebrate communities*. New Zealand Journal of Marine and Freshwater Research, 34: 289–302.

Scarsbrook MR, McBride CG, McBride GB and Bryers G. 2003. Effects of climate variability on rivers: Consequences for long-term water quality analysis. *Journal of the American Water Resources Association,* 39: 1,435–1,447.

Shivas S and Hosken A. 2012. *N & EE Reid annual monitoring report for Resource Consent WAR050090[24586 & 24587].* Unpublished report submitted to Greater Wellington Regional Council.

Snelder T, Biggs B and Weatherhead M. 2004. *New Zealand River Environment Classification User Guide*. Ministry for the Environment, Auckland.

Sorensen P. 2012. *Soil quality and stability in the Wellington region: State and trends.* Greater Wellington Regional Council, Publication No. GW/EMI-T-12/138, Wellington.

Sorensen PG and Milne JR. 2009. *Porirua Harbour targeted intertidal sediment quality assessment.* Greater Wellington Regional Council, Publication No. GW/EMI-T-09-136, Wellington.

Stansfield B, Davis MD, Jayaratne R, Milne J, Stevenson M, Stewart B, Shaw H, Willmott T and Meijer K. *Urban stormwater quality: National perspective on contaminant effects, quality and sources.* Paper presented to the Water New Zealand 2010 Stormwater Conference, Rotorua, 13–14 May 2010.

Stark JD. 1985. *A macroinvertebrate community index of water quality for stony streams*. Water & Soil Miscellaneous Publication 87. National Water and Soil Conservation Authority, Wellington.

Stark JD. 2010. *Determination of ecologically meaningful changes in QMCI*. Evidence presented to One Plan Hearing in officers report: End of Hearing Report relating to Water Quality, FARM Strategy, Water Allocation, Groundwater, and Beds of Rivers & Lakes. http://www.horizons.govt.nz/assets/new-uploads/about-us/one-plan/officer-reports/The-Water-Hearing/EOH-Staff-Report14042010.pdf. Horizons Regional Council.

Stark JD, Boothroyd IKG, Harding JS, Maxted JR and Scarsbrook MR. 2001. Protocols for sampling macroinvertebrates in wadeable streams. *New Zealand Macroinvertebrate Working Group Report No. 1*. Prepared for the Ministry for the Environment, Sustainable Management Fund Project No. 5103.

Stark JD and Maxted JR. 2007. *A user guide for the Macroinvertebrate Community Index*. Report No. 1166 prepared for the Ministry for the Environment by the Cawthron Institute, Nelson.

Storey R. 2010. *Aquatic ecosystem values of headwater streams in the Wellington region*. Report No. HAM2010-095 prepared for Greater Wellington Regional Council by NIWA, Hamilton.

Storey R and Wadwha S. 2009. *An assessment of the lengths of permanent, intermittent and ephemeral streams in the Auckland Region*. Auckland Regional Council, Technical Report No. 2009/028, Auckland.

Suren A and Elliott S. 2004. Impacts of urbanisation on streams. In Harding J, Mosley P, Pearson C and Sorrell B. (eds.) *Freshwaters of New Zealand*, pp. 35.1–35.17. Christchurch, New Zealand: New Zealand Hydrological Society Inc. and New Zealand Limnological Society Inc.

Thompson M and Gordon M. 2010a. *Flow estimation for RSoE sites for the period 2005–2010*. Unpublished internal report, Document #871079, Greater Wellington Regional Council, Wellington.

Thompson M and Gordon M. 2010b. *Periphyton accrual period estimates for RSoE sites*. Unpublished internal report, Document #870495, Greater Wellington Regional Council, Wellington.

Tidswell S, Conwell C and Milne JR. 2012. *Groundwater quality in the Wellington region: State and trends*. Greater Wellington Regional Council, Publication No. GW/EMI-T-12/140, Wellington.

USEPA. 2009. *National recommended water quality criteria*. United States Environmental Protection Agency, 21 p. + appendices (3 p.).

Warr S. 2002. *Rivers State of the Environment monitoring review*. Wellington Regional Council, Publication No. WRC/PRW-G-02/64, Wellington.

Wellington City Council. 2003. *Northern growth area – A framework for growth management*. Wellington City Council, Wellington.

Wellington Regional Council. 1995. *Regional Policy Statement for the Wellington region*. Wellington Regional Council, Publication No. WRC/RP-G-95/28, Wellington.

Wellington Regional Council. 1999. *Regional Freshwater Plan for the Wellington region.* Wellington Regional Council, Publication No. WRC/RP-G-99/31, Wellington.

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

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Appendix 1: Monitoring site details

Site no.	Site name	Site coordinates (NZTM)		Date started	Site type	Substrate	REC	% Landcover types (simplified) in upstream catchment (Source: MfE 2010)							Median hardness (mg/L)[3]	Routinely tested for dissolved metals
		Northing	Easting					Indigenous forest & scrub	Exotic forest	Horticulture	Pasture (high prod.)	Pasture (low prod.)	Urban	Other		
RS01	Mangapouri S at Rahui Rd[1]	5484901	1783373	Sep-2003	Impacted	Soft	WD/L/AI/P	0.0	0.0	0.3	40.7	57.5	1.6	0.0	26	No
RS02	Mangapouri S at Bennetts Rd	5487645	1780903	Sep-2003	Impacted	Soft	WD/L/AI/U[2]	2.3	0.0	3.7	25.4	25.7	42.8	0.0	42	Yes
RS03	Waitohu S at Forest Park	5483689	1787593	Sep-2003	Reference	Hard	CW/H/HS/IF	99.5	0.0	0.0	0.0	0.5	0.0	0.0	16	No
RS04	Waitohu S at Norfolk Cres.	5488304	1779537	Nov-1991	Impacted	Soft	CW/L/HS/P	36.7	4.4	1.4	28.6	20.4	6.8	1.6	33	No
RS05	Otaki R at Pukehinau	5478749	1785426	Sep-1991	Reference	Hard	CW/H/HS/IF	96.0	1.5	0.0	0.1	2.0	0.0	0.3	17.5	No
RS06	Otaki R at Mouth	5485886	1777983	Apr-1990	Impacted	Hard	CW/H/HS/IF	88.0	1.7	0.6	3.1	5.7	0.1	0.8	17.5	No
RS07	Mangaone S at Sims Rd Br	5482408	1776242	Jul-1997	Impacted	Soft	WW/L/AL/P	15.0	6.4	5.1	50.0	21.6	1.2	0.8	45	No
RS08	Ngarara S at Field Way	5474620	1771180	Apr-1990	Impacted	Soft	WW/L/AL/U[2]	21.6	5.1	0.1	23.5	29.0	17.2	3.5	76.5	Yes
RS09	Waikanae R at Mangaone Walkway	5473638	1779974	Sep-2003	Best available	Hard	CW/L/HS/IF	84.3	15.6	0.0	0.0	0.1	0.0	0.0	13	No
RS10	Waikanae R at Greenaway Rd	5472915	1771223	Sep-2003	Impacted	Hard	CW/L/HS/IF[2]	66.9	12.5	0.0	4.4	15.2	0.9	0.1	20	Yes
RS11	Whareroa S at Waterfall Rd	5464532	1768074	Sep-2003	Best available	Hard	WW/L/HS/IF[2]	51.3	26.6	0.0	9.8	12.3	0.0	0.0	38	No
RS12	Whareroa S at Queen Elizabeth Park	5464400	1765976	Sep-2003	Impacted	Soft	WW/L/HS/P	16.9	7.9	0.0	8.5	61.4	4.4	0.8	60.5	No
RS13	Horokiri S at Snodgrass	5450653	1761804	Sep-2003	Impacted	Hard	CW/L/HS/P	15.1	25.9	0.2	4.1	54.7	0.0	0.0	28	No
RS14	Pauatahanui S at Elmwood Br	5446783	1761097	Jul-1997	Impacted	Hard	CW/L/HS/P	17.1	12.9	0.0	31.4	37.3	1.3	0.0	27.5	No
RS15	Porirua S at Glenside	5438364	1753289	Mar-1988	Impacted	Hard	CW/L/HS/U	15.1	3.9	0.0	13.7	40.0	27.4	0.0	37.5	Yes
RS16	Porirua S at Wall Park (Milk Depot)	5443031	1754366	Aug-1987	Impacted	Hard	WW/L/HS/U	14.6	11.3	0.0	13.6	29.9	30.6	0.0	41	Yes
RS17	Makara S at Kennels	5433635	1743530	Jul-1987	Impacted	Hard	CW/L/HS/P	40.6	9.3	0.0	10.7	37.4	2.0	0.0	36	No
RS18	Karori S at Makara Peak Mt Bike Pk	5426874	1744213	Apr-1988	Impacted	Hard	CW/L/HS/U	45.7	0.6	0.0	0.0	2.4	50.7	0.6	33	Yes
RS19	Kaiwharawhara S at Ngaio Gorge	5431077	1749069	Jun-1987	Impacted	Hard	CW/L/HS/U	47.6	6.5	0.0	0.0	7.0	38.6	0.3	45.5	Yes
RS20	Hutt R at Te Marua Intake Site	5450158	1780071	May-1987	Impacted	Hard	CX/H/HS/IF	90.9	3.1	0.0	3.9	1.9	0.1	0.2	16	No
RS21	Hutt R opp. Manor Pk Golf Club	5442285	1766679	Jul-1997	Impacted	Hard	CW/H/HS/IF	72.6	11.7	0.0	5.0	6.3	4.2	0.3	20.5	Yes
RS22	Hutt R at Boulcott	5437486	1760858	Sep-2003	Impacted	Hard	CW/L/HS/IF	70.7	11.0	0.0	4.7	7.3	6.1	0.3	19	Yes
RS23	Pakuratahi R 50m below Farm Ck	5451677	1784607	Dec-1987	Impacted	Hard	CX/H/HS/IF	79.9	6.7	0.0	9.3	3.7	0.0	0.4	18	No
RS24	Mangaroa R at Te Marua	5448643	1778543	Sep-1987	Impacted	Hard	CW/L/HS/P	53.3	13.9	0.0	15.2	16.2	1.3	0.0	19.5	No
RS25	Akatarawa R at Hutt R confluence	5449184	1776183	Jul-1997	Impacted	Hard	CW/L/HS/IF	83.5	14.1	0.0	0.8	1.4	0.0	0.2	16	No
RS26	Whakatikei R at Riverstone	5446748	1772256	Sep-2003	Impacted	Hard	CW/L/HS/S	67.7	23.3	0.0	1.7	7.2	0.1	0.1	18.5	No
RS27	Waiwhetu S at Wainuiomata Hill Br[1]	5434141	1760565	Jun-1987	Impacted	Soft	WW/L/HS/U	41.4	0.1	0.0	0.0	5.0	53.5	0.0	50.5	Yes
RS28	Wainuiomata R at Manuka Track	5430634	1768242	Jun-1987	Reference	Hard	CW/L/HS/IF	99.9	0.0	0.0	0.0	0.0	0.0	0.0	15.5	No
RS29	Wainuiomata R u/s of White Br	5415724	1757316	Jul-1997	Impacted	Hard	CW/L/HS/IF	79.6	3.7	0.0	2.9	7.5	6.2	0.1	21	No
RS30	Orongorongo R at Orongorongo Stn	5413095	1758930	Apr-1988	Impacted	Hard	CW/H/HS/IF	95.0	0.2	0.0	0.0	4.1	0.0	0.7	32.5	No
RS31	Ruamahanga R at McLays	5485809	1818149	Sep-2003	Reference	Hard	CX/H/HS/S	99.8	0.0	0.0	0.0	0.0	0.0	0.2	15	No
RS32	Ruamahanga R at Te Ore Ore	5463019	1825574	Feb-1997	Impacted	Hard	CW/L/SS/P	24.4	2.3	0.1	34.6	36.9	1.0	0.7	50	No
RS33	Ruamahanga R at Gladstone Br	5450327	1821208	Feb-1997	Impacted	Hard	CW/L/SS/P	18.5	7.0	0.7	34.2	38.0	1.1	0.6	37	No
RS34	Ruamahanga R at Pukio	5431010	1797832	Sep-2003	Impacted	Hard	CW/L/SS/P	22.8	4.9	1.1	37.4	32.3	0.8	0.6	41	No
RS35	Mataikona trib. at Sugar Loaf Rd	5490906	1871844	Sep-2003	Best available	Hard	CW/L/SS/IF[2]	50.5	39.2	0.0	0.0	10.3	0.0	0.0	150	No
RS36	Taueru R at Castlehill	5484198	1852300	Sep-2003	Best available	Soft	CW/L/SS/P	29.6	16.4	0.0	12.9	41.1	0.0	0.1	68.5	No
RS37	Taueru R at Gladstone	5450815	1824148	Feb-1997	Impacted	Hard	CD/L/SS/P	4.4	15.2	0.0	29.0	51.2	0.0	0.2	140	No
RS38	Kopuaranga R at Stewarts	5469569	1826761	Feb-1997	Impacted	Hard	CW/L/SS/P	1.3	2.7	0.0	44.4	51.5	0.0	0.1	140	No
RS39	Whangaehu R at 250m from conf.	5459407	1826267	Feb-1997	Impacted	Soft	CD/L/SS/P	1.6	4.7	1.6	48.1	43.8	0.0	0.2	97	No
RS40	Waipoua R at Colombo Rd Br	5462890	1825018	Feb-1997	Impacted	Hard	CW/L/HS/P	22.7	0.5	1.3	47.7	24.1	3.3	0.3	30.5	No
RS41	Waingawa R at South Rd	5460649	1820716	Nov-1991	Impacted	Hard	CX/H/HS/IF	75.7	1.7	0.1	5.7	15.4	0.4	1.0	19	No
RS42	Whareama R at Gauge	5461229	1856090	Sep-2003	Impacted	Soft	WW/L/SS/P	7.8	21.3	0.0	23.6	47.2	0.0	0.2	165	No
RS43	Motuwaireka S at Headwaters	5450302	1852018	Sep-2003	Best available	Hard	CW/L/HS/S	68.6	31.4	0.0	0.0	0.0	0.0	0.0	80	No
RS44	Totara S at Stronvar	5444916	1848025	Sep-2003	Best available	Hard	CW/L/HS/EF	1.7	96.6	0.0	0.0	1.7	0.0	0.0	101.5	No
RS45	Parkvale Trib. at Lowes Reserve	5458352	1818094	Sep-2003	Best available	Hard	WD/L/AI/P	28.2	0.0	0.0	56.6	15.1	0.0	0.0	40	No
RS46	Parkvale S at Weir	5449469	1813515	Sep-2003	Impacted	Hard	WD/L/AI/P	0.9	0.6	0.0	69.7	28.8	0.0	0.1	39.5	No
RS47	Waiohine R at Gorge	5455995	1801889	Nov-1991	Reference	Hard	CX/H/HS/IF	98.5	0.6	0.0	0.0	0.5	0.0	0.4	15.5	No
RS48	Waiohine R at Bicknells	5448099	1810615	Nov-1991	Impacted	Hard	CW/H/HS/P	66.0	2.3	0.4	22.7	7.2	0.7	0.6	19	No
RS49	Beef Ck at Headwaters	5456398	1803963	Sep-2003	Reference	Hard	CW/L/HS/S	99.3	0.0	0.0	0.0	0.7	0.0	0.0	21.5	No
RS50	Mangatarere S at SH 2	5452160	1809768	Feb-1997	Impacted	Hard	CW/L/HS/P	45.2	5.1	0.0	32.6	16.1	1.0	0.0	30.5	No
RS51	Huangarua R at Ponatahi Br	5435213	1807009	Feb-1997	Impacted	Hard	CD/L/SS/P	16.6	3.3	1.3	30.7	47.9	0.0	0.2	135	No
RS52	Tauanui R at Whakatomotomo Rd	5414515	1790648	Sep-2003	Reference	Hard	CW/H/HS/IF	100.0	0.0	0.0	0.0	0.0	0.0	0.0	32	No
RS53	Awhea R at Tora Rd	5403289	1809951	Sep-2003	Impacted	Hard	WW/L/SS/P	25.1	10.6	0.0	10.0	54.2	0.0	0.2	135	No
RS54	Coles Ck trib. at Lagoon Hill Rd	5415217	1814020	Sep-2003	Best available	Hard	WW/L/SS/S	93.1	6.9	0.0	0.0	0.0	0.0	0.0	104	No
RS55	Tauherenikau R at Websters	5439942	1797082	Nov-1991	Impacted	Hard	CW/H/HS/P[2]	72.3	0.1	0.1	20.6	6.0	0.2	0.8	18.5	No
RS56	Waiorongomai R at Forest Park	5430559	1779604	Sep-2003	Reference	Hard	CW/H/HS/IF	100.0	0.0	0.0	0.0	0.0	0.0	0.0	25.5	No
RS57	Waiwhetu S at Whites Line East	5434510	1760977	Jul-2011	Impacted	Soft	WW/L/HS/U	42.2	0.1	0.0	0.0	5.4	52.3	0.0	–	Yes

[1] No longer monitored (see Section 2.3).

[2] REC landcover class was changed to reflect more up-to-date catchment scale landcover information from MfE (2010).

[3] From Perrie (2009), total hardness calculated from monthly sampling between January and December 2008.

Appendix 2: River Environmental Classification (REC)

As outlined in Section 2.1, rivers and streams in the Wellington region are diverse and some may have differing water quality simply due to their size, climate and underlying geology rather than due to human-induced impacts. To reduce this bias, comparisons between RSoE sites are undertaken using the River Environment Classification (REC). REC characterises river environments at six hierarchical levels, corresponding to a controlling environmental factor (Snelder et al. 2003). The factors, in order from the largest spatial scale to the smallest, are climate, source-of-flow, geology, landcover, network position and valley landform. The first four REC factors are explained in Table A2.1. See Appendix 1 for the REC description for each RSoE site.

Table A2.1: REC classification levels, classes, mapping characteristics and criteria used to assign river segments to REC classes (after Snelder et al. 2003)

Classification level and scale	Classes and notation	Mapping characteristics	Class assignment criteria
Climate (10^3 – 10^4 km^2)	Warm extremely wet (WX) Warm wet (WW) Warm dry (WD) Cool extremely wet (CX) Cool wet (CW) Cool dry (DC)	Mean annual precipitation, mean annual potential evapotranspiration, mean annual temperature.	*Warm:* mean annual temperature ≥ 12˚C *Cool:* mean annual temperature <12˚C *Extremely wet*: mean annual effective precipitation ≥ 1,500 mm *Wet*: mean annual effective precipitation >500 mm and <1,500 mm *Dry:* mean annual effective precipitation ≤ 500 mm
Source of flow (10^2 – 10^3 km^2)	Mountain (M) Hill (H) Low elevation (L) Lake (Lk)	Catchment rainfall volume in elevation categories, lake influence index.	*M:* >50% annual precipitation volume >1,000 m ASL *H:* 50% precipitation volume 400 to 1,000 m ASL *L:* >50% rainfall <400 m ASL *Lk:* Lake influence index >0.033
Geology (10 – 10^2 km^2)	Alluvium (Al) Hard sedimentary (HS) Soft sedimentary (SS) Volcanic basic (VB) Volcanic acidic (VA) Plutonic (Pl) Miscellaneous (M)	Proportions of each geological category in section catchment.	Class = spatially dominant geology category unless combined soft sedimentary geological categories exceed 25% of catchment area, in which case class = SS.
Landcover* (10 km^2)	Bare (B) Indigenous forest (IF) Pastoral (P) Tussock (T) Scrub (S) Exotic forest (EF) Wetland (W) Urban (U)	Proportions of each landcover category in section catchment.	Class = spatially dominant landcover category unless pastoral exceeds 25% of catchment area, in which case class = P, or unless urban exceeds 15% of catchment area, in which case class = U.

* It is important to note that landcover types that are not classified as dominant using the REC criteria may still significant affect river and stream water quality and ecology. Further, in many cases, the current 'condition', as measured at each RSoE site, is the result of the cumulative impacts of all landcover types and associated activities in the upstream catchment.

Appendix 3: Monitoring variables and methods

Core variables

Table A3.1 lists the core water quality and biological variables currently examined in the RSoE programme and provides a brief explanation of their relevance from a surface water quality perspective.

Table A3.1: Key water quality and biological variables examined in the RSoE programme

Variable	Explanation/relevance
Water temperature	• Indicator of biological activity – temperature affects the functioning of aquatic ecosystems and the physiology of biota, including cell function, enzyme activity, bacteriological reproduction rates, and plant growth rates. • Requirement for aquatic life (eg, temperatures >19°C can stress trout). • Influences dissolved oxygen concentrations (the higher the temperature, the lower the oxygen concentration) and can affect the toxicity of certain pollutants such as ammonia.
Dissolved oxygen (DO)	• Essential for aquatic life – concentrations less than 5 mg/L adversely affect trout and concentrations of 2–3 mg/L may result in fish kills. • Indicator of organic pollution (eg, sewage) – DO concentrations are reduced as bacteria require oxygen to break organic matter down. • Indicator of photosynthesis (plant growth).
pH	• Protection of aquatic life – particularly high (alkaline) or low (acidic) pH levels may adversely impact on aquatic biota. Alkaline conditions may also increase the toxicity of certain pollutants such as ammonia. • Indicator of industrial discharges.
Conductivity	• Indicator of total salts/mineral content – the lower the value, the purer the water is. Wastewater/effluents therefore have higher concentrations of minerals than natural water and a large increase in the conductivity in a water body can often be traced back to wastewater discharges. However, considerable natural variation exists and some rivers and streams may have naturally elevated conductivity concentrations.
Visual clarity, turbidity and suspended solids	• Aesthetic appearance. • Aquatic life protection – differences in water clarity affect the ability of sight-feeding predators (e.g., fish, birds) to locate prey and the ability of algae to photosynthesise and hence provide food for animals further up the food chain. • Indicator of light availability for excessive plant growth. • Indicator of catchment condition, land use. • Suspended sediment in the water column can clog the gills of invertebrates and fish. • Excessive deposition of sediment on the streambed can block and seal off interstitial spaces (the spaces between cobbles/stones where most fauna live or rest), reduce water flow to the hyporheic zone (water under the streambed) where some stream animals live, degrade fish spawning habitat and encourage the growth of nuisance aquatic plants.
Total organic carbon	• Indicator of organic carbon content of a water body – provides a quick and convenient way of determining the degree of organic contamination (e.g., as a result of wastewater discharges).

Variable	Explanation/relevance
Nutrients - Nitrogen - Phosphorus	• Vital elements for aquatic plant and algal growth – may be limiting factors in plant growth when in short supply but in sufficient quantities they may also promote unsightly algal blooms and nuisance plant growth. Dissolved inorganic nutrient concentrations (ammoniacal nitrogen, nitrite-nitrate nitrogen and dissolved reactive phosphorus) are most relevant for predicting the potential for nuisance plant growth as they are the principal forms available to plants (ie, soluble). Total nutrient concentrations are also relevant in surface waters, because particulate matter can settle out in quiescent areas and become biologically available to plants via mineralisation. • Nitrate, in sufficient concentrations, is harmful to livestock and humans, and toxic to aquatic life. • Ammoniacal nitrogen comprises ammonium (NH_{4+}) and unionised ammonia (NH_3). Ammonia is rarely found in any significant amounts in natural waters and its presence most commonly indicates the presence of domestic, agricultural or industrial effluent. Ammonia is very soluble in water and can be toxic to aquatic life, especially fish. Toxicity is a function of both temperature and pH, with toxicity increasing with increasing water temperature and alkalinity.
E. coli	• Indicator of pollution with faecal matter, useful for determining the suitability of waters for contact recreation and stock drinking – presence in water may indicate the presence of harmful pathogens that can cause eye, ear, nose and throat infections, skin diseases, and gastrointestinal disorders – a number of parasites and pathogens can also be transmitted by contaminated water to livestock and affect their health. • *E. coli* is the most specific indicator of faecal contamination and is nearly always found in high numbers in the gut of humans and warm blooded animals. *E. coli* is the preferred microbiological indicator for faecal contamination and health effects in fresh waters.
Heavy metals	• Natural elements of which some (eg, copper and zinc) are essential for metabolism. Can be toxic to aquatic life at higher concentrations and tend to bioaccumulate. Toxicity can vary depending on many factors, including water temperature, pH and hardness.
Periphyton	• Periphyton is the slimy material attached to the surfaces of rocks and other bottom substrate in rivers and streams. It comprises algae, diatoms, bacteria, and fungi and plays a key role in aquatic food webs because it is the main source of food for benthic invertebrates, which in turn are an important food source for fish. • Excessive periphyton growths may block intake screens for water supply, and reduce the aesthetic, recreational and ecosystem values of rivers and streams.
Macroinvertebrates	• Macroinvertebrates are organisms that lack a backbone and are larger than 250 microns in size. Four major groups of macroinvertebrates exist: *insects* such as mayflies, caddisflies and dragonflies; *molluscs* such as snails and mussels; *crustaceans* such as freshwater shrimps and amphipods; and *oligochaetes*, aquatic worm species that live in muddy streambeds. • Different macroinvertebrate species have different tolerances to environmental factors such as dissolved oxygen, nutrients and fine sediment, such that the presence or absence of different species in an environment may indicate changes in water quality. • Macroinvertebrates indicate long-term water quality conditions compared with spot physico-chemical samples which only represent water quality at time of sampling.

Water quality

Variables measured/analysed at each RSoE site are presented in Table A3.2. As far as practicable, individual RSoE monitoring sites are sampled at the same time of the month (and usually at the same time of the day) throughout the year[36], and where possible all sites on a river or stream are sampled on the same day. Water samples are collected in mid stream (where possible), typically in run-type habitat from a representative reach of stream. Samples requiring laboratory analysis are placed in chillibins with ice and couriered overnight to RJ Hill Laboratories in Hamilton. Field meters are calibrated on the morning of the day of sampling.

Table A3.2: Current field and analytical water quality methods and detection limits

Variable	Method	Detection limit
Water temperature	Field Meter – generally YSI 550A and YSI 556 meters	0.01 ºC
Dissolved oxygen	Field Meter – generally YSI 550A and YSI 556 meters	0.01 mg/L
Visual clarity	Black disc (20 mm disc if clarity <0.5 m, 60 mm disc for clarity between 0.5 m and 1.5 m, 200 mm disc for clarity >1.5 m)	0.01 m
pH	Field Meter – generally YSI 550A and YSI 556 meters	0.01 units
Conductivity	Field Meter – generally YSI 550A and YSI 556 meters	0.1 uS/cm
Turbidity	Analysis using a Hach 2100N, Turbidity meter. APHA 2130 B 21st ed. 2005	0.05 NTU
Total suspended solids	Gravimetric. APHA 2540 D 21st ed. 2005	2 mg/L
Total organic carbon	Catalytic oxidation, IR detection, for Total C. Acidification, purging for Total Inorganic C. TOC = TC – TIC. APHA5310 B 21st ed. 2005	0.5 mg/L
Ammoniacal nitrogen	Filtered sample. Phenol/hyperclorite colorimetry. Discrete Analyser. (NH4-N = NH_4+-N + NH_3-N) APHA 4500-NH_3 F (modified from manual analysis) 21st ed. 2005	0.001 mg/L
Nitrite	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I (proposed) 21st ed. 2005	0.002 mg/L
Nitrate	Calculation: (Nitrate-N + Nitrite-N) – Nitrite-N	0.002 mg/L
Nitrate + nitrite nitrogen	Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO_3^- I (Proposed) 21st ed. 2005	0.002 mg/L
Total Kjeldahl nitrogen	Kjeldahl digestion, phenol/hyperclorite colorimetry (Discrete Analysis). APHA 4500-N Org C. (modified) 4500-NH_3 F (modified) 21st ed. 2005	0.1 mg/L
Total nitrogen	Calculation: TKN + Nitrate-N +Nitrite-N	0.1 mg/L
Total phosphorus	Total Phosphorus digestion, ascorbic acid colorimetry. Discrete Analyser. APHA 4500-P E (modified from manual analysis) 21st ed. 2005	0.004 mg/L
Dissolved reactive phosphorus	Filtered sample. Molybdenum blue colorimetry. Discrete Analyser. APHA 4500-P E (modified from manual analysis) 21st ed. 2005	0.004 mg/L
Faecal coliforms	APHA 21st ed. Method 9222D	1 cfu/100mL
E. coli	APHA 21st ed. Method 9222G	1 cfu/100mL
Dissolved copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005	0.0005 mg/L
Dissolved lead	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005	0.0001 mg/L
Dissolved zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005	0.0010 mg/L

[36] Some variation has occurred as a result of changes in sampling rounds/personnel.

Periphyton

Formal periphyton assessments are limited to the 46 RSoE sites with hard substrates.

Monthly assessment of visible streambed cover

Periphyton cover is determined by estimating the percentage of visible mats (>0.3 cm thick) and filaments (>2 cm long) present on the stream or river bed within a 20 cm diameter metal ring. Ten observations are made across the width of the stream or river, along a transect. If the stream or river is not wide enough for 10 observations, five observations are made across the width of the waterway in two locations at the site. Two transects of five observations (usually to 0.6 m depth) are also used where it is not possible to wade across more than half of the river's width.

Visible streambed assessments are typically carried out in a run, as opposed to riffle or pool-type habitats.

Annual assessment of biomass

Periphyton samples for quantitative biomass assessments (chlorophyll *a* and Ash Free Dry Matter) are collected over late summer/early months at the time of macroinvertebrate sample collection. Sampling protocols follow a modified version of quantitative method 1a (QM-1a), as outlined by Biggs and Kilroy (2000) that involves pooling periphyton samples from 10 rocks into a single composite sample for analysis.

Biomass assessments are carried out on periphyton samples collected in riffle-type habitats in close proximity to macroinvertebrate sampling sites.

Macroinvertebrates

Macroinvertebrate samples (3 replicate samples in years 2004 to 2009 and one thereafter) are collected at or adjacent to each RSoE water sampling site over late summer/early autumn months. The timing of sampling is determined at random, although macroinvertebrate sampling is, where practicable, avoided within two weeks of any flood event (flood events are defined as flows greater than three times the median river flow).

Samples are collected with the use of a kick-net (0.5 mm mesh size) following Protocol C1 of the national macroinvertebrate sampling protocols (Stark et al. 2001) for the 46 RSoE sites with hard substrate (in riffle habitat) and Protocol C2 for the nine RSoE sites with a soft substrate. All samples are processed in accordance with protocol P2 (Stark et al. 2001).

Calculation of Biotic Indices: MCI, QMCI, %EPT taxa and %EPT individuals

Macroinvertebrate Community Index (MCI) values were developed by Stark (1985) for assessing organic enrichment of stony or hard-bottomed streams based on sampling macroinvertebrates from riffle (preferably) or run habitats. The MCI relies on prior allocation of scores (between 1 and 10) to macroinvertebrate taxa (usually genera) based on their tolerance of organic enrichment (the most recent tolerance scores can be found in Stark and Maxted 2007). Taxa that are characteristic of unenriched conditions score more highly than taxa found in polluted conditions. The MCI is calculated as follows:

$$\text{MCI} = \frac{\sum_{i=1}^{i=S} a_i}{S} \text{ x } 20$$

where S = the total number of taxa in the sample, and a_i is the tolerance score for the ith taxon. MCI scores range from 0 (when no taxa are present) to 200 (when all taxa score 10 points each) although scores < 40 or > 150 are rare.

The QMCI is calculated from fixed count data as follows:

$$\text{QMCI} = \sum_{i=1}^{i=S} \frac{(n_i \times a_i)}{N}$$

where S = the total number of taxa in the sample, n_i is the abundance for the ith scoring taxon, a_i is the score for the i^{th} taxon and N is the total fixed count for the sample. QMCI scores range from 0 to 10.

The percentage of pollution sensitive Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly) (%EPT) taxa is calculated by dividing the number of EPT taxa by the total number of taxa identified in the sample. Similarly, the percentage of EPT individuals is calculated by dividing the number of EPT individuals by the total macroinvertebrate count for the sample. Both %EPT taxa and %EPT individuals calculations exclude the caddisfly taxa *Oxyethira* and *Paroxyethira* as they are known to be relatively insensitive to pollution.

Habitat assessments

In 2008, qualitative habitat assessments following methods outlined in Rowe et al. (2006) were undertaken at the same time as macroinvertebrate sampling at all RSoE sites. This assessment involved allocating a score to various instream and riparian habitat characteristics, including aquatic habitat abundance and diversity, hydrologic heterogeneity, channel shade, and the integrity of the riparian margin. These scores are summed to provide an overall habitat score and can range from 0 (lowest) to 140 (highest).

Streambed substrate size assessments and index

River and streambed substrate size is assessed annually (during macroinvertebrate sampling), at all RSoE sites using the Wentworth Scale which assigns substrate to the following categories: bedrock, boulder, cobble, pebble, gravel, sand and silt (see Harding et al. (2009) for further details on the size of each substrate type). For each site, a substrate index is calculated using the equation outlined in Harding et al. (2009).

Appendix 4: Availability of flow data at RSoE sites

Summary of availability of flow data (actual and estimated) at RSoE sites (after Thompson & Gordon 2010a). An indication of the level of confidence in the accuracy of sites where flow is based on estimates is also indicated

Site No.	Site name	Flow data available (confidence in estimate)
RS02	Mangapouri Stream at Bennetts Rd	No
RS03	Waitohu Stream at Forest Park	Estimate (high)
RS04	Waitohu Stream at Norfolk Crescent	Estimate (moderate)
RS05	Otaki River at Pukehinau	Actual (high)
RS06	Otaki River at Mouth	Estimate (moderate)
RS07	Mangaone Stream at Sims Road Bridge	Estimate (moderate)
RS08	Ngarara Stream at Field Way	No
RS09	Waikanae River at Mangaone Walkway	Estimate (moderate)
RS10	Waikanae River at Greenaway Rd	No
RS11	Whareroa Stream at Waterfall Rd	Estimate (low)
RS12	Whareroa Stream at QE Park	Estimate (low)
RS13	Horokiri Stream at Snodgrass	Actual (high)
RS14	Pauatahanui Stream at Elmwood Bridge	Estimate (high)
RS15	Porirua Stream at Glenside	Estimate (high)
RS16	Porirua Stream at Wall Park (Milk Station)	Estimate (moderate)
RS17	Makara Stream at Kennels	Estimate (moderate)
RS18	Karori Stream at Makara Peak Mountain Bike Park	Estimate (moderate)
RS19	Kaiwharawhara Stream at Ngaio Gorge	Estimate (moderate)
RS20	Hutt River at Te Marua Intake Site	Actual (high)
RS21	Hutt River Opposite Manor Park Golf Club	Estimate (high)
RS22	Hutt River at Boulcott	Estimate (high)
RS23	Pakuratahi River 50 m below Farm Creek	Estimate (moderate)
RS24	Mangaroa River at Te Marua	Actual (high)
RS25	Akatarawa River at Hutt R confluence	Actual (high)
RS26	Whakatiki River at Riverstone	Estimate (moderate)
RS27	Waiwhetu Stream at Wainuiomata Hill Bridge	Estimate (High)
RS28	Wainuiomata River at Manuka Track	Actual (high)
RS29	Wainuiomata River u/s of White Bridge	Estimate (moderate)
RS30	Orongorongo River at Orongorongo Station	Estimate (moderate)
RS31	Ruamahanga River at McLays	Estimate (high)
RS32	Ruamahanga River at Te Ore Ore	Estimate (moderate)
RS33	Ruamahanga River at Gladstone Bridge	Estimate (moderate)
RS34	Ruamahanga River at Pukio	Estimate (high)
RS35	Mataikona tributary at Sugar Loaf Rd	No
RS36	Taueru River at Castlehill	Estimate (moderate)
RS37	Taueru River at Gladstone	No
RS38	Kopuaranga Stream at Stewarts	Estimate (moderate)
RS39	Whangaehu River at 250 m from confluence	No
RS40	Waipoua River at Colombo Rd Bridge	Estimate (moderate)
RS41	Waingawa River at South Rd	Estimate (moderate)
RS42	Whareama River at Gauge	Actual (high)
RS43	Motuwaireka Stream at Headwaters	Estimate (moderate)
RS44	Totara Stream at Stronvar	Estimate (moderate)
RS45	Parkvale tributary at Lowes Reserve	No
RS46	Parkvale Stream at weir	Actual (high)
RS47	Waiohine River at Gorge	Actual (high)
RS48	Waiohine River at Bicknells	Estimate (high)
RS49	Beef Creek at headwaters	No
RS50	Mangatarere Stream at SH 2	Estimate (moderate)
RS51	Huangarua River at Ponatahi Bridge	No
RS52	Tauanui River at Whakatomotomo Rd	Estimate (moderate)
RS53	Awhea River at Tora Rd	No
RS54	Coles Creek tributary at Lagoon Hill Rd	No
RS55	Tauherenikau River at Websters	Estimate (high)
RS56	Waiorongomai River at Forest Park	Estimate (moderate)

Appendix 5: Water quality indices

Greater Wellington's WQI

Greater Wellington's WQI was first presented in Milne and Perrie (2005), derived from the median values of the following six variables: visual clarity (black disc), dissolved oxygen (DO, as % saturation), dissolved reactive phosphorus (DRP), ammoniacal nitrogen (Amm N), nitrate nitrogen and faecal coliforms (see Milne and Perrie (2005) for the rationale behind the selection of these six variables). The WQI used in subsequent reports, including this report, differs slightly in that nitrite-nitrate nitrogen (NNN) and *E. coli* are used in place of nitrate nitrogen and faecal coliforms, respectively. These changes relate to changes in RSoE analytes and have little material effect on the WQI; nitrite nitrogen concentrations are usually below detection in surface waters while *E. coli* counts are generally similar to (or a little lower than) faecal coliform counts.

Greater Wellington's WQI is for comparative purposes rather than an absolute measure of water quality. Because the WQI is based on median values (ie, 50 % compliance), sites awarded the same water quality grade may exhibit varying degrees of compliance (from 51 to 100%) with the different guideline values. Therefore to differentiate between sites within a water quality class, in this report sites within each WQI grade were ranked according to the sum of guideline compliance across all six water quality variables (eg, an 'excellent' site that complied with DO%, visual clarity, DRP, Amm N, NNN and *E. coli* guidelines on 90%, 80%, 90%, 90%, 70% and 75% of sampling occasions (respectively) had an overall compliance 'score' of 495 and so ranked higher than an 'excellent' site with an overall compliance score of 482).

Canadian WQI

As noted in Section 4.1.1(a), the Canadian WQI was also trialled in this report. The opportunity was taken at this time to revisit Greater Wellington's existing suite of WQI variables (see Table 4.1). This led to the addition of water temperature into the index and a re-arrangement of the nitrogen species, with both dissolved inorganic nitrogen and nitrate toxicity incorporated into the index. In addition, the threshold for *E. coli* was amended from 100 cfu/100mL to 550 cfu/100mL; as noted in Section 4.1.1, 100 cfu/100mL is considered a conservative threshold for stock drinking water.

Information on the calculations behind the Canadian WQI is outlined below, drawn on material from CCME (2001). Because Greater Wellington's WQI was used in this report for the formal assignment of a water quality grade to each RSoE site, the index scores generated from the Canadian WQI were only interpreted through assignment of RSoE sites into quartiles (see Section 4.1.13). Further work is needed to determine the thresholds for grades of 'excellent', 'good', 'fair' and 'poor' using the Canadian WQI.

The Canadian WQI is based on three elements:

- *Scope*: the number of variables that do not meet the assigned compliance thresholds (known as the *objectives*) on at least one sampling occasion.
- *Frequency*: the frequency with which individual sample results fail to meet the assigned compliance thresholds.

- *Magnitude*: the amount by which individual sample results fail to meet the assigned compliance thresholds.

Calculation of water quality indices:

F_1 (Scope) represents the percentage of variables that do not meet their objectives at least once during the time period under consideration ('failed variables'), relative to the total number of variables measured:

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

F_2 (Frequency) represents the percentage of individual tests that do not meet objectives ('failed tests'):

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

F_3 (Magnitude) represents the amount by which 'failed' test values do not meet objectives. F_3 is calculated in three steps.

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:

$$\text{excursions}_i = \left(\frac{\text{Failed test value}_i}{\text{Objective}_j} \right) - 1$$

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

$$\text{excursions}_i = \left(\frac{\text{Objective}_j}{\text{Failed test value}_i} \right) - 1$$

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 normalised sum of excursions, or *nse*, is calculated as:

$$nse = \frac{\sum_{i=1}^{n} \text{excursions}_i}{\#\text{ of tests}}$$

iii) F_3 is then calculated by an asymptotic function that scales the normalised sum of the excursions from objectives (*nse*) to yield a range between 0 and 100.

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

Once the factors have been obtained, the index itself can be calculated by summing the three factors as if they were vectors. The sum of the squares of each factor is therefore equal to the square of the index. This approach treats the index as a three-dimensional space defined by each factor along one axis. With this model, the index changes in direct proportion to changes in all three factors.

The CCME Water Quality Index (CCME WQI):

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

The divisor 1.732 normalises the resultant values to a range between 0 and 100, where 0 represents the ‘worst’ water quality and 100 represents the ‘best’ water quality.

Appendix 6: Supplementary water quality state data

Summary of selected water quality data for 55 RSoE sites sampled monthly between July 2008 and June 2011. Note that 1.7 mg/L nitrate nitrogen is the chronic aquatic toxicity TV recommended by Hickey and Martin (2009)

Site No.	Site name	Dissolved oxygen (mg/L)				Nitrate nitrogen (mg/L)					Total Kjeldahl nitrogen (mg/L)			
		Median	Min	Max	*n*	Median	Min	Max	*n*	%*n*>1.7	Median	Min	Max	*n*
RS02	Mangapouri S at Bennetts Rd	7.2	3.0	11.1	35	2.450	0.590	3.900	36	69.4	0.525	0.260	1.040	36
RS03	Waitohu S at Forest Pk	11.1	9.7	14.8	34	0.023	0.001	0.066	35	0	0.050	0.050	0.440	35
RS04	Waitohu S at Norfolk Cres	9.1	6.8	13.9	35	0.500	0.057	1.300	36	0	0.315	0.210	0.510	36
RS05	Otaki R at Pukehinau	11.3	9.2	14.5	35	0.033	0.001	2.800	36	2.8	0.050	0.050	0.230	36
RS06	Otaki R at Mouth	11.1	8.7	14.1	35	0.046	0.001	0.130	36	0	0.050	0.050	0.150	36
RS07	Mangaone S at Sims Rd Br	8.3	4.6	10.9	35	1.910	0.530	3.900	36	66.7	0.505	0.340	0.930	36
RS08	Ngarara S at Field Way	5.8	0.8	8.4	35	0.108	0.001	8.800	36	2.8	0.780	0.140	1.400	36
RS09	Waikanae R at Mangaone Walkway	11.0	9.1	12.5	35	0.099	0.031	0.173	36	0	0.050	0.050	0.260	36
RS10	Waikanae R at Greenaway Rd	10.4	8.8	12.7	35	0.205	0.031	0.860	36	0	0.050	0.050	0.750	36
RS11	Whareroa S at Waterfall Rd	10.5	7.8	12.9	35	0.335	0.120	0.850	36	0	0.205	0.100	0.890	36
RS12	Whareroa S at QE Park	7.7	3.3	10.5	35	0.365	0.058	1.500	36	0	0.655	0.330	1.360	36
RS13	Horokiri S at Snodgrass	11.3	9.1	13.3	35	0.370	0.007	1.100	36	0	0.160	0.050	0.400	36
RS14	Pauatahanui S at Elmwood Br	10.6	7.1	13.6	35	0.210	0.001	0.900	36	0	0.230	0.050	0.810	36
RS15	Porirua S at Glenside	11.9	9.1	14.1	35	0.965	0.290	2.200	36	8.3	0.245	0.110	1.450	36
RS16	Porirua S at Wall Park (Milk Depot)	11.5	9.2	14.0	35	0.950	0.330	4.400	36	11.1	0.270	0.140	1.100	36
RS17	Makara S at Kennels	10.7	8.5	13.9	35	0.285	0.004	1.400	36	0	0.290	0.130	1.570	36
RS18	Karori S at Makara Peak	11.1	8.6	12.6	35	1.280	0.350	4.300	36	5.6	0.210	0.146	0.640	36
RS19	Kaiwharawhara S at Ngaio Gorge	11.1	8.9	12.7	35	1.100	0.001	2.300	36	2.8	0.265	0.160	0.520	36
RS20	Hutt R at Te Marua Intake Site	11.3	9.5	13.3	35	0.081	0.025	0.154	36	0	0.050	0.050	0.210	36
RS21	Hutt R opp. Manor Park G.C.	10.6	8.3	13.1	35	0.210	0.049	0.890	36	0	0.115	0.050	0.480	36
RS22	Hutt R at Boulcott	10.6	8.1	12.9	35	0.175	0.044	1.500	36	0	0.050	0.050	0.420	36
RS23	Pakuratahi R 50m d/s Farm Ck	10.8	9.3	13.4	35	0.225	0.076	0.410	36	0	0.050	0.050	0.350	36
RS24	Mangaroa R at Te Marua	10.8	9.6	12.5	34	0.465	0.250	0.800	36	0	0.170	0.050	0.840	36
RS25	Akatarawa R at Hutt R confl.	10.8	9.6	13.0	35	0.090	0.002	0.480	36	0	0.050	0.050	0.260	36
RS26	Whakatikei R at Riverstone	11.0	9.6	12.6	35	0.077	0.016	0.310	36	0	0.050	0.050	0.190	36
RS27	Waiwhetu S at Wainui Hill Br	8.5	4.3	14.4	35	0.455	0.075	1.100	36	0	0.285	0.050	0.830	36
RS28	Wainuiomata R at Manuka Track	11.4	9.5	12.6	34	0.069	0.006	0.230	35	0	0.050	0.050	0.380	35
RS29	Wainuiomata R u/s of White Br	11.0	7.9	12.9	35	0.205	0.001	0.610	36	0	0.120	0.050	0.740	36
RS30	Orongorongo R at Orongorongo Stn	10.4	6.4	12.4	35	0.037	0.001	0.079	36	0	0.050	0.050	1.380	36
RS31	Ruamahanga R at McLays	10.9	8.4	105.0	35	0.022	0.001	0.045	36	0	0.050	0.050	0.190	36
RS32	Ruamahanga R at Te Ore Ore	10.1	8.3	12.4	35	0.355	0.013	0.940	36	0	0.145	0.050	0.720	36
RS33	Ruamahanga R at Gladstone Br	10.1	8.1	14.5	35	0.385	0.022	0.970	36	0	0.175	0.050	0.780	36
RS34	Ruamahanga R at Pukio	10.1	7.3	12.0	35	0.345	0.001	0.930	36	0	0.195	0.050	1.600	36
RS35	Mataikona Trib at Sugar Loaf Rd	10.9	8.6	12.9	35	0.014	0.001	0.179	36	0	0.125	0.050	1.850	36
RS36	Taueru R at Castlehill	10.9	8.4	12.2	35	0.073	0.001	0.440	36	0	0.295	0.050	2.600	36
RS37	Taueru R at Gladstone	10.1	6.7	16.4	35	0.600	0.190	1.900	36	5.6	0.405	0.190	0.860	36
RS38	Kopuaranga R at Stewarts	9.9	6.7	14.1	35	0.950	0.450	1.360	36	0	0.350	0.170	1.600	36
RS39	Whangaehu R 250m u/s confl.	8.9	4.2	13.8	35	0.795	0.210	2.900	36	8.3	0.550	0.180	2.200	36
RS40	Waipoua R at Colombo Rd Br	10.4	7.2	12.6	35	0.905	0.210	2.600	36	11.1	0.170	0.050	0.620	36
RS41	Waingawa R at South Rd	10.5	6.9	13.1	35	0.054	0.014	0.400	36	0	0.050	0.050	0.240	36
RS42	Whareama R at Gauge	10.2	7.5	12.1	35	0.004	0.001	0.680	36	0	0.395	0.250	2.000	36
RS43	Motuwaireka S at Headwaters	11.1	6.6	13.0	34	0.026	0.003	0.410	35	0	0.050	0.050	0.130	35
RS44	Totara S at Stronvar	10.6	5.6	104.0	34	0.010	0.001	0.200	35	0	0.050	0.050	0.910	35
RS45	Parkvale Trib at Lowes Reserve	7.4	6.1	10.5	28	4.300	2.400	6.800	28	77.8	0.410	0.230	0.830	28
RS46	Parkvale S at Weir	10.2	7.3	14.1	35	1.245	0.001	4.300	36	41.7	0.590	0.320	1.900	36
RS47	Waiohine R at Gorge	11.4	9.5	14.6	35	0.030	0.001	0.097	36	0	0.050	0.050	0.270	36
RS48	Waiohine R at Bicknells	10.3	8.9	13.6	35	0.285	0.008	1.100	36	0	0.120	0.050	0.330	36
RS49	Beef Ck at Headwaters	10.9	8.5	14.3	35	0.019	0.001	0.058	36	0	0.050	0.050	0.300	36
RS50	Mangatarere S at SH 2	10.2	7.3	13.1	35	1.200	0.490	2.100	36	13.9	0.355	0.200	0.940	36
RS51	Huangarua R at Ponatahi Br	11.0	7.7	15.5	35	0.235	0.001	0.720	36	0	0.260	0.050	0.970	36
RS52	Tauanui R at Whakatomotomo Rd	10.6	8.6	12.9	34	0.009	0.001	0.046	35	0	0.050	0.050	0.230	35
RS53	Awhea R at Tora Rd	10.9	7.0	13.6	35	0.027	0.001	0.350	36	0	0.220	0.050	1.020	36
RS54	Coles Ck Trib at Lagoon Hill Rd	9.9	6.6	12.8	27	0.005	0.001	0.052	28	0	0.200	0.120	0.300	28
RS55	Tauherenikau R at Websters	10.3	8.0	12.8	35	0.028	0.001	0.330	36	0	0.050	0.050	0.240	36
RS56	Waiorongomai R at Forest Pk	10.7	7.6	13.7	35	0.012	0.001	0.070	36	0	0.050	0.050	0.450	36

Appendix 7: Temporal trend analyses – tabulated results

Physico-chemical and microbiological water quality

The following tables set out the trend results for selected water quality variables. Refer to Section 4.2 for methods. MASS=Median Annual Sen Slope calculated using the Seasonal Kendall trend test (performed in NIWA's TimeTrends software, version 3.20).

Water temperature (°C)

Site	Site name	Raw data					Flow-adjusted data				
		Median	*n*	MASS	*p*	% Change	Median	*n*	MASS	*p*	% Change
RS02	Mangapouri S at Bennetts Rd	13.32	60	-0.221	0.358	-1.66	-	-	-	-	-
RS03	Waitohu S at Forest Pk	10.12	59	0.138	0.425	1.37	10.04	57	0.035	0.327	0.35
RS04	Waitohu S at Norfolk Cres	13.01	60	-0.181	0.437	-1.39	12.89	58	-0.228	0.606	-1.77
RS05	Otaki R at Pukehinau	10.43	60	-0.341	0.040	-3.27	10.46	60	-0.575	0.000	-5.50
RS06	Otaki R at Mouth	12.05	60	-0.374	0.040	-3.10	12.29	60	-0.510	0.002	-4.15
RS07	Mangaone S at Sims Rd Br	13.12	60	-0.611	0.000	-4.66	13.03	60	-0.647	0.000	-4.97
RS08	Ngarara S at Field Way	14.50	60	-0.272	0.065	-1.88	-	-	-	-	-
RS09	Waikanae R at Mangaone Walkway	11.47	60	-0.226	0.119	-1.97	11.20	60	-0.365	0.020	-3.26
RS10	Waikanae R at Greenaway Rd	14.40	60	-0.162	0.434	-1.12	-	-	-	-	-
RS11	Whareroa S at Waterfall Rd	11.37	60	-0.398	0.006	-3.50	11.57	57	-0.231	0.029	-1.99
RS12	Whareroa S at QE Park	13.57	60	-0.683	0.000	-5.03	14.41	57	-0.675	0.001	-4.69
RS13	Horokiri S at Snodgrass	13.31	60	-0.819	0.001	-6.15	13.64	59	-0.828	0.003	-6.07
RS14	Pauatahanui S at Elmwood Br	12.75	60	-0.714	0.000	-5.60	13.03	60	-0.659	0.001	-5.06
RS15	Porirua S at Glenside	13.00	60	-0.379	0.104	-2.91	13.28	60	-0.260	0.229	-1.96
RS16	Porirua S at Wall Park (Milk Depot)	13.55	60	-0.618	0.003	-4.56	13.66	60	-0.401	0.009	-2.93
RS17	Makara S at Kennels	13.82	60	-0.113	0.832	-0.82	15.26	60	-0.086	0.724	-0.57
RS18	Karori S at Makara Peak	13.23	60	-0.042	0.724	-0.32	13.67	60	-0.143	0.621	-1.04
RS19	Kaiwharawhara S at Ngaio Gorge	13.27	60	0.003	1.000	0.02	13.31	60	-0.028	0.724	-0.21
RS20	Hutt R at Te Marua Intake Site	10.43	60	-0.023	0.944	-0.22	10.26	60	0.128	0.229	1.25
RS21	Hutt R opp. Manor Park G.C.	13.64	60	0.186	0.104	1.37	13.40	59	0.088	0.718	0.66
RS22	Hutt R at Boulcott	13.10	60	0.087	0.525	0.66	13.11	59	0.021	0.829	0.16
RS23	Pakuratahi R 50m d/s Farm Ck	11.20	60	-0.044	0.943	-0.39	10.81	60	-0.079	0.724	-0.73
RS24	Mangaroa R at Te Marua	12.43	60	0.088	0.525	0.71	12.76	59	0.207	0.220	1.62
RS25	Akatarawa R at Hutt confl.	11.18	60	-0.026	0.777	-0.23	11.25	60	0.050	0.724	0.45
RS26	Whakatikei R at Riverstone	11.15	60	0.193	0.525	1.73	11.11	60	0.254	0.179	2.29
RS27	Waiwhetu S at Wainui Hill Br	14.90	59	-0.360	0.008	-2.42	15.22	59	-0.639	0.005	-4.20
RS28	Wainuiomata R at Manuka Track	10.45	58	-0.128	0.712	-1.23	10.36	57	-0.022	1.000	-0.21
RS29	Wainuiomata R u/s of White Br	13.08	59	-0.328	0.097	-2.51	13.10	59	-0.320	0.279	-2.44
RS30	Orongorongo R at Orongorongo Stn	14.15	59	0.043	0.942	0.30	14.32	53	-0.022	1.000	-0.15
RS31	Ruamahanga R at McLays	9.70	60	0.092	0.525	0.95	9.00	60	0.389	0.077	4.32
RS32	Ruamahanga R at Te Ore Ore	12.90	60	0.238	0.179	1.84	12.91	60	0.623	0.020	4.83
RS33	Ruamahanga R at Gladstone Br	13.92	60	-0.113	0.229	-0.81	13.56	60	0.482	0.138	3.55
RS34	Ruamahanga R at Pukio	12.90	60	0.029	0.724	0.22	12.48	59	0.593	0.012	4.75
RS35	Mataikona Trib at Sugar Loaf Rd	10.44	60	0.256	0.077	2.46	-	-	-	-	-
RS36	Taueru R at Castlehill	10.30	60	0.167	0.525	1.62	9.30	60	0.446	0.056	4.79
RS37	Taueru R at Gladstone	14.54	60	-0.231	0.104	-1.59	-	-	-	-	-
RS38	Kopuaranga R at Stewarts	12.60	60	-0.053	0.832	-0.42	12.51	60	0.325	0.138	2.60
RS39	Whangaehu R 250m u/s confl.	14.10	60	0.036	0.571	0.26	-	-	-	-	-
RS40	Waipoua R at Colombo Rd Br	14.07	60	0.593	0.002	4.22	12.70	52	0.391	0.145	3.08
RS41	Waingawa R at South Rd	13.44	60	0.062	0.777	0.46	12.16	60	-0.181	0.437	-1.49
RS42	Whareama R at Gauge	13.39	60	-0.025	0.832	-0.19	13.50	60	0.278	0.229	2.06
RS43	Motuwaireka S at Headwaters	11.29	59	-0.286	0.279	-2.53	11.18	59	-0.220	0.348	-1.97
RS44	Totara S at Stronvar	13.82	58	-0.101	0.301	-0.73	13.00	58	0.040	0.941	0.31
RS45	Parkvale Trib at Lowes Res.	13.73	47	-0.238	0.047	-1.73	-	-	-	-	-
RS46	Parkvale S at Weir	15.66	60	0.049	0.832	0.31	15.42	59	0.047	0.829	0.31
RS47	Waiohine R at Gorge	10.05	60	-0.184	0.138	-1.83	9.42	60	0.146	0.289	1.55
RS48	Waiohine R at Bicknells	13.00	60	-0.210	0.104	-1.62	12.64	60	-0.008	0.944	-0.06
RS49	Beef Ck at Headwaters	10.61	60	-0.361	0.040	-3.41	-	-	-	-	-
RS50	Mangatarere S at SH 2	14.10	60	-0.284	0.179	-2.02	14.17	59	-0.083	0.718	-0.59
RS51	Huangarua R at Ponatahi Br	14.69	60	-0.353	0.028	-2.41	-	-	-	-	-
RS52	Tauanui R at Whakatomotomo Rd	11.30	59	-0.150	0.427	-1.33	11.05	59	-0.044	0.829	-0.40
RS53	Awhea R at Tora Rd	14.54	60	0.491	0.040	3.38	-	-	-	-	-
RS54	Coles Ck Trib at Lagoon Hill Rd	13.07	50	0.046	0.931	0.35	-	-	-	-	-
RS55	Tauherenikau R at Websters	13.25	60	-0.487	0.056	-3.67	12.57	60	-0.605	0.056	-4.82
RS56	Waiorongomai R at Forest Pk	12.31	60	-0.302	0.077	-2.45	11.73	60	-0.252	0.289	-2.15

Dissolved oxygen (% saturation)

Site	Site name	Raw data					Flow-adjusted data				
		Median	*n*	MASS	*p*	% Change	Median	*n*	MASS	*p*	% Change
RS02	Mangapouri S at Bennetts Rd	71.55	60	-0.489	0.724	-0.68	-	-	-	-	-
RS03	Waitohu S at Forest Pk	100.00	59	0.000	0.884	0.00	99.25	57	0.169	0.940	0.17
RS04	Waitohu S at Norfolk Cres	83.90	60	1.150	0.437	1.37	83.71	58	0.991	0.269	1.18
RS05	Otaki R at Pukehinau	99.90	60	-0.413	0.669	-0.41	99.96	60	-0.537	0.358	-0.54
RS06	Otaki R at Mouth	102.00	60	-0.989	0.227	-0.97	102.19	60	-1.280	0.077	-1.25
RS07	Mangaone S at Sims Rd Br	77.85	60	-3.251	0.013	-4.18	77.87	60	-3.167	0.006	-4.07
RS08	Ngarara S at Field Way	57.45	60	-2.568	0.104	-4.47	-	-	-	-	-
RS09	Waikanae R at Mangaone Walkway	97.90	60	-0.881	0.200	-0.90	97.38	60	-0.291	0.289	-0.30
RS10	Waikanae R at Greenaway Rd	102.00	60	-0.783	0.134	-0.77	-	-	-	-	-
RS11	Whareroa S at Waterfall Rd	94.70	60	0.218	0.887	0.23	95.08	57	-0.401	0.407	-0.42
RS12	Whareroa S at QE Park	72.90	60	0.327	0.724	0.45	72.22	57	-1.785	0.113	-2.47
RS13	Horokiri S at Snodgrass	102.00	60	0.749	0.134	0.73	101.84	59	1.113	0.170	1.09
RS14	Pauatahanui S at Elmwood Br	97.80	60	0.092	0.944	0.09	96.49	60	-0.861	0.525	-0.89
RS15	Porirua S at Glenside	106.00	60	3.222	0.005	3.04	106.69	60	3.290	0.000	3.08
RS16	Porirua S at Wall Park (Milk Depot)	106.00	60	1.865	0.286	1.76	105.65	60	1.559	0.028	1.48
RS17	Makara S at Kennels	102.00	60	1.864	0.175	1.83	101.54	60	2.304	0.020	2.27
RS18	Karori S at Makara Peak	100.00	60	3.038	0.000	3.04	99.20	60	3.245	0.000	3.27
RS19	Kaiwharawhara S at Ngaio Gorge	101.50	60	4.310	0.002	4.25	100.77	60	3.247	0.004	3.22
RS20	Hutt R at Te Marua Intake Site	100.50	60	1.841	0.003	1.83	100.37	60	1.278	0.028	1.27
RS21	Hutt R opp. Manor Park G.C.	102.00	60	0.669	0.286	0.66	101.84	59	1.038	0.279	1.02
RS22	Hutt R at Boulcott	102.00	59	0.964	0.467	0.94	100.98	58	1.289	0.090	1.28
RS23	Pakuratahi R 50m d/s Farm Ck	96.85	60	1.440	0.023	1.49	96.54	60	1.310	0.040	1.36
RS24	Mangaroa R at Te Marua	101.00	59	1.007	0.111	1.00	100.12	58	1.971	0.065	1.97
RS25	Akatarawa R at Hutt confl.	101.00	60	1.000	0.199	0.99	100.55	60	0.916	0.179	0.91
RS26	Whakatikei R at Riverstone	101.00	60	0.250	0.565	0.25	100.81	60	0.635	0.358	0.63
RS27	Waiwhetu S at Wainui Hill Br	78.60	59	-1.939	0.427	-2.47	76.92	59	-1.842	0.279	-2.39
RS28	Wainuiomata R at Manuka Track	99.55	58	-0.260	0.657	-0.26	98.51	57	-0.403	0.135	-0.41
RS29	Wainuiomata R u/s of White Br	100.00	59	1.420	0.193	1.42	100.43	59	1.083	0.348	1.08
RS30	Orongorongo R at Orongorongo Stn	99.20	59	2.281	0.001	2.30	100.56	53	2.505	0.002	2.49
RS31	Ruamahanga R at McLays	98.25	60	0.858	0.179	0.87	96.75	60	0.692	0.289	0.72
RS32	Ruamahanga R at Te Ore Ore	99.05	60	0.399	0.887	0.40	96.82	60	0.707	0.289	0.73
RS33	Ruamahanga R at Gladstone Br	99.30	60	-0.718	0.434	-0.72	99.34	60	0.891	0.437	0.90
RS34	Ruamahanga R at Pukio	96.60	60	0.347	0.722	0.36	96.57	59	0.864	0.427	0.89
RS35	Mataikona Trib at Sugar Loaf Rd	98.80	60	0.430	0.478	0.44	-	-	-	-	-
RS36	Taueru R at Castlehill	96.40	60	1.031	0.179	1.07	95.75	60	0.968	0.056	1.01
RS37	Taueru R at Gladstone	99.20	60	-2.913	0.156	-2.94	-	-	-	-	-
RS38	Kopuaranga R at Stewarts	93.85	60	0.601	0.722	0.64	93.62	60	2.057	0.229	2.20
RS39	Whangaehu R 250m u/s confl.	86.25	60	2.018	0.395	2.34	-	-	-	-	-
RS40	Waipoua R at Colombo Rd Br	104.00	60	1.602	0.076	1.54	103.18	52	1.973	0.103	1.91
RS41	Waingawa R at South Rd	99.45	60	1.133	0.254	1.14	101.53	60	0.441	0.437	0.43
RS42	Whareama R at Gauge	93.60	60	1.724	0.102	1.84	93.92	60	1.806	0.077	1.92
RS43	Motuwaireka S at Headwaters	98.30	59	0.202	0.717	0.21	98.24	59	1.088	0.718	1.11
RS44	Totara S at Stronvar	99.75	58	1.508	0.234	1.51	99.24	58	1.085	0.417	1.09
RS45	Parkvale Trib at Lowes Res.	72.10	47	0.627	0.619	0.87	-	-	-	-	-
RS46	Parkvale S at Weir	103.50	60	-0.996	0.254	-0.96	103.94	59	-0.403	0.942	-0.39
RS47	Waiohine R at Gorge	101.00	60	0.139	0.831	0.14	100.96	60	0.297	0.621	0.29
RS48	Waiohine R at Bicknells	97.85	60	-0.619	0.724	-0.63	96.77	60	-0.735	0.525	-0.76
RS49	Beef Ck at Headwaters	99.35	60	1.452	0.038	1.46	-	-	-	-	-
RS50	Mangatarere S at SH 2	96.35	60	-2.861	0.138	-2.97	93.25	59	-2.589	0.279	-2.78
RS51	Huangarua R at Ponatahi Br	108.50	60	-2.401	0.358	-2.21	-	-	-	-	-
RS52	Tauanui R at Whakatomotomo Rd	99.10	59	0.998	0.060	1.01	99.81	59	0.658	0.348	0.66
RS53	Awhea R at Tora Rd	99.90	60	1.343	0.478	1.34	-	-	-	-	-
RS54	Coles Ck Trib at Lagoon Hill Rd	94.05	50	-0.267	0.666	-0.28	-	-	-	-	-
RS55	Tauherenikau R at Websters	96.45	60	0.812	0.777	0.84	96.66	60	0.035	1.000	0.04
RS56	Waiorongomai R at Forest Pk	99.05	60	1.184	0.055	1.20	100.00	60	1.231	0.077	1.23

Dissolved oxygen (mg/L)

Site	Site name	Raw data					Flow-adjusted data				
		Median	*n*	MASS	*p*	% Change	Median	*n*	MASS	*p*	% Change
RS02	Mangapouri S at Bennetts Rd	7.47	60	0.048	0.832	0.64	-	-	-	-	-
RS03	Waitohu S at Forest Pk	11.10	59	-0.050	0.556	-0.45	11.01	57	-0.019	0.940	-0.17
RS04	Waitohu S at Norfolk Cres	9.05	60	0.169	0.179	1.87	9.04	58	0.183	0.122	2.03
RS05	Otaki R at Pukehinau	11.30	60	-0.025	0.722	-0.22	11.33	60	-0.032	0.621	-0.29
RS06	Otaki R at Mouth	11.05	60	0.000	1.000	0.00	11.05	60	-0.026	0.724	-0.24
RS07	Mangaone S at Sims Rd Br	8.26	60	-0.169	0.104	-2.04	8.41	60	-0.217	0.179	-2.58
RS08	Ngarara S at Field Way	6.01	60	-0.202	0.229	-3.36	-	-	-	-	-
RS09	Waikanae R at Mangaone Walkway	11.00	60	-0.017	0.943	-0.15	11.10	60	0.049	0.437	0.44
RS10	Waikanae R at Greenaway Rd	10.50	60	-0.151	0.027	-1.43	-	-	-	-	-
RS11	Whareroa S at Waterfall Rd	10.45	60	0.081	0.356	0.77	10.40	57	0.003	1.000	0.02
RS12	Whareroa S at QE Park	7.72	60	0.117	0.138	1.51	7.70	57	-0.033	0.940	-0.43
RS13	Horokiri S at Snodgrass	10.90	60	0.214	0.033	1.96	10.95	59	0.146	0.097	1.34
RS14	Pauatahanui S at Elmwood Br	10.60	60	0.177	0.064	1.67	10.65	60	0.053	0.621	0.50
RS15	Porirua S at Glenside	11.50	60	0.343	0.002	2.98	11.60	60	0.380	0.001	3.28
RS16	Porirua S at Wall Park (Milk Depot)	11.20	60	0.308	0.006	2.75	11.32	60	0.315	0.001	2.78
RS17	Makara S at Kennels	10.60	60	0.156	0.054	1.47	10.24	60	0.183	0.040	1.79
RS18	Karori S at Makara Peak	10.80	60	0.258	0.023	2.39	10.67	60	0.353	0.040	3.30
RS19	Kaiwharawhara S at Ngaio Gorge	10.80	60	0.402	0.001	3.72	10.84	60	0.381	0.001	3.51
RS20	Hutt R at Te Marua Intake Site	11.20	60	0.183	0.074	1.64	11.30	60	0.141	0.289	1.24
RS21	Hutt R opp. Manor Park G.C.	10.70	60	-0.100	0.434	-0.93	10.60	59	-0.065	0.718	-0.61
RS22	Hutt R at Boulcott	10.60	59	-0.032	0.828	-0.31	10.63	58	-0.002	0.941	-0.01
RS23	Pakuratahi R 50m d/s Farm Ck	10.55	60	0.111	0.227	1.05	10.55	60	0.080	0.525	0.76
RS24	Mangaroa R at Te Marua	10.70	59	0.142	0.383	1.33	10.71	58	0.123	0.161	1.15
RS25	Akatarawa R at Hutt confl.	10.95	60	0.000	0.943	0.00	10.93	60	0.017	0.832	0.15
RS26	Whakatikei R at Riverstone	10.95	60	0.067	0.254	0.61	10.99	60	0.016	0.724	0.15
RS27	Waiwhetu S at Wainui Hill Br	8.15	59	-0.199	0.427	-2.44	7.77	59	-0.131	0.718	-1.69
RS28	Wainuiomata R at Manuka Track	11.30	58	0.100	0.372	0.89	11.19	57	0.057	0.550	0.51
RS29	Wainuiomata R u/s of White Br	10.70	59	0.116	0.274	1.08	10.75	59	0.177	0.220	1.64
RS30	Orongorongo R at Orongorongo Stn	10.00	59	0.294	0.059	2.94	10.09	53	0.185	0.032	1.83
RS31	Ruamahanga R at McLays	10.90	60	0.098	0.434	0.89	10.94	60	-0.026	0.944	-0.24
RS32	Ruamahanga R at Te Ore Ore	10.20	60	-0.069	0.525	-0.68	10.11	60	-0.132	0.077	-1.30
RS33	Ruamahanga R at Gladstone Br	10.30	60	-0.086	0.568	-0.83	10.31	60	-0.079	0.525	-0.76
RS34	Ruamahanga R at Pukio	10.02	60	0.158	0.289	1.57	10.07	59	0.021	0.942	0.21
RS35	Mataikona Trib at Sugar Loaf Rd	10.85	60	0.000	0.943	0.00	-	-	-	-	-
RS36	Taueru R at Castlehill	10.70	60	0.101	0.175	0.94	10.82	60	0.122	0.358	1.12
RS37	Taueru R at Gladstone	10.30	60	-0.131	0.177	-1.27	-	-	-	-	-
RS38	Kopuaranga R at Stewarts	9.95	60	0.118	0.724	1.18	9.89	60	0.121	0.621	1.23
RS39	Whangaehu R 250m u/s confl.	9.01	60	0.136	0.321	1.51	-	-	-	-	-
RS40	Waipoua R at Colombo Rd Br	10.35	60	0.068	0.393	0.65	10.44	52	-0.022	0.932	-0.21
RS41	Waingawa R at South Rd	10.30	60	0.043	0.832	0.41	10.77	60	-0.025	0.944	-0.23
RS42	Whareama R at Gauge	9.69	60	0.209	0.065	2.16	9.89	60	0.094	0.138	0.95
RS43	Motuwaireka S at Headwaters	10.85	58	0.122	0.137	1.12	10.91	58	0.120	0.210	1.10
RS44	Totara S at Stronvar	10.30	58	0.091	0.712	0.88	10.07	58	-0.061	0.712	-0.60
RS45	Parkvale Trib at Lowes Res.	7.42	47	0.151	0.407	2.04	-	-	-	-	-
RS46	Parkvale S at Weir	10.40	60	-0.190	0.257	-1.83	10.38	59	-0.171	0.097	-1.65
RS47	Waiohine R at Gorge	11.20	60	0.107	0.395	0.95	11.25	60	-0.045	0.944	-0.40
RS48	Waiohine R at Bicknells	10.30	60	-0.066	0.617	-0.64	9.99	60	-0.026	0.832	-0.26
RS49	Beef Ck at Headwaters	10.90	60	0.158	0.023	1.45	-	-	-	-	-
RS50	Mangatarere S at SH 2	10.25	60	-0.281	0.104	-2.74	10.11	59	-0.204	0.220	-2.02
RS51	Huangarua R at Ponatahi Br	11.00	60	-0.099	0.393	-0.90	-	-	-	-	-
RS52	Tauanui R at Whakatomotomo Rd	10.60	59	0.200	0.128	1.88	10.52	59	0.035	0.613	0.33
RS53	Awhea R at Tora Rd	10.70	60	0.066	0.571	0.62	-	-	-	-	-
RS54	Coles Ck Trib at Lagoon Hill Rd	9.90	50	0.115	0.666	1.16	-	-	-	-	-
RS55	Tauherenikau R at Websters	10.10	59	0.102	0.095	1.01	10.12	59	0.054	0.516	0.53
RS56	Waiorongomai R at Forest Pk	10.60	59	0.122	0.049	1.15	10.70	59	0.199	0.025	1.86

pH											
Site	Site name	Raw data					Flow-adjusted data				
		Median	*n*	MASS	*p*	% Change	Median	*n*	MASS	*p*	% Change
RS02	Mangapouri S at Bennetts Rd	6.85	58	-0.055	0.018	-0.81	-	-	-	-	-
RS03	Waitohu S at Forest Pk	7.22	57	-0.107	0.008	-1.48	7.24	55	-0.108	0.001	-1.49
RS04	Waitohu S at Norfolk Cres	6.82	58	-0.045	0.122	-0.66	6.81	56	-0.062	0.047	-0.90
RS05	Otaki R at Pukehinau	7.24	58	-0.112	0.005	-1.55	7.22	58	-0.138	0.001	-1.91
RS06	Otaki R at Mouth	7.36	58	-0.149	0.033	-2.03	7.28	58	-0.147	0.003	-2.02
RS07	Mangaone S at Sims Rd Br	6.85	58	-0.117	0.001	-1.71	6.82	58	-0.104	0.001	-1.52
RS08	Ngarara S at Field Way	6.79	58	-0.035	0.333	-0.52	-	-	-	-	-
RS09	Waikanae R at Mangaone Walkway	7.28	58	-0.099	0.010	-1.36	7.26	58	-0.057	0.006	-0.79
RS10	Waikanae R at Greenaway Rd	7.16	58	-0.099	0.104	-1.38	-	-	-	-	-
RS11	Whareroa S at Waterfall Rd	7.46	58	-0.077	0.047	-1.03	7.47	55	-0.084	0.033	-1.12
RS12	Whareroa S at QE Park	6.70	58	-0.039	0.139	-0.58	6.69	55	-0.018	0.385	-0.26
RS13	Horokiri S at Snodgrass	7.34	58	-0.086	0.047	-1.17	7.32	57	-0.058	0.019	-0.79
RS14	Pauatahanui S at Elmwood Br	7.29	58	-0.145	0.015	-1.99	7.24	58	-0.104	0.006	-1.43
RS15	Porirua S at Glenside	7.69	58	-0.065	0.335	-0.85	7.62	58	-0.050	0.507	-0.65
RS16	Porirua S at Wall Park (Milk Depot)	7.61	58	-0.058	0.460	-0.76	7.61	58	-0.049	0.161	-0.65
RS17	Makara S at Kennels	7.43	58	-0.063	0.038	-0.84	7.44	58	-0.072	0.065	-0.96
RS18	Karori S at Makara Peak	7.30	57	-0.081	0.096	-1.11	7.32	57	-0.082	0.083	-1.12
RS19	Kaiwharawhara S at Ngaio Gorge	7.62	57	-0.020	0.650	-0.26	7.60	57	-0.009	0.940	-0.12
RS20	Hutt R at Te Marua Intake Site	7.20	58	-0.094	0.010	-1.31	7.18	58	-0.072	0.010	-1.01
RS21	Hutt R opp. Manor Park G.C.	7.34	58	-0.112	0.122	-1.53	7.29	57	-0.081	0.083	-1.12
RS22	Hutt R at Boulcott	7.12	58	-0.054	0.183	-0.76	7.13	57	-0.039	0.327	-0.55
RS23	Pakuratahi R 50m d/s Farm Ck	6.85	58	-0.113	0.001	-1.65	6.89	58	-0.103	0.001	-1.50
RS24	Mangaroa R at Te Marua	7.02	58	-0.097	0.015	-1.39	6.99	57	-0.090	0.008	-1.29
RS25	Akatarawa R at Hutt confl.	7.26	58	-0.087	0.008	-1.20	7.26	58	-0.072	0.010	-1.00
RS26	Whakatikei R at Riverstone	7.46	58	-0.033	0.237	-0.44	7.44	58	0.007	0.712	0.10
RS27	Waiwhetu S at Wainui Hill Br	6.79	57	-0.060	0.004	-0.88	6.76	57	-0.057	0.013	-0.84
RS28	Wainuiomata R at Manuka Track	7.07	56	-0.116	0.002	-1.64	7.00	55	-0.107	0.028	-1.53
RS29	Wainuiomata R u/s of White Br	7.21	57	-0.046	0.598	-0.64	7.16	57	-0.048	0.407	-0.66
RS30	Orongorongo R at Orongorongo Stn	7.52	57	-0.072	0.197	-0.95	7.48	51	-0.034	0.437	-0.46
RS31	Ruamahanga R at McLays	7.15	57	-0.104	0.060	-1.45	7.11	57	-0.112	0.008	-1.58
RS32	Ruamahanga R at Te Ore Ore	7.69	58	-0.043	0.375	-0.56	7.72	58	-0.016	0.712	-0.21
RS33	Ruamahanga R at Gladstone Br	7.51	58	-0.084	0.159	-1.12	7.51	58	-0.045	0.338	-0.60
RS34	Ruamahanga R at Pukio	7.56	58	-0.068	0.055	-0.90	7.53	57	-0.041	0.060	-0.55
RS35	Mataikona Trib at Sugar Loaf Rd	7.91	58	-0.002	1.000	-0.03	-	-	-	-	-
RS36	Taueru R at Castlehill	7.64	58	-0.069	0.015	-0.90	7.67	58	-0.055	0.047	-0.71
RS37	Taueru R at Gladstone	7.94	58	-0.124	0.006	-1.56	-	-	-	-	-
RS38	Kopuaranga R at Stewarts	7.63	58	-0.010	0.882	-0.13	7.63	58	0.010	0.606	0.14
RS39	Whangaehu R 250m u/s confl.	7.32	58	0.009	0.711	0.12	-	-	-	-	-
RS40	Waipoua R at Colombo Rd Br	7.53	58	-0.055	0.062	-0.73	7.41	50	-0.032	0.279	-0.43
RS41	Waingawa R at South Rd	7.36	59	-0.140	0.001	-1.90	7.43	59	-0.144	0.001	-1.94
RS42	Whareama R at Gauge	7.83	58	-0.018	0.767	-0.23	7.82	58	0.000	1.000	0.00
RS43	Motuwaireka S at Headwaters	7.49	58	-0.082	0.032	-1.10	7.51	58	-0.064	0.139	-0.86
RS44	Totara S at Stronvar	7.52	57	-0.042	0.253	-0.56	7.50	57	-0.067	0.131	-0.89
RS45	Parkvale Trib at Lowes Res.	6.44	45	-0.080	0.014	-1.24	-	-	-	-	-
RS46	Parkvale S at Weir	7.49	58	-0.089	0.183	-1.19	7.57	57	-0.027	0.295	-0.36
RS47	Waiohine R at Gorge	7.17	58	-0.098	0.005	-1.37	7.11	58	-0.100	0.033	-1.40
RS48	Waiohine R at Bicknells	6.77	58	-0.125	0.018	-1.85	6.69	58	-0.109	0.047	-1.63
RS49	Beef Ck at Headwaters	7.29	58	-0.153	0.000	-2.10	-	-	-	-	-
RS50	Mangatarere S at SH 2	6.83	58	-0.100	0.000	-1.46	6.90	57	-0.112	0.005	-1.62
RS51	Huangarua R at Ponatahi Br	8.11	58	-0.129	0.002	-1.59	-	-	-	-	-
RS52	Tauanui R at Whakatomotomo Rd	7.46	57	-0.083	0.005	-1.11	7.44	57	-0.079	0.008	-1.06
RS53	Awhea R at Tora Rd	8.05	58	-0.022	0.604	-0.28	-	-	-	-	-
RS54	Coles Ck Trib at Lagoon Hill Rd	7.85	49	-0.070	0.291	-0.89	-	-	-	-	-
RS55	Tauherenikau R at Websters	7.11	58	-0.108	0.018	-1.52	7.09	58	-0.102	0.022	-1.44
RS56	Waiorongomai R at Forest Pk	7.34	58	-0.118	0.018	-1.61	7.32	58	-0.113	0.010	-1.55

Visual clarity (m)												
Site	Site name	Raw data					Flow-adjusted data					% Cen.
		Median	n	MASS	p	% Change	Median	n	MASS	p	% Change	
RS02	Mangapouri S at Bennetts Rd	0.55	59	-0.083	0.128	-15.07	-	-	-	-	-	0.00
RS03	Waitohu S at Forest Pk	2.65	59	0.116	0.516	4.37	2.63	57	-0.007	0.940	-0.28	1.72
RS04	Waitohu S at Norfolk Cres	0.61	60	-0.068	0.028	-11.15	0.53	58	-0.079	0.122	-15.04	0.00
RS05	Otaki R at Pukehinau	3.48	60	0.125	0.724	3.60	3.33	60	-0.034	0.944	-1.01	0.00
RS06	Otaki R at Mouth	2.39	60	-0.042	0.724	-1.74	2.38	60	-0.119	0.437	-5.00	0.00
RS07	Mangaone S at Sims Rd Br	0.46	56	-0.034	0.190	-7.36	0.41	56	-0.058	0.143	-14.15	0.00
RS08	Ngarara S at Field Way	0.42	60	-0.060	0.020	-14.41	-	-	-	-	-	0.00
RS09	Waikanae R at Mangaone Walkway	3.38	60	-0.121	0.437	-3.60	3.33	60	-0.086	0.525	-2.59	6.78
RS10	Waikanae R at Greenaway Rd	2.36	60	0.220	0.437	9.32	-	-	-	-	-	0.00
RS11	Whareroa S at Waterfall Rd	0.62	60	-0.110	0.028	-17.80	0.57	57	-0.064	0.028	-11.27	0.00
RS12	Whareroa S at QE Park	0.49	60	-0.022	0.321	-4.40	0.51	57	-0.003	1.000	-0.56	1.69
RS13	Horokiri S at Snodgrass	1.88	60	-0.266	0.007	-14.15	1.65	59	-0.174	0.012	-10.52	0.00
RS14	Pauatahanui S at Elmwood Br	1.43	60	-0.094	0.119	-6.57	1.42	60	-0.046	0.525	-3.25	0.00
RS15	Porirua S at Glenside	1.49	58	-0.055	0.712	-3.67	1.53	58	0.056	0.606	3.64	0.00
RS16	Porirua S at Wall Park (Milk Depot)	1.35	60	0.032	0.724	2.39	1.35	60	0.050	0.437	3.67	0.00
RS17	Makara S at Kennels	1.16	60	-0.031	0.832	-2.70	1.24	60	-0.017	0.832	-1.36	0.00
RS18	Karori S at Makara Peak	2.56	60	-0.073	0.437	-2.84	2.79	60	-0.028	0.724	-1.01	0.00
RS19	Kaiwharawhara S at Ngaio Gorge	2.10	60	-0.129	0.289	-6.13	2.13	60	-0.068	0.724	-3.18	0.00
RS20	Hutt R at Te Marua Intake Site	2.95	60	-0.161	0.229	-5.44	2.82	60	-0.123	0.437	-4.34	0.00
RS21	Hutt R opp. Manor Park G.C.	1.62	60	-0.041	0.671	-2.55	1.64	59	-0.079	0.097	-4.80	0.00
RS22	Hutt R at Boulcott	1.48	60	-0.128	0.202	-8.66	1.56	59	-0.129	0.097	-8.29	0.00
RS23	Pakuratahi R 50m d/s Farm Ck	2.86	60	-0.053	0.621	-1.85	2.73	60	-0.043	0.832	-1.57	0.00
RS24	Mangaroa R at Te Marua	1.21	60	-0.137	0.104	-11.39	1.18	59	-0.053	0.516	-4.49	0.00
RS25	Akatarawa R at Hutt confl.	3.14	60	0.021	1.000	0.67	3.05	60	0.056	0.724	1.83	0.00
RS26	Whakatikei R at Riverstone	2.72	60	-0.053	0.619	-1.94	2.58	60	-0.112	0.358	-4.37	0.00
RS27	Waiwhetu S at Wainui Hill Br	0.55	59	0.092	0.071	16.68	0.50	59	0.070	0.051	13.91	0.00
RS28	Wainuiomata R at Manuka Track	2.60	56	-0.197	0.022	-7.57	2.43	56	-0.273	0.000	-11.24	0.00
RS29	Wainuiomata R u/s of White Br	1.33	59	0.044	0.469	3.30	1.31	59	0.025	0.942	1.89	0.00
RS30	Orongorongo R at Orongorongo Stn	0.93	59	0.019	0.942	2.07	0.91	53	-0.044	0.322	-4.91	0.00
RS31	Ruamahanga R at McLays	3.65	60	-0.148	0.289	-4.05	2.77	60	-0.015	0.832	-0.55	0.00
RS32	Ruamahanga R at Te Ore Ore	1.17	60	-0.004	0.944	-0.35	1.00	60	0.057	0.621	5.65	0.00
RS33	Ruamahanga R at Gladstone Br	1.24	60	-0.064	0.227	-5.18	1.17	60	0.027	0.358	2.27	0.00
RS34	Ruamahanga R at Pukio	0.61	60	-0.094	0.179	-15.48	0.58	59	-0.015	0.718	-2.61	0.00
RS35	Mataikona Trib at Sugar Loaf Rd	1.75	59	-0.051	0.279	-2.92	-	-	-	-	-	8.62
RS36	Taueru R at Castlehill	1.11	60	-0.091	0.040	-8.19	1.01	60	-0.007	0.944	-0.69	0.00
RS37	Taueru R at Gladstone	0.55	60	-0.033	0.621	-5.91	-	-	-	-	-	0.00
RS38	Kopuaranga R at Stewarts	0.84	60	-0.020	0.571	-2.37	0.79	60	0.025	0.437	3.20	0.00
RS39	Whangaehu R 250m u/s confl.	0.72	60	-0.131	0.016	-18.16	-	-	-	-	-	0.00
RS40	Waipoua R at Colombo Rd Br	2.87	60	0.060	0.525	2.08	2.66	52	-0.049	0.797	-1.85	0.00
RS41	Waingawa R at South Rd	2.89	60	0.099	0.887	3.43	2.89	60	-0.011	1.000	-0.37	0.00
RS42	Whareama R at Gauge	0.52	57	-0.027	0.226	-5.23	0.47	57	-0.026	0.152	-5.51	0.00
RS43	Motuwaireka S at Headwaters	2.55	58	0.042	0.606	1.64	2.56	58	0.016	0.825	0.63	26.32
RS44	Totara S at Stronvar	2.77	58	0.049	0.882	1.78	2.91	58	0.052	0.338	1.80	10.53
RS45	Parkvale Trib at Lowes Res.	2.38	41	0.003	0.922	0.14	-	-	-	-	-	22.50
RS46	Parkvale S at Weir	0.85	60	-0.037	0.478	-4.39	0.85	59	-0.017	0.613	-2.04	0.00
RS47	Waiohine R at Gorge	3.05	59	-0.351	0.427	-11.52	2.96	59	-0.039	0.829	-1.32	0.00
RS48	Waiohine R at Bicknells	1.89	60	-0.044	0.525	-2.31	1.89	60	-0.102	0.138	-5.39	0.00
RS49	Beef Ck at Headwaters	2.30	58	-0.306	0.001	-13.35	-	-	-	-	-	15.79
RS50	Mangatarere S at SH 2	1.87	57	-0.112	0.226	-6.01	1.84	56	-0.107	0.054	-5.80	0.00
RS51	Huangarua R at Ponatahi Br	1.30	60	-0.015	0.621	-1.13	-	-	-	-	-	0.00
RS52	Tauanui R at Whakatomotomo Rd	3.70	59	-0.070	0.613	-1.89	3.39	59	-0.159	0.220	-4.70	5.17
RS53	Awhea R at Tora Rd	0.94	60	-0.001	0.943	-0.09	-	-	-	-	-	1.69
RS54	Coles Ck Trib at Lagoon Hill Rd	1.03	50	-0.114	0.262	-11.04	-	-	-	-	-	2.04
RS55	Tauherenikau R at Websters	1.64	60	0.105	0.395	6.40	1.36	60	0.139	0.056	10.20	0.00
RS56	Waiorongomai R at Forest Pk	2.71	60	0.027	0.832	1.01	2.59	60	-0.022	0.832	-0.84	1.69

Turbidity (NTU)											
Site	Site name	Raw data					Flow-adjusted data				
		Median	*n*	MASS	*p*	% Change	Median	*n*	MASS	*p*	% Change
RS02	Mangapouri S at Bennetts Rd	4.95	60	0.062	0.724	1.25	-	-	-	-	-
RS03	Waitohu S at Forest Pk	0.76	59	-0.015	0.772	-1.98	0.80	57	0.025	0.327	3.12
RS04	Waitohu S at Norfolk Cres	4.94	60	0.101	0.434	2.04	4.70	58	0.095	0.417	2.02
RS05	Otaki R at Pukehinau	0.85	60	-0.080	0.136	-9.49	0.81	60	-0.054	0.621	-6.72
RS06	Otaki R at Mouth	1.33	60	-0.045	0.621	-3.39	1.19	60	0.002	1.000	0.21
RS07	Mangaone S at Sims Rd Br	5.60	60	0.135	0.724	2.42	5.26	60	-0.083	0.724	-1.58
RS08	Ngarara S at Field Way	9.20	60	-1.160	0.056	-12.61	-	-	-	-	-
RS09	Waikanae R at Mangaone Walkway	0.64	60	-0.013	0.478	-2.11	0.56	60	-0.025	0.621	-4.53
RS10	Waikanae R at Greenaway Rd	1.03	60	-0.070	0.179	-6.81	-	-	-	-	-
RS11	Whareroa S at Waterfall Rd	5.55	60	0.723	0.104	13.02	3.91	57	0.517	0.200	13.23
RS12	Whareroa S at QE Park	8.64	60	0.240	0.156	2.78	7.81	57	0.206	0.407	2.63
RS13	Horokiri S at Snodgrass	1.30	60	0.017	0.832	1.34	1.12	59	0.009	0.942	0.77
RS14	Pauatahanui S at Elmwood Br	2.56	60	0.000	1.000	0.00	2.37	60	-0.103	0.289	-4.34
RS15	Porirua S at Glenside	2.20	60	-0.126	0.289	-5.73	1.88	60	-0.343	0.040	-18.21
RS16	Porirua S at Wall Park (Milk Depot)	2.89	60	-0.080	0.321	-2.78	2.80	60	-0.159	0.289	-5.68
RS17	Makara S at Kennels	3.30	60	0.000	1.000	0.01	3.05	60	-0.069	0.832	-2.27
RS18	Karori S at Makara Peak	1.12	60	0.049	0.525	4.38	0.46	60	0.211	0.077	46.28
RS19	Kaiwharawhara S at Ngaio Gorge	1.49	60	0.119	0.437	8.04	1.41	60	0.045	0.724	3.16
RS20	Hutt R at Te Marua Intake Site	1.00	60	0.009	0.887	0.88	0.93	60	0.030	0.437	3.20
RS21	Hutt R opp. Manor Park G.C.	2.37	60	-0.260	0.119	-10.99	2.22	59	-0.179	0.516	-8.03
RS22	Hutt R at Boulcott	2.70	60	0.055	0.777	2.04	2.23	59	0.030	0.942	1.36
RS23	Pakuratahi R 50m d/s Farm Ck	0.85	60	-0.014	0.724	-1.67	0.80	60	-0.003	0.944	-0.37
RS24	Mangaroa R at Te Marua	1.75	60	-0.047	0.437	-2.66	1.69	59	-0.027	0.613	-1.63
RS25	Akatarawa R at Hutt confl.	0.60	60	-0.070	0.724	-11.79	0.54	60	-0.037	0.358	-6.80
RS26	Whakatikei R at Riverstone	0.89	60	-0.018	0.832	-1.99	0.66	60	0.004	1.000	0.60
RS27	Waiwhetu S at Wainui Hill Br	6.59	59	-1.025	0.014	-15.55	4.21	59	-1.023	0.005	-24.29
RS28	Wainuiomata R at Manuka Track	0.99	58	0.028	0.606	2.79	0.96	57	0.004	0.881	0.40
RS29	Wainuiomata R u/s of White Br	2.60	59	-0.243	0.070	-9.36	2.53	59	-0.285	0.036	-11.28
RS30	Orongorongo R at Orongorongo Stn	7.06	59	-0.331	0.469	-4.68	3.78	53	0.108	0.509	2.85
RS31	Ruamahanga R at McLays	1.06	60	0.062	0.321	5.84	1.00	60	0.002	0.944	0.23
RS32	Ruamahanga R at Te Ore Ore	4.35	60	0.071	0.832	1.64	4.17	60	-0.438	0.009	-10.51
RS33	Ruamahanga R at Gladstone Br	3.20	60	0.059	0.944	1.86	2.98	60	-0.136	0.040	-4.58
RS34	Ruamahanga R at Pukio	7.77	60	1.090	0.229	14.03	7.82	59	-0.289	0.516	-3.69
RS35	Mataikona Trib at Sugar Loaf Rd	1.80	60	0.015	0.832	0.85	-	-	-	-	-
RS36	Taueru R at Castlehill	3.54	60	0.259	0.020	7.30	3.23	60	-0.072	0.832	-2.23
RS37	Taueru R at Gladstone	5.30	59	-0.140	0.664	-2.63	-	-	-	-	-
RS38	Kopuaranga R at Stewarts	3.42	60	0.153	0.395	4.48	3.42	60	-0.035	0.887	-1.02
RS39	Whangaehu R 250m u/s confl.	4.78	60	0.921	0.011	19.29	-	-	-	-	-
RS40	Waipoua R at Colombo Rd Br	0.73	60	-0.006	0.887	-0.87	0.63	52	0.044	0.198	7.03
RS41	Waingawa R at South Rd	1.10	60	-0.046	0.356	-4.18	0.18	60	-0.041	0.437	-23.23
RS42	Whareama R at Gauge	6.40	59	0.591	0.071	9.24	6.27	59	0.217	0.170	3.45
RS43	Motuwaireka S at Headwaters	0.70	58	0.063	0.335	8.98	0.52	58	0.049	0.417	9.33
RS44	Totara S at Stronvar	0.71	58	-0.045	0.338	-6.33	0.43	58	-0.030	0.606	-6.91
RS45	Parkvale Trib at Lowes Res.	1.10	47	0.020	0.678	1.79	-	-	-	-	-
RS46	Parkvale S at Weir	3.48	60	0.277	0.202	7.96	2.65	59	-0.054	0.829	-2.03
RS47	Waiohine R at Gorge	0.82	60	0.092	0.138	11.32	0.81	60	-0.002	0.832	-0.27
RS48	Waiohine R at Bicknells	1.69	60	0.121	0.321	7.16	1.32	60	0.010	0.832	0.73
RS49	Beef Ck at Headwaters	1.15	60	0.156	0.056	13.55	-	-	-	-	-
RS50	Mangatarere S at SH 2	1.77	60	0.124	0.321	7.02	1.71	59	0.059	0.516	3.45
RS51	Huangarua R at Ponatahi Br	2.03	60	-0.045	0.257	-2.22	-	-	-	-	-
RS52	Tauanui R at Whakatomotomo Rd	0.78	59	0.009	0.717	1.12	0.71	59	0.009	0.829	1.25
RS53	Awhea R at Tora Rd	4.45	60	-0.192	0.179	-4.33	-	-	-	-	-
RS54	Coles Ck Trib at Lagoon Hill Rd	3.92	50	-0.088	0.796	-2.24	-	-	-	-	-
RS55	Tauherenikau R at Websters	2.62	60	-0.137	0.724	-5.23	1.64	60	-0.274	0.621	-16.66
RS56	Waiorongomai R at Forest Pk	1.05	60	0.049	0.286	4.71	0.94	60	0.009	0.944	0.91

Conductivity (µS/cm)

Site	Site name	Raw data					Flow-adjusted data				
		Median	*n*	MASS	*p*	% Change	Median	*n*	MASS	*p*	% Change
RS02	Mangapouri S at Bennetts Rd	211.00	60	-1.872	0.156	-0.89	-	-	-	-	-
RS03	Waitohu S at Forest Pk	84.00	59	1.101	0.081	1.31	83.98	57	0.243	0.327	0.29
RS04	Waitohu S at Norfolk Cres	150.50	60	1.922	0.777	1.28	150.08	58	0.580	0.712	0.39
RS05	Otaki R at Pukehinau	65.50	60	1.688	0.102	2.58	65.68	60	0.147	0.832	0.22
RS06	Otaki R at Mouth	67.25	60	1.414	0.254	2.10	66.94	60	0.390	0.358	0.58
RS07	Mangaone S at Sims Rd Br	201.00	59	-0.502	0.664	-0.25	203.23	59	-0.781	0.516	-0.38
RS08	Ngarara S at Field Way	311.00	59	-10.942	0.097	-3.52	-	-	-	-	-
RS09	Waikanae R at Mangaone Walkway	84.00	60	0.251	0.830	0.30	84.01	60	0.053	0.944	0.06
RS10	Waikanae R at Greenaway Rd	103.00	60	3.241	0.040	3.15	-	-	-	-	-
RS11	Whareroa S at Waterfall Rd	237.50	60	0.745	0.777	0.31	238.65	57	0.418	0.880	0.18
RS12	Whareroa S at QE Park	262.00	60	-6.906	0.227	-2.64	259.67	57	-2.265	0.258	-0.87
RS13	Horokiri S at Snodgrass	185.00	60	-0.741	0.517	-0.40	185.11	59	0.009	1.000	0.01
RS14	Pauatahanui S at Elmwood Br	176.00	60	-2.339	0.395	-1.33	174.89	60	-1.400	0.138	-0.80
RS15	Porirua S at Glenside	250.00	59	0.626	0.664	0.25	250.01	59	0.379	0.942	0.15
RS16	Porirua S at Wall Park (Milk Depot)	258.00	59	-1.004	0.469	-0.39	257.85	59	-1.306	0.279	-0.51
RS17	Makara S at Kennels	271.00	59	-2.810	0.193	-1.04	267.97	59	-1.134	0.613	-0.42
RS18	Karori S at Makara Peak	225.00	58	-0.998	0.656	-0.44	225.58	58	-0.961	0.507	-0.43
RS19	Kaiwharawhara S at Ngaio Gorge	286.00	59	-1.382	0.772	-0.48	285.39	59	1.364	0.516	0.48
RS20	Hutt R at Te Marua Intake Site	66.50	58	0.927	0.415	1.39	66.33	58	1.220	0.065	1.84
RS21	Hutt R opp. Manor Park G.C.	99.00	59	2.246	0.309	2.27	99.25	58	2.735	0.122	2.76
RS22	Hutt R at Boulcott	87.00	59	0.988	0.348	1.14	86.28	58	1.006	0.090	1.17
RS23	Pakuratahi R 50m d/s Farm Ck	82.00	59	0.418	0.561	0.51	82.19	59	0.147	0.613	0.18
RS24	Mangaroa R at Te Marua	102.00	58	-0.420	0.499	-0.41	101.96	57	-0.155	0.821	-0.15
RS25	Akatarawa R at Hutt confl.	80.00	59	1.003	0.311	1.25	80.80	59	0.627	0.097	0.78
RS26	Whakatikei R at Riverstone	106.00	59	4.363	0.001	4.12	108.50	59	3.498	0.005	3.22
RS27	Waiwhetu S at Wainui Hill Br	236.00	56	7.951	0.221	3.37	197.00	56	3.894	0.878	1.98
RS28	Wainuiomata R at Manuka Track	104.00	55	1.177	0.263	1.13	104.38	55	0.639	0.140	0.61
RS29	Wainuiomata R u/s of White Br	141.00	57	0.000	1.000	0.00	141.48	57	0.321	0.706	0.23
RS30	Orongorongo R at Orongorongo Stn	135.50	58	-2.007	0.183	-1.48	136.97	52	-3.805	0.001	-2.78
RS31	Ruamahanga R at McLays	48.50	60	-1.845	0.202	-3.80	48.05	60	-0.463	0.138	-0.96
RS32	Ruamahanga R at Te Ore Ore	126.00	59	-2.719	0.385	-2.16	125.06	59	2.255	0.220	1.80
RS33	Ruamahanga R at Gladstone Br	114.00	59	-1.099	0.715	-0.96	115.43	59	0.306	0.613	0.27
RS34	Ruamahanga R at Pukio	130.00	59	0.000	1.000	0.00	127.78	58	-1.092	0.941	-0.85
RS35	Mataikona Trib at Sugar Loaf Rd	374.50	60	14.858	0.089	3.97	-	-	-	-	-
RS36	Taueru R at Castlehill	221.00	60	-4.384	0.356	-1.98	220.81	60	0.898	0.621	0.41
RS37	Taueru R at Gladstone	415.50	60	7.313	0.156	1.76	-	-	-	-	-
RS38	Kopuaranga R at Stewarts	269.00	60	3.634	0.437	1.35	265.28	60	4.664	0.020	1.76
RS39	Whangaehu R 250m u/s confl.	289.00	59	-2.161	0.427	-0.75	-	-	-	-	-
RS40	Waipoua R at Colombo Rd Br	102.00	60	0.911	0.522	0.89	101.69	52	1.241	0.021	1.22
RS41	Waingawa R at South Rd	60.00	60	-0.995	0.571	-1.66	59.15	60	-0.021	0.944	-0.03
RS42	Whareama R at Gauge	544.00	60	3.755	0.621	0.69	552.50	60	2.105	0.832	0.38
RS43	Motuwaireka S at Headwaters	289.00	59	3.616	0.309	1.25	285.08	59	0.538	0.942	0.19
RS44	Totara S at Stronvar	318.50	58	-7.772	0.038	-2.44	299.82	58	-5.575	0.047	-1.86
RS45	Parkvale Trib at Lowes Res.	179.00	47	2.438	0.739	1.36	-	-	-	-	-
RS46	Parkvale S at Weir	151.00	60	0.000	1.000	0.00	150.33	59	0.457	0.829	0.30
RS47	Waiohine R at Gorge	54.00	60	-0.753	0.476	-1.39	53.86	60	0.075	1.000	0.14
RS48	Waiohine R at Bicknells	72.00	60	2.155	0.089	2.99	70.96	60	1.155	0.077	1.63
RS49	Beef Ck at Headwaters	90.50	60	0.940	0.671	1.04	-	-	-	-	-
RS50	Mangatarere S at SH 2	115.00	60	-1.985	0.724	-1.73	115.50	59	-1.066	0.427	-0.92
RS51	Huangarua R at Ponatahi Br	375.00	59	6.102	0.193	1.63	-	-	-	-	-
RS52	Tauanui R at Whakatomotomo Rd	147.50	58	0.289	0.824	0.20	145.60	58	0.270	0.712	0.19
RS53	Awhea R at Tora Rd	439.00	59	-5.365	0.311	-1.22	-	-	-	-	-
RS54	Coles Ck Trib at Lagoon Hill Rd	618.50	50	-3.815	0.931	-0.62	-	-	-	-	-
RS55	Tauherenikau R at Websters	68.00	60	2.150	0.202	3.16	68.08	60	1.408	0.002	2.07
RS56	Waiorongomai R at Forest Pk	115.00	59	-0.333	0.885	-0.29	115.08	59	-0.190	0.829	-0.17

Total organic carbon (mg/L)

Site	Site name	Raw data					Flow-adjusted data					% Cen.
		Median	*n*	MASS	*p*	% Change	Median	*n*	MASS	*p*	% Change	
RS02	Mangapouri S at Bennetts Rd	5.35	60	-0.23	0.522	-4.21	-	-	-	-	-	0.00
RS03	Waitohu S at Forest Pk	1.90	59	0.06	0.244	3.02	1.86	57	0.04	0.15	2.28	0.00
RS04	Waitohu S at Norfolk Cres	4.20	60	-0.14	0.392	-3.35	4.12	58	-0.13	0.42	-3.07	0.00
RS05	Otaki R at Pukehinau	1.10	60	0.08	0.252	7.39	1.13	60	0.08	0.01	7.54	6.67
RS06	Otaki R at Mouth	1.04	60	0.05	0.319	4.76	1.04	60	0.08	0.01	8.17	1.67
RS07	Mangaone S at Sims Rd Br	4.90	60	-0.19	0.254	-3.81	4.78	60	-0.25	0.02	-5.08	0.00
RS08	Ngarara S at Field Way	15.80	60	-0.29	0.254	-1.84	-	-	-	-	-	0.00
RS09	Waikanae R at Mangaone Walkway	1.30	60	0.07	0.351	5.51	1.26	60	0.03	0.52	2.29	0.00
RS10	Waikanae R at Greenaway Rd	1.20	60	0.10	0.027	8.34	-	-	-	-	-	0.00
RS11	Whareroa S at Waterfall Rd	3.70	60	0.25	0.039	6.76	3.66	57	0.22	0.17	5.88	0.00
RS12	Whareroa S at QE Park	12.55	60	-0.20	0.434	-1.60	11.92	57	-0.16	0.71	-1.28	0.00
RS13	Horokiri S at Snodgrass	2.00	60	0.10	0.061	5.02	1.95	59	0.06	0.43	2.86	0.00
RS14	Pauatahanui S at Elmwood Br	3.70	60	0.20	0.177	5.43	3.63	60	0.13	0.06	3.61	0.00
RS15	Porirua S at Glenside	3.70	60	0.00	1.000	0.00	3.79	60	-0.02	0.94	-0.56	1.67
RS16	Porirua S at Wall Park (Milk Depot)	3.45	60	-0.23	0.136	-6.61	3.53	60	-0.23	0.10	-6.61	0.00
RS17	Makara S at Kennels	4.50	60	0.02	0.830	0.38	4.56	60	0.06	0.62	1.32	0.00
RS18	Karori S at Makara Peak	2.10	60	0.07	0.432	3.38	2.13	60	0.02	0.72	0.98	3.33
RS19	Kaiwharawhara S at Ngaio Gorge	3.30	60	-0.02	1.000	-0.51	3.31	60	-0.06	0.62	-1.85	0.00
RS20	Hutt R at Te Marua Intake Site	2.25	60	0.12	0.722	5.19	2.19	60	0.05	0.83	2.18	0.00
RS21	Hutt R opp. Manor Park G.C.	2.70	60	0.09	0.356	3.27	2.72	59	0.14	0.10	5.10	0.00
RS22	Hutt R at Boulcott	2.30	60	0.09	0.621	4.08	2.19	59	0.10	0.07	4.28	0.00
RS23	Pakuratahi R 50m d/s Farm Ck	2.20	60	0.05	0.722	2.28	2.04	60	0.10	0.44	4.65	0.00
RS24	Mangaroa R at Te Marua	4.50	60	0.30	0.011	6.67	4.57	59	0.26	0.00	5.68	0.00
RS25	Akatarawa R at Hutt confl.	1.70	60	-0.03	0.617	-1.96	1.61	60	0.02	0.83	0.92	0.00
RS26	Whakatikei R at Riverstone	1.68	60	0.00	1.000	0.00	1.62	60	-0.06	0.52	-3.56	0.00
RS27	Waiwhetu S at Wainui Hill Br	4.00	59	-0.30	0.082	-7.48	3.99	59	-0.30	0.05	-7.56	0.00
RS28	Wainuiomata R at Manuka Track	1.90	58	0.00	0.821	0.00	1.89	57	0.09	0.30	4.60	0.00
RS29	Wainuiomata R u/s of White Br	1.90	59	0.00	0.826	0.00	1.85	59	0.03	0.43	1.56	0.00
RS30	Orongorongo R at Orongorongo Stn	1.70	59	0.10	0.144	5.96	1.85	53	0.15	0.25	8.43	11.67
RS31	Ruamahanga R at McLays	1.55	60	0.07	0.319	4.54	1.55	60	0.10	0.29	6.48	1.67
RS32	Ruamahanga R at Te Ore Ore	3.10	60	-0.03	0.943	-1.06	3.01	60	-0.01	0.94	-0.43	1.67
RS33	Ruamahanga R at Gladstone Br	2.55	60	0.41	0.023	16.16	2.61	60	0.18	0.23	7.20	3.33
RS34	Ruamahanga R at Pukio	3.25	60	0.43	0.229	13.31	3.38	59	0.06	0.83	1.80	1.67
RS35	Mataikona Trib at Sugar Loaf Rd	3.10	60	0.00	1.000	0.00	-	-	-	-	-	0.00
RS36	Taueru R at Castlehill	5.60	60	-0.02	0.943	-0.44	5.22	60	-0.11	0.52	-1.93	0.00
RS37	Taueru R at Gladstone	5.70	59	0.50	0.095	8.77	-	-	-	-	-	0.00
RS38	Kopuaranga R at Stewarts	4.35	60	-0.10	0.522	-2.33	4.16	60	-0.26	0.14	-5.93	1.67
RS39	Whangaehu R 250m u/s confl.	7.05	60	0.81	0.104	11.43	-	-	-	-	-	0.00
RS40	Waipoua R at Colombo Rd Br	1.75	60	0.10	0.478	5.65	1.71	52	0.01	1.00	0.34	10.00
RS41	Waingawa R at South Rd	1.10	60	0.07	0.119	6.41	1.14	60	0.08	0.18	7.50	5.00
RS42	Whareama R at Gauge	6.70	59	0.01	0.942	0.19	6.59	59	-0.03	0.83	-0.44	1.69
RS43	Motuwaireka S at Headwaters	2.20	58	-0.16	0.159	-7.23	2.24	58	-0.08	0.42	-3.68	1.72
RS44	Totara S at Stronvar	3.20	58	-0.30	0.053	-9.49	3.07	58	-0.24	0.09	-7.62	3.45
RS45	Parkvale Trib at Lowes Res.	4.60	47	-0.25	0.320	-5.41	-	-	-	-	-	0.00
RS46	Parkvale S at Weir	5.95	60	0.04	0.831	0.70	5.95	57	0.15	0.50	2.53	0.00
RS47	Waiohine R at Gorge	1.20	60	0.07	0.286	5.46	1.17	60	0.06	0.10	5.07	3.33
RS48	Waiohine R at Bicknells	1.40	60	0.08	0.117	5.91	1.32	60	0.07	0.08	4.93	1.67
RS49	Beef Ck at Headwaters	1.70	60	0.10	0.038	5.90	-	-	-	-	-	3.33
RS50	Mangatarere S at SH 2	2.20	60	0.23	0.074	10.34	2.13	59	0.17	0.13	7.81	1.67
RS51	Huangarua R at Ponatahi Br	3.95	60	-0.17	0.478	-4.37	-	-	-	-	-	0.00
RS52	Tauanui R at Whakatomotomo Rd	2.90	59	0.16	0.068	5.57	2.94	59	0.11	0.22	3.78	0.00
RS53	Awhea R at Tora Rd	4.10	60	-0.10	0.619	-2.42	-	-	-	-	-	0.00
RS54	Coles Ck Trib at Lagoon Hill Rd	5.65	50	0.00	1.000	0.00	-	-	-	-	-	0.00
RS55	Tauherenikau R at Websters	1.55	60	0.04	0.430	2.47	1.45	60	0.04	0.52	2.46	1.67
RS56	Waiorongomai R at Forest Pk	2.45	60	0.30	0.046	12.17	2.44	54	0.28	0.03	11.46	0.00

Nitrite-nitrate nitrogen (mg/L)

Site	Site name	Raw data					Flow-adjusted data					% Cen.
		Median	*n*	MASS	*p*	% Change	Median	*n*	MASS	*p*	% Change	
RS02	Mangapouri S at Bennetts Rd	2.135	60	0.050	0.525	2.35	-	-	-	-	-	0.00
RS03	Waitohu S at Forest Pk	0.028	59	-0.003	0.095	-11.36	0.029	57	-0.002	0.083	-6.30	5.08
RS04	Waitohu S at Norfolk Cres	0.530	60	-0.006	0.722	-1.08	0.535	58	-0.004	0.825	-0.73	0.00
RS05	Otaki R at Pukehinau	0.038	60	-0.003	0.007	-8.65	0.035	60	-0.004	0.004	-10.51	3.33
RS06	Otaki R at Mouth	0.053	60	-0.003	0.129	-6.27	0.049	60	-0.002	0.229	-4.73	8.33
RS07	Mangaone S at Sims Rd Br	2.000	60	-0.103	0.200	-5.15	1.990	60	-0.072	0.056	-3.59	0.00
RS08	Ngarara S at Field Way	0.255	60	-0.054	0.000	-20.98	-	-	-	-	-	1.67
RS09	Waikanae R at Mangaone Walkway	0.110	60	-0.004	0.289	-3.19	0.111	60	-0.005	0.179	-4.23	0.00
RS10	Waikanae R at Greenaway Rd	0.219	60	-0.011	0.227	-5.17	-	-	-	-	-	0.00
RS11	Whareroa S at Waterfall Rd	0.320	60	0.000	1.000	-0.08	0.277	57	-0.009	0.706	-3.14	0.00
RS12	Whareroa S at QE Park	0.362	60	0.023	0.077	6.37	0.320	57	0.033	0.200	9.29	0.00
RS13	Horokiri S at Snodgrass	0.407	60	0.006	0.619	1.50	0.366	59	-0.017	0.130	-4.28	0.00
RS14	Pauatahanui S at Elmwood Br	0.215	60	-0.002	0.776	-1.02	0.202	60	0.002	0.724	1.08	3.33
RS15	Porirua S at Glenside	1.000	60	-0.058	0.011	-5.82	0.954	60	-0.042	0.056	-4.15	0.00
RS16	Porirua S at Wall Park (Milk Depot)	0.990	60	-0.044	0.047	-4.47	1.000	60	-0.020	0.229	-2.05	0.00
RS17	Makara S at Kennels	0.316	60	-0.002	1.000	-0.53	0.286	60	-0.009	0.289	-2.85	1.67
RS18	Karori S at Makara Peak	1.325	60	-0.042	0.177	-3.17	1.408	60	-0.028	0.358	-2.12	0.00
RS19	Kaiwharawhara S at Ngaio Gorge	1.150	60	-0.026	0.434	-2.29	1.130	60	-0.012	0.437	-1.01	1.67
RS20	Hutt R at Te Marua Intake Site	0.087	60	-0.002	0.569	-2.03	0.083	60	-0.001	0.832	-1.41	0.00
RS21	Hutt R opp. Manor Park G.C.	0.220	60	-0.007	0.393	-3.04	0.222	59	-0.008	0.220	-3.77	0.00
RS22	Hutt R at Boulcott	0.200	60	-0.010	0.200	-4.92	0.183	59	-0.003	0.516	-1.72	0.00
RS23	Pakuratahi R 50m d/s Farm Ck	0.229	60	-0.009	0.136	-3.93	0.202	60	-0.007	0.358	-2.93	0.00
RS24	Mangaroa R at Te Marua	0.484	60	-0.029	0.039	-6.05	0.489	59	-0.023	0.051	-4.68	0.00
RS25	Akatarawa R at Hutt confl.	0.102	60	-0.005	0.102	-5.20	0.107	60	-0.008	0.013	-7.97	0.00
RS26	Whakatikei R at Riverstone	0.098	60	-0.005	0.179	-5.48	0.099	60	-0.004	0.724	-3.64	0.00
RS27	Waiwhetu S at Wainui Hill Br	0.450	59	-0.020	0.277	-4.44	0.454	59	-0.007	0.613	-1.66	0.00
RS28	Wainuiomata R at Manuka Track	0.075	58	-0.006	0.020	-8.27	0.075	57	-0.006	0.007	-7.69	0.00
RS29	Wainuiomata R u/s of White Br	0.200	59	-0.011	0.514	-5.51	0.188	59	-0.012	0.427	-6.02	0.00
RS30	Orongorongo R at Orongorongo Stn	0.056	59	-0.014	0.000	-25.50	0.052	53	-0.015	0.000	-28.71	1.67
RS31	Ruamahanga R at McLays	0.025	60	-0.002	0.037	-6.90	0.022	60	-0.001	0.525	-2.80	0.00
RS32	Ruamahanga R at Te Ore Ore	0.397	60	-0.037	0.028	-9.45	0.404	60	-0.033	0.229	-8.43	0.00
RS33	Ruamahanga R at Gladstone Br	0.403	60	-0.014	0.522	-3.51	0.402	60	-0.038	0.040	-9.48	0.00
RS34	Ruamahanga R at Pukio	0.331	60	-0.026	0.434	-7.91	0.347	59	-0.035	0.071	-10.47	3.33
RS35	Mataikona Trib at Sugar Loaf Rd	0.016	60	0.000	0.289	-1.27	-	-	-	-	-	11.67
RS36	Taueru R at Castlehill	0.071	60	-0.005	0.138	-7.66	0.073	60	-0.010	0.020	-14.54	1.67
RS37	Taueru R at Gladstone	0.910	59	-0.120	0.008	-13.22	-	-	-	-	-	0.00
RS38	Kopuaranga R at Stewarts	0.967	60	-0.006	0.671	-0.67	0.954	60	-0.017	0.229	-1.76	0.00
RS39	Whangaehu R 250m u/s confl.	0.965	60	-0.214	0.013	-22.20	-	-	-	-	-	0.00
RS40	Waipoua R at Colombo Rd Br	0.895	60	-0.064	0.202	-7.18	0.910	52	-0.051	0.072	-5.72	0.00
RS41	Waingawa R at South Rd	0.066	60	-0.008	0.065	-11.84	0.063	60	-0.003	0.179	-5.02	0.00
RS42	Whareama R at Gauge	0.005	60	0.000	0.943	0.00	0.004	60	0.000	0.437	0.21	38.98
RS43	Motuwaireka S at Headwaters	0.033	58	-0.010	0.090	-31.55	0.006	58	-0.013	0.122	-39.56	1.72
RS44	Totara S at Stronvar	0.010	58	0.000	0.825	-0.94	0.009	58	-0.001	0.417	-9.89	12.07
RS45	Parkvale Trib at Lowes Res.	4.400	47	-0.154	0.360	-3.50	-	-	-	-	-	0.00
RS46	Parkvale S at Weir	1.285	60	-0.058	0.076	-4.48	1.196	57	-0.130	0.008	-10.51	1.67
RS47	Waiohine R at Gorge	0.028	60	0.000	0.943	0.00	0.028	60	-0.001	0.229	-3.01	3.33
RS48	Waiohine R at Bicknells	0.295	60	-0.006	0.832	-2.18	0.265	60	-0.014	0.525	-4.72	0.00
RS49	Beef Ck at Headwaters	0.024	60	-0.003	0.003	-12.43	-	-	-	-	-	3.33
RS50	Mangatarere S at SH 2	1.240	60	-0.085	0.104	-6.82	1.317	59	-0.051	0.025	-4.11	0.00
RS51	Huangarua R at Ponatahi Br	0.210	60	0.009	0.395	4.14	-	-	-	-	-	1.67
RS52	Tauanui R at Whakatomotomo Rd	0.012	59	-0.001	0.002	-8.76	0.011	59	-0.001	0.025	-12.26	3.39
RS53	Awhea R at Tora Rd	0.019	60	-0.001	0.437	-3.89	-	-	-	-	-	13.33
RS54	Coles Ck Trib at Lagoon Hill Rd	0.007	50	0.000	0.666	-3.30	-	-	-	-	-	12.00
RS55	Tauherenikau R at Websters	0.029	60	0.001	0.832	3.51	0.023	60	0.000	1.000	1.19	1.67
RS56	Waiorongomai R at Forest Pk	0.013	60	0.000	0.474	-3.32	0.008	54	0.000	0.570	3.83	8.33

Ammoniacal nitrogen (mg/L)

Site	Site name	Raw data					Flow-adjusted data					% Cen.
		Median	*n*	MASS	*p*	% Change	Median	*n*	MASS	*p*	% Change	
RS02	Mangapouri S at Bennetts Rd	0.041	60	-0.004	0.227	-9.66	-	-	-	-	-	11.67
RS03	Waitohu S at Forest Pk	-	-	-	-	-	-	-	-	-	-	84.75
RS04	Waitohu S at Norfolk Cres	0.040	60	-0.001	0.777	-2.93	0.040	58	-0.001	0.606	-2.89	5.00
RS05	Otaki R at Pukehinau	-	-	-	-	-	-	-	-	-	-	85.00
RS06	Otaki R at Mouth	0.001	60	0.000	0.179	-1.34	0.000	60	-0.001	0.056	-54.64	80.00
RS07	Mangaone S at Sims Rd Br	0.085	60	-0.004	0.202	-4.30	0.092	60	-0.006	0.138	-6.75	3.33
RS08	Ngarara S at Field Way	0.025	60	-0.007	0.000	-26.67	-	-	-	-	-	15.00
RS09	Waikanae R at Mangaone Walkway	-	-	-	-	-	-	-	-	-	-	86.67
RS10	Waikanae R at Greenaway Rd	0.002	60	0.000	0.007	-14.65	0.002	35	0.000	0.534	-23.92	76.67
RS11	Whareroa S at Waterfall Rd	0.003	60	0.000	0.944	-0.97	0.002	57	0.000	0.498	-7.76	66.67
RS12	Whareroa S at QE Park	0.090	60	-0.005	0.076	-5.62	0.090	57	-0.007	0.200	-8.45	5.00
RS13	Horokiri S at Snodgrass	0.004	60	0.000	0.358	-4.89	0.003	59	0.000	0.427	-6.98	78.33
RS14	Pauatahanui S at Elmwood Br	0.012	60	0.000	0.887	0.34	0.011	60	0.000	1.000	0.33	38.33
RS15	Porirua S at Glenside	0.003	60	-0.001	0.033	-14.76	0.001	60	-0.001	0.001	-34.77	66.67
RS16	Porirua S at Wall Park (Milk Depot)	0.014	60	-0.003	0.104	-18.82	0.009	60	-0.002	0.040	-17.04	41.67
RS17	Makara S at Kennels	0.012	60	-0.002	0.006	-17.43	0.011	60	-0.002	0.020	-17.72	41.67
RS18	Karori S at Makara Peak	0.013	60	-0.001	0.046	-10.60	0.013	60	-0.001	0.289	-7.87	30.00
RS19	Kaiwharawhara S at Ngaio Gorge	0.010	60	-0.001	0.040	-8.01	0.002	60	-0.003	0.358	-25.14	46.67
RS20	Hutt R at Te Marua Intake Site	0.002	60	0.000	0.007	-15.69	0.001	60	0.000	0.077	-21.20	80.00
RS21	Hutt R opp. Manor Park G.C.	0.004	60	0.000	0.229	-7.47	0.003	59	0.000	0.613	-5.82	75.00
RS22	Hutt R at Boulcott	-	-	-	-	-	-	-	-	-	-	85.00
RS23	Pakuratahi R 50m d/s Farm Ck	-	-	-	-	-	-	-	-	-	-	81.67
RS24	Mangaroa R at Te Marua	0.003	60	0.000	0.321	-3.55	-0.001	59	-0.001	0.097	-28.16	65.00
RS25	Akatarawa R at Hutt confl.	0.001	60	0.000	0.004	-14.79	0.000	60	-0.001	0.040	-74.79	78.33
RS26	Whakatikei R at Riverstone	-	-	-	-	-	-	-	-	-	-	85.00
RS27	Waiwhetu S at Wainui Hill Br	0.076	59	-0.008	0.082	-11.06	0.067	59	-0.008	0.071	-10.51	8.33
RS28	Wainuiomata R at Manuka Track	-	-	-	-	-	-	-	-	-	-	81.36
RS29	Wainuiomata R u/s of White Br	0.011	59	-0.001	0.025	-11.56	0.009	59	-0.001	0.130	-9.88	43.33
RS30	Orongorongo R at Orongorongo Stn	-	-	-	-	-	-	-	-	-	-	81.67
RS31	Ruamahanga R at McLays	-	-	-	-	-	-	-	-	-	-	81.67
RS32	Ruamahanga R at Te Ore Ore	0.004	60	0.000	0.321	-4.75	0.004	60	0.000	0.040	-10.66	75.00
RS33	Ruamahanga R at Gladstone Br	0.019	60	0.000	0.522	-1.73	0.019	60	-0.002	0.056	-12.25	30.00
RS34	Ruamahanga R at Pukio	0.007	60	0.000	1.000	0.00	0.005	59	-0.001	0.220	-15.96	55.00
RS35	Mataikona Trib at Sugar Loaf Rd	0.006	59	0.000	0.664	-1.78	-	-	-	-	-	76.27
RS36	Taueru R at Castlehill	0.005	59	-0.001	0.006	-15.56	0.005	59	-0.002	0.008	-31.24	64.41
RS37	Taueru R at Gladstone	0.005	60	-0.001	0.179	-9.78	-	-	-	-	-	55.93
RS38	Kopuaranga R at Stewarts	0.011	60	0.000	0.887	-2.02	0.009	60	-0.001	0.028	-11.36	40.00
RS39	Whangaehu R 250m u/s confl.	0.007	60	0.000	0.522	3.58	-	-	-	-	-	53.33
RS40	Waipoua R at Colombo Rd Br	0.002	60	0.000	0.039	-8.09	0.001	52	0.000	0.797	-2.91	80.00
RS41	Waingawa R at South Rd	-	-	-	-	-	-	-	-	-	-	88.33
RS42	Whareama R at Gauge	0.004	60	0.000	0.437	-2.24	0.003	60	0.000	0.229	-5.68	67.80
RS43	Motuwaireka S at Headwaters	-	-	-	-	-	-	-	-	-	-	82.76
RS44	Totara S at Stronvar	0.003	58	0.000	0.122	-14.05	0.001	58	-0.001	0.065	-21.60	77.59
RS45	Parkvale Trib at Lowes Res.	0.002	47	0.000	0.185	-12.35	-	-	-	-	-	74.47
RS46	Parkvale S at Weir	0.016	60	0.000	0.434	1.57	0.013	57	0.000	1.000	0.59	33.33
RS47	Waiohine R at Gorge	-	-	-	-	-	-	-	-	-	-	81.67
RS48	Waiohine R at Bicknells	0.011	60	0.000	0.943	-0.08	0.009	60	0.000	0.525	4.02	43.33
RS49	Beef Ck at Headwaters	-	-	-	-	-	-	-	-	-	-	81.67
RS50	Mangatarere S at SH 2	0.100	60	0.000	0.942	0.00	0.101	59	-0.003	0.516	-2.54	8.33
RS51	Huangarua R at Ponatahi Br	0.004	60	0.000	0.229	-6.82	-	-	-	-	-	68.33
RS52	Tauanui R at Whakatomotomo Rd	0.002	59	0.000	0.111	-10.46	0.002	59	0.000	0.051	-22.97	79.66
RS53	Awhea R at Tora Rd	0.003	60	-0.001	0.001	-14.78	-	-	-	-	-	70.00
RS54	Coles Ck Trib at Lagoon Hill Rd	0.004	50	-0.002	0.024	-51.11	-	-	-	-	-	62.00
RS55	Tauherenikau R at Websters	-	-	-	-	-	-	-	-	-	-	81.67
RS56	Waiorongomai R at Forest Pk	-	-	-	-	-	-	-	-	-	-	90.00

Total Kjeldahl Nitrogen (mg/L)

Site	Site name	Raw data					Flow-adjusted data					% Cen.
		Median	*n*	MASS	*p*	% Change	Median	*n*	MASS	*p*	% Change	
RS02	Mangapouri S at Bennetts Rd	0.540	60	-0.030	0.016	-5.57	-	-	-	-	-	0.00
RS03	Waitohu S at Forest Pk	0.025	59	-0.003	0.311	-10.46	0.020	57	-0.003	0.060	-12.97	76.27
RS04	Waitohu S at Norfolk Cres	0.325	60	-0.014	0.195	-4.20	0.312	58	-0.009	0.269	-2.70	0.00
RS05	Otaki R at Pukehinau	-	-	-	-	-	-	-	-	-	-	81.67
RS06	Otaki R at Mouth	-	-	-	-	-	-	-	-	-	-	88.33
RS07	Mangaone S at Sims Rd Br	0.500	60	-0.010	0.724	-2.00	0.482	60	-0.024	0.229	-4.90	0.00
RS08	Ngarara S at Field Way	0.775	60	-0.035	0.177	-4.49	-	-	-	-	-	0.00
RS09	Waikanae R at Mangaone Walkway	-	-	-	-	-	-	-	-	-	-	81.67
RS10	Waikanae R at Greenaway Rd	0.039	60	-0.006	0.003	-16.51	-	-	-	-	-	70.00
RS11	Whareroa S at Waterfall Rd	0.200	60	0.004	0.615	2.08	0.199	57	-0.002	0.880	-0.91	3.33
RS12	Whareroa S at QE Park	0.655	60	-0.012	0.478	-1.78	0.618	57	-0.008	0.258	-1.26	0.00
RS13	Horokiri S at Snodgrass	0.170	60	-0.004	0.565	-2.44	0.166	59	-0.009	0.130	-5.58	5.00
RS14	Pauatahanui S at Elmwood Br	0.230	60	0.004	0.669	1.62	0.223	60	-0.005	0.437	-2.34	1.67
RS15	Porirua S at Glenside	0.280	60	-0.010	0.172	-3.59	0.285	60	-0.014	0.056	-5.16	0.00
RS16	Porirua S at Wall Park (Milk Depot)	0.280	60	-0.007	0.432	-2.55	0.276	60	-0.012	0.289	-4.13	1.67
RS17	Makara S at Kennels	0.300	60	-0.007	0.429	-2.23	0.312	60	-0.010	0.437	-3.21	0.00
RS18	Karori S at Makara Peak	0.220	60	-0.012	0.132	-5.31	0.224	60	-0.012	0.229	-5.34	3.33
RS19	Kaiwharawhara S at Ngaio Gorge	0.300	60	-0.010	0.353	-3.32	0.285	60	-0.008	0.621	-2.60	0.00
RS20	Hutt R at Te Marua Intake Site	0.070	60	-0.002	0.522	-3.17	0.068	60	-0.001	0.621	-2.15	66.67
RS21	Hutt R opp. Manor Park G.C.	0.110	60	0.001	0.830	0.55	0.094	59	0.004	0.613	3.98	35.00
RS22	Hutt R at Boulcott	0.100	60	0.000	0.615	-0.14	0.096	59	-0.001	0.942	-1.04	46.67
RS23	Pakuratahi R 50m d/s Farm Ck	0.073	60	-0.005	0.286	-6.75	0.072	60	-0.007	0.437	-9.16	55.00
RS24	Mangaroa R at Te Marua	0.185	60	-0.003	0.565	-1.59	0.193	59	-0.005	0.516	-2.50	5.00
RS25	Akatarawa R at Hutt confl.	0.059	60	-0.003	0.671	-4.45	0.056	60	0.001	0.724	1.74	71.67
RS26	Whakatikei R at Riverstone	0.058	60	-0.001	0.777	-1.30	0.056	60	-0.001	0.832	-2.55	73.33
RS27	Waiwhetu S at Wainui Hill Br	0.370	59	-0.045	0.006	-12.19	0.328	59	-0.042	0.012	-11.23	1.67
RS28	Wainuiomata R at Manuka Track	0.051	58	-0.005	0.055	-9.60	0.046	57	-0.005	0.135	-9.31	67.80
RS29	Wainuiomata R u/s of White Br	0.140	59	-0.020	0.068	-14.34	0.135	59	-0.016	0.002	-11.74	23.33
RS30	Orongorongo R at Orongorongo Stn	0.021	59	0.000	0.772	-1.64	0.015	53	-0.001	0.741	-5.20	75.00
RS31	Ruamahanga R at McLays	0.025	60	0.000	0.395	1.09	0.025	60	0.000	0.832	0.98	75.00
RS32	Ruamahanga R at Te Ore Ore	0.135	60	0.000	0.887	0.34	0.118	60	-0.006	0.358	-4.22	28.33
RS33	Ruamahanga R at Gladstone Br	0.190	60	0.005	0.388	2.60	0.198	60	-0.007	0.525	-3.63	10.00
RS34	Ruamahanga R at Pukio	0.200	60	0.000	1.000	0.00	0.198	59	-0.008	0.348	-4.07	10.00
RS35	Mataikona Trib at Sugar Loaf Rd	0.130	60	-0.015	0.045	-11.58	-	-	-	-	-	21.67
RS36	Taueru R at Castlehill	0.300	60	-0.008	0.617	-2.77	0.279	60	-0.018	0.056	-5.95	3.33
RS37	Taueru R at Gladstone	0.400	59	0.010	0.469	2.50	-	-	-	-	-	0.00
RS38	Kopuaranga R at Stewarts	0.325	60	0.000	1.000	0.00	0.322	60	-0.014	0.289	-4.40	0.00
RS39	Whangaehu R 250m u/s confl.	0.545	60	0.033	0.257	6.12	-	-	-	-	-	0.00
RS40	Waipoua R at Colombo Rd Br	0.200	60	-0.002	0.720	-0.83	0.162	52	-0.003	0.548	-1.86	10.00
RS41	Waingawa R at South Rd	-	-	-	-	-	-	-	-	-	-	83.33
RS42	Whareama R at Gauge	0.400	59	-0.017	0.274	-4.37	0.394	59	-0.010	0.718	-2.45	0.00
RS43	Motuwaireka S at Headwaters	0.046	59	-0.007	0.035	-15.29	0.041	59	-0.008	0.051	-17.41	70.69
RS44	Totara S at Stronvar	0.105	58	-0.020	0.007	-19.46	0.088	58	-0.022	0.010	-21.20	37.93
RS45	Parkvale Trib at Lowes Res.	0.410	47	-0.027	0.243	-6.49	-	-	-	-	-	0.00
RS46	Parkvale S at Weir	0.600	60	-0.003	0.887	-0.48	0.587	57	0.023	0.407	3.78	1.67
RS47	Waiohine R at Gorge	0.042	60	0.002	0.358	5.68	0.035	60	0.000	0.724	0.50	78.33
RS48	Waiohine R at Bicknells	0.100	60	-0.003	0.619	-2.90	0.089	60	0.003	0.724	2.54	40.00
RS49	Beef Ck at Headwaters	0.045	60	-0.004	0.076	-8.41	-	-	-	-	-	65.00
RS50	Mangatarere S at SH 2	0.375	60	-0.010	0.356	-2.64	0.370	59	-0.008	0.427	-2.12	0.00
RS51	Huangarua R at Ponatahi Br	0.250	60	-0.002	0.887	-0.66	-	-	-	-	-	1.67
RS52	Tauanui R at Whakatomotomo Rd	0.039	59	0.001	0.942	1.30	0.015	59	-0.003	0.348	-8.22	69.49
RS53	Awhea R at Tora Rd	0.220	60	-0.004	0.474	-1.90	-	-	-	-	-	3.33
RS54	Coles Ck Trib at Lagoon Hill Rd	0.205	50	-0.007	0.113	-3.24	-	-	-	-	-	2.00
RS55	Tauherenikau R at Websters	0.056	60	0.000	0.887	0.47	0.053	60	-0.001	0.832	-1.80	70.00
RS56	Waiorongomai R at Forest Pk	0.047	60	0.002	0.321	5.05	0.043	54	0.002	0.123	5.26	63.33

Total nitrogen (mg/L)

Site	Site name	Raw data					Flow-adjusted data					% Cen.
		Median	*n*	MASS	*p*	% Change	Median	*n*	MASS	*p*	% Change	
RS02	Mangapouri S at Bennetts Rd	2.900	60	0.000	1.000	0.00	-	-	-	-	-	0.00
RS03	Waitohu S at Forest Pk	0.058	59	-0.006	0.043	-10.83	0.048	57	-0.011	0.019	-19.67	64.41
RS04	Waitohu S at Norfolk Cres	0.890	60	-0.019	0.356	-2.14	0.881	58	-0.024	0.338	-2.64	0.00
RS05	Otaki R at Pukehinau	0.049	60	0.000	0.724	-0.65	0.036	60	-0.002	0.229	-3.46	65.00
RS06	Otaki R at Mouth	0.071	60	0.000	0.943	0.00	0.063	60	0.003	0.229	4.79	55.00
RS07	Mangaone S at Sims Rd Br	2.600	60	-0.188	0.033	-7.22	2.569	60	-0.117	0.006	-4.48	0.00
RS08	Ngarara S at Field Way	0.995	60	-0.100	0.019	-10.10	-	-	-	-	-	0.00
RS09	Waikanae R at Mangaone Walkway	0.150	60	0.003	0.615	2.20	0.145	60	-0.001	0.944	-0.68	11.67
RS10	Waikanae R at Greenaway Rd	0.300	60	-0.020	0.434	-6.68	-	-	-	-	-	3.33
RS11	Whareroa S at Waterfall Rd	0.500	60	0.000	1.000	0.00	0.464	57	-0.009	0.545	-1.94	0.00
RS12	Whareroa S at QE Park	1.020	60	0.020	0.566	1.96	0.898	57	0.015	0.498	1.53	0.00
RS13	Horokiri S at Snodgrass	0.615	60	-0.018	0.569	-2.99	0.581	59	-0.021	0.097	-3.56	0.00
RS14	Pauatahanui S at Elmwood Br	0.575	60	0.010	0.522	1.74	0.578	60	-0.009	0.437	-1.59	0.00
RS15	Porirua S at Glenside	1.300	60	-0.050	0.254	-3.84	1.267	60	-0.057	0.040	-4.40	0.00
RS16	Porirua S at Wall Park (Milk Depot)	1.300	60	-0.049	0.086	-3.75	1.324	60	-0.034	0.257	-2.61	0.00
RS17	Makara S at Kennels	0.610	60	-0.008	0.617	-1.37	0.597	60	-0.034	0.040	-5.60	0.00
RS18	Karori S at Makara Peak	1.565	60	-0.053	0.073	-3.37	1.642	60	-0.034	0.179	-2.16	0.00
RS19	Kaiwharawhara S at Ngaio Gorge	1.415	60	-0.024	0.476	-1.69	1.391	60	-0.025	0.525	-1.73	0.00
RS20	Hutt R at Te Marua Intake Site	0.166	60	0.001	0.830	0.31	0.165	60	0.004	0.289	2.46	11.67
RS21	Hutt R opp. Manor Park G.C.	0.360	60	-0.002	0.775	-0.46	0.357	59	0.002	0.942	0.54	0.00
RS22	Hutt R at Boulcott	0.300	60	0.000	0.772	0.00	0.284	59	-0.003	0.829	-0.87	1.67
RS23	Pakuratahi R 50m d/s Farm Ck	0.345	60	-0.005	0.615	-1.34	0.312	60	-0.017	0.229	-4.85	0.00
RS24	Mangaroa R at Te Marua	0.705	60	-0.020	0.200	-2.89	0.701	59	-0.031	0.051	-4.44	0.00
RS25	Akatarawa R at Hutt confl.	0.155	60	-0.002	0.831	-1.22	0.151	60	0.008	0.358	5.17	23.33
RS26	Whakatikei R at Riverstone	0.185	60	-0.004	0.478	-2.29	0.183	60	-0.002	0.724	-1.29	23.33
RS27	Waiwhetu S at Wainui Hill Br	0.800	59	-0.049	0.029	-6.12	0.727	59	-0.040	0.012	-4.94	0.00
RS28	Wainuiomata R at Manuka Track	0.140	58	-0.005	0.410	-3.58	0.136	57	-0.007	0.455	-5.19	20.34
RS29	Wainuiomata R u/s of White Br	0.380	59	-0.036	0.025	-9.40	0.358	59	-0.023	0.051	-6.04	10.00
RS30	Orongorongo R at Orongorongo Stn	0.073	59	-0.004	0.244	-6.15	0.068	53	-0.007	0.070	-10.06	53.33
RS31	Ruamahanga R at McLays	0.044	60	0.000	0.722	0.90	0.037	60	0.000	1.000	-0.70	63.33
RS32	Ruamahanga R at Te Ore Ore	0.555	60	-0.049	0.013	-8.91	0.582	60	-0.041	0.056	-7.46	0.00
RS33	Ruamahanga R at Gladstone Br	0.675	60	-0.039	0.356	-5.78	0.684	60	-0.046	0.040	-6.80	0.00
RS34	Ruamahanga R at Pukio	0.550	60	-0.004	0.776	-0.75	0.511	59	-0.030	0.279	-5.47	1.67
RS35	Mataikona Trib at Sugar Loaf Rd	0.190	59	-0.025	0.008	-13.18	-	-	-	-	-	11.86
RS36	Taueru R at Castlehill	0.400	59	-0.011	0.346	-2.86	0.379	59	-0.021	0.051	-5.23	1.69
RS37	Taueru R at Gladstone	1.470	59	-0.151	0.001	-10.29	-	-	-	-	-	0.00
RS38	Kopuaranga R at Stewarts	1.375	60	-0.020	0.393	-1.44	1.346	60	-0.054	0.056	-3.96	0.00
RS39	Whangaehu R 250m u/s confl.	1.700	60	-0.197	0.009	-11.60	-	-	-	-	-	0.00
RS40	Waipoua R at Colombo Rd Br	1.080	60	-0.072	0.099	-6.64	1.079	52	-0.070	0.072	-6.60	1.67
RS41	Waingawa R at South Rd	0.130	60	-0.002	0.619	-1.74	0.120	60	-0.006	0.229	-4.54	38.33
RS42	Whareama R at Gauge	0.410	59	-0.010	0.514	-2.46	0.406	59	-0.014	0.348	-3.53	0.00
RS43	Motuwaireka S at Headwaters	0.130	59	-0.025	0.006	-18.96	0.104	59	-0.021	0.012	-16.45	31.03
RS44	Totara S at Stronvar	0.150	58	-0.026	0.009	-17.16	0.131	58	-0.020	0.004	-13.07	20.69
RS45	Parkvale Trib at Lowes Res.	4.800	47	-0.298	0.024	-6.20	-	-	-	-	-	0.00
RS46	Parkvale S at Weir	1.950	60	-0.041	0.522	-2.11	1.918	57	-0.116	0.019	-6.12	0.00
RS47	Waiohine R at Gorge	0.057	60	0.002	0.358	3.21	0.045	60	0.000	1.000	-0.20	70.00
RS48	Waiohine R at Bicknells	0.420	60	-0.002	0.943	-0.59	0.405	60	-0.009	0.621	-2.11	0.00
RS49	Beef Ck at Headwaters	0.100	60	-0.001	0.353	-1.29	-	-	-	-	-	48.33
RS50	Mangatarere S at SH 2	1.600	60	-0.075	0.200	-4.72	1.683	59	-0.030	0.071	-1.87	0.00
RS51	Huangarua R at Ponatahi Br	0.500	60	-0.015	0.722	-2.98	-	-	-	-	-	0.00
RS52	Tauanui R at Whakatomotomo Rd	0.065	59	0.000	1.000	0.00	0.042	59	-0.001	0.829	-1.94	59.32
RS53	Awhea R at Tora Rd	0.240	60	-0.005	0.667	-2.26	-	-	-	-	-	3.33
RS54	Coles Ck Trib at Lagoon Hill Rd	0.230	50	-0.012	0.026	-5.40	-	-	-	-	-	2.00
RS55	Tauherenikau R at Websters	0.110	60	0.003	0.478	2.74	0.099	60	0.001	0.832	0.94	41.67
RS56	Waiorongomai R at Forest Pk	0.064	60	0.004	0.395	5.75	0.064	54	-0.001	0.808	-0.94	58.33

Dissolved reactive phosphorus (mg/L)

Site	Site name	Raw data					Flow-adjusted data					% Cen.
		Median	*n*	MASS	*p*	% Change	Median	*n*	MASS	*p*	% Change	
RS02	Mangapouri S at Bennetts Rd	0.032	60	0.000	0.721	1.17	-	-	-	-	-	0.00
RS03	Waitohu S at Forest Pk	0.008	59	0.001	0.005	7.11	0.007	57	0.001	0.000	8.61	5.08
RS04	Waitohu S at Norfolk Cres	0.018	60	0.001	0.150	5.53	0.018	58	0.000	0.606	0.89	0.00
RS05	Otaki R at Pukehinau	0.004	60	0.000	0.099	5.83	0.004	60	0.000	0.020	5.78	36.67
RS06	Otaki R at Mouth	0.004	60	0.000	0.944	-0.52	0.004	60	0.000	0.525	5.35	50.00
RS07	Mangaone S at Sims Rd Br	0.025	60	0.000	0.617	-1.99	0.025	60	0.000	0.621	0.72	0.00
RS08	Ngarara S at Field Way	0.047	60	0.000	1.000	0.00	-	-	-	-	-	0.00
RS09	Waikanae R at Mangaone Walkway	0.011	60	0.000	0.095	3.05	0.011	60	0.000	0.179	2.87	0.00
RS10	Waikanae R at Greenaway Rd	0.007	60	0.000	0.669	0.50	-	-	-	-	-	21.67
RS11	Whareroa S at Waterfall Rd	0.029	60	-0.002	0.017	-6.31	0.029	57	-0.001	0.450	-2.04	0.00
RS12	Whareroa S at QE Park	0.043	60	-0.003	0.074	-6.02	0.039	57	-0.001	0.200	-2.84	0.00
RS13	Horokiri S at Snodgrass	0.011	60	0.000	0.390	-4.11	0.011	59	0.000	0.220	-3.65	3.33
RS14	Pauatahanui S at Elmwood Br	0.015	60	-0.001	0.284	-3.34	0.015	60	-0.001	0.138	-4.03	0.00
RS15	Porirua S at Glenside	0.019	60	-0.002	0.009	-7.97	0.019	60	-0.002	0.077	-8.59	1.67
RS16	Porirua S at Wall Park (Milk Depot)	0.020	60	-0.001	0.390	-3.29	0.019	60	0.000	0.724	-1.19	0.00
RS17	Makara S at Kennels	0.029	60	-0.002	0.046	-5.48	0.029	60	-0.001	0.104	-3.35	0.00
RS18	Karori S at Makara Peak	0.039	60	-0.004	0.033	-9.63	0.040	60	-0.002	0.028	-5.39	0.00
RS19	Kaiwharawhara S at Ngaio Gorge	0.034	60	-0.006	0.001	-17.53	0.032	60	-0.004	0.004	-12.30	1.67
RS20	Hutt R at Te Marua Intake Site	0.003	60	0.000	0.671	0.69	0.003	60	0.000	0.621	3.18	55.00
RS21	Hutt R opp. Manor Park G.C.	0.004	60	0.000	0.156	11.98	0.004	59	0.000	0.348	8.57	46.67
RS22	Hutt R at Boulcott	0.003	60	0.000	0.777	1.94	0.003	59	0.000	0.516	3.97	53.33
RS23	Pakuratahi R 50m d/s Farm Ck	0.006	60	0.001	0.076	9.75	0.006	60	0.000	0.179	7.51	25.00
RS24	Mangaroa R at Te Marua	0.010	60	0.001	0.002	12.98	0.010	59	0.001	0.005	12.91	8.33
RS25	Akatarawa R at Hutt confl.	0.003	60	0.001	0.004	16.07	0.003	60	0.000	0.001	15.29	66.67
RS26	Whakatikei R at Riverstone	0.007	60	0.001	0.063	7.31	0.007	60	0.000	0.056	5.75	13.33
RS27	Waiwhetu S at Wainui Hill Br	0.027	59	-0.001	0.717	-1.86	0.025	59	-0.001	0.348	-4.02	1.67
RS28	Wainuiomata R at Manuka Track	0.010	58	0.001	0.005	6.11	0.010	57	0.000	0.017	4.97	0.00
RS29	Wainuiomata R u/s of White Br	0.012	59	0.000	0.509	3.36	0.012	59	0.000	0.718	4.07	3.33
RS30	Orongorongo R at Orongorongo Stn	0.005	59	0.000	0.422	5.12	0.005	53	0.000	0.187	8.51	33.33
RS31	Ruamahanga R at McLays	-	-	-	-	-	-	-	-	-	-	83.33
RS32	Ruamahanga R at Te Ore Ore	0.008	59	0.000	0.467	4.29	0.008	59	0.000	0.427	3.14	22.03
RS33	Ruamahanga R at Gladstone Br	0.024	60	-0.002	0.000	-8.30	0.022	60	-0.001	0.104	-3.80	0.00
RS34	Ruamahanga R at Pukio	0.015	60	0.000	0.831	-1.89	0.014	59	-0.001	0.348	-7.84	8.33
RS35	Mataikona Trib at Sugar Loaf Rd	0.004	60	0.000	0.005	12.80	-	-	-	-	-	50.00
RS36	Taueru R at Castlehill	0.008	60	0.001	0.086	7.38	0.008	60	0.000	0.020	6.45	8.33
RS37	Taueru R at Gladstone	0.009	60	0.001	0.026	6.43	-	-	-	-	-	33.90
RS38	Kopuaranga R at Stewarts	0.016	60	0.000	0.771	0.00	0.015	60	0.000	0.832	0.76	1.67
RS39	Whangaehu R 250m u/s confl.	0.030	60	0.007	0.000	22.49	-	-	-	-	-	0.00
RS40	Waipoua R at Colombo Rd Br	0.002	60	0.000	0.434	1.34	0.001	52	0.000	0.548	3.91	56.67
RS41	Waingawa R at South Rd	0.002	60	0.000	1.000	0.39	0.001	60	0.000	0.724	2.32	68.33
RS42	Whareama R at Gauge	0.003	60	0.000	0.571	-0.37	0.003	60	0.000	0.621	-1.25	52.54
RS43	Motuwaireka S at Headwaters	0.003	59	0.000	0.348	5.22	0.003	59	0.000	0.279	7.60	65.52
RS44	Totara S at Stronvar	-	-	-	-	-	-	-	-	-	-	87.93
RS45	Parkvale Trib at Lowes Res.	0.017	47	0.000	0.612	1.96	-	-	-	-	-	6.38
RS46	Parkvale S at Weir	0.043	60	0.000	1.000	0.00	0.047	57	0.000	0.706	-0.67	0.00
RS47	Waiohine R at Gorge	0.002	60	0.000	0.525	-3.35	0.002	60	0.000	0.104	-6.86	73.33
RS48	Waiohine R at Bicknells	0.016	60	0.000	1.000	0.00	0.015	60	0.000	0.525	1.88	0.00
RS49	Beef Ck at Headwaters	0.007	60	0.000	0.172	3.16	-	-	-	-	-	3.33
RS50	Mangatarere S at SH 2	0.080	60	-0.005	0.138	-6.09	0.078	59	-0.003	0.279	-4.25	0.00
RS51	Huangarua R at Ponatahi Br	0.004	60	0.000	0.289	2.02	-	-	-	-	-	45.00
RS52	Tauanui R at Whakatomotomo Rd	0.006	59	0.000	0.826	0.00	0.006	59	0.000	1.000	0.08	8.47
RS53	Awhea R at Tora Rd	0.006	60	0.001	0.003	19.31	-	-	-	-	-	40.00
RS54	Coles Ck Trib at Lagoon Hill Rd	0.005	50	0.001	0.119	16.34	-	-	-	-	-	38.00
RS55	Tauherenikau R at Websters	0.002	60	0.000	1.000	1.16	0.002	60	0.000	0.229	4.48	73.33
RS56	Waiorongomai R at Forest Pk	0.001	60	0.000	0.724	2.78	0.001	54	0.000	1.000	-0.30	70.00

Total phosphorus (mg/L)

Site	Site name	Raw data					Flow-adjusted data					% Cen.
		Median	*n*	MASS	*p*	% Change	Median	*n*	MASS	*p*	% Change	
RS02	Mangapouri S at Bennetts Rd	0.062	60	-0.001	0.522	-2.02	-	-	-	-	-	0.00
RS03	Waitohu S at Forest Pk	0.011	59	-0.001	0.067	-9.05	0.011	57	-0.001	0.083	-4.80	0.00
RS04	Waitohu S at Norfolk Cres	0.047	60	-0.002	0.227	-3.20	0.045	58	0.000	0.825	-0.97	0.00
RS05	Otaki R at Pukehinau	0.007	60	-0.001	0.002	-12.06	0.006	60	-0.001	0.001	-10.79	16.67
RS06	Otaki R at Mouth	0.007	60	-0.001	0.004	-14.96	0.006	60	-0.001	0.004	-13.66	16.67
RS07	Mangaone S at Sims Rd Br	0.058	60	-0.004	0.252	-6.90	0.056	60	-0.003	0.358	-5.04	0.00
RS08	Ngarara S at Field Way	0.108	60	-0.005	0.356	-4.25	-	-	-	-	-	0.00
RS09	Waikanae R at Mangaone Walkway	0.015	60	-0.001	0.002	-10.28	0.015	60	-0.001	0.001	-7.86	0.00
RS10	Waikanae R at Greenaway Rd	0.011	60	-0.001	0.152	-9.05	-	-	-	-	-	0.00
RS11	Whareroa S at Waterfall Rd	0.045	60	0.000	1.000	-0.55	0.045	57	0.000	0.762	0.74	0.00
RS12	Whareroa S at QE Park	0.082	60	-0.002	0.252	-2.66	0.077	57	-0.003	0.029	-4.11	0.00
RS13	Horokiri S at Snodgrass	0.019	60	-0.002	0.010	-11.39	0.019	59	-0.002	0.017	-12.04	0.00
RS14	Pauatahanui S at Elmwood Br	0.031	60	-0.002	0.013	-7.18	0.030	60	-0.003	0.002	-8.56	0.00
RS15	Porirua S at Glenside	0.031	60	-0.004	0.001	-11.85	0.027	60	-0.004	0.000	-14.40	0.00
RS16	Porirua S at Wall Park (Milk Depot)	0.036	60	-0.002	0.156	-6.84	0.036	60	-0.002	0.138	-6.21	0.00
RS17	Makara S at Kennels	0.049	60	-0.002	0.177	-4.17	0.047	60	-0.002	0.437	-3.57	0.00
RS18	Karori S at Makara Peak	0.051	60	-0.004	0.001	-8.58	0.052	60	-0.003	0.013	-5.82	0.00
RS19	Kaiwharawhara S at Ngaio Gorge	0.049	60	-0.006	0.009	-11.51	0.044	60	-0.005	0.013	-9.99	0.00
RS20	Hutt R at Te Marua Intake Site	0.007	60	-0.001	0.100	-7.16	0.007	60	-0.001	0.009	-8.69	10.00
RS21	Hutt R opp. Manor Park G.C.	0.012	60	-0.002	0.089	-12.57	0.012	59	-0.001	0.097	-7.24	8.33
RS22	Hutt R at Boulcott	0.010	60	-0.001	0.154	-9.32	0.009	59	-0.001	0.071	-12.95	11.67
RS23	Pakuratahi R 50m d/s Farm Ck	0.009	60	-0.001	0.284	-5.57	0.009	60	-0.001	0.179	-6.70	6.67
RS24	Mangaroa R at Te Marua	0.019	60	0.000	0.566	-2.63	0.018	59	0.000	0.613	-1.74	0.00
RS25	Akatarawa R at Hutt confl.	0.006	60	0.000	0.569	-2.82	0.006	60	0.000	0.104	-4.53	21.67
RS26	Whakatikei R at Riverstone	0.011	60	-0.001	0.130	-9.14	0.011	60	-0.001	0.056	-6.68	6.67
RS27	Waiwhetu S at Wainui Hill Br	0.064	59	-0.008	0.002	-11.77	0.052	59	-0.005	0.097	-8.25	0.00
RS28	Wainuiomata R at Manuka Track	0.015	58	-0.001	0.021	-6.68	0.014	57	-0.001	0.036	-5.65	0.00
RS29	Wainuiomata R u/s of White Br	0.023	59	-0.003	0.003	-13.08	0.023	59	-0.002	0.001	-8.73	1.67
RS30	Orongorongo R at Orongorongo Stn	0.011	59	-0.001	0.217	-6.90	0.008	53	0.000	0.741	-0.77	20.00
RS31	Ruamahanga R at McLays	0.005	60	0.000	0.776	-0.26	0.005	60	0.000	0.077	-6.76	38.33
RS32	Ruamahanga R at Te Ore Ore	0.018	60	-0.001	0.831	-3.67	0.016	60	-0.002	0.056	-11.64	1.67
RS33	Ruamahanga R at Gladstone Br	0.037	60	-0.002	0.286	-6.69	0.034	60	-0.003	0.056	-8.03	0.00
RS34	Ruamahanga R at Pukio	0.038	60	0.002	0.257	5.29	0.040	59	-0.001	0.613	-2.56	0.00
RS35	Mataikona Trib at Sugar Loaf Rd	0.008	60	0.000	1.000	0.00	-	-	-	-	-	8.33
RS36	Taueru R at Castlehill	0.025	60	0.000	1.000	0.00	0.026	60	0.000	0.621	-0.61	0.00
RS37	Taueru R at Gladstone	0.043	59	0.000	0.942	-0.31	-	-	-	-	-	0.00
RS38	Kopuaranga R at Stewarts	0.035	60	-0.002	0.434	-4.49	0.034	60	-0.002	0.358	-4.42	0.00
RS39	Whangaehu R 250m u/s confl.	0.065	60	0.012	0.000	18.12	-	-	-	-	-	0.00
RS40	Waipoua R at Colombo Rd Br	0.008	60	0.000	0.315	-4.65	0.007	52	0.000	0.548	1.26	6.67
RS41	Waingawa R at South Rd	0.005	60	0.000	0.615	0.08	0.004	60	0.000	0.724	0.66	25.00
RS42	Whareama R at Gauge	0.025	59	0.000	0.826	0.00	0.025	59	-0.001	0.170	-4.93	0.00
RS43	Motuwaireka S at Headwaters	0.005	59	0.000	0.612	-2.42	0.004	59	0.000	0.311	-7.17	34.48
RS44	Totara S at Stronvar	0.005	58	0.000	0.882	0.16	0.005	58	0.000	0.269	2.78	41.38
RS45	Parkvale Trib at Lowes Res.	0.024	47	-0.001	0.065	-5.47	-	-	-	-	-	0.00
RS46	Parkvale S at Weir	0.076	60	0.001	0.617	1.59	0.073	57	0.001	0.327	1.25	0.00
RS47	Waiohine R at Gorge	0.005	60	0.000	0.227	-5.38	0.005	60	0.000	0.077	-9.38	35.00
RS48	Waiohine R at Bicknells	0.024	60	-0.001	0.152	-4.22	0.022	60	-0.001	0.138	-4.27	0.00
RS49	Beef Ck at Headwaters	0.011	60	-0.001	0.043	-6.48	-	-	-	-	-	0.00
RS50	Mangatarere S at SH 2	0.105	60	-0.009	0.028	-8.92	0.098	59	-0.001	0.829	-1.10	0.00
RS51	Huangarua R at Ponatahi Br	0.012	60	0.000	0.434	-4.16	-	-	-	-	-	3.33
RS52	Tauanui R at Whakatomotomo Rd	0.009	59	-0.001	0.016	-8.18	0.009	59	-0.001	0.001	-8.90	1.69
RS53	Awhea R at Tora Rd	0.019	60	0.000	1.000	0.00	-	-	-	-	-	1.67
RS54	Coles Ck Trib at Lagoon Hill Rd	0.016	50	0.000	0.793	-0.78	-	-	-	-	-	0.00
RS55	Tauherenikau R at Websters	0.007	60	0.000	0.076	-6.65	0.006	60	0.000	0.358	-6.96	16.67
RS56	Waiorongomai R at Forest Pk	0.006	60	0.000	0.569	-3.37	0.006	54	0.000	0.292	-2.55	23.33

E. coli (cfu/100mL)												
Site	Site name	Raw data					Flow-adjusted data					% Cen.
		Median	*n*	MASS	*p*	% Change	Median	*n*	MASS	*p*	% Change	
RS02	Mangapouri S at Bennetts Rd	670.0	60	0.00	0.886	0.00	-	-	-	-	-	0.00
RS03	Waitohu S at Forest Pk	6.0	59	-1.01	0.050	-16.84	5.04	57	-2.30	0.04	-38.33	5.08
RS04	Waitohu S at Norfolk Cres	320.0	60	20.90	0.476	6.53	210.71	58	-14.90	0.94	-4.73	0.00
RS05	Otaki R at Pukehinau	6.0	60	-0.33	0.721	-5.53	5.10	60	-0.36	0.36	-6.02	6.67
RS06	Otaki R at Mouth	33.5	60	-3.00	0.476	-8.96	22.67	60	-6.96	0.14	-20.79	1.67
RS07	Mangaone S at Sims Rd Br	500.0	60	39.95	0.525	7.99	438.08	60	5.24	0.94	1.05	0.00
RS08	Ngarara S at Field Way	135.0	60	-6.46	0.671	-4.79	-	-	-	-	-	0.00
RS09	Waikanae R at Mangaone Walkway	12.5	60	-1.00	0.173	-8.03	9.45	60	-2.31	0.02	-18.47	5.00
RS10	Waikanae R at Greenaway Rd	20.5	60	-2.00	0.522	-9.74	-	-	-	-	-	1.67
RS11	Whareroa S at Waterfall Rd	95.0	60	-2.51	0.944	-2.65	76.68	57	-20.81	0.15	-20.81	0.00
RS12	Whareroa S at QE Park	195.0	60	12.42	0.434	6.37	187.67	57	-2.75	0.94	-1.53	0.00
RS13	Horokiri S at Snodgrass	220.0	60	29.96	0.119	13.62	190.87	59	8.81	0.28	4.00	0.00
RS14	Pauatahanui S at Elmwood Br	255.0	60	28.30	0.033	11.10	233.11	60	24.93	0.23	9.78	0.00
RS15	Porirua S at Glenside	230.0	60	24.30	0.138	10.57	233.04	60	20.84	0.10	9.06	0.00
RS16	Porirua S at Wall Park (Milk Depot)	785.0	60	166.49	0.065	21.21	753.20	60	43.54	0.62	5.55	0.00
RS17	Makara S at Kennels	245.0	60	23.78	0.286	9.71	80.62	60	32.12	0.14	13.11	1.67
RS18	Karori S at Makara Peak	1100.0	60	188.07	0.202	17.10	891.00	60	141.42	0.18	12.86	0.00
RS19	Kaiwharawhara S at Ngaio Gorge	425.0	60	-60.54	0.289	-14.24	-36.60	60	-25.58	0.83	-6.02	0.00
RS20	Hutt R at Te Marua Intake Site	26.0	60	1.00	0.724	3.85	23.38	60	1.18	0.52	4.54	0.00
RS21	Hutt R opp. Manor Park G.C.	125.0	60	-6.28	0.393	-5.03	77.55	59	-7.14	0.61	-5.49	0.00
RS22	Hutt R at Boulcott	105.0	60	-14.47	0.028	-13.78	100.17	59	-6.84	0.43	-6.22	0.00
RS23	Pakuratahi R 50m d/s Farm Ck	66.5	60	14.84	0.006	22.32	40.81	60	13.35	0.10	20.08	0.00
RS24	Mangaroa R at Te Marua	160.0	60	5.59	0.567	3.50	109.44	59	12.58	0.43	7.86	0.00
RS25	Akatarawa R at Hutt confl.	56.0	60	-10.84	0.001	-19.36	50.75	60	-10.54	0.01	-18.83	0.00
RS26	Whakatikei R at Riverstone	25.0	60	-2.42	0.087	-9.69	19.60	60	-2.88	0.08	-11.53	1.67
RS27	Waiwhetu S at Wainui Hill Br	440.0	59	-103.56	0.193	-23.54	70.63	59	-107.18	0.35	-24.36	0.00
RS28	Wainuiomata R at Manuka Track	4.0	58	-0.82	0.111	-20.45	2.15	57	-0.63	0.65	-15.72	13.56
RS29	Wainuiomata R u/s of White Br	100.0	59	-7.30	0.467	-7.30	53.06	59	-26.14	0.04	-26.14	0.00
RS30	Orongorongo R at Orongorongo Stn	27.0	59	-0.75	0.664	-2.78	12.60	53	14.76	0.14	52.72	0.00
RS31	Ruamahanga R at McLays	5.0	60	0.00	1.000	0.00	3.12	60	-0.10	0.94	-2.01	8.33
RS32	Ruamahanga R at Te Ore Ore	100.0	60	0.00	0.943	0.00	71.98	60	-1.73	0.52	-1.73	0.00
RS33	Ruamahanga R at Gladstone Br	40.0	60	12.58	0.089	31.45	23.45	60	0.73	0.94	1.84	1.67
RS34	Ruamahanga R at Pukio	105.0	60	25.22	0.023	24.02	71.52	59	12.57	0.43	12.57	0.00
RS35	Mataikona Trib at Sugar Loaf Rd	49.0	60	-2.85	0.319	-5.81	-	-	-	-	-	0.00
RS36	Taueru R at Castlehill	94.0	60	9.52	0.115	10.13	67.23	60	8.29	0.62	8.81	0.00
RS37	Taueru R at Gladstone	100.0	59	11.73	0.277	11.73	-	-	-	-	-	0.00
RS38	Kopuaranga R at Stewarts	210.0	60	43.32	0.033	20.63	164.83	60	38.91	0.08	18.53	0.00
RS39	Whangaehu R 250m u/s confl.	285.0	60	84.71	0.009	29.72	-	-	-	-	-	0.00
RS40	Waipoua R at Colombo Rd Br	72.5	60	-11.49	0.023	-15.84	25.99	52	-10.56	0.05	-19.19	0.00
RS41	Waingawa R at South Rd	33.0	59	-4.38	0.082	-13.26	32.09	59	-2.10	0.61	-6.37	0.00
RS42	Whareama R at Gauge	90.0	59	2.26	0.664	2.52	57.71	59	3.07	0.35	3.41	0.00
RS43	Motuwaireka S at Headwaters	6.0	57	-0.50	0.444	-8.35	0.91	57	-0.85	0.50	-14.12	14.04
RS44	Totara S at Stronvar	5.0	57	1.44	0.031	28.85	-2.74	57	2.76	0.03	55.21	17.54
RS45	Parkvale Trib at Lowes Res.	25.0	47	-0.99	0.407	-3.97	-	-	-	-	-	0.00
RS46	Parkvale S at Weir	475.0	60	18.89	0.432	3.98	414.64	57	11.79	0.94	2.14	1.67
RS47	Waiohine R at Gorge	4.5	60	0.99	0.021	21.98	3.24	60	1.19	0.02	26.52	8.33
RS48	Waiohine R at Bicknells	57.0	60	6.51	0.358	11.43	34.27	60	4.99	0.52	8.75	0.00
RS49	Beef Ck at Headwaters	7.5	60	0.00	0.943	0.00	-	-	-	-	-	11.67
RS50	Mangatarere S at SH 2	105.0	60	18.88	0.286	17.98	41.79	59	18.61	0.13	18.61	0.00
RS51	Huangarua R at Ponatahi Br	79.5	60	5.05	0.724	6.35	-	-	-	-	-	0.00
RS52	Tauanui R at Whakatomotomo Rd	4.0	59	-0.29	0.415	-7.23	2.91	59	-0.46	0.35	-11.57	11.86
RS53	Awhea R at Tora Rd	150.0	60	-16.82	0.229	-11.21	-	-	-	-	-	1.67
RS54	Coles Ck Trib at Lagoon Hill Rd	72.0	50	1.01	0.727	1.40	-	-	-	-	-	4.00
RS55	Tauherenikau R at Websters	20.5	60	0.74	0.887	3.62	14.41	60	0.13	1.00	0.65	0.00
RS56	Waiorongomai R at Forest Pk	7.0	60	0.50	0.192	7.15	3.93	54	1.75	0.17	23.28	5.00

Faecal coliforms (cfu/100mL)

Site	Site name	Raw data					Flow-adjusted data					% Cen.
		Median	*n*	MASS	*p*	% Change	Median	*n*	MASS	*p*	% Change	
RS02	Mangapouri S at Bennetts Rd	800.0	60	-37.44	0.887	-4.68	-	-	-	-	-	0.00
RS03	Waitohu S at Forest Pk	7.0	59	-1.98	0.043	-28.32	6.62	57	-3.02	0.02	-43.21	3.39
RS04	Waitohu S at Norfolk Cres	375.0	60	-29.99	0.476	-8.00	288.77	58	-60.95	0.34	-16.93	0.00
RS05	Otaki R at Pukehinau	6.0	60	-0.33	0.667	-5.51	4.88	60	-0.38	0.62	-6.41	5.00
RS06	Otaki R at Mouth	43.5	60	-2.97	0.286	-6.82	30.50	60	-6.40	0.10	-14.72	0.00
RS07	Mangaone S at Sims Rd Br	610.0	60	47.06	0.321	7.72	531.57	60	6.94	0.83	1.14	0.00
RS08	Ngarara S at Field Way	150.0	60	-11.53	0.437	-7.69	-	-	-	-	-	0.00
RS09	Waikanae R at Mangaone Walkway	14.0	60	-1.74	0.254	-12.42	10.15	60	-2.58	0.01	-18.41	5.00
RS10	Waikanae R at Greenaway Rd	29.0	60	-3.41	0.154	-11.75	-	-	-	-	-	1.67
RS11	Whareroa S at Waterfall Rd	110.0	60	-6.23	0.621	-5.67	80.82	57	-42.87	0.11	-38.97	0.00
RS12	Whareroa S at QE Park	230.0	60	5.01	0.776	2.18	176.06	57	-6.49	0.33	-3.09	0.00
RS13	Horokiri S at Snodgrass	285.0	60	15.11	0.393	5.30	261.80	59	12.45	0.35	4.15	0.00
RS14	Pauatahanui S at Elmwood Br	335.0	60	20.22	0.319	6.03	322.23	60	4.47	0.62	1.34	0.00
RS15	Porirua S at Glenside	300.0	60	-3.34	0.830	-1.11	299.12	60	8.80	0.72	2.93	0.00
RS16	Porirua S at Wall Park (Milk Depot)	950.0	60	208.56	0.020	21.95	657.52	60	109.83	0.29	11.56	0.00
RS17	Makara S at Kennels	300.0	60	3.36	1.000	1.12	72.72	60	10.10	0.44	3.37	0.00
RS18	Karori S at Makara Peak	1350.0	60	150.06	0.434	11.12	1097.51	60	141.96	0.29	10.52	0.00
RS19	Kaiwharawhara S at Ngaio Gorge	555.0	60	-56.54	0.437	-10.19	3.55	60	-90.44	0.62	-16.29	0.00
RS20	Hutt R at Te Marua Intake Site	29.0	60	0.83	0.671	2.88	23.53	60	1.58	0.62	5.46	0.00
RS21	Hutt R opp. Manor Park G.C.	140.0	60	-9.09	0.434	-6.49	66.88	59	8.67	0.83	6.19	0.00
RS22	Hutt R at Boulcott	110.0	60	-16.09	0.019	-14.63	71.06	59	-9.56	0.43	-8.69	0.00
RS23	Pakuratahi R 50m d/s Farm Ck	79.0	60	15.92	0.007	20.15	55.38	60	20.77	0.02	26.29	0.00
RS24	Mangaroa R at Te Marua	215.0	60	0.00	1.000	0.00	167.06	59	19.57	0.43	9.32	0.00
RS25	Akatarawa R at Hutt confl.	64.0	60	-14.22	0.001	-22.21	53.02	60	-13.91	0.00	-21.73	0.00
RS26	Whakatikei R at Riverstone	30.0	60	-3.04	0.321	-10.12	22.99	60	-4.06	0.06	-13.53	1.67
RS27	Waiwhetu S at Wainui Hill Br	590.0	59	-111.91	0.247	-18.97	64.13	59	-139.26	0.43	-23.60	0.00
RS28	Wainuiomata R at Manuka Track	5.0	58	-0.59	0.202	-11.71	3.06	57	-0.51	0.65	-10.21	10.17
RS29	Wainuiomata R u/s of White Br	140.0	59	-23.23	0.111	-16.59	89.40	59	-42.55	0.03	-30.39	0.00
RS30	Orongorongo R at Orongorongo Stn	31.0	59	-0.13	1.000	-0.41	15.20	53	12.49	0.10	36.74	0.00
RS31	Ruamahanga R at McLays	6.0	60	0.12	0.720	2.06	3.96	60	0.24	0.83	4.04	8.33
RS32	Ruamahanga R at Te Ore Ore	120.0	60	-1.49	0.777	-1.24	80.02	60	-7.17	0.44	-5.97	0.00
RS33	Ruamahanga R at Gladstone Br	47.5	60	14.35	0.077	30.21	24.74	60	0.01	1.00	0.02	1.67
RS34	Ruamahanga R at Pukio	110.0	60	27.11	0.013	24.65	78.51	59	12.07	0.22	10.97	0.00
RS35	Mataikona Trib at Sugar Loaf Rd	56.5	60	-1.17	0.619	-2.08	-	-	-	-	-	0.00
RS36	Taueru R at Castlehill	100.0	60	5.22	0.476	5.22	70.90	60	0.38	1.00	0.38	0.00
RS37	Taueru R at Gladstone	110.0	59	9.76	0.512	8.87	-	-	-	-	-	0.00
RS38	Kopuaranga R at Stewarts	230.0	60	35.13	0.089	15.28	175.18	60	50.03	0.36	21.75	0.00
RS39	Whangaehu R 250m u/s confl.	340.0	60	89.28	0.047	26.26	-	-	-	-	-	0.00
RS40	Waipoua R at Colombo Rd Br	80.0	60	-17.56	0.010	-21.95	32.30	52	-13.74	0.03	-21.80	0.00
RS41	Waingawa R at South Rd	39.0	59	-4.26	0.070	-10.91	38.53	59	-3.88	0.13	-9.94	0.00
RS42	Whareama R at Gauge	90.0	59	3.53	0.613	3.92	43.75	59	6.44	0.28	7.15	0.00
RS43	Motuwaireka S at Headwaters	8.0	57	-1.09	0.091	-13.65	1.40	57	-0.75	0.20	-9.40	10.53
RS44	Totara S at Stronvar	5.0	57	1.44	0.025	28.85	-4.55	57	3.15	0.02	63.09	15.79
RS45	Parkvale Trib at Lowes Res.	33.0	47	-0.99	0.561	-3.01	-	-	-	-	-	0.00
RS46	Parkvale S at Weir	570.0	60	10.18	0.571	1.79	449.25	57	39.55	0.60	6.70	1.67
RS47	Waiohine R at Gorge	5.0	60	0.99	0.032	19.89	3.46	60	0.93	0.08	18.55	8.33
RS48	Waiohine R at Bicknells	70.0	60	9.51	0.321	13.58	51.24	60	3.67	0.62	5.24	0.00
RS49	Beef Ck at Headwaters	8.0	60	0.00	0.829	0.00	-	-	-	-	-	11.67
RS50	Mangatarere S at SH 2	125.0	60	15.16	0.571	12.12	57.63	59	20.27	0.35	16.90	0.00
RS51	Huangarua R at Ponatahi Br	91.0	60	0.33	1.000	0.37	-	-	-	-	-	0.00
RS52	Tauanui R at Whakatomotomo Rd	5.0	59	-0.25	0.462	-4.97	2.61	59	-0.62	0.35	-12.34	8.47
RS53	Awhea R at Tora Rd	160.0	60	-17.62	0.289	-11.02	-	-	-	-	-	1.67
RS54	Coles Ck Trib at Lagoon Hill Rd	84.0	50	2.99	0.434	3.56	-	-	-	-	-	4.00
RS55	Tauherenikau R at Websters	23.5	60	-0.99	0.832	-4.21	19.67	60	-1.05	0.62	-4.46	0.00
RS56	Waiorongomai R at Forest Pk	8.5	60	0.41	0.384	4.85	6.90	54	1.84	0.17	19.40	5.00

Periphyton

Summary of Spearman Rank results for five periphyton metrics assessed at 46 RSoE sites with hard substrate (2004–2011, n=8[1]). r_s=Spearman correlation co-efficient. p-values in italics indicate 'possible' trends, while values in bold indicate 'probable' trends and values that are bold and underlined indicate 'clear' trends (refer to Section 5.2 for further details)

Site no.	Site name	Streambed cover								Biomass	
		Mean mat		Max mat		Mean filamentous		Max filamentous		Chlorophyll a	
		r_s	p	r_s	p	r_s	p	r_s	p	r_s	p
RS03	Waitohu S at Forest Pk	-0.317	0.423	-0.122	0.749	0.051	0.885	0.051	0.885	-0.833	**0.005**
RS05	Otaki R at Pukehinau	0.518	0.160	0.518	0.160	0.464	0.233	0.464	0.233	-0.024	0.931
RS06	Otaki R at Mouth	-0.190	0.619	-0.095	0.794	0.738	**0.029**	0.667	*0.059*	-0.405	0.290
RS09	Waikanae R at Mangaone Walkway	-0.247	0.537	-0.247	0.537	-0.247	0.537	-0.247	0.537	-0.524	0.160
RS10	Waikanae R at Greenaway Rd	0.310	0.423	0.238	0.537	-0.071	0.839	0.000	0.977	-0.381	0.321
RS11	Whareroa S at Waterfall Rd	-0.355	0.353	-0.355	0.353	-0.136	0.705	-0.136	0.705	0.238	0.537
RS13	Horokiri S at Snodgrass	-0.675	*0.059*	-0.374	0.321	0.095	0.794	0.238	0.537	0.667	*0.059*
RS14	Pauatahanui S at Elmwood Br	–	–	–	–	0.805	**0.010**	0.781	**0.015**	0.452	0.233
RS15	Porirua S at Glenside	-0.262	0.498	-0.359	0.353	0.671	*0.059*	0.671	*0.059*	0.571	0.120
RS16	Porirua S at Wall Park (Milk Depot)	0.098	0.794	0.098	0.794	0.833	**0.005**	0.833	**0.005**	0.452	0.233
RS17	Makara S at Kennels	-0.406	0.290	-0.406	0.290	0.073	0.839	0.061	0.839	0.119	0.749
RS18	Karori S at Makara Peak	-0.048	0.885	-0.096	0.794	0.619	*0.086*	0.667	*0.059*	-0.190	0.619
RS19	Kaiwharawhara S at Ngaio Gorge	-0.286	0.460	-0.190	0.619	0.714	**0.037**	0.874	**0.000**	0.238	0.537
RS20	Hutt R at Te Marua Intake Site	-0.247	0.537	-0.247	0.537	-0.247	0.537	-0.247	0.537	0.000	0.977
RS21	Hutt R opp. Manor Park G.C.	0.802	**0.010**	0.874	**0.000**	0.690	**0.047**	0.651	*0.072*	0.357	0.353
RS22	Hutt R at Boulcott	0.994	**0.000**	0.922	**0.000**	0.635	*0.072*	0.491	0.182	0.381	0.321
RS23	Pakuratahi R 50m d/s Farm Ck	0.738	**0.029**	0.683	**0.047**	-0.244	0.537	-0.342	0.387	-0.024	0.931
RS24	Mangaroa R at Te Marua	0.714	**0.037**	0.524	0.160	0.395	0.290	0.539	0.139	0.905	**0.000**
RS25	Akatarawa R at Hutt R confl.	0.381	0.321	0.319	0.423	-0.265	0.498	-0.265	0.498	0.381	0.321
RS26	Whakatikei R at Riverstone	0.371	0.321	0.371	0.321	0.000	0.977	-0.024	0.931	0.167	0.662
RS28	Wainuiomata R at Manuka Track	-0.466	0.207	-0.401	0.290	-0.483	0.207	-0.483	0.207	-0.238	0.537
RS29	Wainuiomata R u/s of White Br	0.488	0.207	0.512	0.160	-0.548	0.139	-0.667	*0.059*	0.905	**0.000**
RS30	Orongorongo R at Orongorongo Stn	0.748	**0.029**	0.647	*0.072*	0.714	**0.037**	0.755	**0.021**	0.167	0.662
RS31	Ruamahanga R at McLays	0.047	0.885	0.047	0.885	0.136	0.705	0.136	0.705	-0.500	0.182
RS32	Ruamahanga R at Te Ore Ore	-0.072	0.839	-0.072	0.839	0.262	0.498	0.096	0.794	0.452	0.233
RS33	Ruamahanga R at Gladstone Br	0.268	0.498	0.268	0.498	0.561	0.120	0.561	0.120	0.786	**0.015**
RS34	Ruamahanga R at Pukio	-0.247	0.537	-0.247	0.537	0.359	0.353	0.359	0.353	0.333	0.387
RS35	Mataikona Trib at Sugar Loaf Rd	-0.136	0.705	-0.136	0.705	-0.204	0.578	-0.180	0.619	0.667	*0.059*
RS37	Taueru R at Gladstone	-0.024	0.931	0.072	0.839	0.714	**0.037**	0.732	**0.029**	0.667	*0.059*
RS38	Kopuaranga R at Stewarts	0.357	0.353	-0.190	0.619	0.500	0.182	0.755	**0.021**	0.667	*0.059*
RS40	Waipoua R at Colombo Rd Br	0.619	*0.086*	0.619	*0.086*	0.762	**0.021**	0.690	**0.047**	0.405	0.290
RS41	Waingawa R at South Rd	0.464	0.233	0.464	0.233	0.390	0.321	0.390	0.321	0.262	0.498
RS43	Motuwaireka S at Headwaters	-0.016	0.931	-0.016	0.931	-0.533	0.160	-0.507	0.182	-0.381	0.321
RS44	Totara S at Stronvar	-0.095	0.794	0.108	0.749	0.619	*0.086*	0.714	**0.037**	0.119	0.749
RS45	Parkvale Trib at Lowes Reserve	0.083	0.839	0.083	0.839	–	–	–	–	0.238	0.537
RS46	Parkvale S at Weir	0.539	0.139	0.563	0.120	0.286	0.460	0.238	0.537	0.167	0.662
RS47	Waiohine R at Gorge	0.089	0.794	0.190	0.619	-0.439	0.260	-0.390	0.321	-0.381	0.321
RS48	Waiohine R at Bicknells	0.764	**0.021**	0.764	**0.021**	0.366	0.353	0.171	0.662	0.524	0.160
RS49	Beef Ck at Headwaters	0.439	0.260	0.439	0.260	-0.464	0.233	-0.464	0.233	0.548	0.139
RS50	Mangatarere S at SH 2	0.500	0.182	0.335	0.387	0.548	0.139	0.524	0.160	0.143	0.705
RS51	Huangarua R at Ponatahi Br	0.714	**0.037**	0.500	0.182	0.667	*0.059*	0.810	**0.010**	0.524	0.160
RS52	Tauanui R at Whakatomotomo Rd	0.327	0.387	0.327	0.387	-0.024	0.931	0.119	0.749	-0.024	0.931
RS53	Awhea R at Tora Rd	-0.371	0.321	-0.371	0.321	0.905	**0.000**	0.791	**0.015**	0.333	0.387
RS54	Coles Ck Trib at Lagoon Hill Rd	-0.600	0.102	-0.600	0.102	0.548	0.139	0.190	0.619	0.595	0.102
RS55	Tauherenikau R at Websters	-0.405	0.290	-0.405	0.290	0.778	**0.015**	0.651	*0.072*	0.000	0.977
RS56	Waiorongomai R at Forest Pk	–	–	–	–	-0.527	0.160	-0.527	0.160	-0.571	0.120

[1] n=7 for periphyton biomass at the three Hutt River sites (the 2011 biomass results were excluded due to the influence of a fresh).

Macroinvertebrates

Summary of Spearman Rank results for four macroinvertebrate metrics assessed at 55 RSoE sites (2004–2011). r_s=Spearman correlation co-efficient. *p*-values in italics indicate 'possible' trends, while values in bold indicate 'probable' trends and values that are bold and underlined indicate 'clear' trends (refer to Section 6.2 for further details)

Site no.	Site name	QMCI		MCI		%EPT taxa		%EPT individuals		*n*
		r_s	*p*	r_s .	*p*	r_s	*p*	r_s	*p*	
RS02	Mangapouri S at Bennetts Rd	-0.690	**0.047**	0.731	**0.029**	0.180	0.619	0.381	0.321	8
RS03	Waitohu S at Forest Pk	0.310	0.423	0.429	0.260	0.333	0.387	0.833	**0.005**	8
RS04	Waitohu S at Norfolk Cres	0.262	0.498	0.071	0.839	0.143	0.705	0.333	0.387	8
RS05	Otaki R at Pukehinau	0.143	0.705	-0.286	0.460	-0.108	0.749	0.214	0.578	8
RS06	Otaki R at Mouth	0.071	0.839	-0.012	0.931	0.157	0.662	0.429	0.260	8
RS07	Mangaone S at Sims Rd Br	-0.548	0.139	-0.310	0.423	-0.506	0.182	-0.443	0.233	8
RS08	Ngarara S at Field Way	0.048	0.885	0.238	0.537	0.133	0.705	-0.060	0.839	8
RS09	Waikanae R at Mangaone Walkway	0.405	0.290	-0.310	0.423	-0.262	0.498	0.167	0.662	8
RS10	Waikanae R at Greenaway Rd	-0.333	0.387	-0.214	0.578	-0.095	0.794	-0.310	0.423	8
RS11	Whareroa S at Waterfall Rd	-0.548	0.139	-0.810	**0.010**	-0.857	**0.002**	-0.762	**0.021**	8
RS12	Whareroa S at QE Park	0.548	0.139	-0.024	0.931	-0.263	0.498	-0.190	0.619	8
RS13	Horokiri S at Snodgrass	-0.381	0.321	0.096	0.794	-0.049	0.885	0.143	0.705	8
RS14	Pauatahanui S at Elmwood Br	0.071	0.839	0.619	*0.086*	0.587	0.102	0.595	0.102	8
RS15	Porirua S at Glenside	0.167	0.662	-0.548	0.139	-0.571	0.120	-0.167	0.662	8
RS16	Porirua S at Wall Park (Milk Depot)	0.286	0.460	-0.619	*0.086*	-0.443	0.233	-0.238	0.537	8
RS17	Makara S at Kennels	0.310	0.423	0.595	0.102	0.563	0.120	0.000	0.977	8
RS18	Karori S at Makara Peak	0.048	0.885	-0.571	0.120	-0.595	0.102	0.190	0.619	8
RS19	Kaiwharawhara S at Ngaio Gorge	-0.571	0.120	-0.405	0.290	-0.405	0.290	0.262	0.498	8
RS20	Hutt R at Te Marua Intake Site	0.429	0.260	-0.143	0.705	-0.299	0.423	0.286	0.460	7
RS21	Hutt R opp. Manor Park G.C.	-0.548	0.139	-0.214	0.578	-0.060	0.839	-0.548	0.139	7
RS22	Hutt R at Boulcott	-0.405	0.290	-0.524	0.160	-0.539	0.139	-0.429	0.260	7
RS23	Pakuratahi R 50m d/s Farm Ck	-0.310	0.423	-0.548	0.139	-0.500	0.182	-0.548	0.139	8
RS24	Mangaroa R at Te Marua	-0.238	0.537	-0.190	0.619	-0.240	0.537	-0.619	*0.086*	8
RS25	Akatarawa R at Hutt R confl.	-0.524	0.160	-0.619	*0.086*	-0.643	*0.072*	-0.643	*0.072*	8
RS26	Whakatikei R at Riverstone	-0.548	0.139	0.167	0.662	0.000	0.977	-0.405	0.290	8
RS27	Waiwhetu S at Wainui Hill Br	-0.024	0.931	-0.762	**0.021**	-0.683	**0.047**	-0.275	0.460	8
RS28	Wainuiomata R at Manuka Track	-0.643	*0.072*	0.095	0.794	0.071	0.839	-0.952	**0.000**	8
RS29	Wainuiomata R u/s of White Br	0.071	0.839	-0.262	0.498	-0.359	0.353	0.024	0.931	8
RS30	Orongorongo R at Orongorongo Stn	-0.095	0.794	0.238	0.537	-0.143	0.705	0.238	0.537	8
RS31	Ruamahanga R at McLays	0.476	0.207	0.143	0.705	0.371	0.321	0.238	0.537	8
RS32	Ruamahanga R at Te Ore Ore	-0.143	0.705	0.000	0.977	0.405	0.290	0.595	0.102	8
RS33	Ruamahanga R at Gladstone Br	0.095	0.794	-0.833	**0.005**	-0.667	*0.059*	0.500	0.182	8
RS34	Ruamahanga R at Pukio	0.595	0.102	-0.647	*0.072*	-0.230	0.537	0.738	**0.029**	8
RS35	Mataikona Trib at Sugar Loaf Rd	0.119	0.749	0.167	0.662	0.310	0.423	0.048	0.885	8
RS36	Taueru R at Castlehill	0.214	0.578	-0.286	0.460	0.238	0.537	-0.476	0.207	8
RS37	Taueru R at Gladstone	-0.690	**0.047**	-0.286	0.460	-0.310	0.423	-0.333	0.387	8
RS38	Kopuaranga R at Stewarts	-0.762	**0.021**	-0.786	**0.015**	-0.695	**0.047**	-0.381	0.321	8
RS39	Whangaehu R 250m u/s confl.	-0.571	0.120	-0.429	0.260	-0.714	**0.037**	-0.143	0.705	8
RS40	Waipoua R at Colombo Rd Br	-0.833	**0.005**	0.024	0.931	0.119	0.749	-0.452	0.233	8
RS41	Waingawa R at South Rd	-0.381	0.321	-0.905	**0.000**	-0.738	**0.029**	-0.167	0.662	8
RS42	Whareama R at Gauge	-0.286	0.460	-0.167	0.662	0.048	0.885	-0.048	0.885	8
RS43	Motuwaireka S at Headwaters	0.095	0.794	-0.095	0.794	0.405	0.290	-0.452	0.233	8
RS44	Totara S at Stronvar	-0.476	0.207	-0.619	*0.086*	-0.429	0.260	0.048	0.885	8
RS45	Parkvale Trib at Lowes Res.	-0.500	0.182	0.071	0.839	0.419	0.260	-0.071	0.839	8
RS46	Parkvale S at Weir	-0.762	**0.021**	0.095	0.794	0.143	0.705	0.333	0.387	8
RS47	Waiohine R at Gorge	0.357	0.353	-0.143	0.705	-0.204	0.578	0.690	**0.047**	8
RS48	Waiohine R at Bicknells	-0.286	0.460	0.190	0.619	0.286	0.460	0.238	0.537	8
RS49	Beef Ck at Headwaters	-0.595	0.102	-0.476	0.207	-0.333	0.387	-0.738	**0.029**	8
RS50	Mangatarere S at SH 2	-0.833	**0.005**	-0.643	*0.072*	-0.571	0.120	-0.119	0.749	8
RS51	Huangarua R at Ponatahi Br	-0.643	*0.072*	-0.548	0.139	-0.238	0.537	0.119	0.749	8
RS52	Tauanui R at Whakatomotomo Rd	0.190	0.619	0.286	0.460	0.476	0.207	0.667	*0.059*	8
RS53	Awhea R at Tora Rd	-0.167	0.662	-0.167	0.662	-0.167	0.662	-0.357	0.353	8
RS54	Coles Ck Trib at Lagoon Hill Rd	-0.214	0.602	-0.107	0.781	-0.107	0.781	-0.286	0.491	7
RS55	Tauherenikau R at Websters	0.048	0.885	-0.286	0.460	-0.443	0.233	0.119	0.749	8
RS56	Waiorongomai R at Forest Pk	-0.524	0.160	-0.048	0.885	0.119	0.749	-0.214	0.578	8

Appendix 8: Stream habitat scores

Summary of stream habitat and shade scores based on one-off assessments undertaken in 2008, and substrate index scores based on mean scores from annual assessments undertaken between 2009 and 2011 (see Appendix 3 for assessment methods). Each site was allocated a habitat 'grade', based on which quartile its total habitat score fell within.

LQ=lower quartile, UQ=upper quartile, Med=median

Site no.	Site name	Habitat score	Habitat score quartile	Shade score	Substrate index
RS02	Mangapouri S at Bennetts Rd	73	LQ (poor)	10	3.00
RS03	Waitohu S at Forest Pk	124.5	UQ (excellent)	10.5	6.02
RS04	Waitohu S at Norfolk Cres	77.5	LQ to Med. (fair)	8	3.00
RS05	Otaki R at Pukehinau	118	UQ (excellent)	9	5.87
RS06	Otaki R at Mouth	76	LQ to Med. (fair)	0	5.19
RS07	Mangaone S at Sims Rd Br	52.5	LQ (poor)	0	3.00
RS08	Ngarara S at Field Way	49	LQ (poor)	0	3.00
RS09	Waikanae R at Mangaone Walkway	140	UQ (excellent)	20	5.81
RS10	Waikanae R at Greenaway Rd	102	Med. to UQ (good)	3	5.24
RS11	Whareroa S at Waterfall Rd	92	Med. to UQ (good)	18	4.83
RS12	Whareroa S at QE Park	39	LQ (poor)	0	3.00
RS13	Horokiri S at Snodgrass	74.5	LQ to Med. (fair)	2	5.13
RS14	Pauatahanui S at Elmwood Br	81	LQ to Med. (fair)	0	4.42
RS15	Porirua S at Glenside	66.5	LQ (poor)	2.5	5.22
RS16	Porirua S at Wall Park (Milk Depot)	60	LQ (poor)	2	5.13
RS17	Makara S at Kennels	80	LQ to Med. (fair)	6	4.41
RS18	Karori S at Makara Peak	87	LQ to Med. (fair)	0	5.80
RS19	Kaiwharawhara S at Ngaio Gorge	78.5	LQ to Med. (fair)	0.5	5.85
RS20	Hutt R at Te Marua Intake Site	106	Med. to UQ (good)	2	5.84
RS21	Hutt R opp. Manor Park G.C.	81	LQ to Med. (fair)	1	5.17
RS22	Hutt R at Boulcott	92.5	Med. to UQ (good)	3	5.00
RS23	Pakuratahi R 50m d/s Farm Ck	90	Med. to UQ (good)	0.5	5.50
RS24	Mangaroa R at Te Marua	111.5	UQ (excellent)	7	5.37
RS25	Akatarawa R at Hutt R confl.	121	UQ (excellent)	10	5.83
RS26	Whakatikei R at Riverstone	118.5	UQ (excellent)	10.5	5.67
RS27	Waiwhetu S at Wainui Hill Br	21.5	LQ (poor)	0.5	3.00
RS28	Wainuiomata R at Manuka Track	135	UQ (excellent)	19	5.49
RS29	Wainuiomata R u/s of White Br	80	LQ to Med. (fair)	0	5.97
RS30	Orongorongo R at Orongorongo Stn	65.5	LQ (poor)	0	5.03
RS31	Ruamahanga R at McLays	130	UQ (excellent)	10	5.77
RS32	Ruamahanga R at Te Ore Ore	97	Med. to UQ (good)	3	5.54
RS33	Ruamahanga R at Gladstone Br	101	Med. to UQ (good)	1	4.87
RS34	Ruamahanga R at Pukio	76.5	LQ to Med. (fair)	2	4.57
RS35	Mataikona Trib at Sugar Loaf Rd	110	UQ (excellent)	13	5.47
RS36	Taueru R at Castlehill	88	LQ to Med. (fair)	12.5	3.00
RS37	Taueru R at Gladstone	52	LQ (poor)	0	4.78
RS38	Kopuaranga R at Stewarts	98	Med. to UQ (good)	10	6.03
RS39	Whangaehu R 250m u/s confl.	65.5	LQ (poor)	2.5	3.00
RS40	Waipoua R at Colombo Rd Br	98	Med. to UQ (good)	5	5.96
RS41	Waingawa R at South Rd	100	Med. to UQ (good)	0	5.62
RS42	Whareama R at Gauge	42.5	LQ (poor)	0	3.00
RS43	Motuwaireka S at Headwaters	85.5	LQ to Med. (fair)	6	5.57
RS44	Totara S at Stronvar	80	LQ to Med. (fair)	0	5.62
RS45	Parkvale Trib at Lowes Reserve	121	UQ (excellent)	19	5.18
RS46	Parkvale S at Weir	64	LQ (poor)	0	5.06
RS47	Waiohine R at Gorge	115	UQ (excellent)	1	6.00
RS48	Waiohine R at Bicknells	101	Med. to UQ (good)	3	5.44
RS49	Beef Ck at Headwaters	127.5	UQ (excellent)	15.5	5.64
RS50	Mangatarere S at SH 2	85.5	LQ to Med. (fair)	3.5	5.13
RS51	Huangarua R at Ponatahi Br	105	Med. to UQ (good)	5	5.28
RS52	Tauanui R at Whakatomotomo Rd	104	Med. to UQ (good)	8	5.60
RS53	Awhea R at Tora Rd	56	LQ (poor)	1	4.27
RS54	Coles Ck Trib at Lagoon Hill Rd	108	UQ (excellent)	12	5.46
RS55	Tauherenikau R at Websters	100	Med. to UQ (good)	2	5.14
RS56	Waiorongomai R at Forest Pk	128	UQ (excellent)	10	5.49

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