State of the Environment Monitoring: River Water Quality Annual Report 2015

August 2016

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State of the Environment Monitoring: River Water Quality Annual Report 2015

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Executive summary

The Auckland Council operates a long-term river water quality monitoring programme throughout the region. The objectives of this monitoring include State of the Environment (SoE) reporting, identification of major environmental issues and the assessment of the efficacy of council policy initiatives and strategies. This report provides a summary of the data collected during the 2015 calendar year.

Water quality is assessed monthly at 36 sites around the region covering a range of parameters using a combination of field and laboratory based measurement. The results are presented as box plots, which display the annual variation in the measured parameters at each of the sites, and in tables, which provide a statistical summary of each parameter at each of the sites.

Further, the data was used to produce water quality indices, which allowed sites to be ranked and assigned a water quality class. This analysis allows the complex water quality data to be communicated in a simple form. In 2015 the rivers with the highest ranked water quality class were the Wairoa Tributary and West Hoe streams, followed by Cascades Stream (Waitakere) and Opanuku Stream. The catchments of these streams are mostly dominated by native forest. These were the only four sites classified as having ‘excellent’ water quality in 2015. Poor water quality was observed in streams with a mix of urban and rural land use, with Omaru Creek having the lowest ranked water quality of those sites monitored.

1 Introduction

1.1 Auckland's rivers

The Auckland region has an estimated 16,500km of permanently flowing rivers, which increases to 28,240km when intermittent and ephemeral rivers are included (Storey and Wadhwa, 2009). As no mainland location in the region is greater than 20km from the coast, the catchment areas of each river are relatively small, with most reaching the sea before they merge with others to form larger rivers. Consequently, most rivers are first and second order (Table 1), meaning they are small, with most less than a few metres wide.

The relatively gentle topography of the Auckland region and the underlying geology also have a profound influence on the nature of the rivers, usually resulting in slow flowing, low gradient rivers with soft substrate beds. Fast flowing, high gradient rivers with hard stony substrates are mostly restricted to catchments that drain the Waitakere or Hunua Ranges.

Table 1: Permanent rivers of the Auckland region stratified by stream order (Storey and Wadhwa, 2009).

Stream order	Length (km)	% in order	Cumulative %
1	8753	52.7	52.7
2	4262	25.6	78.3
3	2121	12.7	91.0
4	1003	6.0	97.0
5	372	2.2	99.2
6	122	0.7	99.9
7	16	0.1	100

1.2 Water quality

The water quality (physical and chemical characteristics) of a river partly determines how suitable it is for supporting animal and plant life and for use by people.

At a given point in a river, water quality is a function of the temperature, amount of nutrients, oxygen, sediment and other pollutants in the water, and is dependent upon many factors derived from the surrounding catchment. In the absence of human influences, these factors include climate, topography, geology and soil type. Where there are human influences, the type of land cover and activities in the river's catchment can also strongly affect water quality (Mason, 1998)

The sites in the River Water Quality Programme have been grouped according to the River Environment Classification (REC) (Snelder *et al*., 2004), which classifies rivers by the dominant land cover in their catchments, as well as soil type, climate and topography among other variables. This classification is used because land cover is known to affect the quality and quantity of water, the types of ecological habitats and flow patterns in rivers. The classification used in this report is broad and based on the following land cover classes:

- Native forest (including natural alpine environments)
- Exotic forest
- Rural (includes all non-forested rural land)
- Urban

The majority (63%) of rivers within the Auckland region drain non-forested rural catchments (i.e. pastoral farming, horticultural and rural residential areas), followed by native forest catchments (21%), with exotic forest and urban catchments accounting for 8% each (Table 2).

The catchment land cover of rivers within the Auckland region is quite different from New Zealand as a whole (Table 2). Auckland's high population density means that a greater percentage of the region's rivers are classed as 'urban' compared to New Zealand overall, making the environmental pressures in Auckland unique in a national context.

Table 2: Catchment land cover for rivers in Auckland and New Zealand

Land cover	% of rivers	
	Auckland	New Zealand
Rural	63	43
Native forest (incl. alpine)	21	51
Exotic forest	8	5
Urban	8	1

1.3 Auckland Council's freshwater monitoring programmes

One of the objectives of the Auckland Council's freshwater State of the Environment (SoE) monitoring programme is to describe the quality of the region's freshwater resources. This allows for the assessment and evaluation of the effects of environmental stressors and the efficacy of the council's policy initiatives and management approaches. To meet this objective, the council's freshwater monitoring is carried out under a water quality work stream, which measures the condition of the region's freshwater resource using a combination of physical, chemical and biological measures. The Auckland Council operates four monitoring programmes within the fresh water quality work stream: the River Water Quality Programme, which is the focus of this report, and also River Ecology, Lakes Water Quality and Groundwater Monitoring programmes, which are reported elsewhere. All reports can be obtained from the publications area of the Auckland Council website (www.aucklandcouncil.govt.nz/en/planspoliciesprojects/reports/technicalpublications/Pages/home.aspx).

1.3.1 River water quality programme

The Water Quality Programme monitors the physical, chemical and microbiological properties of 31 rivers at 36 sites. This monitoring provides information on temperature, amounts of nutrients, oxygen, sediment and other variables in the sampled rivers. The results enable Auckland Council to assess the life-supporting capacity of the river and its suitability for human use.

1.3.1.1 Programme design

The River Water Quality Programme commenced with 8 sites in 1977-78 and ran in this fashion until 1981; it was re-started with 17 sites in 1986 and has been running continuously ever since. The programme has evolved throughout its duration, with sites added or moved according to requirements. The programme was last reviewed in 2008 and subsequent changes were described in the 2009 Annual Report (Neale, 2010). Between 2009 and 2011 31 sites were monitored. Three new sites were added to the network at the beginning of 2012, and a further two in February of 2013, bringing the current total to 36 sites.

Each of the 36 sites is sampled monthly, and data is used to provide information for the freshwater report cards (see http://stateofauckland.aucklandcouncil.govt.nz/). It should be noted that two of the sites are monitored by the National Institute for Water and Atmospheric Research (NIWA) as part of the National River Water Quality Network (NRWQN).

The monitoring programme is regionally representative in that it monitors a variety of sizes and types of rivers, and also covers the range of different catchment land cover classes found across the region. This enables a region-wide perspective on water quality and can allow for the extrapolation of the results to infer the likely water quality of rivers that are not sampled.

1.4 Report scope

This report provides a tabular and graphical summary of the data collected from the 36 sites in the River Water Quality Programme during the 2015 calendar year. This data is also used to produce a water quality index class for each site, which allows the complex water quality data to be communicated in a simple format.

This is the 26th annual report since the inception of the River water quality monitoring programme, and the eleventh time since 2000 that the river water quality data has been reported separately from the marine and lake data. In addition, a comprehensive state and trends analysis of the water quality data was recently carried out in 2016 (http://www.aucklandcouncil.govt.nz/SiteCollectionDocuments/aboutcouncil/planspoliciespublications/technicalpublications/tr2016008riverwaterqualitystatetrendsauckland20052014.pdf).

2 Methods

2.1 Sample sites

The current River Water Quality Programme operates with a network of 36 sites (Table 3) with 34 operated by Auckland Council and 2 operated by NIWA. The location of the 36 sites is displayed in Figure 1.

2.2 Sampling methodology

For the 34 sites monitored by Auckland Council, all sample collection was carried out by Council staff. Sampling is carried out monthly, with sites visited within the same week each month. Up to19 water quality parameters are routinely monitored in the programme (Table 4). Six parameters are determined in the field using the EXO Sonde, a portable water quality meter by YSI Inc. and the remainder are determined by laboratory analysis.

There are four rivers that have two sampling sites including Mahurangi River, Otara Creek, Pakuranga Creek and Papakura Stream. In all cases, while the names of the rivers are the same, the site locations drain very different catchments. In the case of the Mahurangi River and Papakura Stream, these catchments are very large and the sites are a large distance from each other. In the case of the Otara Creek and Pakuranga Stream, these sites were strategically chosen as they represent water drained from different types of catchments within a highly urbanised area.

A number of sites have no significant sources of heavy metals within their catchments and previous monitoring showed heavy metals to be below detection limits. These sites are therefore not routinely monitored for heavy metals, but are tested on an intermittent basis. This testing was most recently carried out in 2009 and the results reported in Neale (2010). These sites are identified in Table 3 as having no metals measured. Prior to 2015 soluble and total lead were measured at all metals sites, but as it was found in most cases to be less than the laboratory detection limit, continuous monitoring has ceased and these parameters will be monitored on an intermittent basis in future.

Quality control measures are undertaken in accordance with Auckland Council's internal Stream Water Quality Sampling Protocol which meet ISO 9001:2008 standards. This covers procedures for the collection, transport and storage of samples, methods for data verification and quality assurance to ensure consistency and accuracy across the various AC monitoring programmes.

Laboratory samples are analysed under contract by Watercare Laboratory Services Ltd, an IANZ accredited laboratory. Analytical methods (for all analytes except metals) follow the "Standard Methods for the Examination of Water and Wastewater" 22nd Edition (APHA, 2012). Metal analytes are tested according to US EPA Method 200.8 for the "Determination of Trace Metals in Waters and Wastes by Inductively Coupled Plasma – Mass Spectrometry" Revision 5.4 (US EPA, 1994).

For the two National River Water Quality Network (NRWQN) sites, sample collection is carried out by NIWA field teams. The NRWQN sites are monitored for the same parameters listed in Table 4, with the exception of salinity, suspended solids and heavy metals. Temperature and dissolved oxygen are determined in the field; the remainder are determined by laboratory tests at NIWA's water quality laboratory in Hamilton. Further information can be obtained from https://www.niwa.co.nz/freshwater/water-quality-monitoring-and-advice/national-river-water-quality-network-nrwqn.

Table 3: Sites sampled in 2015 in the River Water Quality Programme, together with their location details, REC catchment land cover category, analysis type and record start date.

Site name	NZTM X	NZTM Y	Land cover	Analysis Type	Start date
Avondale Stream	1750600	5912264	Urban	Metals	2012
Cascades Stream (Waitakere)	1735628	5916378	Native forest	No Metals	1978
Cascades Stream (Waiheke)	1785942	5923254	Rural	No Metals	2013
Hoteo River (NIWA operated)	1735254	5972546	Rural	No Metals	1986
Kaukapakapa River	1735833	5944978	Rural	No Metals	2009
Kumeu River	1739252	5928781	Rural	Metals	1993
Lucas Creek	1751468	5934510	Urban	Metals	1993
Mahurangi River (Forestry HQ)	1747750	5965035	Exotic forest	Metals	1993
Mahurangi River (Water Supply)	1748864	5970457	Rural	Metals	1993
Makarau River	1736150	5953126	Rural	Metals	2009
Matakana River	1753500	5976481	Rural	Metals	1986
Ngakoroa Stream	1775164	5881624	Rural	No Metals	1993
Nukumea Stream	1749411	5951400	Native forest	Metals	2012
Oakley Creek	1751963	5917636	Urban	Metals	1994
Okura Creek	1751405	5938716	Rural	Metals	2003
Omaru Creek	1766268	5916749	Urban	Metals	1985
Onetangi Stream	1786243	5926204	Rural	No Metals	2013
Opanuku Stream	1742086	5915581	Rural	No Metals	1978
Otaki Creek	1764306	5907216	Urban	Metals	1985
Otara Creek (East Tamaki)	1767422	5907535	Urban	Metals	1986
Otara Creek (Kennell Hill)	1768335	5908376	Urban	Metals	1992
Oteha Stream	1751325	5933519	Urban	Metals	1986
Pakuranga Creek (Botany Rd)	1770686	5913036	Urban	Metals	1985
Pakuranga Creek (Greenmount Drive)	1769473	5910813	Urban	Metals	1985
Papakura Stream (Alfriston Rd)	1774247	5902648	Rural	Metals	2012
Papakura Stream (Porchester Rd)	1771240	5900290	Rural	Metals	1993
Puhinui Stream	1766440	5904295	Urban	Metals	1994
Rangitopuni River (NIWA operated)	1744450	5932301	Rural	No Metals	1986
Riverhead Forest Stream	1737125	5933216	Exotic forest	Metals	2009
Vaughan Stream	1755414	5938729	Rural	Metals	2001
Wairoa River	1782682	5901720	Rural	Metals	1978
Wairoa Tributary	1786700	5892817	Native forest	No Metals	2009
Waitangi River	1754343	5878534	Rural	No Metals	2009
Waiwera River	1748628	5953665	Rural	Metals	1986
West Hoe Stream	1748314	5950610	Native forest	No Metals	2002
Whangamaire Stream	1763578	5884625	Rural	No Metals	2009

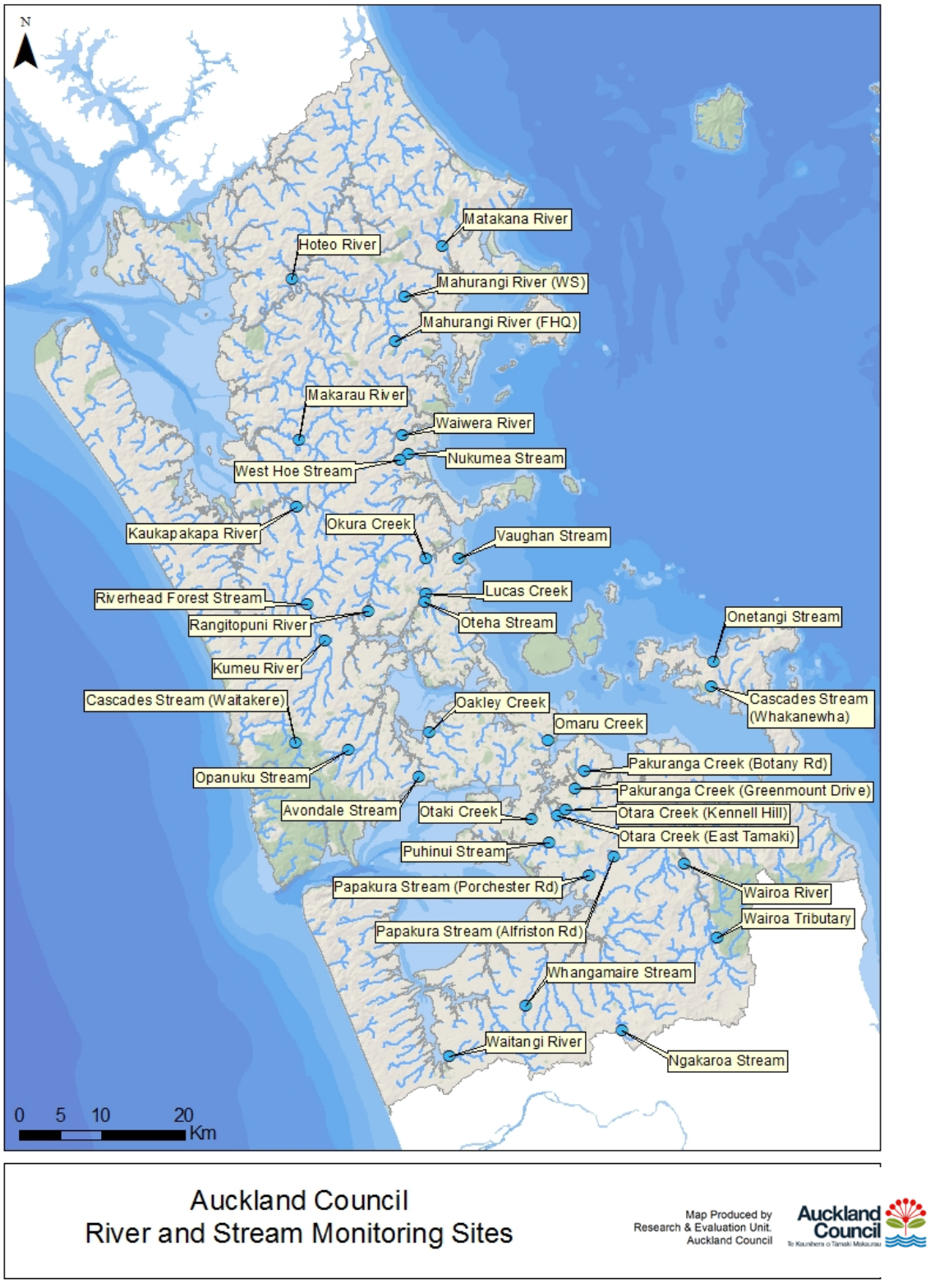

Figure 1: The distribution of the 36 sampling sites used in the Auckland Council River Water Quality Programme for 2015.

Table 4: Parameters tested in 2015 as part of the River Water Quality Programme (laboratory test methods refer to those tests carried out by Watercare Services Ltd. under contract).

Parameter	Code	Units	Method
Dissolved oxygen	DO (sat)	% sat	EXO sonde
Dissolved oxygen	DO (ppm)	ppm	EXO sonde
Temperature	Temp	^{o}C	EXO sonde
Conductivity	Cond	mS/cm	EXO sonde
Salinity	Salinity	ppt	EXO sonde
pH (field)	pH		EXO sonde
pH (lab)	pH		APHA (2012) 4500-H B
Suspended solids	TSS	mg/L	APHA (2012) 2540 D
Turbidity	Turb	NTU	APHA (2012) 2130 B (modified)
Ammoniacal nitrogen	Ammonia	mg N/L	APHA (2012) 4500-NH3 G (Modified)
Total oxidised nitrogen	TON	mg N/L	APHA (2012) 4500-NO3 F (Modified)
Total nitrogen	TN	mg N/L	APHA (2012) 4500-P J, 4500-NO3 F (Modified)
Soluble reactive phosphorus	SRP	mg P/L	APHA (2012) 4500-P B, F (Modified)
Total phosphorus	TP	mg P/L	APHA (2012) 4500-P B, J (Modified)
Soluble copper	Cu sol	µg/L	USEPA 200.8 (Modified)
Total copper	Cu tot	µg/L	USEPA 200.8 (Modified)
Soluble zinc	Zn sol	µg/L	USEPA 200.8 (Modified)
Total zinc	Zn tot	µg/L	USEPA 200.8 (Modified)
Escherichia coli	E. coli	cfu/100mL	USEPA Method 1603 (2002)

2.3 Data processing and analysis

All field and laboratory data collected by council are stored in the council's water quality archiving database (HYDSTRA). The data from the two sites operated by NIWA was extracted from the NIWA's web-based Water Quality Information System. The 2015 data was collated and used to produce:

- Box plots which display the annual variation in each parameter at each site. These were produced in the software package Sigmaplot 12.5 using the default percentile functions.
- Summary tables which provide a basic statistical summary of each parameter at each site (Appendix 1).
- Water Quality Indices calculated based on the approach of the Canadian Council of Ministers of the Environment (2001) using the data for seven of the measured water quality parameters Each site was assigned a water quality class based on these water quality indices.

For the purposes of this report, censored laboratory results that were reported as below the limit of detection were halved as recommended by Chapman (1996). For example, a value reported as <1 mg/L would be included in the data analysis as 0.5 mg/L.

3 Results

3.1 Relevant guideline comparisons

To provide context for the data in the box plots below, the data has been compared to National Objectives Framework (NOF) "national bottom lines" and Australia New Zealand Environment Conservation Council (ANZECC) trigger values, where they are relevant:

- *NOF national bottom lines*

The National Policy Statement for Freshwater Management (NPS-FM), 2014 provides a statutory context for the assessment of water quality in freshwater environments. The NPS-FM includes two compulsory national values (ecosystem health and human health for recreation) and nine water quality attributes (parameters) that must be managed to meet these values. The National Objectives Framework (NOF, section CA of the NPS-FM) provides the context for these nine water quality attributes, which are specified in Appendix 2 of the NPS-FM. Each attribute has a series of both numeric and descriptive 'states': A, B, C and a National Bottom Line, D. The National Bottom Line is considered the minimum acceptable state for that attribute to meet the compulsory values. The relevant attributes for rivers and their associated national bottom lines are shown in Table 5 below. Note that the vast majority of total oxidised nitrogen is in the nitrate form; therefore in this report, the 'total oxidised nitrogen' parameter is used interchangeably with the 'nitrate' attribute in the NOF. Also note that the NOF guidelines for ammonia toxicity are based on data standardised to pH 8. The purpose of this report is not yet to report on comparisons with the NOF and NPS-FM, it is used here for context only; therefore, the ammonium data presented in this report has not been standardised to pH8.

Table 5: National Objectives Framework "National Bottom Line" values for nitrate toxicity (in this report represented by total oxidised nitrogen rather than nitrate), ammonia toxicity and *Escherichia coli* (*E. coli*). Also presented is 'State C' for *E. coli*, the primary contact for recreation.

NOF attribute and associated value	Attribute measure	Numeric Attribute State (Value)
Nitrate toxicity for ecological health	Annual 95th percentile	9.8 mg/L
	Annual median	6.9 mg/L
Ammonia toxicity for ecological health (standardised to pH 8).	Annual maximum	2.20 mg/L
	Annual median	1.30 mg/L
E. Coli for human health for recreation (secondary contact)	Annual median	>1000 cfu/100 mL
E. Coli for human health for recreation (primary contact, state "C")	95th percentile	>540 cfu/100 mL

- *ANZECC Guidelines*

The ANZECC Guidelines for Fresh and Marine Water Quality provide an authoritative guide for setting water quality objectives to maintain current and future environmental values for both natural and semi-natural water resources. The ANZECC guidelines

present ‘trigger values’ for different levels of species protection (i.e. 99, 95, 90 and 80%) based on toxicant-specific concentration-response data for a range of species. The data in this report has been compared to the ANZECC trigger values for copper and zinc (Table 6). The trigger values can be applied to both total and soluble metals; however comparison with the soluble form of metals is more conservative in terms of stream ecological health.

Table 6: ANZECC trigger values for copper and zinc in freshwater.

Water Quality Parameter	Trigger Values for Freshwater (µg/L)			
	Level of Protection (% Species)			
	99%	95%	90%	80%
Copper	1.0	1.4	1.8	2.5
Zinc	2.4	8.0	15	31

3.2 Box plots

The following box plots show the annual variation within the 2015 data set for each parameter tested at each of the 36 sites. The boxes represent the inter-quartile range (25th to 75th percentile) and the whiskers represent the 10th and 90th percentiles. The median is the centre line in each box. A basic statistical summary for each parameter at each site is also presented in Appendix 2.

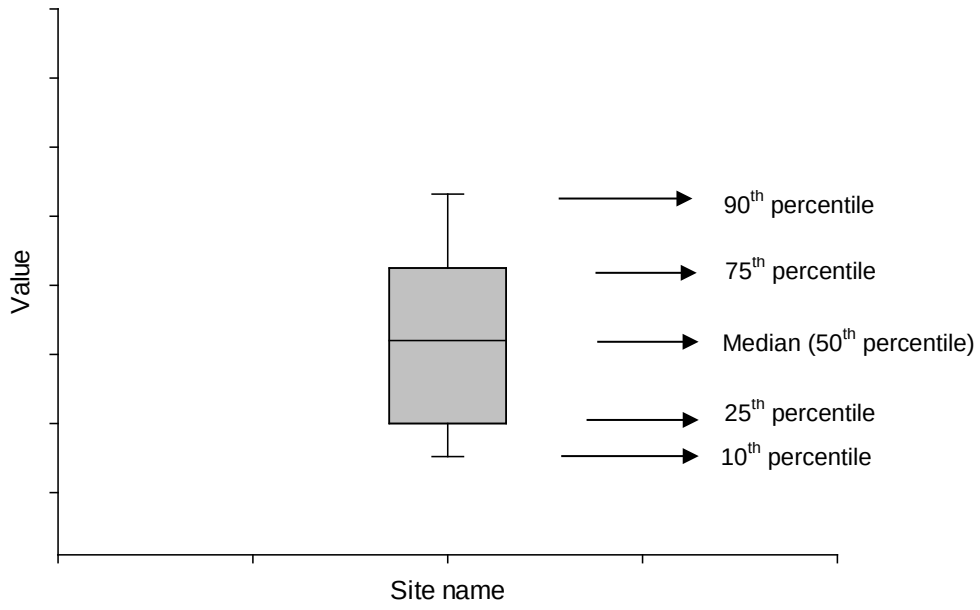

Figure 2: Info graphic illustrating the different measures within a box plot

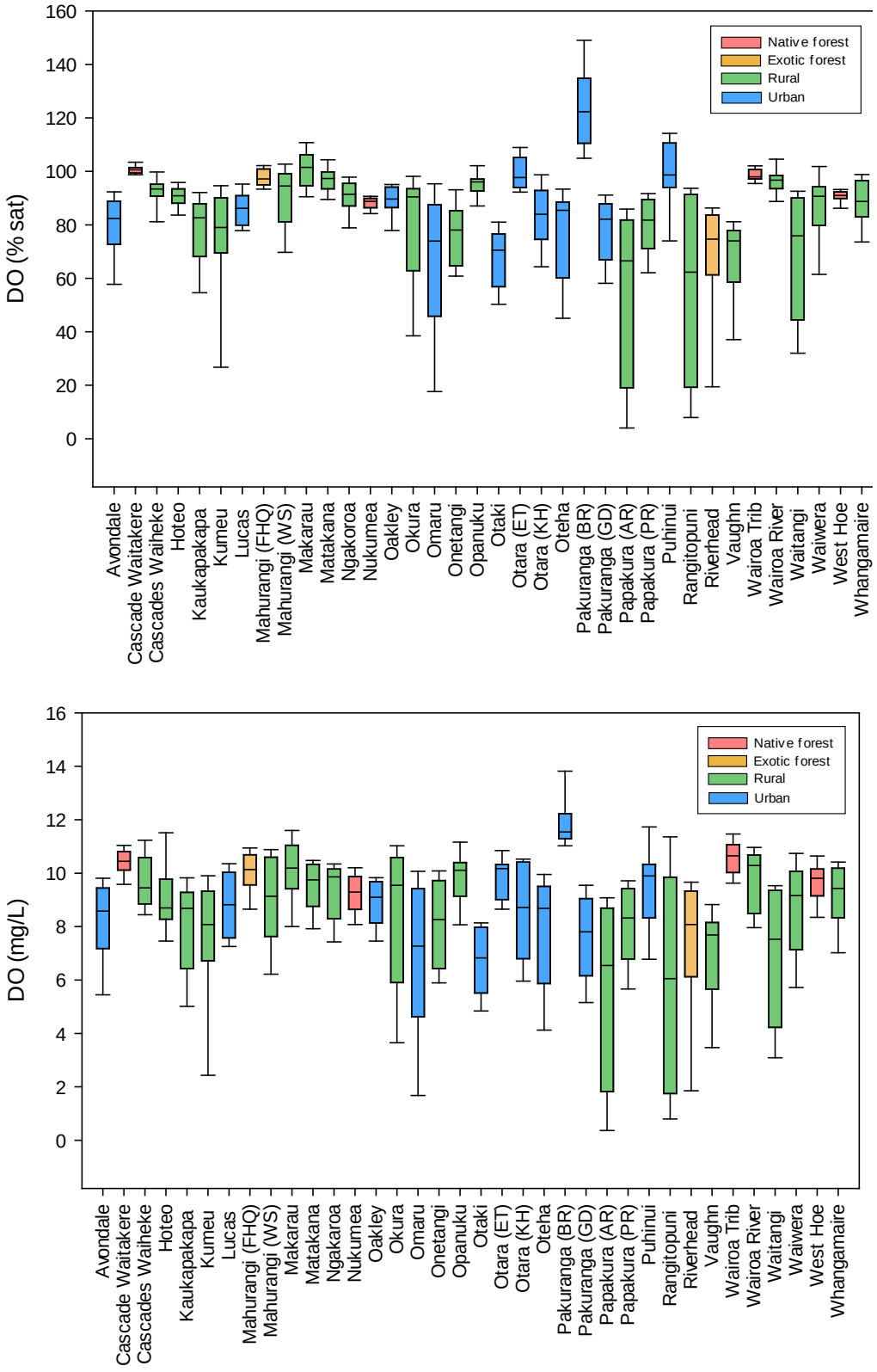

Figure 3: Box plots showing the annual variation in dissolved oxygen (DO) % saturation (upper plot) and mg/L (lower plot) at the 36 sites using data collected during the 2015 calendar year.

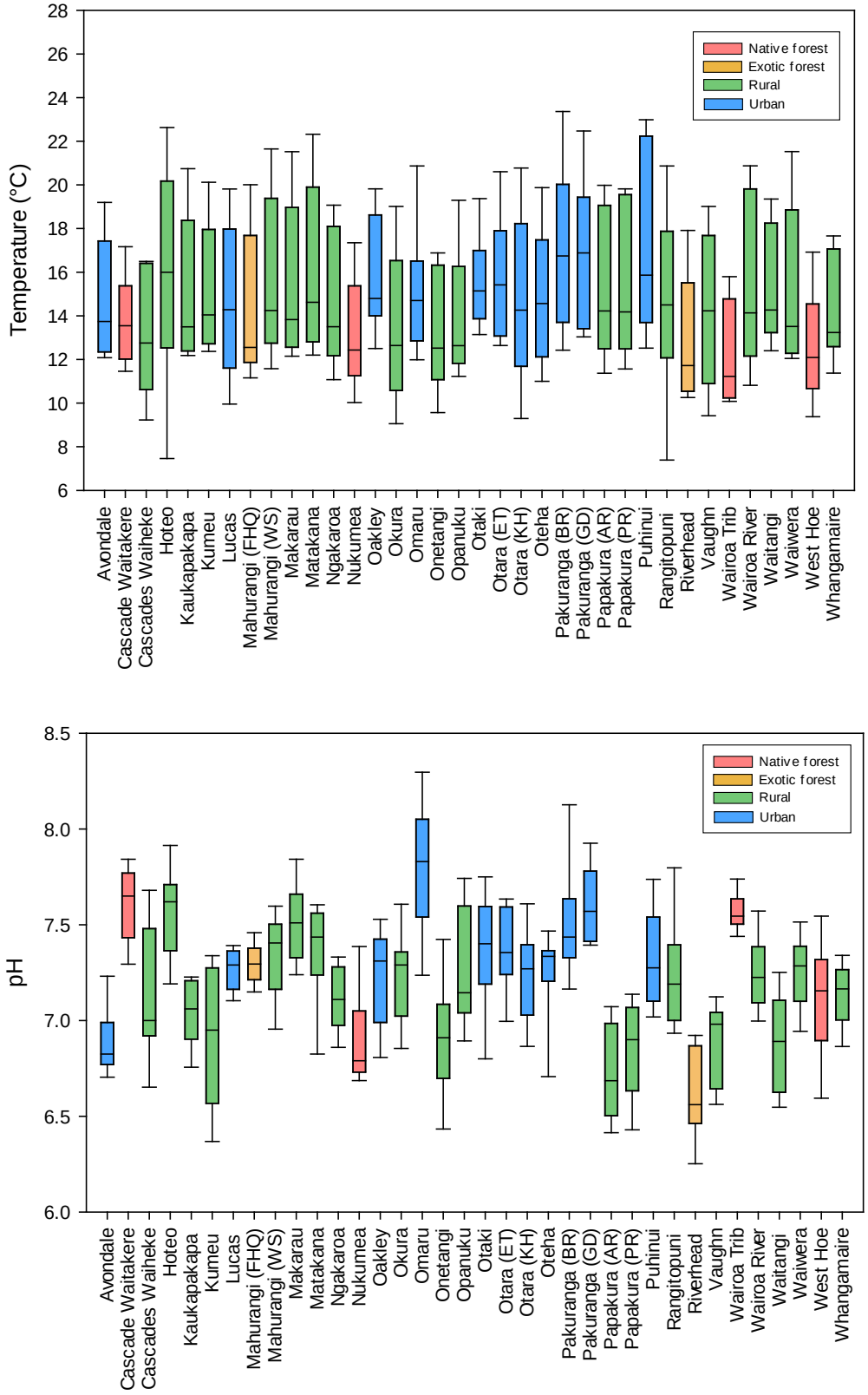

Figure 4: Box plots showing the annual variation in temperature (upper plot) and laboratory measured pH (lower plot) at the 36 sites using data collected during the 2015 calendar year.

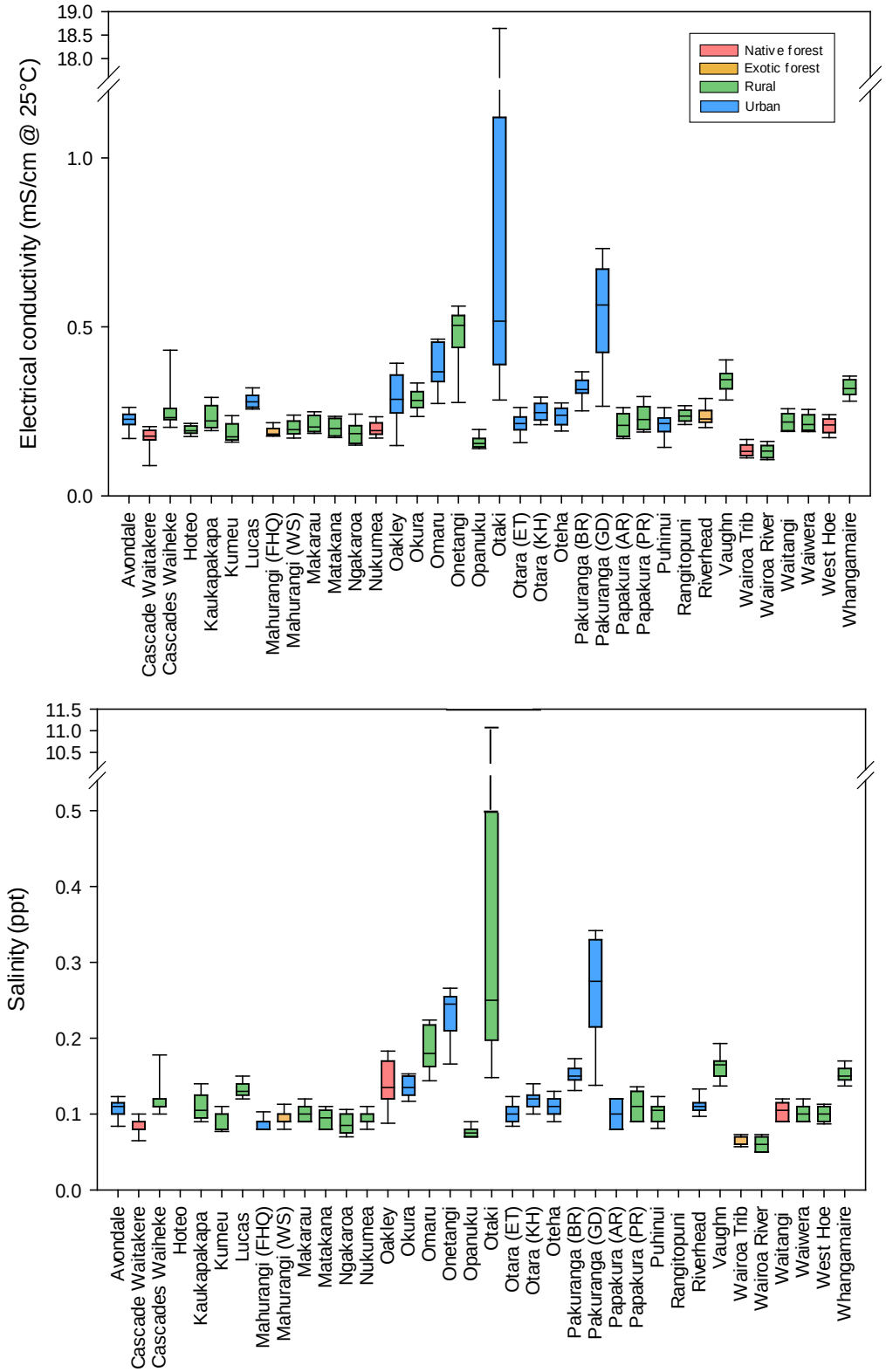

Figure 5: Box plot showing the annual variation in conductivity (upper plot) and salinity (lower plot) at the 36 sites using data collected during the 2015 calendar year. In both plots, a y-axis break is necessary to display the Otaki Stream data, which has a saline influence. Note that no salinity data is collected by NIWA for Hoteo and Rangitopuni Rivers.

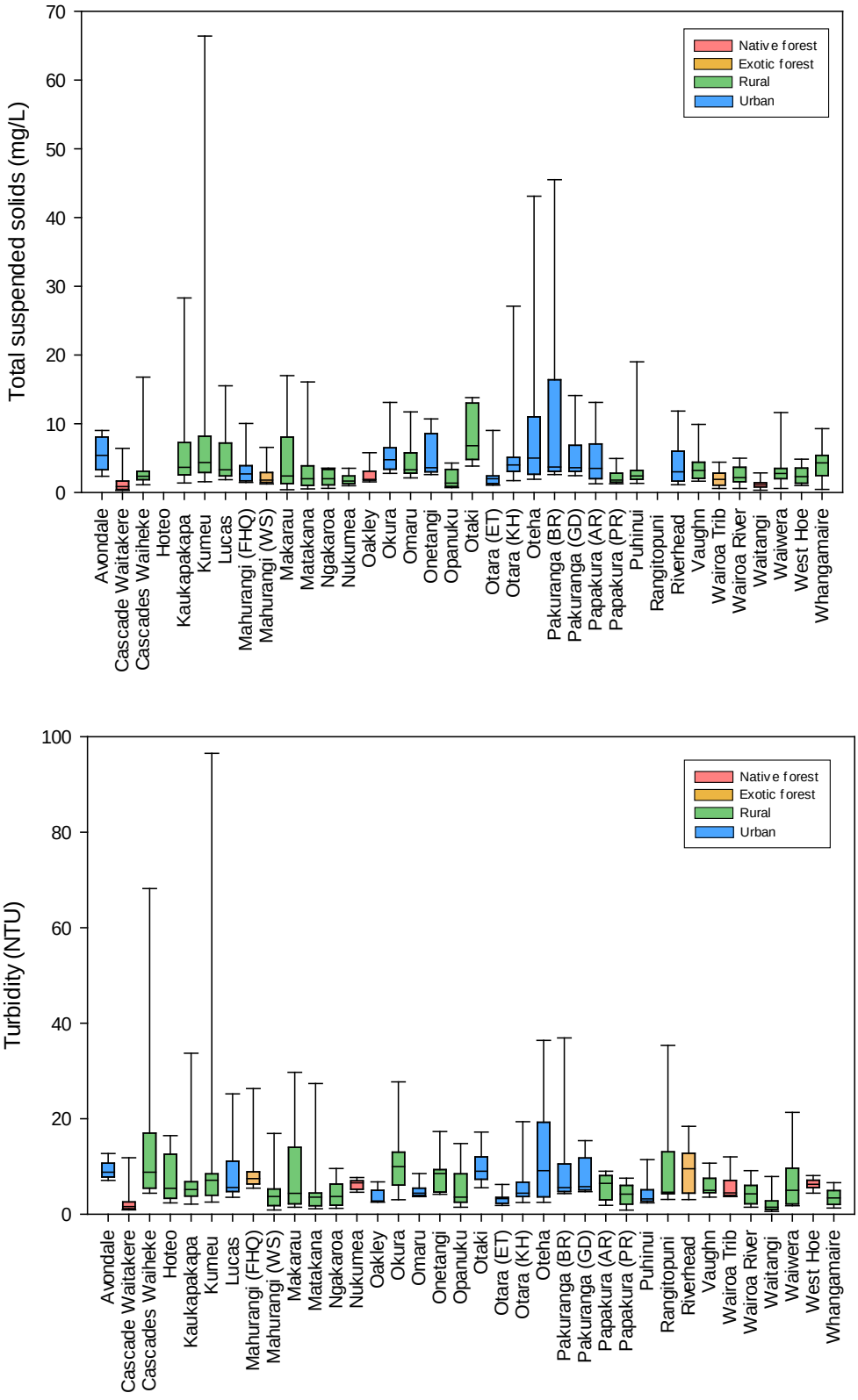

Figure 6: Box plots showing the annual variation in suspended sediment (upper plot) and turbidity (lower plot) at the 36 sites using data collected during the 2015 calendar year. Note that no suspended sediment data is collected by NIWA for Hoteo and Rangitopuni Rivers.

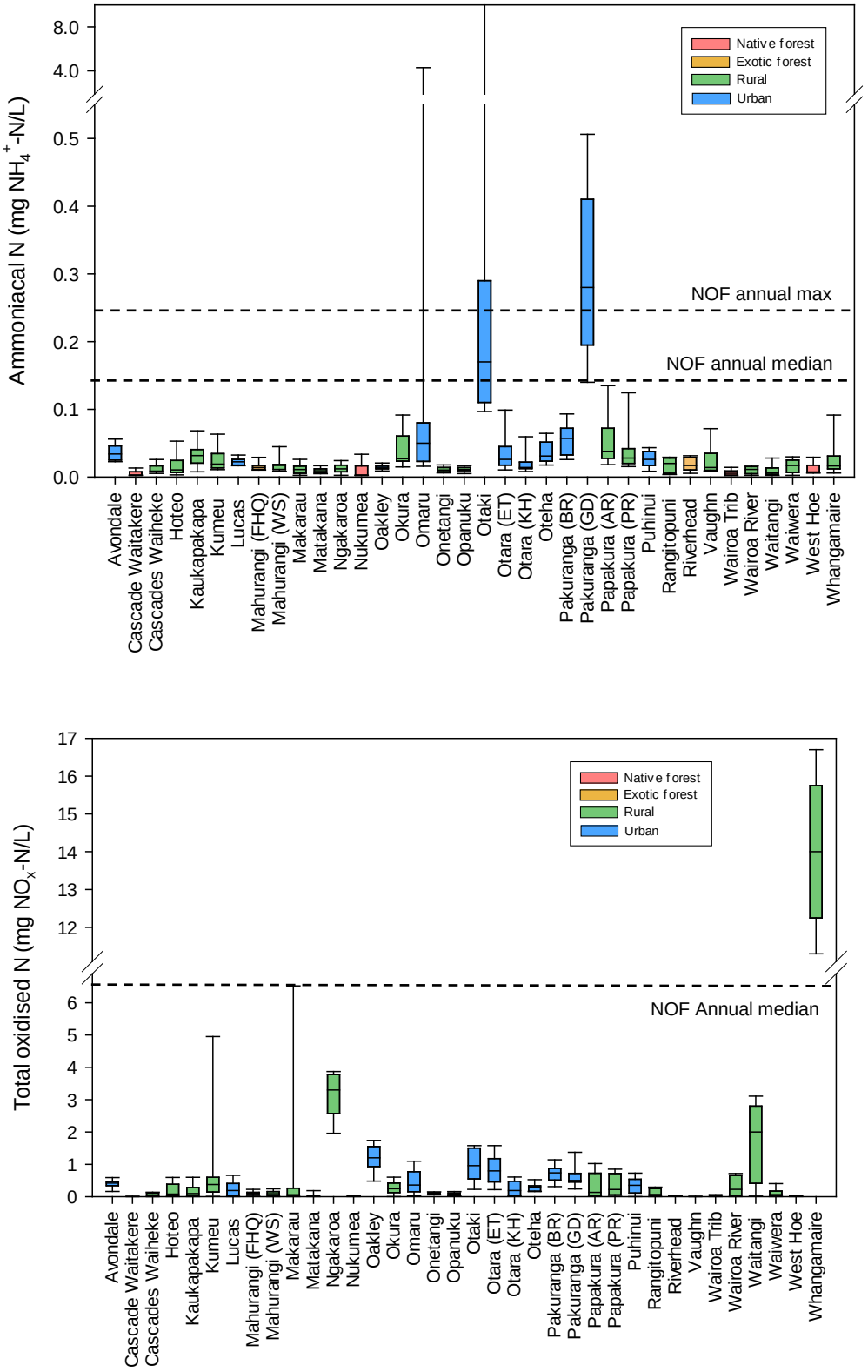

Figure 7: Box plots showing the annual variation in ammoniacal nitrogen (upper plot) and total oxidised nitrogen (lower plot) at the 36 sites using data collected during the 2015 calendar year. NOF National Bottom Line values for nitrate, as presented in Table 5, are displayed using dotted lines for context. Note that the NOF annual 95th percentile for nitrate of 9.8mg/L falls within the axis break.

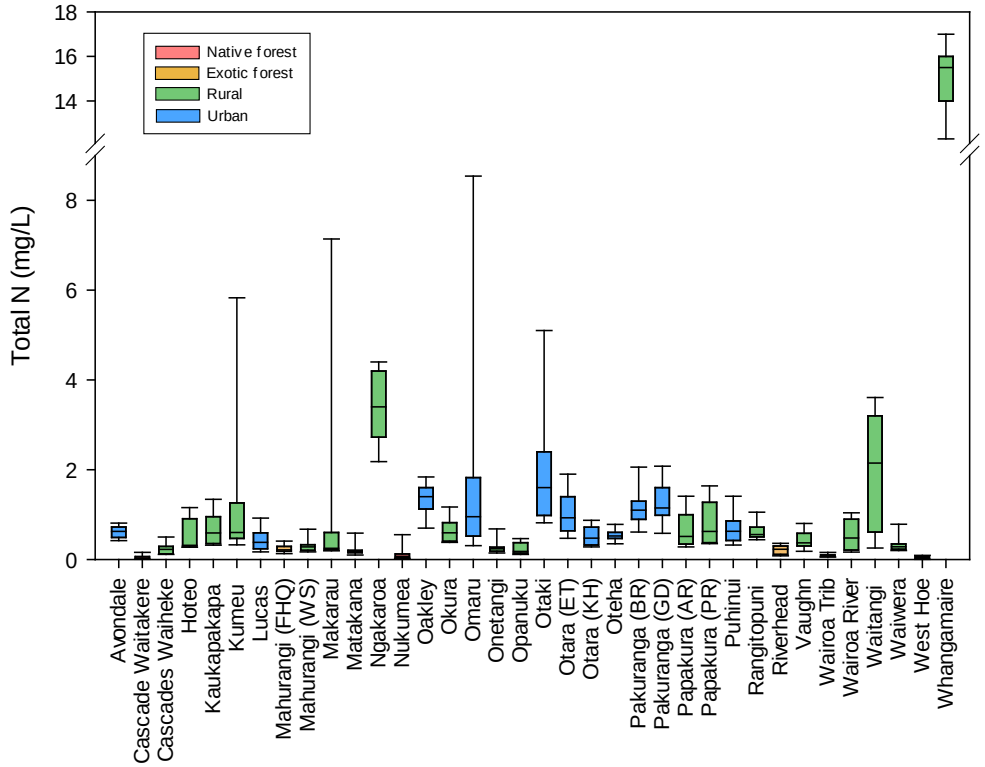

Figure 8: Box plot showing the annual variation in total nitrogen at the 36 sites using data collected during the 2015 calendar year. An axis break was necessary to display all data clearly.

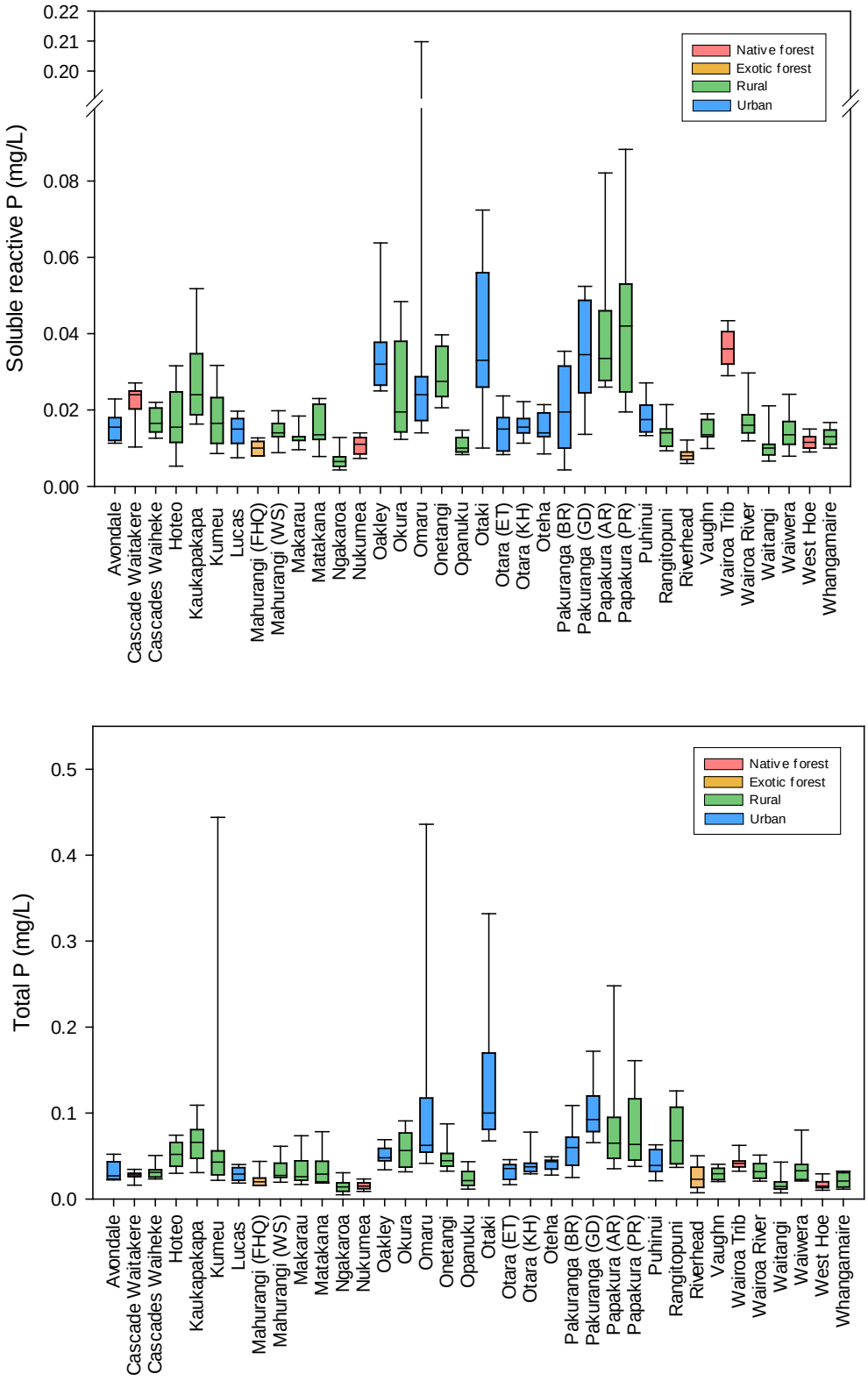

Figure 9: Box plots showing the annual variation in soluble reactive phosphorus (upper plot) and total phosphorus (lower plot) at the 36 sites using data collected during the 2015 calendar year. An axis break (upper plot) was necessary to display soluble reactive phosphorus data clearly.

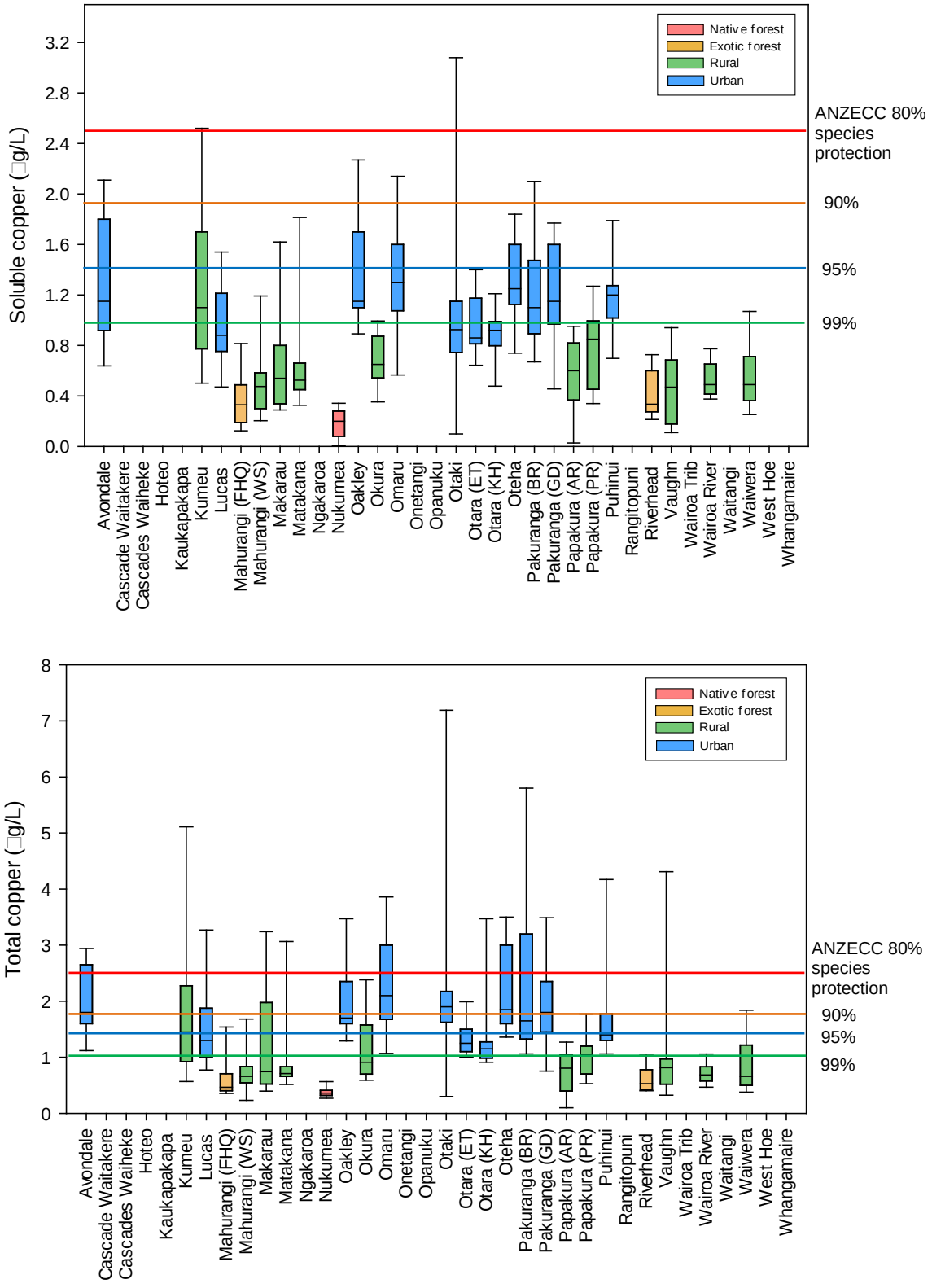

Figure 10: Box plots showing the annual variation in soluble copper (upper plot) and total copper (lower plot) at the 24 sites where it is monitored, using data collected during the 2015 calendar year. The ANZECC Guidelines for freshwater, as presented in Table 6, are displayed using coloured lines to give context to the data.

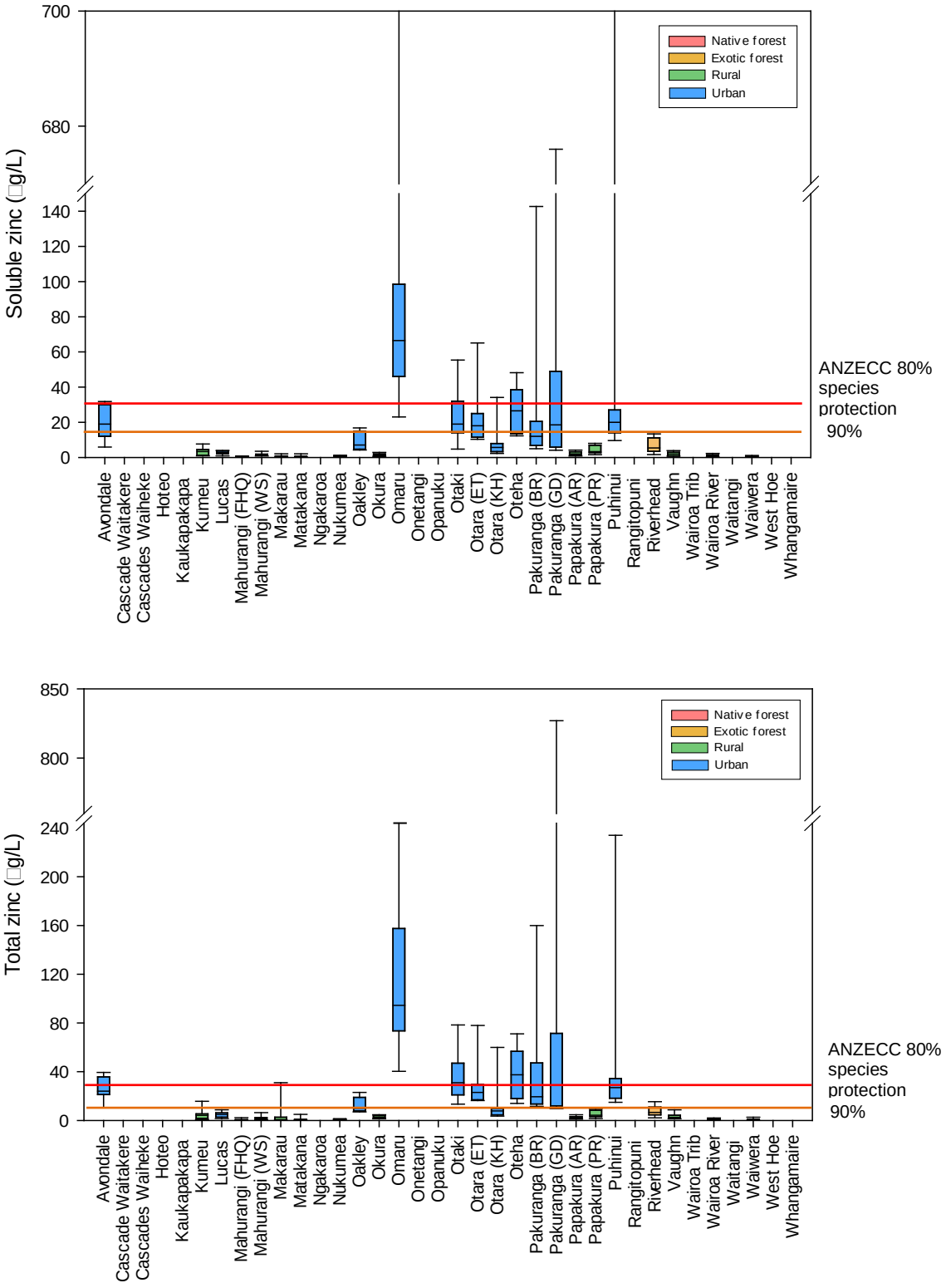

Figure 11: Box plots showing the annual variation in soluble zinc (upper plot) and total zinc (lower plot) at the 24 sites where it is monitored, using data collected during the 2015 calendar year. The ANZECC Guidelines for freshwater, as presented in Table 6, are displayed using dotted lines to give context to the data. An axis break was necessary to display all data clearly for both plots.

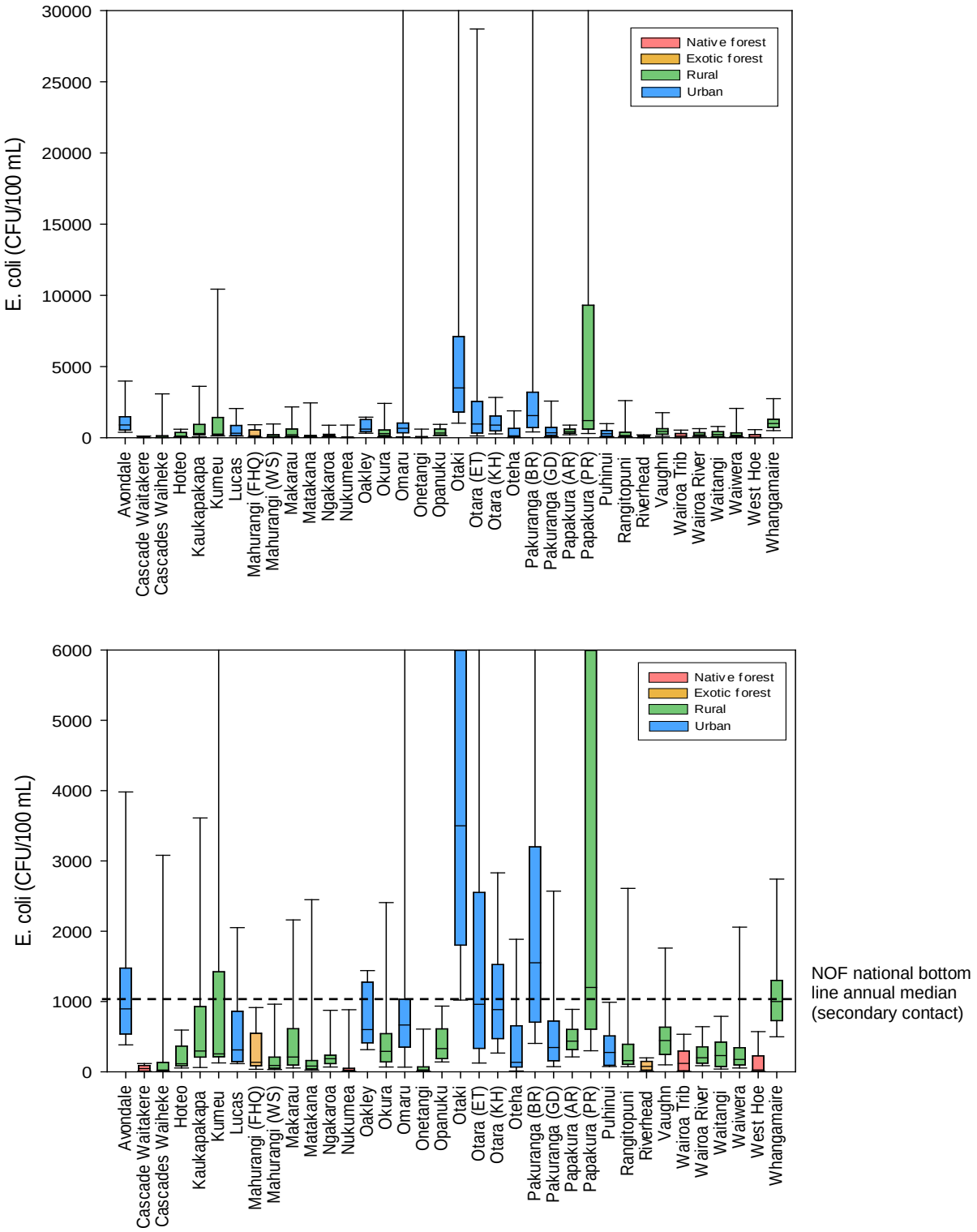

Figure 12: Box plot showing the annual variation in *Escherichia coli* at the 36 sites using data collected during the 2015 calendar year. The upper plot has a y-axis which covers the majority of the data range; the lower plot y-axis is limited to 6000 cfu/100 mL to provide greater resolution for sites with lower *Escherichia coli* levels, and shows the 1000 /100 mL NOF national bottom line annual median for secondary contact recreation as a black dotted line. Note: The 90th percentiles for *Escherichia coli* at Omaru Creek, Otaki, Pakuranga (BR) and Papakura (PR), are 270000, 106000, 49000 and 940000 cfu/100 mL, respectively.

3.3 Water quality indices and classes

3.3.1 Water Quality Index methodology

The communication of water quality data can be a challenge due to the volume and complexity of the data. For this reason, a Water Quality Index (WQI) is calculated to provide a broad summary of the state of water quality at each site to enable improved understanding and communication of the work. We used a water quality index developed by the Canadian Council of Ministers for the Environment (CCME) (2001). This approach uses the water quality results of specific parameters to produce four water quality indices, from which a water quality class is then assigned.

The water quality indices are calculated for each site based on seven water quality parameters (Table 7). Baseline objective values, or thresholds (Table 7), were derived from the data observed at the three Auckland Council reference sites (Cascades Stream (Waitakere), Wairoa Tributary and West Hoe Stream) over the five years preceding this report (2010 to 2014). These reference sites were used to represent the best achievable water quality in un-impacted environments in Auckland The rest of the water quality data were tested against these objectives to determine the relative deviation from natural conditions in the Auckland Region.

Table 7: The seven water quality parameters, and their objectives, used to produce the water quality indices in this report. The objectives are based on the 98th percentile (and 2nd percentile where applicable) of the data from reference sites in the programme collected between 2010 and 2014.

Parameter	Objective (acceptable if…)
Dissolved oxygen (% saturation)	Between 84 and 104%
pH	Between 6.1 and 7.8
Turbidity	Less than 35 NTU
Ammoniacal nitrogen	Less than 0.04 mg N l^{-1}
Temperature	Less than 17 ^{o}C
Total phosphorus	Less than 0.07 mg P l^{-1}
Total nitrogen	Less than 0.5 mg N l^{-1}

The water quality indices include

- Scope – the percentage of parameters that failed to meet the objective at least once during the time period under consideration (the lower this index, the better).
- Frequency – the percentage of all individual tests that failed to meet the objective during the time period under consideration (the lower this index, the better).
- Magnitude – the amount by which failed tests exceeded the objective (the lower this index, the better). This is based on the collective amount by which individual tests are out of compliance with the objectives and is scaled to be between 1 and 100. This is the most complex part of the index derivation and the reader is referred to CCME (2001) for full details.
- WQI – an overall water quality index based on a combination of the above three indices:

$$WQI = 100 - [\{\sqrt{(Scope^2 + Frequency^2 + Magnitude^2)}\} \div 1.732]$$

**Note the divisor 1.732 normalises the results to a range between 0 and 100, with 0 being the "worst" possible water quality and 100 being the "best" possible water quality.*

A water quality "class" is then assigned to each site based on the following WQI ranges:

- Greater than 90 = "Excellent"
- Between 70 and 90 = "Good"
- Between 50 and 70 = "Fair"
- Lower than 50 = "Poor"

3.3.2 Water Quality Index results

Wairoa Tributary and West Hoe streams were classed as having the best water quality in 2015, both with a Water Quality Index (WQI) score of 100. Two other sites, Cascades Stream (Waitakere) and Opanuku Stream were classified as having excellent water quality, with WQI scores of 91.7 and 91.6 respectively (Table 8). The Wairoa Tributary, West Hoe and Cascades Stream (Waitakere) all have native forest land cover and the Opanuku Stream has predominantly rural land cover.

Nine sites were classed as having good water quality in 2015. Of these, one (Cascades Stream (Whakanewha)) had declined from an excellent class in 2014. A further five sites maintained a 'good' rating from 2014. The remaining three sites improved from 'fair' in 2014 to 'good' in 2015. One of these, the Wairoa River, is in a rural catchment and the other two, Lucas Creek and Otara Creek (East Tamaki), are in urban catchments. These two urban streams have not achieved a 'good' water quality rating since 2009.

A total of 13 sites were classed as 'fair'. Six of these are in rural catchments and seven are in urban catchments. Ten sites were classed as 'poor'. Six of these are in rural catchments and four are in urban catchments. For the second year in a row, the Omaru Creek had the worst water quality rating of all monitored sites, with all parameters except turbidity exceeding the parameter thresholds at some stage during the year.

Overall 20 of the 36 sites had the same water quality class as 2014. Class changes were observed in 16 sites, with eight falling to a lower class and eight rising to a higher class.

The WQI has been used since 2007 for reporting the results of the water quality programme. The 2015 WQI classes for each site are shown in Table 8 along with the previous three years WQI scores. The annual WQI scores are subject to the inherently variable nature of water quality data, but could indicate patterns in overall water quality. Note that increases or decreases in the WQI scores over time do not indicate statistical or ecological trends.

In terms of catchment land cover, native forest sites had the highest WQI classes, followed by exotic forest sites, rural sites and urban sites consecutively (Table 8). Refer to Table 3 for catchment land cover categories for each site.

Table 8: Site-based water quality indices and classes based on 2015 data. The 2012, 2013 and 2014 WQI data are presented to provide temporal context. Classes are indicated by colour: Blue = "Excellent"; Green = "Good"; Orange = "Fair"; Red = "Poor".

Site	2012 WQI	2013 WQI	2014 WQI	2015 WQI	2015 WQI Class
Wairoa Tributary	91.7	91.7	100.0	100.0	Excellent
West Hoe Stream	91.7	91.7	83.3	100.0	Excellent
Cascade Stream (Waitakere)	100.0	91.4	91.7	91.7	Excellent
Opanuku Stream	100.0	100.0	83.4	91.6	Excellent
Mahurangi River (Water Supply)	65.9	74.6	82.6	83.1	Good
Wairoa River	65.7	74.6	66.3	82.0	Good
Riverhead Forest Stream	83.4	81.3	79.4	81.3	Good
Cascades (Whakanewha)	-	91.7	100.0	75.1	Good
Matakana River	58.3	74.6	83.1	74.8	Good
Lucas Creek	66.5	57.9	65.7	74.1	Good
Onetangi Stream	-	90.2	73.3	74.1	Good
Otara Creek (East Tamaki)	56.3	40.4	61.6	72.0	Good
Oakley Creek	71.6	56.0	71.2	71.2	Good
Nukumea Stream	83.4	91.6	83.1	66.9	Fair
Waitangi River	76.8	69.5	62.2	66.6	Fair
Waiwera River	66.1	82.4	74.3	66.3	Fair
Mahurangi River (Forestry HQ)	82.8	91.6	75.0	66.1	Fair
Makarau River	66.1	91.3	75.0	64.8	Fair
Puhinui Stream	56.9	55.8	56.8	64.6	Fair
Avondale Stream	58.2	49.2	55.4	64.2	Fair
Ngakaroa Stream	80.9	72.6	59.3	64.0	Fair
Vaughn Stream	57.1	57.6	64.8	64.0	Fair
Oteha Stream	49.2	58.1	66.0	57.2	Fair
Otara Creek (Kennel Hill)	56.4	57.0	47.9	56.9	Fair
Okura Creek	66.4	57.1	48.1	55.6	Fair
Papakura Stream (Porchester Rd)	55.5	54.1	47.4	54.3	Fair
Hoteo River	58.4	74.6	49.7	49.5	Poor
Papakura Stream (Alfriston)	46.5	50.1	47.5	47.4	Poor
Kaukapakapa River	49.5	65.8	65.5	46.8	Poor
Rangitopuni River	74.9	56.9	38.9	45.7	Poor
Kumeu River	58.5	65.4	64.5	45.4	Poor
Whangamaire Stream	41.3	50.4	45.2	42.6	Poor
Otaki Creek	54.2	41.7	41.8	35.4	Poor
Pakuranga Creek (Botany)	55.0	55.3	53.7	35.3	Poor
Pakuranga Creek (Greenmount Drive)	36.3	42.7	37.0	33.1	Poor
Omaru Creek	57.6	56.1	31.4	27.9	Poor

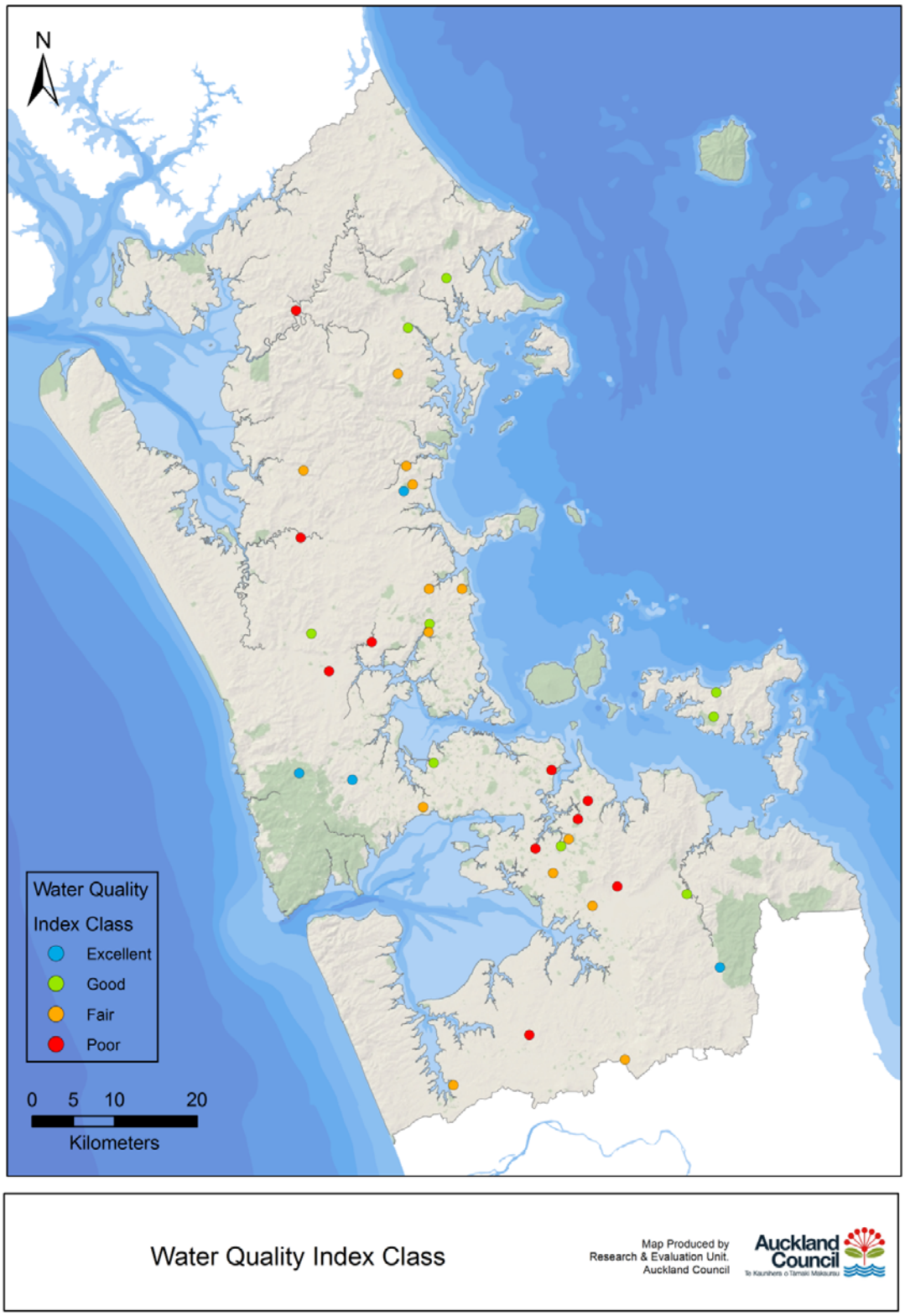

Figure 13: The sampling sites used in the Auckland Council River Water Quality Programme for 2015 with symbols coded by Water Quality Index Class.

Table 9: Mean 2015 water quality index scores and water quality class for all sites within a catchment land cover class. Mean WQI scores for each catchment land cover class are also presented for 2012, 2013 and 2014 to give temporal context to the data.

Land Cover (number of sites)	Average WQI 2012	Average WQI 2013	Average WQI 2014	Average WQI 2015	Water Quality Class 2015
Native forest (4)	91.7	91.6	89.5	89.0	Good
Exotic forest (2)	83.1	86.5	77.2	74.4	Good
Rural (19)	64.0	71.6	64.8	63.9	Fair
Urban (11)	56.2	53.0	53.5	52.1	Fair

4 Summary

This report summarises the results from Auckland Council's long-term river water quality monitoring programme for the 2015 calendar year. Water quality was assessed monthly at 36 sites across the region for a variety of parameters using a combination of field and laboratory based measurements. The results were presented as box plots to show annual variation within and between sites for each of the parameters. National bottom line values from the NPS-FM and ANZECC trigger values were compared to the appropriate parameters to provide context for the data.

The data was also used to produce water quality indices, which summarise the complex multivariate dataset into water quality classes which are easy to communicate. The WQI indicated that for 2015 the best river water quality was in the Wairoa Tributary and West Hoe Stream, followed by Cascades Stream (Waitakere) and Opanuku Stream. These were the only four sites classified as having excellent water quality in 2015. Poor water quality was observed in streams in a mix of urban and rural areas, with the Omaru Creek having the lowest classed water quality in 2015.

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The Auckland Council river water quality monitoring has benefitted from the efforts of numerous people since its inception in 1977.

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The data from the Rangitopuni River and Hoteo River sites are used under licence from NIWA.

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7 Appendix

Summary tables

Table A 1: Dissolved oxygen (% saturation)

Site	Count	Minimum	Maximum	Median	Mean	Standard Error
Avondale Stream	12	52.9	93.5	82.4	80.3	3.30
Cascade Stream (Waitakere)	12	98.6	104.1	100.6	100.6	0.43
Cascades Stream (Whakanewha)	11	79.6	100.9	93.4	92.1	1.61
Hoteo River (NIWA operated)	12	82.6	96.3	90.9	90.6	1.10
Kaukapakapa River	12	52.6	92.4	82.6	77.8	3.73
Kumeu River	12	14.2	95.8	79.0	74.7	6.37
Lucas Creek	12	77.2	95.4	86.2	86.0	1.79
Mahurangi River (Forestry HQ)	12	93.3	102.4	97.2	97.7	0.91
Mahurangi River (Water Supply)	12	65.6	103.2	94.5	90.0	3.26
MakarauRiver	12	90.4	111.0	101.5	100.8	2.03
Matakana River	12	89.5	106.1	97.3	96.6	1.37
Ngakaroa Stream	12	76.6	97.9	91.4	90.5	1.76
Nukumea Stream	11	83.8	90.8	88.8	88.2	0.66
Oakley Creek	12	75.3	95.1	89.7	89.3	1.65
Okura Creek	12	34.3	98.3	90.5	79.3	6.11
Omaru Creek	11	17.3	97.1	73.9	65.4	8.36
Onetangi Stream	12	59.4	94.1	78.1	76.8	3.28
Opanuku Stream	12	86.7	104.1	96.1	94.8	1.34
Otaki Creek	9	50.3	81.0	70.5	67.4	3.63
Otara Creek (East Tamaki)	12	92.0	109.5	97.7	99.4	1.76
Otara Creek (Kennel Hill)	12	63.5	99.3	84.0	83.1	3.51
Oteha Stream	12	44.6	93.8	85.4	76.0	5.17
Pakuranga Creek (Botany Rd)	12	104.8	152.5	122.3	124.2	4.35
Pakuranga Creek (Greenmount Rd)	12	56.5	92.0	82.1	78.2	3.44
Papakura Stream (Alfriston Rd)	12	3.5	86.7	66.5	53.3	9.22
Papakura Stream (Porchester Rd)	12	60.6	92.4	81.8	79.5	3.00
Puhinui Stream	12	69.3	114.4	98.7	98.5	3.71
Rangitopuni River (NIWA operated)	12	7.7	93.8	62.3	58.1	9.88
Riverhead Stream	12	11.6	86.3	74.7	68.0	6.50
Vaughan Stream	12	31.7	81.5	74.0	68.0	4.33
Wairoa Tributary	12	95.1	102.4	98.0	98.5	0.63
Wairoa River	12	87.3	104.7	96.7	96.6	1.39
Waitangi River	12	30.0	92.8	75.9	67.5	6.68
Waiwera River	12	57.3	102.5	90.7	86.8	3.66
West Hoe Stream	12	85.8	93.4	91.0	90.6	0.65
Whangamaire Stream	12	72.5	98.9	88.7	88.7	2.47

Table A 2: Dissolved oxygen (ppm)

Site	Count	Minimum	Maximum	Median	Mean	Standard Error
Avondale Stream	12	4.95	9.91	8.58	8.19	0.436
Cascade Stream (Waitakere)	12	9.44	11.08	10.45	10.42	0.136
Cascades Stream (Whakanewha)	11	8.42	11.29	9.45	9.69	0.299
Hoteo River (NIWA operated)	12	7.40	11.90	8.70	9.12	0.371
Kaukapakapa River	12	4.93	9.85	8.68	7.91	0.507
Kumeu River	12	1.34	10.05	8.08	7.57	0.696
Lucas Creek	12	7.25	10.46	8.82	8.80	0.344
Mahurangi River (Forestry HQ)	12	8.49	11.04	10.14	10.01	0.222
Mahurangi River (Water Supply)	12	5.93	10.89	9.14	9.01	0.484
MakarauRiver	12	7.83	11.77	10.19	10.08	0.334
Matakana River	12	7.67	10.52	9.75	9.55	0.258
Ngakaroa Stream	12	7.18	10.40	9.86	9.24	0.316
Nukumea Stream	11	8.02	10.24	9.29	9.28	0.216
Oakley Creek	12	7.31	9.88	9.10	8.87	0.254
Okura Creek	12	3.17	11.13	9.55	8.44	0.769
Omaru Creek	11	1.66	10.21	7.27	6.71	0.914
Onetangi Stream	12	5.75	10.11	8.26	8.09	0.453
Opanuku Stream	12	7.97	11.47	10.11	9.78	0.289
Otaki Creek	9	4.84	8.14	6.83	6.68	0.438
Otara Creek (East Tamaki)	12	8.62	10.85	10.17	9.88	0.226
Otara Creek (Kennel Hill)	12	5.86	10.53	8.72	8.55	0.525
Oteha Stream	12	4.11	9.97	8.68	7.78	0.629
Pakuranga Creek (Botany Rd)	12	11.02	13.85	11.54	11.92	0.278
Pakuranga Creek (Greenmount Rd)	12	5.12	9.65	7.81	7.65	0.458
Papakura Stream (Alfriston Rd)	12	0.32	9.11	6.55	5.52	0.989
Papakura Stream (Porchester Rd)	12	5.52	9.77	8.32	8.03	0.430
Puhinui Stream	12	6.57	11.90	9.90	9.52	0.451
Rangitopuni River (NIWA operated)	12	0.80	11.60	6.05	6.21	1.147
Riverhead Stream	12	1.14	9.67	8.08	7.28	0.761
Vaughan Stream	12	2.94	8.97	7.69	7.05	0.525
Wairoa Tributary	12	9.62	11.53	10.65	10.56	0.185
Wairoa River	12	7.79	11.03	10.29	9.71	0.328
Waitangi River	12	2.94	9.59	7.53	6.83	0.731
Waiwera River	12	5.30	10.81	9.16	8.73	0.496
West Hoe Stream	12	8.30	10.65	9.81	9.65	0.218
Whangamaire Stream	12	6.89	10.44	9.43	9.13	0.340

Table A 3: Temperature (^{o}C)

Site	Count	Minimum	Maximum	Median	Mean	Standard Error
Avondale Stream	12	12.05	19.47	13.74	14.81	0.789
Cascade Stream (Waitakere)	12	11.34	17.66	13.55	13.84	0.588
Cascades Stream (Whakanewha)	11	8.94	16.50	12.76	13.24	0.828
Hoteo River (NIWA operated)	12	6.80	23.20	16.00	15.79	1.446
Kaukapakapa River	12	12.11	21.70	13.50	15.24	0.958
Kumeu River	12	12.37	20.94	14.04	15.30	0.842
Lucas Creek	12	9.42	19.90	14.28	14.67	0.978
Mahurangi River (Forestry HQ)	12	11.03	20.93	12.55	14.46	0.962
Mahurangi River (Water Supply)	12	11.31	22.26	14.24	15.87	1.088
MakarauRiver	12	12.11	22.45	13.83	15.67	1.028
Matakana River	12	12.03	23.06	14.62	16.16	1.101
Ngakaroa Stream	12	10.77	19.33	13.50	14.69	0.883
Nukumea Stream	11	10.00	17.46	12.43	13.18	0.759
Oakley Creek	12	12.03	20.20	14.80	15.84	0.752
Okura Creek	12	8.73	19.05	12.64	13.44	0.997
Omaru Creek	11	11.98	21.60	14.70	14.99	0.882
Onetangi Stream	12	9.16	16.92	12.52	13.40	0.777
Opanuku Stream	12	11.03	20.11	12.64	14.15	0.826
Otaki Creek	9	13.14	19.37	15.14	15.69	0.670
Otara Creek (East Tamaki)	12	12.58	21.53	15.42	15.73	0.784
Otara Creek (Kennel Hill)	12	9.21	21.41	14.26	14.74	1.144
Oteha Stream	12	10.67	20.13	14.57	14.94	0.870
Pakuranga Creek (Botany Rd)	12	12.09	24.74	16.74	17.21	1.068
Pakuranga Creek (Greenmount Rd)	12	12.99	23.50	16.88	16.92	0.983
Papakura Stream (Alfriston Rd)	12	11.26	20.03	14.22	15.34	0.975
Papakura Stream (Porchester Rd)	12	11.52	19.92	14.18	15.42	0.976
Puhinui Stream	12	12.15	23.11	15.87	17.30	1.168
Rangitopuni River (NIWA operated)	12	6.70	21.80	14.50	14.66	1.222
Riverhead Stream	12	10.25	18.60	11.73	13.13	0.835
Vaughan Stream	12	9.02	19.02	14.23	14.34	1.013
Wairoa Tributary	12	10.07	15.82	11.23	12.33	0.665
Wairoa River	12	10.55	20.96	14.13	15.49	1.127
Waitangi River	12	12.07	19.77	14.27	15.39	0.764
Waiwera River	12	11.97	22.57	13.51	15.42	1.052
West Hoe Stream	12	9.30	16.96	12.10	12.68	0.731
Whangamaire Stream	12	11.24	17.78	13.24	14.24	0.685

Table A 4: Conductivity (Millisiemens/cm @ 25°C)

Site	Count	Minimum	Maximum	Median	Mean	Standard Error
Avondale Stream	12	0.157	0.263	0.227	0.224	0.0082
Cascade Stream (Waitakere)	12	0.058	0.206	0.177	0.171	0.0110
Cascades Stream (Whakanewha)	11	0.203	0.459	0.232	0.260	0.0231
Hoteo River (NIWA operated)	12	0.172	0.216	0.193	0.194	0.0037
Kaukapakapa River	12	0.192	0.295	0.222	0.233	0.0103
Kumeu River	12	0.157	0.238	0.175	0.188	0.0085
Lucas Creek	12	0.257	0.322	0.278	0.281	0.0062
Mahurangi River (Forestry HQ)	12	0.176	0.222	0.183	0.189	0.0040
Mahurangi River (Water Supply)	12	0.168	0.242	0.196	0.202	0.0067
MakarauRiver	12	0.183	0.251	0.204	0.212	0.0071
Matakana River	12	0.172	0.235	0.199	0.202	0.0071
Ngakaroa Stream	12	0.149	0.253	0.184	0.187	0.0095
Nukumea Stream	11	0.169	0.236	0.193	0.200	0.0063
Oakley Creek	12	0.122	0.403	0.286	0.287	0.0225
Okura Creek	12	0.230	0.339	0.282	0.284	0.0092
Omaru Creek	11	0.258	0.465	0.367	0.381	0.0195
Onetangi Stream	12	0.223	0.570	0.504	0.469	0.0279
Opanuku Stream	12	0.139	0.198	0.155	0.160	0.0056
Otaki Creek	9	0.284	18.643	0.517	2.666	2.0004
Otara Creek (East Tamaki)	12	0.141	0.269	0.214	0.214	0.0091
Otara Creek (Kennel Hill)	12	0.209	0.295	0.246	0.248	0.0080
Oteha Stream	12	0.191	0.276	0.238	0.235	0.0084
Pakuranga Creek (Botany Rd)	12	0.232	0.371	0.315	0.317	0.0103
Pakuranga Creek (Greenmount Rd)	12	0.240	0.753	0.565	0.540	0.0463
Papakura Stream (Alfriston Rd)	12	0.170	0.263	0.209	0.210	0.0106
Papakura Stream (Porchester Rd)	12	0.188	0.306	0.226	0.231	0.0112
Puhinui Stream	12	0.125	0.267	0.214	0.210	0.0104
Rangitopuni River (NIWA operated)	12	0.211	0.269	0.236	0.238	0.0057
Riverhead Stream	12	0.198	0.292	0.227	0.235	0.0080
Vaughan Stream	12	0.279	0.408	0.344	0.341	0.0107
Wairoa Tributary	12	0.110	0.173	0.132	0.136	0.0054
Wairoa River	12	0.106	0.165	0.133	0.132	0.0057
Waitangi River	12	0.191	0.259	0.218	0.220	0.0078
Waiwera River	12	0.190	0.259	0.211	0.216	0.0071
West Hoe Stream	12	0.169	0.243	0.210	0.208	0.0068
Whangamaire Stream	12	0.279	0.357	0.318	0.319	0.0075

Table A 5: Salinty (ppt)

Site	Count	Minimum	Maximum	Median	Mean	Standard Error
Avondale Stream	12	0.07	0.13	0.11	0.11	0.004
Cascade Stream (Waitakere)	12	0.03	0.10	0.08	0.08	0.005
Cascades Stream (Whakanewha)	11	0.10	0.22	0.11	0.12	0.010
Hoteo River (NIWA operated)			Not measured at this site			
Kaukapakapa River	12	0.09	0.14	0.11	0.11	0.005
Kumeu River	12	0.07	0.11	0.08	0.09	0.004
Lucas Creek	12	0.12	0.15	0.13	0.13	0.003
Mahurangi River (Forestry HQ)	12	0.08	0.11	0.09	0.09	0.003
Mahurangi River (Water Supply)	12	0.08	0.12	0.09	0.10	0.003
MakarauRiver	12	0.09	0.12	0.10	0.10	0.003
Matakana River	12	0.08	0.11	0.10	0.09	0.004
Ngakaroa Stream	12	0.07	0.12	0.09	0.09	0.005
Nukumea Stream	11	0.08	0.11	0.09	0.09	0.003
Oakley Creek	12	0.06	0.19	0.14	0.14	0.011
Okura Creek	12	0.11	0.16	0.14	0.14	0.004
Omaru Creek	11	0.12	0.23	0.18	0.18	0.010
Onetangi Stream	12	0.11	0.28	0.25	0.23	0.013
Opanuku Stream	12	0.07	0.09	0.08	0.08	0.002
Otaki Creek	9	0.14	11.09	0.25	1.53	1.197
Otara Creek (East Tamaki)	12	0.07	0.13	0.10	0.10	0.005
Otara Creek (Kennel Hill)	12	0.10	0.14	0.12	0.12	0.004
Oteha Stream	12	0.09	0.13	0.11	0.11	0.004
Pakuranga Creek (Botany Rd)	12	0.11	0.18	0.15	0.15	0.005
Pakuranga Creek (Greenmount Rd)	12	0.11	0.37	0.28	0.26	0.024
Papakura Stream (Alfriston Rd)	12	0.08	0.12	0.10	0.10	0.005
Papakura Stream (Porchester Rd)	12	0.09	0.15	0.11	0.11	0.006
Puhinui Stream	12	0.06	0.13	0.11	0.10	0.005
Rangitopuni River (NIWA operated)			Not measured at this site			
Riverhead Stream	12	0.09	0.14	0.11	0.11	0.004
Vaughan Stream	12	0.13	0.20	0.17	0.16	0.006
Wairoa Tributary	12	0.05	0.08	0.06	0.06	0.002
Wairoa River	12	0.05	0.08	0.06	0.06	0.003
Waitangi River	12	0.09	0.12	0.11	0.10	0.004
Waiwera River	12	0.09	0.12	0.10	0.10	0.003
West Hoe Stream	12	0.08	0.12	0.10	0.10	0.003
Whangamaire Stream	12	0.13	0.17	0.15	0.15	0.004

Table A 6: pH (pH units)

Site	Count	Minimum	Maximum	Median	Mean	Standard Error
Avondale Stream	12	6.7	7.2	6.8	6.9	0.05
Cascade Stream (Waitakere)	12	7.2	7.9	7.7	7.6	0.05
Cascades Stream (Whakanewha)	11	6.6	7.7	7.0	7.1	0.10
Hoteo River (NIWA operated)	12	7.2	7.9	7.6	7.6	0.07
Kaukapakapa River	12	6.7	7.2	7.1	7.0	0.05
Kumeu River	12	6.4	7.4	7.0	6.9	0.10
Lucas Creek	12	7.1	7.4	7.3	7.3	0.03
Mahurangi River (Forestry HQ)	12	7.1	7.5	7.3	7.3	0.03
Mahurangi River (Water Supply)	12	6.9	7.6	7.4	7.3	0.06
MakarauRiver	12	7.2	7.9	7.5	7.5	0.06
Matakana River	12	6.7	7.6	7.4	7.4	0.08
Ngakaroa Stream	12	6.8	7.3	7.1	7.1	0.05
Nukumea Stream	11	6.7	7.4	6.8	6.9	0.07
Oakley Creek	12	6.8	7.5	7.3	7.2	0.07
Okura Creek	12	6.8	7.7	7.3	7.2	0.07
Omaru Creek	11	7.2	8.3	7.8	7.8	0.11
Onetangi Stream	12	6.4	7.5	6.9	6.9	0.09
Opanuku Stream	12	6.9	7.8	7.1	7.3	0.09
Otaki Creek	9	6.8	7.8	7.4	7.4	0.10
Otara Creek (East Tamaki)	12	7.0	7.6	7.4	7.4	0.06
Otara Creek (Kennel Hill)	12	6.8	7.7	7.3	7.2	0.07
Oteha Stream	12	6.7	7.5	7.3	7.2	0.07
Pakuranga Creek (Botany Rd)	12	7.1	8.2	7.4	7.5	0.09
Pakuranga Creek (Greenmount Rd)	12	7.4	8.0	7.6	7.6	0.06
Papakura Stream (Alfriston Rd)	12	6.4	7.1	6.7	6.7	0.07
Papakura Stream (Porchester Rd)	12	6.4	7.1	6.9	6.8	0.07
Puhinui Stream	12	7.0	7.8	7.3	7.3	0.07
Rangitopuni River (NIWA operated)	12	6.9	8.0	7.2	7.2	0.08
Riverhead Stream	12	6.2	6.9	6.6	6.6	0.07
Vaughan Stream	12	6.6	7.2	7.0	6.9	0.06
Wairoa Tributary	12	7.4	7.8	7.5	7.6	0.03
Wairoa River	12	7.0	7.6	7.2	7.3	0.06
Waitangi River	12	6.5	7.3	6.9	6.9	0.07
Waiwera River	12	6.9	7.6	7.3	7.3	0.05
West Hoe Stream	12	6.5	7.6	7.2	7.1	0.09
Whangamaire Stream	12	6.8	7.3	7.2	7.1	0.05

Table A 7: Suspended sediment (mg/L)

Site	Count	Minimum	Maximum	Median	Mean	Standard Error
Avondale Stream	12	2.2	9.2	5.4	5.6	0.69
Cascade Stream (Waitakere)	12	0.3	7.8	0.9	1.6	0.61
Cascades Stream (Whakanewha)	12	1.0	22.0	2.4	4.0	1.66
Hoteo River (NIWA operated)	Not measured at this site					
Kaukapakapa River	12	1.2	34.0	3.7	7.2	2.66
Kumeu River	12	1.2	76.0	4.4	13.5	6.60
Lucas Creek	12	1.8	19.0	3.3	5.4	1.38
Mahurangi River (Forestry HQ)	12	1.4	11.0	2.7	3.7	0.83
Mahurangi River (Water Supply)	12	1.2	6.8	1.8	2.6	0.53
MakarauRiver	12	0.4	17.0	2.4	5.1	1.74
Matakana River	12	0.4	21.0	2.0	3.7	1.62
Ngakaroa Stream	12	0.5	3.6	2.0	2.2	0.33
Nukumea Stream	12	0.9	3.6	1.7	1.9	0.25
Oakley Creek	12	1.5	6.8	1.9	2.6	0.42
Okura Creek	12	2.6	14.0	4.8	5.8	0.99
Omaru Creek	12	2.0	14.0	3.3	4.6	0.95
Onetangi Stream	12	2.6	11.0	3.6	5.5	0.91
Opanuku Stream	12	0.7	4.4	1.4	1.9	0.39
Otaki Creek	11	3.8	14.0	6.8	8.1	1.17
Otara Creek (East Tamaki)	12	1.0	9.8	2.0	2.9	0.79
Otara Creek (Kennel Hill)	12	1.6	34.0	4.0	6.7	2.57
Oteha Stream	12	1.8	50.0	5.0	10.8	4.09
Pakuranga Creek (Botany Rd)	12	2.6	53.0	3.7	11.4	4.42
Pakuranga Creek (Greenmount Rd)	12	2.2	15.0	3.6	5.7	1.15
Papakura Stream (Alfriston Rd)	12	1.1	14.0	3.5	4.9	1.16
Papakura Stream (Porchester Rd)	12	1.2	5.6	1.8	2.3	0.35
Puhinui Stream	12	1.2	19.0	2.4	5.1	1.89
Rangitopuni River (NIWA operated)	Not measured at this site					
Riverhead Stream	12	1.0	14.0	3.0	4.2	1.05
Vaughan Stream	12	1.6	12.0	3.2	3.9	0.80
Wairoa Tributary	12	0.4	5.0	1.9	2.1	0.36
Wairoa River	12	0.4	5.4	2.2	2.5	0.40
Waitangi River	12	0.3	3.4	1.1	1.2	0.23
Waiwera River	12	0.4	13.0	2.8	3.7	1.02
West Hoe Stream	12	1.0	5.2	2.3	2.6	0.38
Whangamaire Stream	12	0.4	9.4	4.3	4.4	0.80

Table A 8: Turbidity (NTU)

Site	Count	Minimum	Maximum	Median	Mean	Standard Error
Avondale Stream	12	6.9	13.0	8.8	9.3	0.54
Cascade Stream (Waitakere)	12	0.9	14.0	1.6	3.0	1.10
Cascades Stream (Whakanewha)	12	4.3	85.0	8.8	16.6	6.55
Hoteo River (NIWA operated)	12	2.3	16.9	5.4	7.3	1.51
Kaukapakapa River	12	1.9	40.0	5.2	8.9	3.10
Kumeu River	12	2.4	110.0	7.1	19.5	9.60
Lucas Creek	12	3.5	30.0	5.6	8.7	2.16
Mahurangi River (Forestry HQ)	12	5.1	29.0	7.5	10.0	2.06
Mahurangi River (Water Supply)	12	0.8	19.0	3.7	5.2	1.52
MakarauRiver	12	1.4	33.0	4.4	8.5	2.90
Matakana River	12	1.0	37.0	3.6	5.9	2.85
Ngakaroa Stream	12	1.1	10.0	3.7	4.3	0.81
Nukumea Stream	12	4.4	7.8	6.6	6.2	0.30
Oakley Creek	12	2.5	7.0	2.8	3.6	0.47
Okura Creek	12	2.8	31.0	10.0	11.5	2.22
Omaru Creek	12	3.6	9.1	4.4	5.0	0.47
Onetangi Stream	12	4.0	20.0	8.5	8.2	1.28
Opanuku Stream	12	1.2	16.0	3.6	5.5	1.33
Otaki Creek	11	5.5	18.0	9.0	9.7	1.15
Otara Creek (East Tamaki)	12	1.7	7.3	3.3	3.3	0.41
Otara Creek (Kennel Hill)	12	2.3	24.0	4.4	6.2	1.69
Oteha Stream	12	2.3	40.0	9.1	12.9	3.35
Pakuranga Creek (Botany Rd)	12	4.2	45.0	5.6	10.1	3.38
Pakuranga Creek (Greenmount Rd)	12	4.7	16.0	5.8	8.1	1.17
Papakura Stream (Alfriston Rd)	12	1.8	9.3	6.5	5.8	0.77
Papakura Stream (Porchester Rd)	12	0.5	7.9	4.2	4.2	0.66
Puhinui Stream	12	2.3	14.0	3.2	4.4	0.93
Rangitopuni River (NIWA operated)	12	3.0	42.8	4.6	9.9	3.28
Riverhead Stream	12	2.8	19.0	9.5	9.5	1.51
Vaughan Stream	12	3.4	11.0	5.0	6.0	0.69
Wairoa Tributary	12	3.6	13.0	4.5	5.8	0.83
Wairoa River	12	1.2	9.6	4.3	4.5	0.73
Waitangi River	12	0.6	9.8	1.5	2.3	0.73
Waiwera River	12	1.7	24.0	5.0	6.9	1.93
West Hoe Stream	12	3.9	8.2	6.3	6.3	0.34
Whangamaire Stream	12	1.2	7.2	3.4	3.5	0.51

Table A 9: Ammoniacal Nitrogen (mg N /L)

Site	Count	Minimum	Maximum	Median	Mean	Standard Error
Avondale Stream	12	0.022	0.065	0.034	0.036	0.0039
Cascade Stream (Waitakere)	12	0.003	0.021	0.003	0.006	0.0016
Cascades Stream (Whakanewha)	12	0.003	0.044	0.009	0.013	0.0031
Hoteo River (NIWA operated)	12	0.003	0.064	0.011	0.019	0.0056
Kaukapakapa River	12	0.003	0.120	0.032	0.036	0.0086
Kumeu River	12	0.008	0.078	0.019	0.027	0.0061
Lucas Creek	12	0.016	0.033	0.023	0.023	0.0017
Mahurangi River (Forestry HQ)	12	0.008	0.043	0.014	0.016	0.0027
Mahurangi River (Water Supply)	12	0.003	0.100	0.017	0.022	0.0073
MakarauRiver	12	0.003	0.026	0.011	0.012	0.0023
Matakana River	12	0.003	0.018	0.009	0.010	0.0013
Ngakaroa Stream	12	0.003	0.027	0.012	0.013	0.0022
Nukumea Stream	12	0.003	0.044	0.003	0.011	0.0039
Oakley Creek	12	0.007	0.027	0.014	0.014	0.0014
Okura Creek	12	0.003	0.093	0.027	0.040	0.0087
Omaru Creek	12	0.006	9.200	0.050	0.986	0.7679
Onetangi Stream	12	0.006	0.022	0.010	0.011	0.0014
Opanuku Stream	12	0.003	0.021	0.011	0.011	0.0013
Otaki Creek	11	0.092	1.800	0.170	0.336	0.1503
Otara Creek (East Tamaki)	12	0.007	0.150	0.026	0.040	0.0115
Otara Creek (Kennel Hill)	12	0.008	0.072	0.014	0.022	0.0058
Oteha Stream	12	0.017	0.084	0.031	0.038	0.0057
Pakuranga Creek (Botany Rd)	12	0.018	0.110	0.057	0.056	0.0078
Pakuranga Creek (Greenmount Rd)	12	0.140	0.520	0.280	0.303	0.0388
Papakura Stream (Alfriston Rd)	12	0.014	0.170	0.038	0.057	0.0134
Papakura Stream (Porchester Rd)	12	0.009	0.200	0.028	0.046	0.0153
Puhinui Stream	12	0.008	0.049	0.026	0.027	0.0038
Rangitopuni River (NIWA operated)	12	0.003	0.032	0.020	0.018	0.0031
Riverhead Stream	12	0.003	0.032	0.017	0.018	0.0029
Vaughan Stream	12	0.009	0.110	0.014	0.028	0.0085
Wairoa Tributary	12	0.003	0.015	0.005	0.006	0.0013
Wairoa River	12	0.003	0.018	0.011	0.011	0.0017
Waitangi River	12	0.003	0.030	0.007	0.010	0.0027
Waiwera River	12	0.003	0.034	0.017	0.016	0.0030
West Hoe Stream	12	0.005	0.032	0.008	0.013	0.0026
Whangamaire Stream	12	0.006	0.100	0.017	0.029	0.0091

Table A 10: Total oxidised Nitrogen (mg N /L)

Site	Count	Minimum	Maximum	Median	Mean	Standard Error
Avondale Stream	12	0.1200	0.6000	0.4200	0.4000	0.03727
Cascade Stream (Waitakere)	12	0.0005	0.0076	0.0010	0.0024	0.00067
Cascades Stream (Whakanewha)	12	0.0010	0.1400	0.0010	0.0473	0.01699
Hoteo River (NIWA operated)	12	0.0005	0.6560	0.0780	0.1838	0.06394
Kaukapakapa River	12	0.0010	0.6400	0.0950	0.1860	0.06053
Kumeu River	12	0.0330	6.7000	0.3750	0.8873	0.53321
Lucas Creek	12	0.0010	0.7100	0.1900	0.2341	0.06694
Mahurangi River (Forestry HQ)	12	0.0130	0.2500	0.1200	0.1196	0.01584
Mahurangi River (Water Supply)	12	0.0010	0.2700	0.0920	0.0932	0.02512
MakarauRiver	12	0.0010	9.1000	0.0580	0.8567	0.75067
Matakana River	12	0.0021	0.1900	0.0170	0.0438	0.01869
Ngakaroa Stream	12	1.9000	3.9000	3.3000	3.1417	0.20429
Nukumea Stream	12	0.0010	0.0270	0.0105	0.0104	0.00212
Oakley Creek	12	0.3800	1.8000	1.2000	1.1725	0.11578
Okura Creek	12	0.0010	0.6100	0.2450	0.2748	0.05698
Omaru Creek	12	0.0100	1.2000	0.3600	0.4704	0.10600
Onetangi Stream	12	0.0510	0.1500	0.1030	0.1001	0.00878
Opanuku Stream	12	0.0170	0.1600	0.0770	0.0785	0.01284
Otaki Creek	11	0.1600	1.6000	0.9600	0.9564	0.13783
Otara Creek (East Tamaki)	12	0.1700	1.7000	0.7950	0.8292	0.12917
Otara Creek (Kennel Hill)	12	0.0086	0.6400	0.1900	0.2502	0.06913
Oteha Stream	12	0.1600	0.5500	0.2950	0.2858	0.03665
Pakuranga Creek (Botany Rd)	12	0.2900	1.2000	0.7350	0.7083	0.07603
Pakuranga Creek (Greenmount Rd)	12	0.2300	1.6000	0.5000	0.5933	0.10455
Papakura Stream (Alfriston Rd)	12	0.0028	1.1000	0.1300	0.3532	0.11428
Papakura Stream (Porchester Rd)	12	0.0380	0.8700	0.2200	0.3431	0.09501
Puhinui Stream	12	0.0010	0.8000	0.3500	0.3412	0.07170
Rangitopuni River (NIWA operated)	12	0.0010	0.3080	0.0665	0.1125	0.03380
Riverhead Stream	12	0.0086	0.0340	0.0210	0.0219	0.00202
Vaughan Stream	12	0.0005	0.0055	0.0010	0.0013	0.00039
Wairoa Tributary	12	0.0005	0.0570	0.0350	0.0294	0.00692
Wairoa River	12	0.0010	0.7200	0.2250	0.3211	0.08599
Waitangi River	12	0.0320	3.2000	2.0000	1.7705	0.34464
Waiwera River	12	0.0010	0.4800	0.0620	0.1074	0.04013
West Hoe Stream	12	0.0010	0.0400	0.0056	0.0078	0.00302
Whangamaire Stream	12	11.0000	17.0000	14.0000	14.0833	0.52884

Table A 11: Total Nitrogen (mg N /L)

Site	Count	Minimum	Maximum	Median	Mean	Standard Error
Avondale Stream	12	0.410	0.830	0.625	0.608	0.0388
Cascade Stream (Waitakere)	12	0.005	0.170	0.034	0.050	0.0149
Cascades Stream (Whakanewha)	12	0.110	0.580	0.225	0.235	0.0383
Hoteo River (NIWA operated)	11	0.267	1.216	0.316	0.529	0.0992
Kaukapakapa River	12	0.310	1.400	0.590	0.676	0.1036
Kumeu River	12	0.300	7.600	0.600	1.300	0.5851
Lucas Creek	12	0.160	0.940	0.380	0.443	0.0739
Mahurangi River (Forestry HQ)	12	0.130	0.420	0.215	0.238	0.0261
Mahurangi River (Water Supply)	12	0.160	0.740	0.280	0.317	0.0473
MakarauRiver	12	0.190	9.800	0.250	1.128	0.7912
Matakana River	12	0.088	0.740	0.175	0.216	0.0489
Ngakaroa Stream	12	2.000	4.400	3.400	3.425	0.2447
Nukumea Stream	12	0.020	0.730	0.071	0.126	0.0560
Oakley Creek	12	0.610	1.900	1.400	1.343	0.1039
Okura Creek	12	0.380	1.200	0.595	0.659	0.0798
Omaru Creek	12	0.250	11.000	0.955	1.932	0.8497
Onetangi Stream	12	0.140	0.800	0.240	0.281	0.0513
Opanuku Stream	12	0.110	0.470	0.180	0.241	0.0389
Otaki Creek	11	0.800	5.700	1.600	1.952	0.4224
Otara Creek (East Tamaki)	11	0.440	2.000	0.930	1.042	0.1442
Otara Creek (Kennel Hill)	12	0.270	0.900	0.475	0.533	0.0651
Oteha Stream	12	0.330	0.840	0.525	0.543	0.0372
Pakuranga Creek (Botany Rd)	12	0.590	2.300	1.100	1.159	0.1279
Pakuranga Creek (Greenmount Rd)	12	0.540	2.200	1.150	1.276	0.1378
Papakura Stream (Alfriston Rd)	12	0.270	1.500	0.515	0.679	0.1168
Papakura Stream (Porchester Rd)	12	0.350	1.700	0.625	0.843	0.1410
Puhinui Stream	12	0.300	1.500	0.630	0.690	0.1027
Rangitopuni River (NIWA operated)	11	0.436	1.054	0.556	0.644	0.0657
Riverhead Stream	12	0.078	0.370	0.230	0.217	0.0282
Vaughan Stream	12	0.150	0.880	0.370	0.434	0.0573
Wairoa Tributary	12	0.053	0.170	0.083	0.092	0.0095
Wairoa River	12	0.160	1.100	0.480	0.558	0.1017
Waitangi River	12	0.250	3.700	2.150	2.017	0.3617
Waiwera River	12	0.200	0.880	0.285	0.348	0.0563
West Hoe Stream	12	0.005	0.093	0.048	0.047	0.0085
Whangamaire Stream	12	12.000	17.000	15.500	15.083	0.4516

Table A 12: Soluble Reactive Phosphorus (mg P /L)

Site	Count	Minimum	Maximum	Median	Mean	Standard Error
Avondale Stream	12	0.011	0.025	0.016	0.016	0.0011
Cascade Stream (Waitakere)	12	0.010	0.028	0.024	0.022	0.0016
Cascades Stream (Whakanewha)	12	0.012	0.022	0.017	0.017	0.0009
Hoteo River (NIWA operated)	12	0.005	0.034	0.016	0.017	0.0025
Kaukapakapa River	12	0.016	0.053	0.024	0.028	0.0035
Kumeu River	12	0.008	0.035	0.017	0.017	0.0022
Lucas Creek	12	0.006	0.020	0.015	0.015	0.0012
Mahurangi River (Forestry HQ)	12	0.008	0.013	0.010	0.010	0.0005
Mahurangi River (Water Supply)	12	0.007	0.021	0.014	0.014	0.0010
MakarauRiver	12	0.009	0.019	0.013	0.013	0.0008
Matakana River	12	0.006	0.023	0.014	0.015	0.0015
Ngakaroa Stream	12	0.004	0.014	0.007	0.007	0.0008
Nukumea Stream	12	0.007	0.014	0.011	0.011	0.0007
Oakley Creek	12	0.025	0.071	0.032	0.036	0.0037
Okura Creek	12	0.012	0.052	0.020	0.025	0.0038
Omaru Creek	12	0.014	0.280	0.024	0.045	0.0215
Onetangi Stream	12	0.020	0.040	0.028	0.029	0.0020
Opanuku Stream	12	0.008	0.015	0.010	0.011	0.0006
Otaki Creek	11	0.007	0.073	0.033	0.038	0.0062
Otara Creek (East Tamaki)	12	0.008	0.024	0.015	0.015	0.0016
Otara Creek (Kennel Hill)	12	0.011	0.024	0.016	0.016	0.0010
Oteha Stream	12	0.007	0.022	0.014	0.015	0.0012
Pakuranga Creek (Botany Rd)	12	0.004	0.036	0.020	0.020	0.0033
Pakuranga Creek (Greenmount Rd)	12	0.010	0.053	0.035	0.036	0.0040
Papakura Stream (Alfriston Rd)	12	0.026	0.092	0.034	0.041	0.0055
Papakura Stream (Porchester Rd)	12	0.018	0.094	0.042	0.044	0.0064
Puhinui Stream	12	0.013	0.028	0.018	0.018	0.0013
Rangitopuni River (NIWA operated)	12	0.009	0.022	0.014	0.014	0.0011
Riverhead Stream	12	0.006	0.013	0.008	0.008	0.0006
Vaughan Stream	12	0.009	0.019	0.014	0.015	0.0009
Wairoa Tributary	12	0.029	0.044	0.036	0.036	0.0014
Wairoa River	12	0.011	0.033	0.016	0.018	0.0016
Waitangi River	12	0.006	0.022	0.010	0.011	0.0013
Waiwera River	12	0.007	0.025	0.014	0.015	0.0015
West Hoe Stream	12	0.009	0.015	0.012	0.012	0.0006
Whangamaire Stream	12	0.010	0.017	0.013	0.013	0.0007

Table A 13: Total Phosphorus (mg P /L)

Site	Count	Minimum	Maximum	Median	Mean	Standard Error
Avondale Stream	12	0.022	0.053	0.027	0.032	0.0033
Cascade Stream (Waitakere)	12	0.014	0.036	0.028	0.027	0.0016
Cascades Stream (Whakanewha)	12	0.023	0.057	0.031	0.032	0.0026
Hoteo River (NIWA operated)	11	0.029	0.076	0.052	0.051	0.0046
Kaukapakapa River	12	0.026	0.120	0.066	0.066	0.0071
Kumeu River	12	0.020	0.570	0.043	0.092	0.0445
Lucas Creek	12	0.018	0.041	0.029	0.029	0.0022
Mahurangi River (Forestry HQ)	12	0.016	0.050	0.020	0.023	0.0028
Mahurangi River (Water Supply)	12	0.019	0.062	0.028	0.034	0.0041
MakarauRiver	12	0.016	0.080	0.026	0.034	0.0055
Matakana River	12	0.018	0.090	0.029	0.035	0.0059
Ngakaroa Stream	12	0.005	0.033	0.014	0.015	0.0024
Nukumea Stream	12	0.008	0.024	0.015	0.016	0.0014
Oakley Creek	12	0.032	0.069	0.048	0.051	0.0032
Okura Creek	12	0.031	0.093	0.057	0.059	0.0063
Omaru Creek	12	0.040	0.550	0.063	0.116	0.0409
Onetangi Stream	12	0.030	0.100	0.045	0.049	0.0052
Opanuku Stream	12	0.011	0.045	0.022	0.024	0.0031
Otaki Creek	11	0.067	0.360	0.100	0.137	0.0266
Otara Creek (East Tamaki)	12	0.015	0.047	0.036	0.033	0.0028
Otara Creek (Kennel Hill)	12	0.029	0.085	0.038	0.042	0.0046
Oteha Stream	12	0.027	0.050	0.044	0.040	0.0021
Pakuranga Creek (Botany Rd)	12	0.022	0.120	0.060	0.059	0.0075
Pakuranga Creek (Greenmount Rd)	12	0.062	0.190	0.093	0.102	0.0100
Papakura Stream (Alfriston Rd)	12	0.032	0.290	0.065	0.088	0.0206
Papakura Stream (Porchester Rd)	12	0.035	0.170	0.064	0.078	0.0127
Puhinui Stream	12	0.021	0.064	0.039	0.042	0.0042
Rangitopuni River (NIWA operated)	11	0.036	0.129	0.068	0.074	0.0097
Riverhead Stream	12	0.007	0.054	0.023	0.025	0.0042
Vaughan Stream	12	0.020	0.042	0.030	0.030	0.0021
Wairoa Tributary	12	0.031	0.067	0.042	0.043	0.0027
Wairoa River	12	0.020	0.052	0.032	0.033	0.0030
Waitangi River	12	0.006	0.052	0.015	0.017	0.0034
Waiwera River	12	0.021	0.091	0.033	0.037	0.0057
West Hoe Stream	12	0.010	0.032	0.015	0.017	0.0018
Whangamaire Stream	12	0.011	0.033	0.021	0.022	0.0024

Table A 14: Soluble Copper (µg/L)

Site	Count	Minimum	Maximum	Median	Mean	Standard Error
Avondale Stream	12	0.53	2.20	1.15	1.32	0.146
Cascade Stream (Waitakere)			Not measured at this site			
Cascades Stream (Whakanewha)			Not measured at this site			
Hoteo River (NIWA operated)			Not measured at this site			
Kaukapakapa River			Not measured at this site			
Kumeu River	12	0.48	2.70	1.10	1.25	0.191
Lucas Creek	12	0.39	1.60	0.88	0.95	0.097
Mahurangi River (Forestry HQ)	12	0.10	0.86	0.33	0.37	0.065
Mahurangi River (Water Supply)	12	0.18	1.30	0.48	0.53	0.090
MakarauRiver	12	0.28	1.80	0.54	0.67	0.128
Matakana River	12	0.29	2.30	0.53	0.67	0.152
Ngakaroa Stream			Not measured at this site			
Nukumea Stream	12	0.01	0.36	0.20	0.19	0.033
Oakley Creek	12	0.85	2.30	1.15	1.37	0.137
Okura Creek	12	0.32	1.00	0.65	0.69	0.062
Omaru Creek	12	0.41	2.20	1.30	1.36	0.137
Onetangi Stream			Not measured at this site			
Opanuku Stream			Not measured at this site			
Otaki Creek	12	0.33	3.80	0.93	1.17	0.275
Otara Creek (East Tamaki)	12	0.64	1.40	0.86	0.97	0.076
Otara Creek (Kennel Hill)	12	0.40	1.30	0.92	0.89	0.062
Oteha Stream	12	0.73	1.90	1.25	1.31	0.103
Pakuranga Creek (Botany Rd)	12	0.64	2.10	1.10	1.23	0.138
Pakuranga Creek (Greenmount Rd)	12	0.30	1.80	1.15	1.22	0.126
Papakura Stream (Alfriston Rd)	12	0.01	0.97	0.60	0.58	0.089
Papakura Stream (Porchester Rd)	12	0.34	1.30	0.85	0.80	0.093
Puhinui Stream	12	0.62	2.00	1.20	1.17	0.094
Rangitopuni River (NIWA operated)			Not measured at this site			
Riverhead Stream	12	0.19	0.73	0.34	0.43	0.055
Vaughan Stream	12	0.11	0.98	0.47	0.47	0.084
Wairoa Tributary			Not measured at this site			
Wairoa River	12	0.37	0.78	0.49	0.53	0.041
Waitangi River			Not measured at this site			
Waiwera River	12	0.22	1.10	0.49	0.56	0.079
West Hoe Stream			Not measured at this site			
Whangamaire Stream			Not measured at this site			

Table A 15: Total Copper (µg/L)

Site	Count	Minimum	Maximum	Median	Mean	Standard Error
Avondale Stream	12	1.00	3.00	1.80	1.98	0.179
Cascade Stream (Waitakere)			Not measured at this site			
Cascades Stream (Whakanewha)			Not measured at this site			
Hoteo River (NIWA operated)			Not measured at this site			
Kaukapakapa River			Not measured at this site			
Kumeu River	12	0.53	5.20	1.45	1.94	0.446
Lucas Creek	12	0.74	3.60	1.30	1.53	0.236
Mahurangi River (Forestry HQ)	12	0.35	1.60	0.47	0.65	0.120
Mahurangi River (Water Supply)	12	0.23	2.00	0.66	0.74	0.131
MakarauRiver	12	0.36	3.60	0.75	1.22	0.290
Matakana River	12	0.48	4.00	0.71	0.98	0.276
Ngakaroa Stream			Not measured at this site			
Nukumea Stream	12	0.25	0.58	0.36	0.38	0.027
Oakley Creek	12	1.20	3.50	1.70	2.02	0.213
Okura Creek	12	0.57	2.50	0.91	1.18	0.178
Omaru Creek	12	0.84	4.10	2.10	2.31	0.254
Onetangi Stream			Not measured at this site			
Opanuku Stream			Not measured at this site			
Otaki Creek	12	1.00	9.20	1.90	2.54	0.676
Otara Creek (East Tamaki)	12	1.00	2.20	1.25	1.33	0.096
Otara Creek (Kennel Hill)	12	0.88	4.40	1.15	1.39	0.277
Oteha Stream	12	1.30	3.50	1.85	2.17	0.230
Pakuranga Creek (Botany Rd)	12	1.00	5.80	1.65	2.55	0.490
Pakuranga Creek (Greenmount Rd)	12	0.52	3.70	1.80	1.95	0.238
Papakura Stream (Alfriston Rd)	12	0.01	1.30	0.81	0.72	0.114
Papakura Stream (Porchester Rd)	12	0.50	1.80	1.05	1.06	0.116
Puhinui Stream	12	1.00	5.10	1.40	1.76	0.314
Rangitopuni River (NIWA operated)			Not measured at this site			
Riverhead Stream	12	0.40	1.10	0.53	0.62	0.068
Vaughan Stream	12	0.27	5.60	0.82	1.15	0.413
Wairoa Tributary			Not measured at this site			
Wairoa River	12	0.44	1.10	0.69	0.72	0.054
Waitangi River			Not measured at this site			
Waiwera River	12	0.37	1.90	0.66	0.87	0.146
West Hoe Stream			Not measured at this site			
Whangamaire Stream			Not measured at this site			

Table A 16: Soluble Zinc (µg/L)

Site	Count	Minimum	Maximum	Median	Mean	Standard Error
Avondale Stream	12	5.2000	32.0000	19.0000	20.4545	2.8239
Cascade Stream (Waitakere)			Not measured at this site			
Cascades Stream (Whakanewha)			Not measured at this site			
Hoteo River (NIWA operated)			Not measured at this site			
Kaukapakapa River			Not measured at this site			
Kumeu River	12	0.8700	8.9000	3.3500	3.2225	0.6666
Lucas Creek	12	0.9100	4.0000	2.9500	2.7475	0.3027
Mahurangi River (Forestry HQ)	12	0.1500	0.8000	0.4000	0.3792	0.0670
Mahurangi River (Water Supply)	12	0.7700	4.2000	1.4000	1.6208	0.2632
MakarauRiver	12	0.1500	2.4000	0.4050	0.6050	0.1891
Matakana River	12	0.1500	2.6000	0.4650	0.5892	0.1936
Ngakaroa Stream			Not measured at this site			
Nukumea Stream	12	0.1500	1.3000	0.8250	0.7442	0.0913
Oakley Creek	12	4.2000	17.0000	7.1000	9.1455	1.4630
Okura Creek	12	0.5700	2.9000	1.3500	1.5008	0.2149
Omaru Creek	12	17.0000	230.0000	66.5000	80.4167	15.9195
Onetangi Stream			Not measured at this site			
Opanuku Stream			Not measured at this site			
Otaki Creek	12	4.2000	58.0000	19.0000	24.4727	4.8417
Otara Creek (East Tamaki)	12	10.0000	69.0000	18.0000	24.5000	5.4404
Otara Creek (Kennel Hill)	12	2.2000	45.0000	5.7000	8.5583	3.3737
Oteha Stream	12	12.0000	50.0000	26.5000	27.0000	3.8198
Pakuranga Creek (Botany Rd)	12	4.7000	170.0000	12.0000	29.6667	14.0314
Pakuranga Creek (Greenmount Rd)	12	3.5000	910.0000	18.5000	101.1500	74.2421
Papakura Stream (Alfriston Rd)	12	0.7400	4.4000	2.0000	2.1855	0.3258
Papakura Stream (Porchester Rd)	12	1.5000	8.1000	3.3000	4.6091	0.7608
Puhinui Stream	12	8.5000	190.0000	20.0000	43.8636	17.8697
Rangitopuni River (NIWA operated)			Not measured at this site			
Riverhead Stream	12	1.5000	14.0000	5.4000	6.6167	1.2026
Vaughan Stream	12	0.7700	4.3000	1.9500	2.0142	0.3216
Wairoa Tributary			Not measured at this site			
Wairoa River	12	0.1500	2.5000	0.9400	1.0355	0.1986
Waitangi River			Not measured at this site			
Waiwera River	12	0.1500	1.1000	0.5150	0.5450	0.0901
West Hoe Stream			Not measured at this site			
Whangamaire Stream			Not measured at this site			

Table A 17: Total Zinc (µg/L)

Site	Count	Minimum	Maximum	Median	Mean	Standard Error
Avondale Stream	12	8.90	40.00	24.00	26.58	2.837
Cascade Stream (Waitakere)			Not measured at this site			
Cascades Stream (Whakanewha)			Not measured at this site			
Hoteo River (NIWA operated)			Not measured at this site			
Kaukapakapa River			Not measured at this site			
Kumeu River	12	0.54	16.00	4.25	5.22	1.471
Lucas Creek	12	1.40	9.20	4.90	4.71	0.674
Mahurangi River (Forestry HQ)	12	0.15	2.50	0.51	0.70	0.207
Mahurangi River (Water Supply)	12	0.15	7.60	1.95	2.36	0.538
MakarauRiver	12	0.15	42.00	0.63	4.61	3.429
Matakana River	12	0.15	6.80	0.74	1.08	0.529
Ngakaroa Stream			Not measured at this site			
Nukumea Stream	12	0.54	1.30	0.91	0.94	0.073
Oakley Creek	12	7.00	23.00	10.00	12.86	1.767
Okura Creek	12	1.30	4.90	2.60	2.84	0.366
Omaru Creek	12	31.00	280.00	94.50	116.08	19.035
Onetangi Stream			Not measured at this site			
Opanuku Stream			Not measured at this site			
Otaki Creek	12	12.00	82.00	31.00	37.82	6.277
Otara Creek (East Tamaki)	12	16.00	87.00	23.00	30.25	6.119
Otara Creek (Kennel Hill)	12	3.40	81.00	7.85	13.25	6.200
Oteha Stream	12	14.00	72.00	37.50	40.08	6.108
Pakuranga Creek (Botany Rd)	12	11.00	160.00	19.50	45.42	15.814
Pakuranga Creek (Greenmount Rd)	12	9.60	1100.00	29.00	130.21	89.385
Papakura Stream (Alfriston Rd)	12	0.83	4.90	2.35	2.52	0.330
Papakura Stream (Porchester Rd)	12	1.30	10.00	4.30	5.48	0.874
Puhinui Stream	12	14.00	270.00	27.00	55.42	22.197
Rangitopuni River (NIWA operated)			Not measured at this site			
Riverhead Stream	12	2.00	16.00	6.60	7.85	1.287
Vaughan Stream	12	1.30	10.00	2.60	3.47	0.724
Wairoa Tributary			Not measured at this site			
Wairoa River	12	0.43	2.10	0.98	1.06	0.159
Waitangi River			Not measured at this site			
Waiwera River	12	0.15	2.90	0.74	0.91	0.248
West Hoe Stream			Not measured at this site			
Whangamaire Stream			Not measured at this site			

Table A 18: *Escherichia coli* (cfu/100ml)

Site	Count	Minimum	Maximum	Median	Mean	Standard Error
Avondale Stream	12	380	4400	895	1299	349.7
Cascade Stream (Waitakere)	12	5	130	45	50	12.8
Cascades Stream (Whakanewha)	12	1	4300	24	409	354.3
Hoteo River (NIWA operated)	12	52	649	113	210	55.8
Kaukapakapa River	12	45	4300	295	820	352.8
Kumeu River	12	120	11000	255	2031	1094.4
Lucas Creek	12	110	2200	310	633	196.3
Mahurangi River (Forestry HQ)	12	27	1000	135	289	91.0
Mahurangi River (Water Supply)	12	27	1000	90	234	96.2
MakarauRiver	12	45	2400	210	508	213.5
Matakana River	12	18	3300	81	382	267.5
Ngakaroa Stream	12	63	1100	185	252	80.3
Nukumea Stream	12	3	1200	23	128	98.1
Oakley Creek	12	290	1500	600	798	128.5
Okura Creek	12	54	3100	290	554	239.6
Omaru Creek	12	9	380000	665	32266	31612.4
Onetangi Stream	12	7	820	27	99	66.2
Opanuku Stream	12	130	1000	330	415	78.6
Otaki Creek	11	900	130000	3500	15536	11478.1
Otara Creek (East Tamaki)	12	110	38000	960	4584	3086.7
Otara Creek (Kennel Hill)	12	240	3100	885	1098	247.6
Oteha Stream	12	5	2400	135	460	192.7
Pakuranga Creek (Botany Rd)	12	290	66000	1550	7582	5359.5
Pakuranga Creek (Greenmount Rd)	12	63	3200	345	623	249.8
Papakura Stream (Alfriston Rd)	12	200	890	435	483	64.0
Papakura Stream (Porchester Rd)	12	290	1300000	1200	118318	107723.0
Puhinui Stream	12	72	1100	275	340	91.3
Rangitopuni River (NIWA operated)	12	62	3448	158	485	273.7
Riverhead Stream	12	5	200	77	88	20.0
Vaughan Stream	12	76	2000	445	572	155.7
Wairoa Tributary	12	5	600	120	173	53.4
Wairoa River	12	81	660	200	257	55.8
Waitangi River	12	27	920	230	284	74.6
Waiwera River	12	45	2700	175	408	212.5
West Hoe Stream	12	3	610	27	152	59.6
Whangamaire Stream	12	480	3100	1000	1194	207.4

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