Auckland River Water Quality:
Annual Report and National Policy Statement for Freshwater Management, Current State Assessment, 2018

L Buckthought, R Ingley and C Grant

July 2020

Technical Report 2020/014

Research and Evaluation Unit RIMU

Auckland Council
Te Kaunihera o Tāmaki Makaurau

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Cover photograph credit: Oakley Creek monitoring site, photograph by Danielle Cairns.

Executive summary

Freshwater environments, including our flowing rivers and streams, wetlands and lakes, are valued by the people of Auckland. We monitor the state of rivers and streams in the region to provide evidence for the integrated environmental management outcomes that Auckland Council is responsible for, as required under section 35 of the Resource Management Act 1991 (as amended). To be able to interpret these environmental outcomes clearly, the collection of long-term data is necessary to partition out the inherent natural variability that occurs. This enables the detection of changes that may be attributed to land uses and activities, and/or climate change, and to subsequently assess the efficacy of council initiatives, policies, strategies and operational delivery.

To do this, Auckland Council operates a long-term state of the environment regional river water quality monitoring programme. The programme includes 36 river and stream sites from which water quality samples are collected monthly. Water quality analysis is based on a range of physical, chemical and microbiological variables that can be affected by land use activities, point source discharges, and land and instream erosion. Long-term trend analysis is undertaken periodically and is anticipated to be next updated in late 2020.

Individual water quality parameters assessed were generally consistent with variation previously reported for Auckland. Auckland Council's river water quality index is used to summarise a selection of parameters into five classes (ranging from 'poor' to 'excellent') based on exceedances of regional guideline values that are representative of water quality in native forested catchments in the Auckland region. In general, poorer water quality was observed at sites within catchments dominated by urban land cover and, to a lesser extent, rural and lifestyle catchments. Rivers in urban catchments tended to be affected by the full spectrum of contaminants, while rivers in rural and lifestyle catchments tended to be affected to a lesser extent by nutrients and sediment. As expected, rivers fed by catchments with a high proportion of native forest cover generally have good water quality. Regionally, water quality appears to be slightly declining over the short-term, shown by a small increase in the percentage of sites in the 'poor' class and a decrease in the number of sites in the 'excellent' class. But decline in reference sites may suggest that the decline is in part due to natural variation.

River water quality was assessed against the national objectives framework and attribute states in the National Policy Statement for Freshwater Management (MfE, 2017a, herein referred to as NPS-FM 2017), as well as regionally important Auckland attributes either assessed against regionally derived guidance or proposed guidance outlined in changes to the NPS-FM 2019 (MfE, September 2019).

Faecal contamination of rivers, as indicated by *Escherichia coli,* is a widespread issue across Auckland. The majority of rural and urban monitored river sites failed the NPS-FM 2017 *minimum acceptable state* condition *for E. coli*.

More localised issues were identified, with one rural site failing the national bottom line for nitrate and one urban site failing the national bottom line for ammonia. Several urban river sites failed proposed regional bottom lines for zinc toxicity effects on stream biota. An assessment of dissolved inorganic nutrients with regard to the effects of potential instream eutrophication also highlighted a more refined understanding of nutrient management issues across the region when compared to the assessment against higher toxicity guideline values. A small number of streams also failed to meet the proposed NPS-FM 2019 bottom line for suspended fine sediment.

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1.0 Introduction

Auckland's freshwater environments are valued by the people of Auckland. The Auckland region has an estimated 19,000 kilometres of permanently flowing rivers[1] (Auckland Council Geomaps, V 3.2.1.1). Many of Auckland's rivers are small and drain directly to the coast before they can merge with others to form larger river systems. Consequently, most streams in Auckland are first and second order, as classified by the River Environment Classification (REC) (Snelder et al., 2010), meaning they are small in length, with most less than a few metres wide. Many of Auckland's urban streams experience 'flashy' flows due to the increased proportion of impervious surface in the catchment and thus stormwater runoff under rainfall conditions (Allibone et al., 2001).

Auckland's topography is predominantly gentle in comparison to other regions of New Zealand. This strongly influences the nature of Auckland's rivers, along with the underlying geology, typically resulting in slow flowing, low gradient rivers with predominantly soft substrate beds. High gradient rivers with hard stony substrates are mostly restricted to catchments that drain the Waitākere Ranges, Hunua Ranges and Aotea/Great Barrier Island.

The aesthetics, human use and health of our rivers are influenced by their water quality. River water quality is influenced by natural seasonal variation due to annual changes in flow rate (via variation in rainfall and baseflow supplied from groundwater), as well as longer-term climatic changes. River water quality is also intrinsically related to how the land is used and where land use change occurs.

Long-term monitoring data is necessary to express what natural variability in river water quality looks like so that we can detect real change in water quality that may be attributed to human use and/or long-term climatic changes.

In addition to the long-term state of the environment river water quality programme, Auckland Council also undertakes regional monitoring of river ecology; lake water quality and ecology; groundwater quality and quantity; and coastal and estuarine water and sediment quality and benthic ecology. Microbiological contamination of beaches and recreational water quality are monitored through the Safeswim programme, www.safeswim.org.nz. Combining analysis of river and coastal water quality and ecological monitoring is also important to provide an integrated overview of the physical, chemical, and biological condition of the region. This type of combined

[1] This does not take in to account the considerable number of intermittent streams across the region.

analysis is undertaken on a five-yearly basis in the *State of the Environment* reports (e.g. Auckland Council, 2015).

The purpose of this report is to communicate the state of river water quality within the Auckland region for the 2018 calendar year. River water quality is described using a range of physical, chemical and microbiological variables that can be affected by land use activities, point and diffuse source discharges, and land and instream erosion. This is part of the feedback loop necessary to confirm whether Auckland Council's management strategies are effective in sustaining ecosystem functions and to identify opportunities for future sustainable use of our valued rivers and streams.

This report outlines the following:

- A summary of the variability of individual water quality parameters within and between sites in 2018.
- An assessment of overall water quality state in relation to ecosystem health via ongoing assessment against Auckland Council's river water quality index (non-regulatory).
- For the first time in this report series, a comparison of relevant water quality parameters against the National Objectives Framework (NOF) river attributes set out in the National Policy Statement for Freshwater Management (NPS-FM 2017 and 2019), as an assessment of both ecosystem health and human health values.

As a starting point, to investigate river quality against natural reference conditions, water quality data may be compared to the updated New Zealand Default Guidelines Values (DGV) for physical and chemical stressors in freshwater environments (https://www.waterquality.gov.au/anz-guidelines). These guideline values have recently been developed for REC combined climate and topography classes using New Zealand reference site data (MfE, 2018). Although this assessment has not been undertaken here, the DGVs are provided in Appendix A for quick reference. These DGVs correspond to the concentrations of the water quality variables that are estimated to occur under natural conditions (i.e. in the absence of human influence).

Auckland Council's river water quality index is used to summarise several complex and interactive water quality variables into a single numeric value which represents a narrative water quality statement, in this case one that reflects the ecosystem health state of river water across the region. The water quality index is used to enable comparison between streams in different land cover classes and to outline where further investigation may be warranted. The water quality index does not indicate whether the water quality is suitable for a particular purpose or activity.

The National Policy Statement for Freshwater Management (MfE, 2017a) provides national direction for river water quality management around two key values – ecosystem health and human health. It also outlines specific attributes (water quality parameters) to assess current water quality state.

Councils may choose to include additional regional attributes to this assessment framework. For the Auckland region additional important attributes, such as dissolved copper and zinc, suspended fine sediment, and dissolved nitrogen and phosphorus, have been identified and are compared here against either draft regional guidance or proposed NPS-FM 2019 additional NOF attributes (MfE, 2019). Fine-tuning of this assessment will occur in the future as regional guidelines are finalised or further direction is provided by central government.

Auckland Council's river water quality monitoring programme supports the following objectives:

- Meet council's obligations under section 35 of the Resource Management Act 1991 (as amended) to monitor and report on the state of the environment, with specific regard to river water quality.
- Provide evidence of how the council is maintaining and enhancing the quality of Auckland's river environments (Local Government Act, 2002). Specifically, evidence for the Environment and Cultural Heritage component of the Auckland Plan 2050. A key direction for the region is to manage the effects of growth and development on our natural environment.
- Help inform the efficacy and efficiency of council policy initiatives and strategies.
- Assist with the identification of large scale and/or cumulative impacts of contaminants associated with different land uses and disturbance regimes and correlative links to particular activities.
- Provide baseline, regionally specific data to underpin sustainable management through resource consenting and associated compliance monitoring for freshwater environments.
- Help identify the possible standard of future river water quality in Auckland.
- Continuously increase the knowledge base for Aucklanders and promote awareness of regional freshwater quality issues and their subsequent management.

Water holds special significance to Māori. Mana whenua whakapapa to significant water bodies and have kaitiaki obligations to protect them. This is part of the customary practice of taonga tuku iho (protecting treasures or taonga passed down from previous generations). The results of the river water quality monitoring programme can be

added to matauranga Māori knowledge to support Māori in their role as kaitiaki to protect and enhance te mauri o te wai (the life supporting capacity of water).

1.1 Supporting reports

Previous reports can be obtained from Auckland Council's Knowledge Auckland website, www.knowledgeauckland.org.nz. For further enquiries and data supply, email environmentaldata@aucklandcouncil.govt.nz.

Previous long-term trend analysis is reported in *State of the environment. River water quality state and trends in Auckland 2005-2014*, March 2016, Auckland Council technical report, TR2016/008 (Buckthought and Neale, 2016).

2.0 Methods

Auckland's river water quality monitoring programme currently includes 36 sites. The programme commenced with eight sites in 1977 until 1981. After a five-year hiatus the programme was reinitiated in 1986 with 17 sites and has been running continuously ever since. The programme has evolved over time, with sites added or removed according to varying regional management priorities. The programme was last reviewed internally in 2008 and subsequent changes were described in the 2009 annual report (Neale, 2010). Between 2009-2011, 31 sites were consistently monitored. Three new sites were added to the network at the beginning of 2012 (Lockie and Neale, 2013), and a further two were added in February 2013 (Lockie and Neale, 2014).

Each of the 36 sites is sampled monthly as part of five sampling runs undertaken by council's Research and Evaluation Unit (RIMU), except the Hoteo River, which is monitored exclusively 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 range of river and catchment sizes, stream orders (according to the REC, Snelder et al., 2010), catchment locations (upper, mid, lower) and catchment land uses. This enables Auckland Council to present a region-wide perspective on water quality and infer the likely water quality of other rivers in the region that are not monitored.

2.1 Site information and location

Monitored site location details including the sampling run it belongs to, the year water quality sampling was initiated, the second-level REC classes (climate and topography, known as the source of flow level), suspended sediment class, and the contributing catchment size upstream of the sampling point are outlined in Table 2-1 and sites are mapped in Figure 2-1.

The REC organises information on the physical characteristics of New Zealand's rivers such as climate, topography, geology and catchment land cover. This information is mapped for all rivers in New Zealand and can then be used to help determine the best management approaches for each river type.

Table 2-1: Auckland river water quality monitoring programme site locations, 2018.

AC #	AC site name	Sampling run	NZTM X	NZTM Y	Year initiated	REC Class*	SSC**	Catchment area (ha)
45703	Hoteo River	NIWA	1735254	5972546	1986	WWL	5	26917
7830	Lucas Creek	Northeast	1751468	5934510	1993	WDL	5	616
6811	Mahurangi River (Forestry)	Northeast	1747750	5965035	1993	WWL	5	490
6804	Mahurangi River (Warkworth)	Northeast	1748864	5970457	1993	WWL	5	4844
6604	Matakana River	Northeast	1753500	5976481	1986	WWL	5	1385
7171	Nukumea Stream	Northeast	1749411	5951400	2012	WWL	5	99
7502	Okura Creek	Northeast	1751405	5938716	2003	WWL	5	553
7811	Oteha River	Northeast	1751325	5933519	1986	WDL	5	1221
7506	Vaughan Stream	Northeast	1755414	5938729	2001	WWL	5	239
44603	Cascades Stream (Waitākere)	Northern	1735628	5916378	1986	WWL	1	1388
45415	Kaukapakapa River	Northern	1735833	5944978	2009	WWL	5	6157
45313	Kumeu River	Northern	1739252	5928781	1993	WWL	5	4566
45505	Makarau River	Northern	1736150	5953126	2009	WWL	5	4834
7904	Opanuku Stream	Northern	1742086	5915581	1986	WWL	5	1566
7805	Rangitopuni River	Northern	1744450	5932301	1986	WWL	5	8366
45373	Riverhead Stream	Northern	1737125	5933216	2009	WWL	5	410
7104	Waiwera Stream	Northern	1748628	5953665	1986	WWL	5	3023
7206	West Hoe Stream	Northern	1748314	5950610	2002	WWL	5	53
43829	Ngakoroa Stream	Southern	1775164	5881624	1993	WWL	1	466
1043837	Papakura Stream (Upper)	Southern	1774247	5902648	2012	WWL	6	2324
43856	Papakura Stream (Lower)	Southern	1771240	5900290	1993	WWL	6	4716
43807	Puhinui Stream	Southern	1766440	5904295	1994	WDL	5	124
8568	Wairoa Tributary	Southern	1786700	5892817	2009	WWH	6	227
8516	Wairoa River	Southern	1782682	5901720	1986	WWL	6	14885
43601	Waitangi Stream	Southern	1754343	5878534	2009	WWL	1	1897
438100	Whangamaire Stream	Southern	1763578	5884625	2009	WWL	1	814
8019	Avondale Stream	Tamaki	1750600	5912264	2012	WWL	5	339
8110	Oakley Creek	Tamaki	1751963	5917636	1994	WWL	5	1129
8249	Omaru Creek	Tamaki	1766268	5916749	2009	WDL	5	515
8219	Ōtaki Creek	Tamaki	1764306	5907216	1992	WDL	5	117
8214	Ōtara Creek (South)	Tamaki	1767422	5907535	1985	WDL	5	880
8205	Ōtara Creek (East)	Tamaki	1768335	5908376	1992	WDL	5	1828
8217	Botany Creek	Tamaki	1770686	5913036	1992	WDL	5	665
8215	Pakuranga Creek	Tamaki	1769473	5910813	1992	WDL	5	216
74701	Cascades Stream (Waiheke)	Waiheke	1785942	5923254	2013	WDL	1	64
74401	Onetangi Stream	Waiheke	1786243	5926204	2013	WDL	5	68

*WWL = Warm Wet Climate, Low Elevation; WDL = Warm Dry Climate, Low Elevation; WWH = Warm Wet Climate, Hill
** SSC is the suspended fine sediment classification assigned to streams and rivers in New Zealand (based on climate, geology and topography classes in the REC) for suspended fine sediment attribute assessment (proposed NPS-FM, 2019).

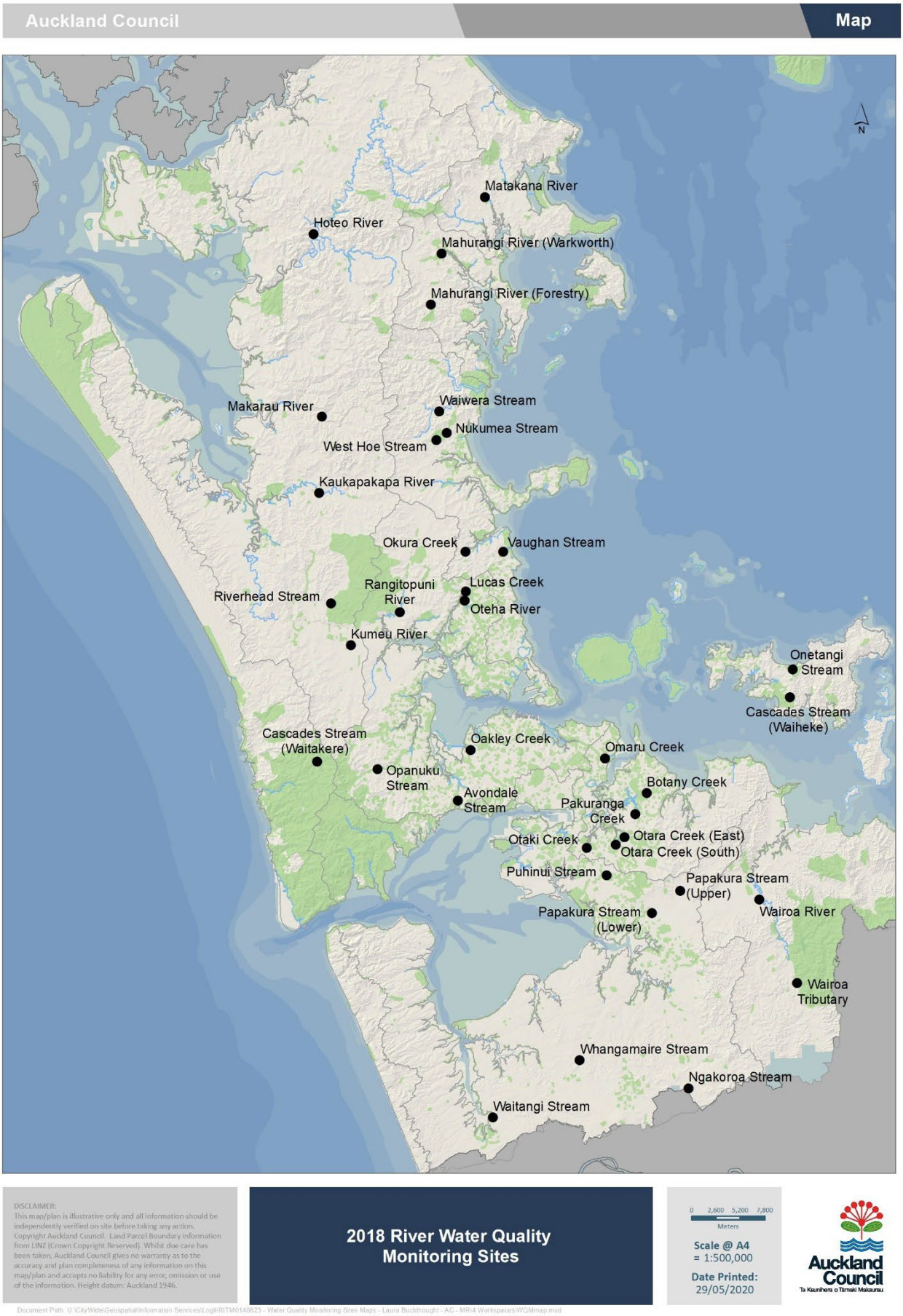

Figure 2-1: Location of the 36 river water quality sites monitored in 2018.

2.2 Catchment land use

A geospatial assessment of land use was carried out for the specific catchment area upstream of each monitored river site, identifying the land use breakdown. The catchment areas were defined using topography and the existing Auckland Council streams network layer[2].

The apportionment of land use classes within each of these catchment areas was informed by a combination of spatial datasets consistent with those used in Auckland Council's Freshwater Management Tool (FWMT)[3] including:

- New Zealand Land Cover Database V4.1 (LCDB4)
- AgriBase®
- Existing impervious areas (based on LiDAR 2009)
- Auckland Council Annual Average Daily Traffic (AADT) and Vehicles Per Day (VPD) data
- Building footprints layer (2008 with supplemented 2010 aerial imagery) and the District Valuation Roll Dataset (DVR) (2018)
- Land Information New Zealand (LINZ) Road Dataset and Primary Parcel Boundaries (2017)
- Coastal Marine Area (CMA) boundary defined by MHWS-10 – the mean of the highest 10 per cent of high tides
- Auckland Unitary Plan (AUP) zoning classifications

A total of 31 land use classes (see Appendix A for full list) were assigned to each of the stream catchment areas. These land use classes were aggregated into four land use groups within the urban boundary (urban, road, pervious areas[4], and waterbodies) and 11 land use groups for rural areas outside of the urban boundary (native forest, exotic forest, grass/shrubland, sheep/beef/deer, pigs/poultry/other, dairy, horticulture, lifestyle, urban, road and waterbody/coast). Land use as a percentage of the catchment area for each site

[2] These catchment land use breakdowns may be different than those used for national water quality reporting, for example Gadd et al., 2020 for recent urban river water quality assessment.

[3] The Freshwater Management Tool (Version 1, 2020) is a process-based simulation model developed for Auckland Council that estimates flow, contaminant concentrations and loads at a region wide scale. The model simulates amounts, sources and conditions under which contaminants are discharged to freshwater and to coastal environments that supports accounting responsibilities under the NPS-FM.

[4] Pervious areas were calculated as the area remaining after roofs, paved surfaces and waterbodies were classified and may include forest, grassland, parkland and other land use types.

is shown in Figure 2-2 (and in table format in Appendix A). Sites are listed in order of increasing proportion of the dominant land cover class.

The sites in the river water quality monitoring programme are representative of a range of different land uses (Figure 2-2). For presentation of the water quality data, land uses for the catchment of each site have been further aggregated according to the methodology in the REC user guide (Snelder et al., 2010) to assign one of four broad 'dominant land cover' classes (urban, rural and lifestyle, native forest and exotic forest).

The dominant land cover type is described as that with the greatest percentage unless (a) pastoral (rural and lifestyle) cover exceeds 25 per cent or (b) urban cover exceeds 15 per cent (as per the approach of Snelder & Biggs, 2002 applied in Larned et al., 2018 and Gadd et al., 2020). If both pastoral and urban cover exceeds the above thresholds, urban will be considered the dominant land cover. The sites are grouped using these decision rules and the land use information breakdown for each catchment (see Appendix A for detail).

Onetangi Stream and Vaughan Stream, had upstream catchments within the urban boundary but had <15 per cent urban cover. For these sites, LCDB4 was referred to, to confirm that the 'pervious' area was dominated by rural land uses meeting the >25 per cent threshold. One exception to this convention was West Hoe Stream. The site exceeds 25 per cent pastoral land use, however, the site maintains >60 per cent native forest in the upstream catchment and is used as one of four reference sites in subsequent analysis.

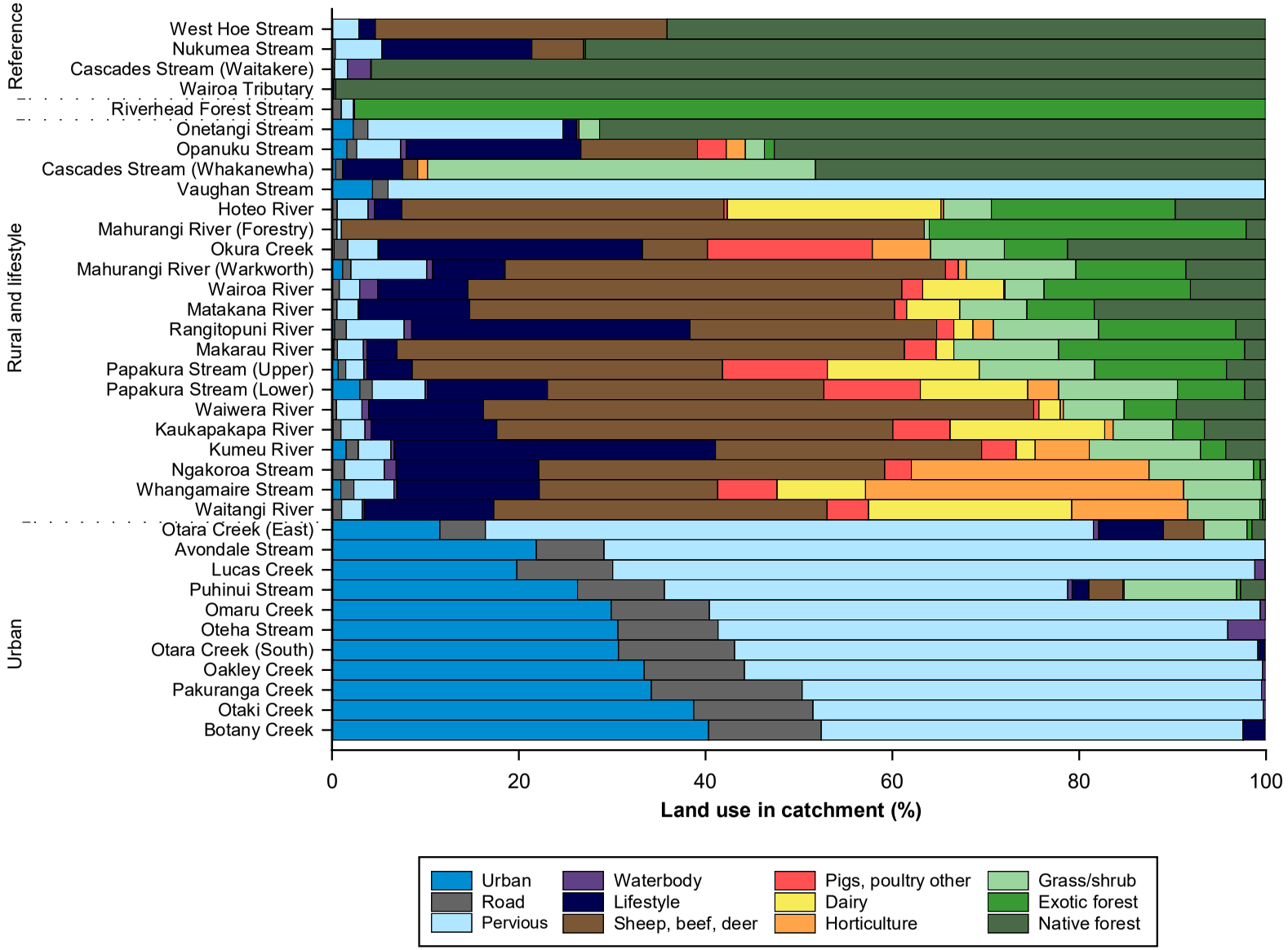

Figure 2-2: Land use as a proportion (%) of the catchment upstream of each of the 36 sites in the Auckland Council river water quality monitoring programme. Sites are ordered on the y-axis in order of increasing percentage of the dominant land cover class.

2.3 Data collection

Sample collection was carried out monthly by RIMU staff, except for the Hoteo River. The 36 sites are grouped into five runs (Table 2-1) and each run is carried out within the same week each month. Sites on each run are visited in the same order each time to ensure sampling occurs at approximately the same time of day each month. A full list of the parameters measured is shown in Table 2-2. 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.

All field practices were conducted according to RIMU's own quality assurance procedures and aligned with National Environmental Monitoring Standards (NEMS) where possible. This covers procedures for the collection, transport and storage of samples, and methods for data verification and quality assurance to ensure consistency and accuracy across monitoring programmes.

Total and dissolved copper and zinc has been monitored at five urban sites since 2000. It was expanded between 2005-2012 to include other urban sites and selected rural and native sites. In July 2018 the programme was expanded to include monitoring of metals of the remaining 11 sites, namely Cascades (Waitākere), Cascades (Waiheke), Kaukapakapa, Ngakoroa, Opanuku, Rangitopuni, Wairoa Tributary, Waitangi, West Hoe and Whangamaire streams, excluding Hoteo River. However, ongoing data collection is required to enable comparison of metal parameters at these additional sites to relevant guidelines (Gadd et al., 2019).

Prior to June 2015 soluble and total lead were measured monthly at all the metals sites, but in many cases, results were below the laboratory detection limit. For this reason, monthly monitoring of lead ceased in July 2015 and is now monitored on an intermittent basis (three-yearly) to ensure concentrations remain low. Monitoring of total and dissolved lead was reinitiated in July 2018 for all monitored sites and will be reported on in the 2020 annual report.

River water samples were analysed by RJ Hills Laboratories Ltd (Hills), an IANZ accredited laboratory. It is noted that not all methods for all parameters are IANZ accredited, however, this is a common issue across laboratory service providers and Hills are actively working towards achieving further accreditation.

The NIWA Hoteo River site is monitored for the same parameters listed in Table 2-2, except for salinity, suspended solids, copper and zinc and field turbidity. Temperature and dissolved oxygen are determined in the field and the remainder are determined by laboratory analysis 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. Additionally, the

Rangitopuni River site reported here was previously part of the NIWA national river network but was taken over by Auckland Council in July 2016. Therefore, analysis of data from this site includes data from three different analytical laboratories (NIWA Hamilton from January 2014 to June 2016, Auckland Council monitored river network via Watercare Services from July 2016 to June 2017, and RJ Hill Laboratories from July 2017 to December 2018).

Table 2-2: Parameters tested in 2018.

Parameter	Abbreviation	Units	Lab/ Field	Equipment/Lab Method*
Dissolved oxygen	DO (sat)	% sat	Field	EXO sonde, optical method
Dissolved oxygen	DO (ppm)	mg/L	Field	EXO sonde, optical method
Temperature	Temp	^{o}C	Field	EXO sonde, thermistor
Conductivity	Cond	mS/cm	Field	EXO sonde, 4-electrode nickel cell
Salinity	Salinity	ppt	Field	EXO sonde, 4-electrode nickel cell
pH	pH		Field	EXO sonde, glass combination electrode
Total suspended solids	TSS	mg/L	Lab	APHA (2012) 2540 D
Turbidity	Turb	NTU	Lab	APHA (2012) 2130 B (modified)
Ammoniacal nitrogen	Ammonia	mg N/L	Lab	APHA (2012) 4500-NH3 G (Modified)
Total oxidised nitrogen	TON	mg N/L	Lab	APHA (2012) 4500-NO3 F (Modified)
Total nitrogen	TN	mg N/L	Lab	APHA (2012) 4500-P J, 4500-NO3 F (Mod)
Dissolved reactive phosphorus	DRP	mg P/L	Lab	APHA (2012) 4500-P B, F (Modified)
Total phosphorus	TP	mg P/L	Lab	APHA (2012) 4500-P B, J (Modified)
Soluble copper	Cu sol	µg/L	Lab	USEPA 200.8 (Modified)
Total copper	Cu tot	µg/L	Lab	USEPA 200.8 (Modified)
Soluble zinc	Zn sol	µg/L	Lab	USEPA 200.8 (Modified)
Total zinc	Zn tot	µg/L	Lab	USEPA 200.8 (Modified)
Escherichia coli	*E. coli*	cfu/100mL	Lab	USEPA Method 1603 (2002)
Modifiers				
Dissolved organic carbon	DNPOC	mg/L	Lab	APHA (2012) 5310 C (modified) 23rd ed.
Total hardness (as $CaCO_3$)	Hardness	mg/L	Lab	APHA (2012) 2340 B 23rd ed.

** As per RJ Hill Laboratories Ltd*

A recent study by Davies-Colley et al., (2016) investigated reproducibility of inter-agency water quality measurements between NIWA and Hills (in collaboration with Greater Wellington Regional Council). They identified strong similarities for total oxidised nitrogen, moderate similarity for total nitrogen and total phosphorous, and weak numerical similarity for turbidity, dissolved reactive phosphorous and ammoniacal nitrogen. The NIWA laboratory tended to return higher values than Hills for paired samples for turbidity and ammoniacal nitrogen.

2.4 Data processing

The river water quality data were processed in a series of steps to ensure the data were accurate and treated consistently. All field and laboratory data were checked and assigned a quality assurance code in accordance with Auckland Council's internal Stream Water Quality Sampling Protocol. Draft updated National Environmental Monitoring Standards (NEMS) were released in April 2019. Therefore, data associated with quality coding prior to this date are not directly comparable with these standards.

The water quality data is stored in Auckland Council's water quality archiving database (HYDSTRA). The data for the Hoteo River were extracted from NIWA's web-based Water Quality Information System.

Data collected for each variable are analysed for each site and initially compared to data previously collected over a 10-year period. These data are used to obtain the 5th and 95th percentiles. If any new data falls outside these boundaries it is flagged. This allows the processor to check for erroneous data and repair (if data is incorrect) or comment as appropriate. Prior to analysis, any data points that were assigned a quality assurance code of questionable quality were removed from the dataset.

In the 2018 data set, two instances of negative field pH values were identified and these were replaced with corresponding laboratory pH data.

On some sampling occasions Ōtaki Creek was tidally influenced (as evidenced by high salinity concentrations not consistent with a freshwater environment). The salinity data (2014-2018) from other non-tidal, predominantly urban catchment East Tamaki stream sites (i.e. Pakuranga Creek, Botany Creek, Ōtara Creek and Omaru Creek) were assessed as a comparison and across these sites salinity never exceeded 0.5 ppt. As such, on sampling occasions where salinity was greater than 0.5 ppt, it was assumed to be saline influenced. Table 2-3 shows the number of times this salinity threshold was exceeded along with the site, month and concentration for the years 2014-2018 inclusive. All data from the Ōtaki Creek site for these dates was removed and not used for analysis.

Table 2-3: Year, number and date that the salinity threshold was exceeded.

Site	Year	# where 0.5 ppt salinity exceeded	Month and salinity concentration (ppt)
Ōtaki Creek	2014	4	13 Feb (2.71), 12 Mar (5.83), 14 Apr (1.15), 13 May (3.02)
	2015	4	18 Mar (11.09), 17 Apr (0.53), 18 May (0.56), 9 Nov (0.56)
	2016	6	22 Jan (0.64), 23 Feb (1.13), 21 Mar (6.56), 21 Apr (0.59), 20 May (2.88), 14 Dec (11.64)
	2017	6	28 Apr (6.26), 27 Jun (10.46), 25 Aug (4.64), 20 Oct (1.02), 21 Nov (4.93), 21 Dec (14.8)
	2018	3	19 Mar (10.84), 18 May (4.50), 16 Aug (0.52)
Vaughan Stream	2014	1	5 Feb (2.19)
	2017	1	13 Feb (3)
Oakley Creek	2014	1	4 Apr (0.64)

2.4.1 Censored data and substituted values

For some water quality parameters, censored values are used when true values are too low or too high to be measured with precision by the analytical method being used by the laboratory. For very low values of a water quality parameter, the minimum acceptable precision corresponds to the analytical method 'detection limit' for that parameter; for very high values, the minimum acceptable precision corresponds to the analytical method 'reporting limit' for that parameter.

For all analyses in this report, censored values that were below the detection limit were substituted with a value of half the detection limit prior to any analysis being undertaken (as per Scarsbrook, M., 2006, but different to the approach taken by Larned et al., 2018). There were no instances of data reported above the 'reporting limit'.

2.4.2 Modifier adjustments

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2018) recommend that soluble copper is adjusted for dissolved organic carbon (DOC) to 0.5 mg/L and that soluble zinc be adjusted to a hardness (as $CaCO_3$) of 30 mg/L and a pH of 8.0 (Warne et al., 2018).

However, because Auckland Council has only been gathering data on DOC and hardness since 2017, no adjustment has been made when assessing against regional draft copper and zinc guidelines, as per the approach outlined in Gadd et. al, (2019).

Total ammoniacal nitrogen refers to two chemical species that are in equilibrium in water –toxic ammonia (NH_3) and the relatively non-toxic ammonium ion (NH_4^+). The

proportion of the two varies, particularly in response to pH and temperature. The NOF toxicity guidelines for ammoniacal nitrogen are standardised to a pH of 8.0. Total ammoniacal nitrogen results are adjusted for pH following a conversion table, as prescribed by the Ministry for the Environment (MfE, 2017b) for comparison to NOF guidelines only. Results presented in the annual data summary (section 3.1) and water quality index (section 3.2) are **unadjusted** values.

2.5 Data analysis

2.5.1 Data summary

This section presents the variability of each water quality parameter measured during the 2018 calendar year. Basic descriptive statistics are presented as box plots which show variation in the data. Box plots were produced using the software package SigmaPlot version 14.0 using the default percentile functions. The boxes represent the inter-quartile range (25th and 75th percentiles) and the whiskers represent the 10th and 90th percentiles. The median is shown as a line within each box. Data tables also provide a basic statistical summary for each parameter at each site. These are presented in Appendix C.

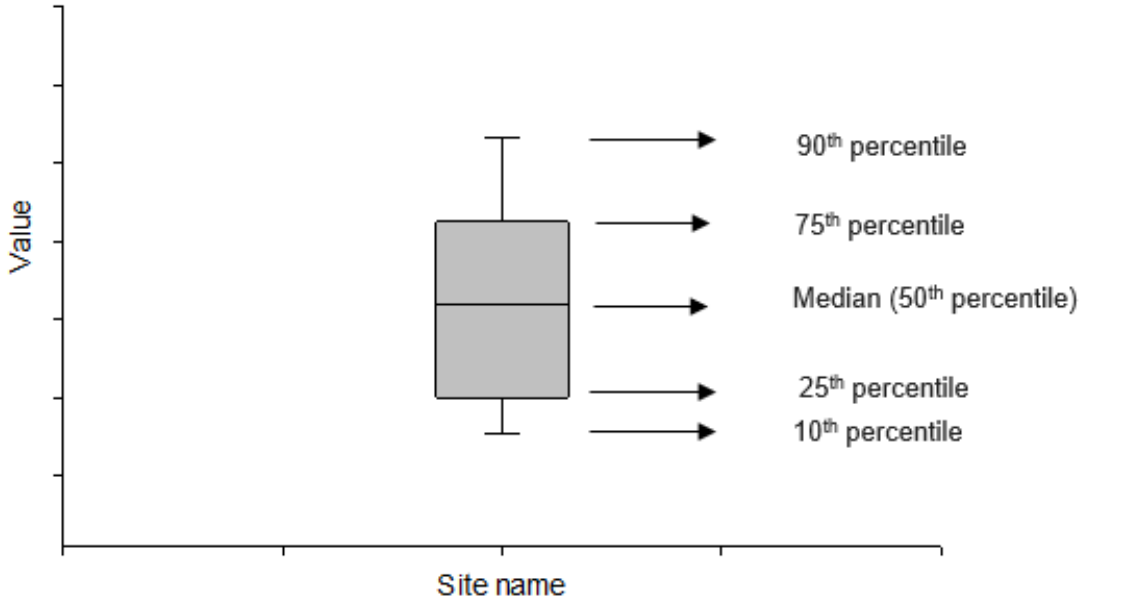

Figure 2-3: The different statistical measures shown within a box plot in this report.

The **annual median values** can be compared to the Australian and New Zealand Default Guidelines Values for physical and chemical stressors in freshwater updated in 2018 (ANZ Guidelines). The New Zealand default guideline values have been developed for the second-level River Environment Classification (REC) classes (climate and topography) using minimally impacted national reference site data (MfE, 2018).

In the Auckland region there are two relevant climate classes: Warm Wet and Warm Dry; and two relevant topography classes: High and Low-Elevation. The combined class for each site, as per the REC class, is shown in Table 2-1.

The ANZ default guideline values have no formal legal status, unless adopted into a regional plan, and are considered a starting point for resource managers to assess water quality that can be further refined according to local conditions. The updated default guideline values for physical and chemical parameters in freshwater for the Auckland-specific REC classes are provided in Appendix A for reference. The proposed default guideline values for copper and zinc in freshwater environments (Gadd and Hickey, 2016a and b) are also in Appendix A.

It is noted that annual median values typically exceed (or fall below) the relevant ANZ default guideline values at two or more of the four monitored reference sites (dominated by native forest cover in the upstream catchments) for turbidity, pH, dissolved oxygen (%), dissolved reactive phosphorous, and electrical conductivity. Therefore, these national level guidelines should be referred to with caution.

Analysis of water quality undertaken in this report is in relation to region-specific guidelines defined for the water quality index and current state assessment, as directed by the National Policy Statement for Freshwater Management (NPS-FM).

2.5.2 Water quality index

Auckland Council uses a water quality index to simplify how we communicate the state or changes of complex water quality data by incorporating multiple factors (parameters) into a single number or score within five water quality classes. This enables us to compare overall river water quality across multiple parameters, in a relative sense, between sites. Each class and its associated narrative outcome is outlined in Table 2-7. The water quality index represents an assessment of water quality as it relates to ecosystem health but does not represent any human health values assessment.

The water quality index used in this report is based on that developed by the Canadian Council of Ministers for the Environment (CCME, 2001) with some modifications (see Appendix D for further detail).

Water quality index guidelines were derived from data observed at four reference sites that represent the best achievable water quality in the Auckland region.

Table 2-4: Water quality index class and scoring ranges used by Auckland Council (CCME, 2001).

Score range	WQI Class	Expected narrative outcome
95-100	**Excellent**	Water quality is protected with a virtual absence of threat or impairment; conditions very close to natural or pristine levels. These index values can only be obtained if all measurements are within guidelines **all** of the time.
80-94	**Good**	Water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels or water quality guidelines.
65-79	**Fair**	Water quality is usually protected, but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels or water quality guidelines.
45-64	**Marginal**	Water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels or water quality guidelines.
0-44	**Poor**	Water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels or water quality guidelines.

Specifically, the water quality index guidelines were derived from the 98th percentile (and 2nd percentile where appropriate) of 10 years of region-specific water quality data (2007-2016) for a subset of six parameters, and the 90th percentile for a seventh parameter (turbidity) (Table 2-5). The reference sites were Cascades Stream (Waitākere), Nukumea Stream, Wairoa Tributary and West Hoe Stream. The 90th percentile was deemed more appropriate for our turbidity data because the 98th percentile only captured very high outlier values and thus resulted in an unrealistically permissive turbidity guideline value for the range of turbidity values we measure.

Significant modifications were made to the application of the *coastal water quality index methodology* in 2018 including: alteration of parameters, separate coastal and estuarine guidelines, setting a static reference site assessment period, and using a rolling three-year average value to calculate scores (Foley, 2018). The river water quality method in this report follows the direction set out in Foley (2018) with three exceptions:

1 A different set and number of parameters are used that are a better reflection of the pressures on freshwater environments, however, the substitution of total nutrients to the dissolved fraction as per Foley (2018) was adopted. The dissolved fraction is considered to reflect the bioavailable forms of nitrogen and phosphorus

that are responsible for observable water quality issues, such as algal blooms or eutrophication.

2 Using three-year monthly *median*, not average values, has been adopted to resolve the effects of skew on average values caused by anomalous events within a single year and is aligned with ANZG 2018 recommendations and other regional councils' application of the method (Perrie, 2007; Griffiths, 2016). By using this approach, exceedances are more indicative of sustained high concentrations (chronic effects) at each site rather than one-off events.

3 Using the 98th percentile of regional reference site data rather than a combination of the 80th percentile and ANZ guideline values for calculation of the water quality guidelines. The 98th percentile was selected as a more appropriate benchmark for freshwater systems, as many of the test sites could be considered highly disturbed, and is consistent with previous Auckland Council river water quality reporting.

Due to these revisions, previously reported water quality index scores for the river water quality monitoring programme are not directly comparable. To enable comparison of water quality index scores over time, scores for 2016 and 2017 were recalculated following the methodology specified here (using data from 2014-2016 and 2015-2017 respectively).

Table 2-5: River water quality index guideline values for the Auckland region.

Parameter	Upper	Lower
Dissolved oxygen (% saturation)	111.4	79.5
pH	8.03	5.96
Turbidity (NTU)	14.0	
Temperature	17.65	
Dissolved reactive phosphorus (mg/L)	0.042	
Nitrate + nitrite nitrogen (mg/L)	0.079	
Ammoniacal nitrogen (mg/L)	0.043	

2.5.3 National Policy Statement for Freshwater Management (national and regional attributes)

The National Policy Statement for Freshwater Management 2017 (NPS-FM) provides guidance to regional councils and unitary authorities toward achieving nationally consistent goals for managing freshwater resources under the Resource Management Act. The NPS-FM sets out high level objectives and policies for freshwater management and requires that freshwater systems are maintained or enhanced through time.

The National Objectives Framework (NOF) within the NPS-FM 2017 was developed to support councils to set effective freshwater objectives, limits and/or targets. River and stream monitoring information is required in both the setting and assessment of progress towards these freshwater objectives. Councils need to:

- understand the current state of each attribute as baseline information for setting freshwater objectives
- use models to demonstrate how land use change and mitigation methods will influence these water quality states through time, and the costs of suggested mitigations
- be able to demonstrate to their community through instream monitoring that they have achieved freshwater objectives over time (MfE, 2017b).

The NOF identifies a core group of attributes which councils must use to grade the quality of river environments. The state of each attribute is graded into specific bands (using various statistical metrics) per water body type (e.g. lakes versus rivers). Each numeric band (A – best, B, C, D/E –worst) is associated with a narrative description which describes the expected ecological outcome of interest (Table 2-6). The '*National Bottom Line'* refers to the minimum state for each attribute that councils must meet or work towards meeting over time; this is generally defined by the boundary between C and D bands.

Two 2017 NOF river attributes are not reported on here. While dissolved oxygen is monitored at all river water quality sites on a discrete monthly sampling basis, these sites are not specifically associated with point source discharges, as required by the NOF guidance. A periphyton monitoring programme is currently being initiated by Auckland Council and a minimum of three years of data is required to assess compliance with the periphyton, trophic state NOF attribute. It should be noted that the NOF nitrate assessment is reported here using the proxy total oxidised nitrogen (nitrate + nitrite nitrogen). This assumes the nitrite fraction is almost always negligible and/or a constant proportion of the total organic nitrogen.

The regionally important attributes copper, zinc and sediment are also included here. Copper and zinc are given a provisional grading using the proposed draft attribute bands developed by Auckland Council (Gadd et al., 2019; Table 2-7). Suspended sediment in Auckland's river environments is given a provisional grade based on the proposed NPS-FM 2019 suspended fine sediment attribute (Table 2-8).

In this preliminary assessment of suspended fine sediment in monitored streams, we note two departures from the proposed NPS-FM 2019 attribute band calculations. Firstly, we have used laboratory determined NTU turbidity values for assessment, not field based FNU turbidity measurements. Secondly, we have used a five-year

assessment period which aligns with that used for all other attributes assessed here (and with Environment Aotearoa reporting on turbidity) rather than the two-year assessment period currently proposed.

Additionally, the proposed NPS-FM 2019 includes a refinement with respect to the management of key nutrients in rivers with the addition of several nutrient attributes (dissolved inorganic nitrogen (DIN) and dissolved reactive phosphorus (DRP)). These nutrients can have effects on instream communities at concentrations well below those identified in the NOF for the toxicity attributes (nitrate and ammonia). These proposed attribute bands are not yet confirmed national attributes, however, a provisional assessment of current state across the region is reported (Table 2-8).

To assess NPS-FM water quality current state, a rolling timeframe approach is used by Auckland Council. The **2018 current state** is based on data for the five-year period 2014-2018 (consistent with the recommendations of McBride, 2016). Using a five-year period rather than a single year reduces the likelihood and frequency of state switching[5].

Current state was determined based on the calculation of the relevant statistical measures, ensuring minimum data requirements were met (MfE, 2017b) and then compared to the relevant current or proposed NOF or regional attribute bands.

Table 2-6: NPS-FM National Objectives Framework 2017, river attributes and instream concentrations within each band.

NOF River Attribute	Metric	Unit	A	B	C	D	E
Ammonia (toxicity)#	Annual Median	mg NH_4-N/L	≤ 0.03	>0.03 and ≤ 0.24	>0.24 and ≤ 1.30	> 1.30	-
Ammonia (toxicity)#	Annual Maximum	mg NH_4-N/L	≤ 0.05	>0.05 and ≤ 0.40	>0.40 and ≤ 2.20	> 2.20	-
Nitrate (toxicity)	Annual Median	mg NO_3-N/L	≤ 1.0	>1.0 and ≤ 2.4	>2.4 and ≤ 6.9	> 6.9	-
Nitrate (toxicity)	Annual 95th %ile	mg NO_3-N/L	≤ 1.5	>1.5 and ≤ 3.5	>3.5 and ≤ 9.8	> 9.8	-
E. coli	% > 540	cfu/100mL	< 5%	5-10%	10-20%	20-30%	> 30%
E. coli	% > 260	cfu/100mL	≤ 20%	20-30%	20-34%	> 34%	> 50%
E. coli	Median	cfu/100mL	≤ 130	≤ 130	≤ 130	> 130	> 260
E. coli	95th %ile	cfu/100mL	≤ 540	≤ 1000	≤ 1200	≤ 1200	> 1200

Ammonia concentrations are adjusted to pH 8 prior to attribute state assessment.

The red line marks the 'National Bottom Line', or 'minimum acceptable state' for *E. coli*.

[5] 'State switching' can occur where sample size is inadequate to reflect real changes within the state of a waterbody. For further detail, refer to Section 3.1 of McBride, 2016.

Table 2-7: Proposed regional river copper and zinc attributes and instream concentrations within each band.

Auckland -specific attributes	Metric	Unit	A	B	C	D
Soluble copper	Annual Median	μg/L	≤ 1	>1 and ≤ 1.4	>1.4 and ≤ 2.5	> 2.5
Soluble copper#	Annual 95th %ile	μg/L	≤ 1.4	>1.4 and ≤ 1.8	>1.8 and ≤ 4.3	> 4.3
Soluble zinc	Annual Median	μg/L	≤ 2.4	>2.4 and ≤ 8	>8 and ≤ 31	> 31
Soluble zinc#	Annual 95th %ile	μg/L	≤ 8	>8 and ≤ 15	>15 and ≤ 42	> 42

Alternative assessment metric for the 'maximum condition', as investigated by Gadd et al., 2019.

Table 2-8: 2019 proposed NPS-FM National Objectives Framework river nutrient and sediment attributes and instream concentrations within each band.

NOF River Attribute	Metric	Unit	A	B	C	D
DIN (trophic state)	Annual Median	mg/L	≤ 0.24	> 0.24 and ≤ 0.50	> 0.50 and ≤ 1.0	> 1.0
DIN (trophic state)	Annual 95th %ile	mg/L	≤ 0.56	> 0.56 and ≤ 1.10	> 1.10 and ≤ 2.05	> 2.05
DRP (trophic state)	Annual Median	mg/L	≤ 0.006	> 0.006 and ≤ 0.010	> 0.010 and ≤ 0.018	> 0.018
DRP (trophic state)	Annual 95th %ile	mg/L	≤ 0.021	> 0.021 and ≤ 0.030	> 0.030 and ≤ 0.054	> 0.054
Suspended Fine Sediment (Turbidity SSC 1) #	Median	FNU	< 2.0	< 2.5	≤ 3.2	>3.2
Suspended Fine Sediment (Turbidity SSC 5) #	Median	FNU	< 7.5	< 9.8	≤ 13.1	>13.1
Suspended Fine Sediment (Turbidity SSC 6) #	Median	FNU	< 4.8	< 6.3	≤ 8.3	> 8.3

SSC is the suspended sediment state classification assigned to streams and rivers in New Zealand (based on climate, geology and topography classes in the REC). Only classes 1, 5 and 6 are found at monitored sites in the Auckland Council river water quality monitoring programme. Although the proposed attribute state assessment outlines a two-year grading period, five years has been used here to align with assessment of all other metrics. Also note the assessment currently reported here uses laboratory reported NTU turbidity values, not field based FNU values.

2.6 Limitations

River water quality monitoring aims to build a robust dataset to improve the confidence in our ability to report on current state and historic water quality trend assessments over time, with the end goal being to better support our understanding of river management outcomes at the regional scale. Due to logistical constraints, changing monitoring priorities and improvements in analytical methodologies, some discontinuities exist within the dataset.

The service provider for laboratory analysis changed in July 2017 from Watercare Services Ltd to Hill Laboratories Ltd (Hills). This changeover coincided with some minor changes to analytical methodologies and detection limits for select parameters. All samples collected in 2018 were analysed by Hills and are comparable between sites within the year.

Diurnal changes in some parameters (namely dissolved oxygen, temperature and pH) are not picked up by this monitoring programme[6].

[6] Diurnal fluctuations in Dissolved Oxygen are monitored at hydrological sites across the regional river network via the River Ecosystem Metabolism SoE monitoring programme.

3.0 Results

3.1 Water quality summary 2018

The range of values recorded for each parameter at each site during 2018 were similar to what has been reported for previous years (see Figure 3-1 to Figure 3-8 and associated data tables in Appendix C). Anomalous events recorded in the 2018 calendar year included:

- Elevated turbidity and total suspended solids were observed at Omaru Creek in July, at Vaughan Stream in October and at Ōtara Creek (East) in November. Moderate to heavy rain in the previous three days or evidence of recent flooding was observed coinciding with these sampling events.
- The Cascades Stream (Waitākere) site had high total and soluble copper concentrations when compared to the other reference sites. This is a native forest reference site where we would expect to see very low or non-detectable concentrations of copper derived from human activities. The underlying geology in this area is classified in the REC as 'volcanic acidic', which may partially explain the higher copper concentrations being derived from contributing volcanic geology and soils (as per Auckland Regional Council, 2002).

3.1.1 Water quality and land cover

Box plots visually representing the spread in data are provided below for each monitored water quality parameter, with sites grouped by land cover and ordered from the highest to lowest percentage of the dominant land cover class (see section 2.2).

Land use classes are a proxy for a wide range of activities or land management practices that ultimately influence water quality (Larned et al., 2019). Nationally, land cover has been found to explain some of the variation in freshwater quality among sites (Snelder et al., 2017; Larned et al., 2018; Larned et al., 2019, Gadd et al., 2020). Nutrient concentrations, *E. coli* and turbidity levels are typically highest at urban stream sites, followed by rural sites, and lowest in native forest catchments (Larned, et al., 2018). Metal contaminants, particularly zinc and copper, also tend to be higher in urban rivers (Gadd et al., 2020).

An exception to these general patterns is the high nitrogen concentrations observed at three rural sites. As observed in previous years' reporting, Waitangi Stream, Ngakoroa Stream and Whangamaire Stream had far higher annual median concentrations of total oxidised nitrogen and total nitrogen than all other sites, (see Figure 3-4). One site, Whangamaire Stream, had median concentrations up to an

order of magnitude higher than other rural sites and instream concentrations may at times exceed New Zealand's drinking water standard of a Maximum Allowable Value (MAV) of 11.3 mg nitrate-N/L). These three sites are situated in the Franklin area where there is a known issue of high nitrate concentrations in the underlying shallow volcanic aquifers, which in turn support stream baseflow (White et al., 2019). The high groundwater nitrate concentrations are a result of nitrate leaching from intensive horticultural land use in the Franklin area (Meijer et al., 2016). These three sites had the highest proportion of horticultural land use of all monitored sites (see Figure 2-2 above).

As expected, the native forest sites had very low concentrations of most contaminants. An exception to this was identified for dissolved reactive phosphorus at two of the four reference sites, namely Wairoa Tributary and Cascades Stream (Waitākere) (Figure 3-5). This reflects the need to better understand the natural variability in water quality parameters across the region, as instream concentrations may be influenced by the natural underlying geology or the natural character of specific catchments (as expressed via the NPS-FM 2017 'natural variability exclusions' principal).

Riverhead Stream, with a predominantly exotic (pine) forest catchment, is typically more acidic than other sites in the monitoring network (Figure 3-1). In contrast, Mahurangi River (forestry) which also has a high percentage of exotic forestry in the upstream catchment, is not more acidic than other rural sites. A review of studies on the influence of forestry land management practices on water quality was undertaken by Larned et al., (2019), however, these studies focused on nutrients and sediment input and did not identify any specific effects on river pH in exotic forestry catchments.

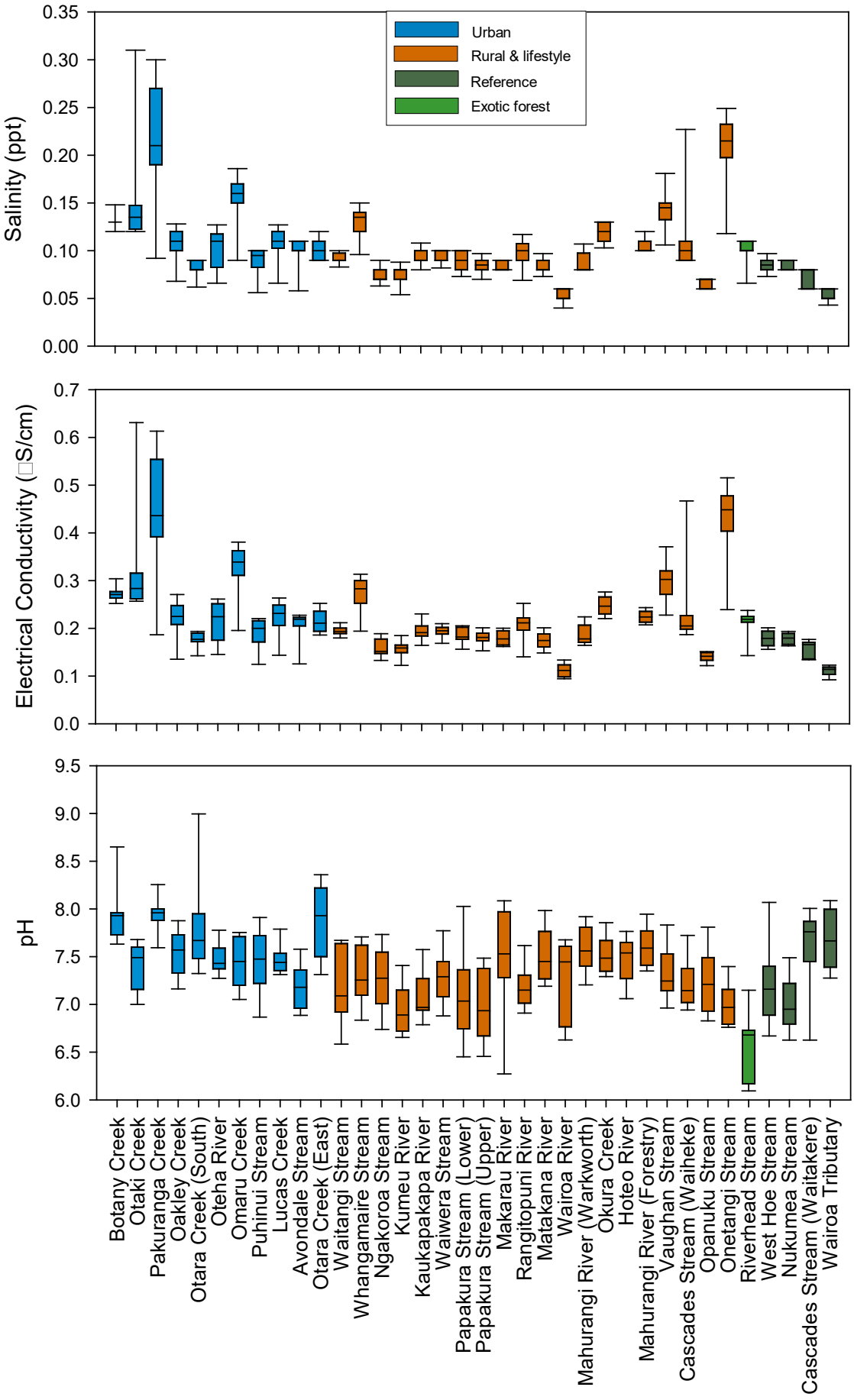

Figure 3-1: Variation in salinity, (ppt) electrical conductivity (µS/cm) salinity (ppt), and pH for river quality data collected from January to December 2018.

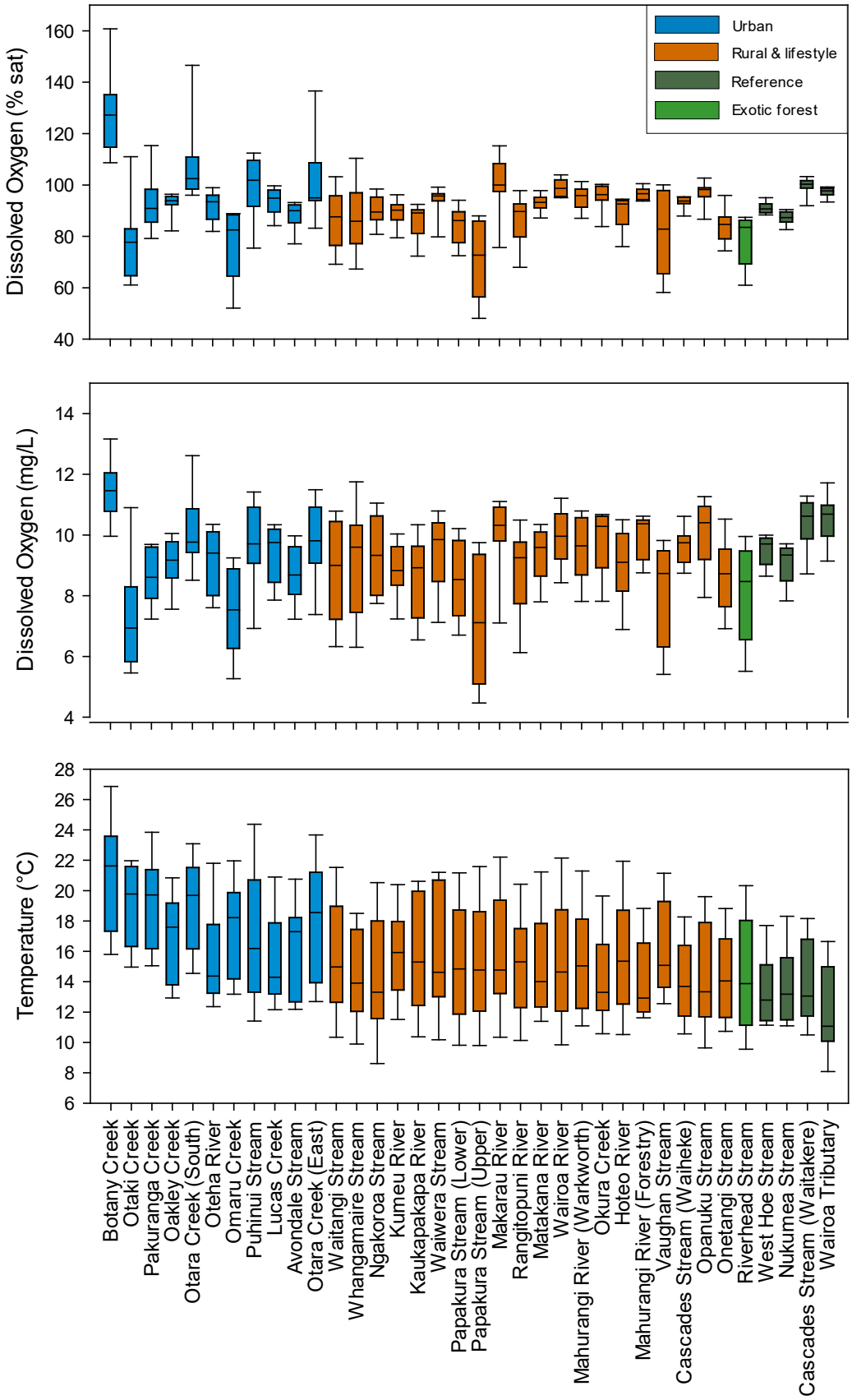

Figure 3-2: Variation in dissolved oxygen as % saturation and concentration (mg/L) and temperature (°C) for river water quality data collected from January to December 2018.

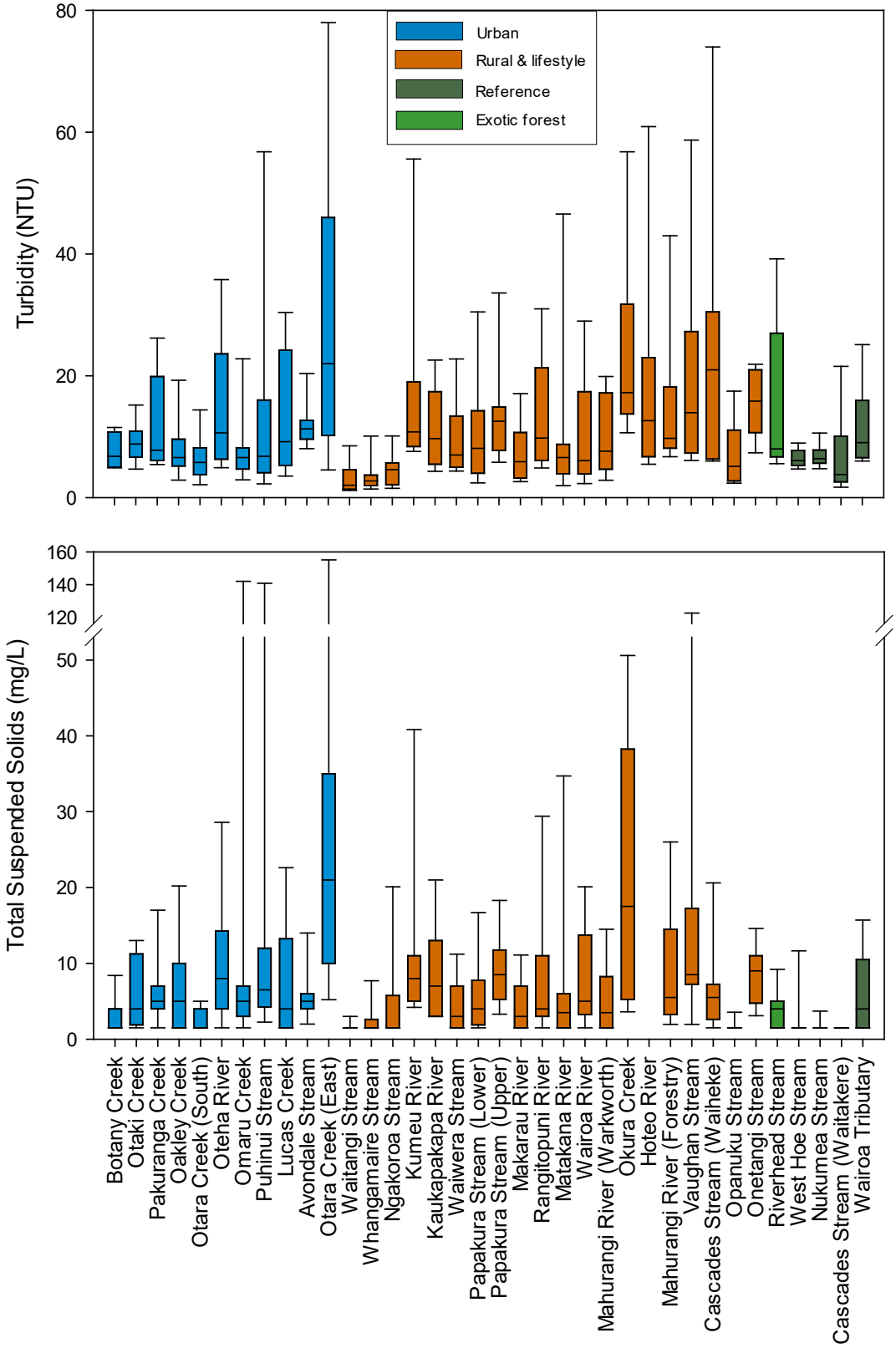

Figure 3-3: Variation in turbidity (NTU) and total suspended solids (mg/L) for river water quality data collected from January to December 2018.

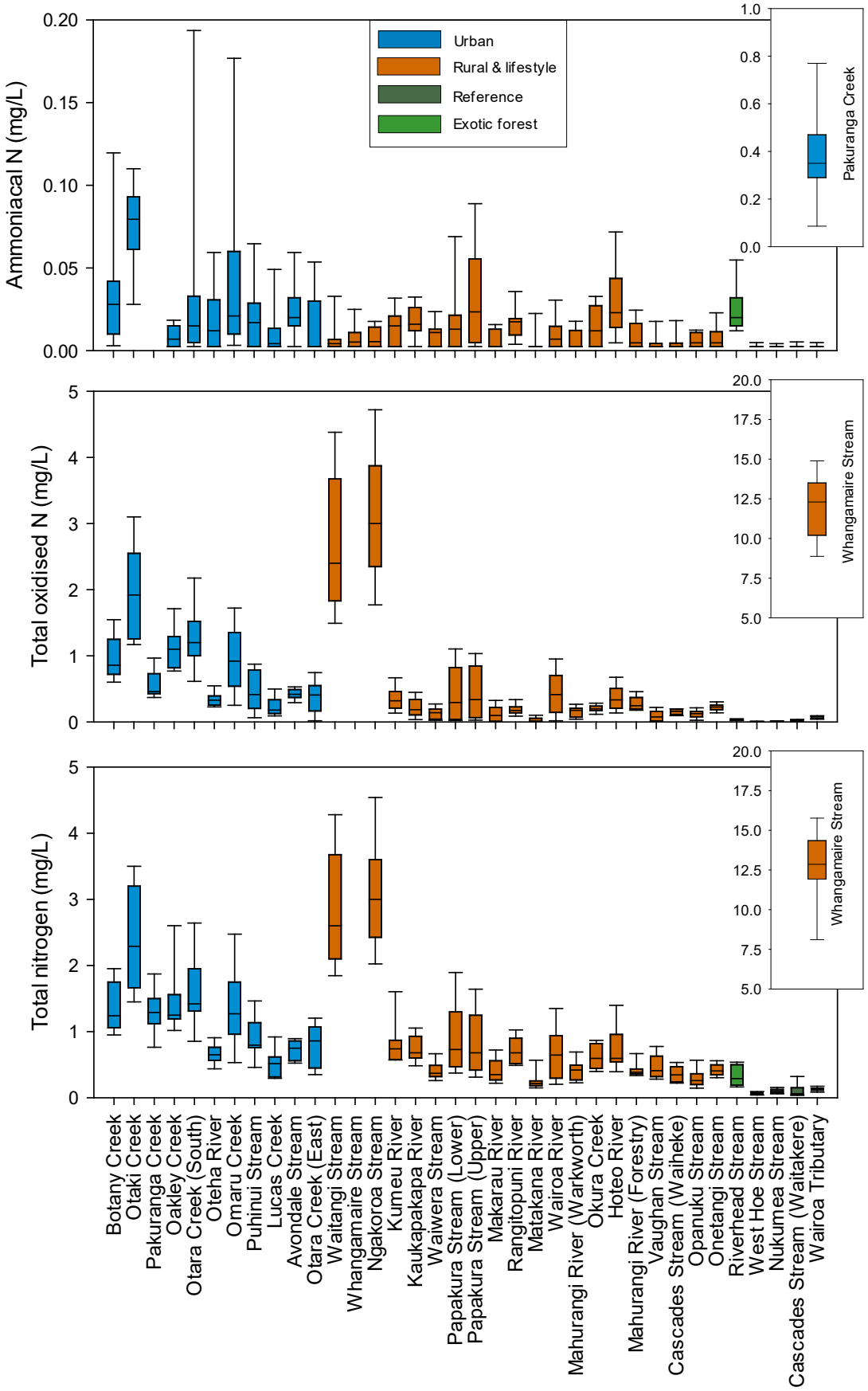

Figure 3-4: Variation in ammoniacal N (mg NH_4-N/L), total oxidised nitrogen (mg NO_X-N/L) and Total nitrogen (mg N/L) for river water quality data collected from January to December 2018.

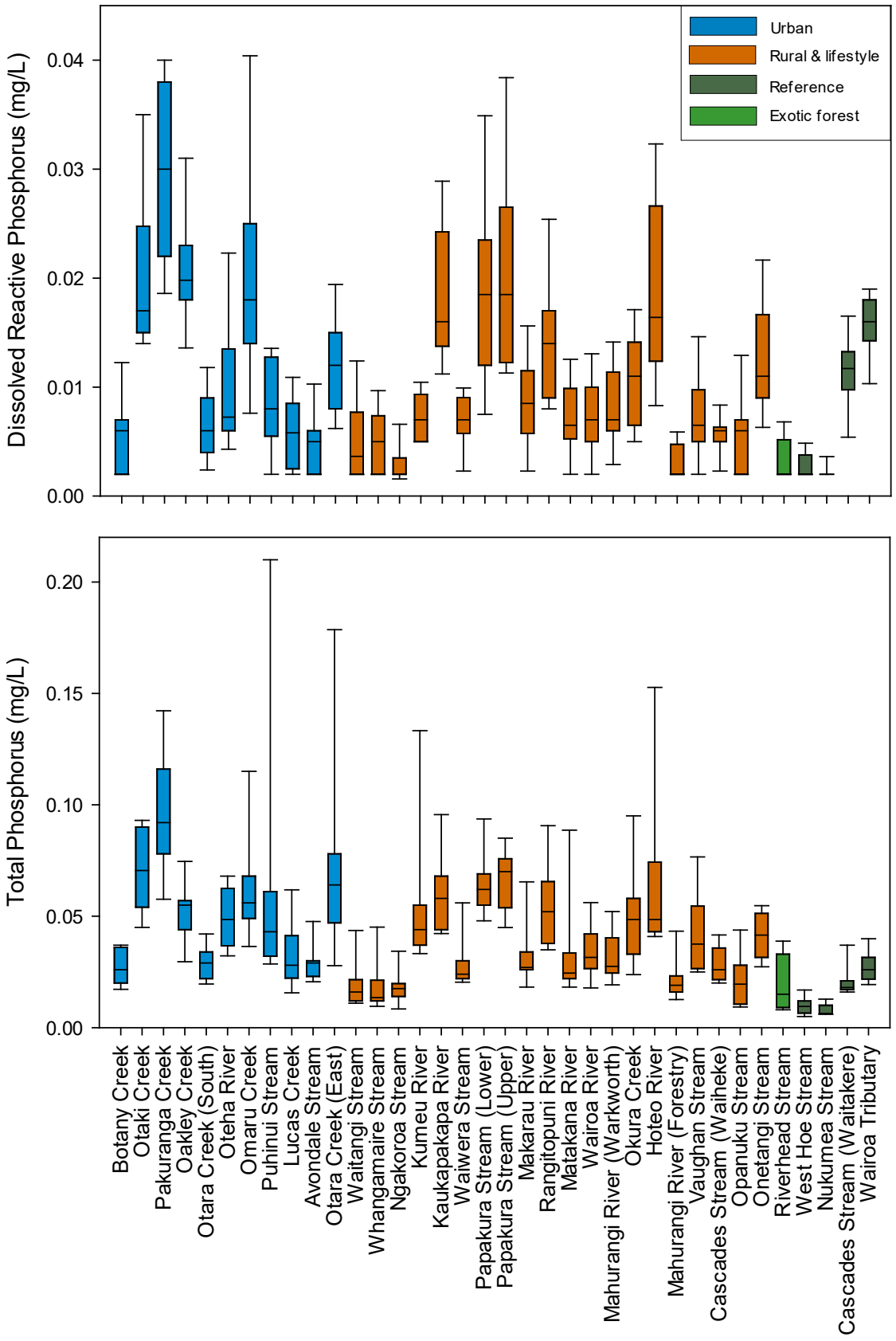

Figure 3-5: Variation in dissolved reactive phosphorus (mg/L) and total phosphorus (mg/L) for river water quality data collected from January to December 2018.

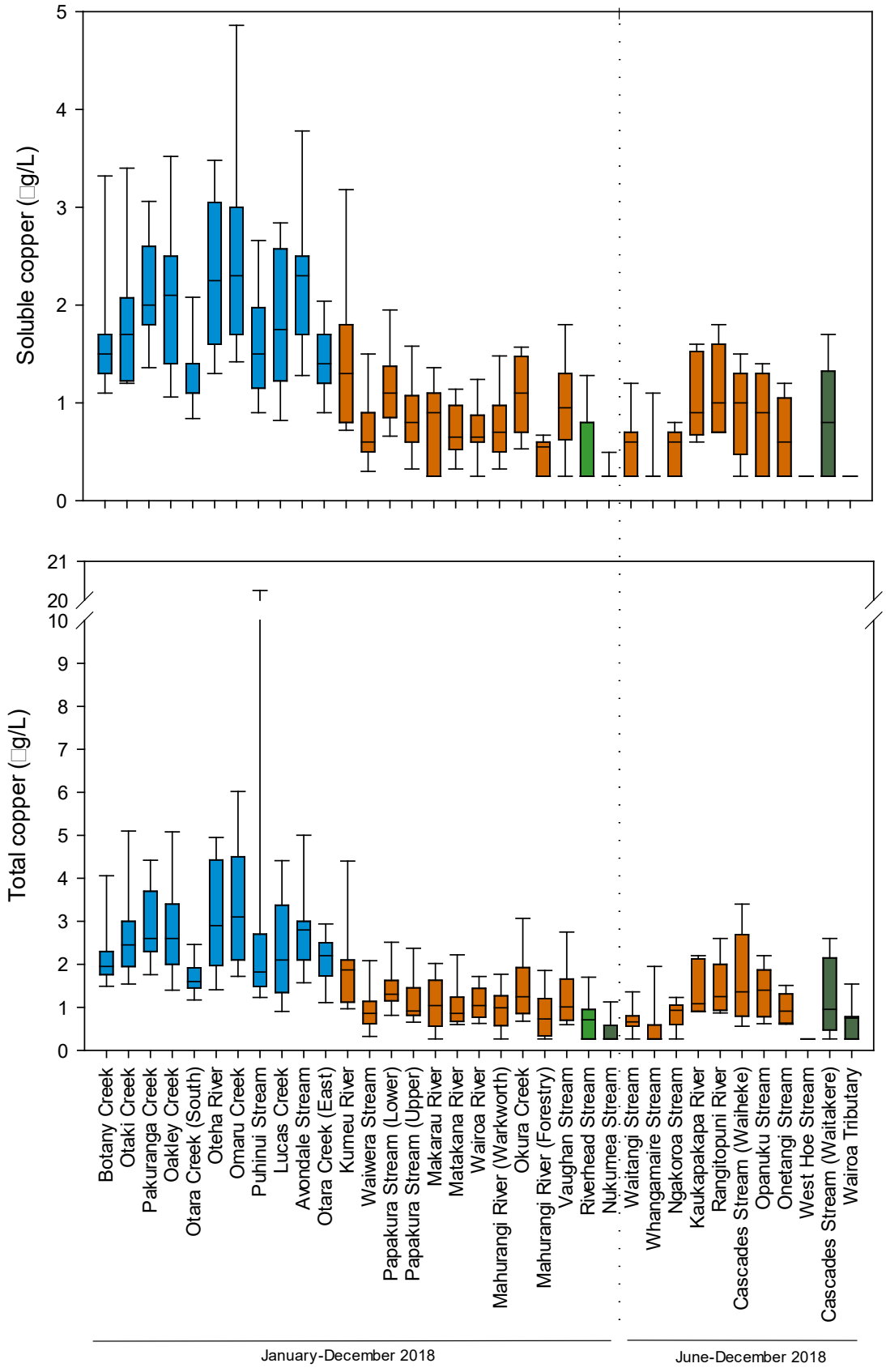

Figure 3-6: Variation in soluble copper (µg/L) and total copper (µg/L) for river water quality data collected from January to December 2018. Urban and some rural and reference sites collected January to December 2018 (left hand panel); monitoring at remaining sites was initiated in June 2018 (right hand panel). No metals data for Hoteo River as NIWA operated site.

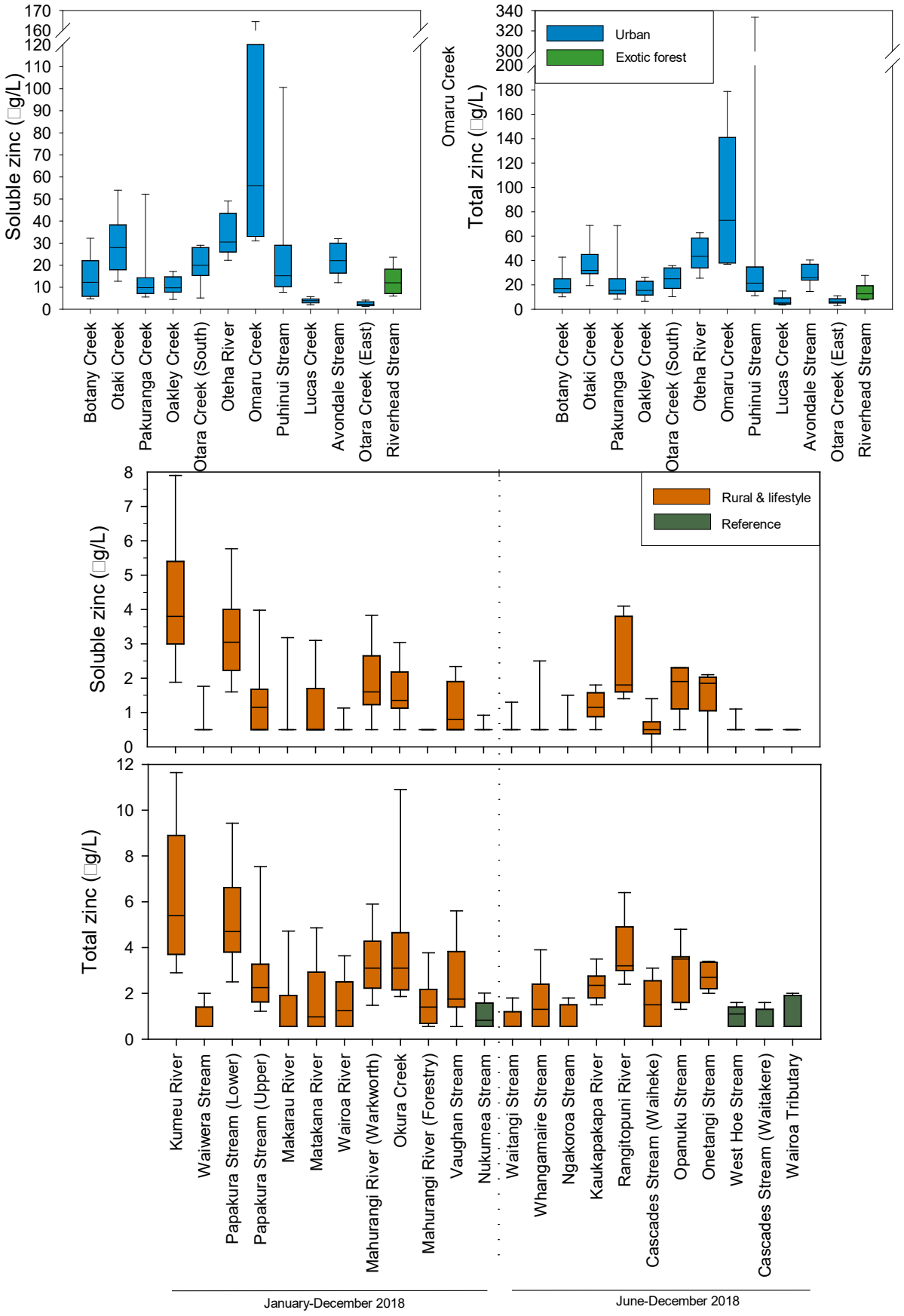

Figure 3-7: Variation in soluble zinc (µg/L) and total zinc (µg/L) for river water quality data. All urban and exotic forest sites collected from January to December 2018. Urban and some rural and reference sites collected January to December 2018 (left hand panel); monitoring at remaining sites was initiated in June 2018 (right hand panel). No metals data for Hoteo River as NIWA operated site.

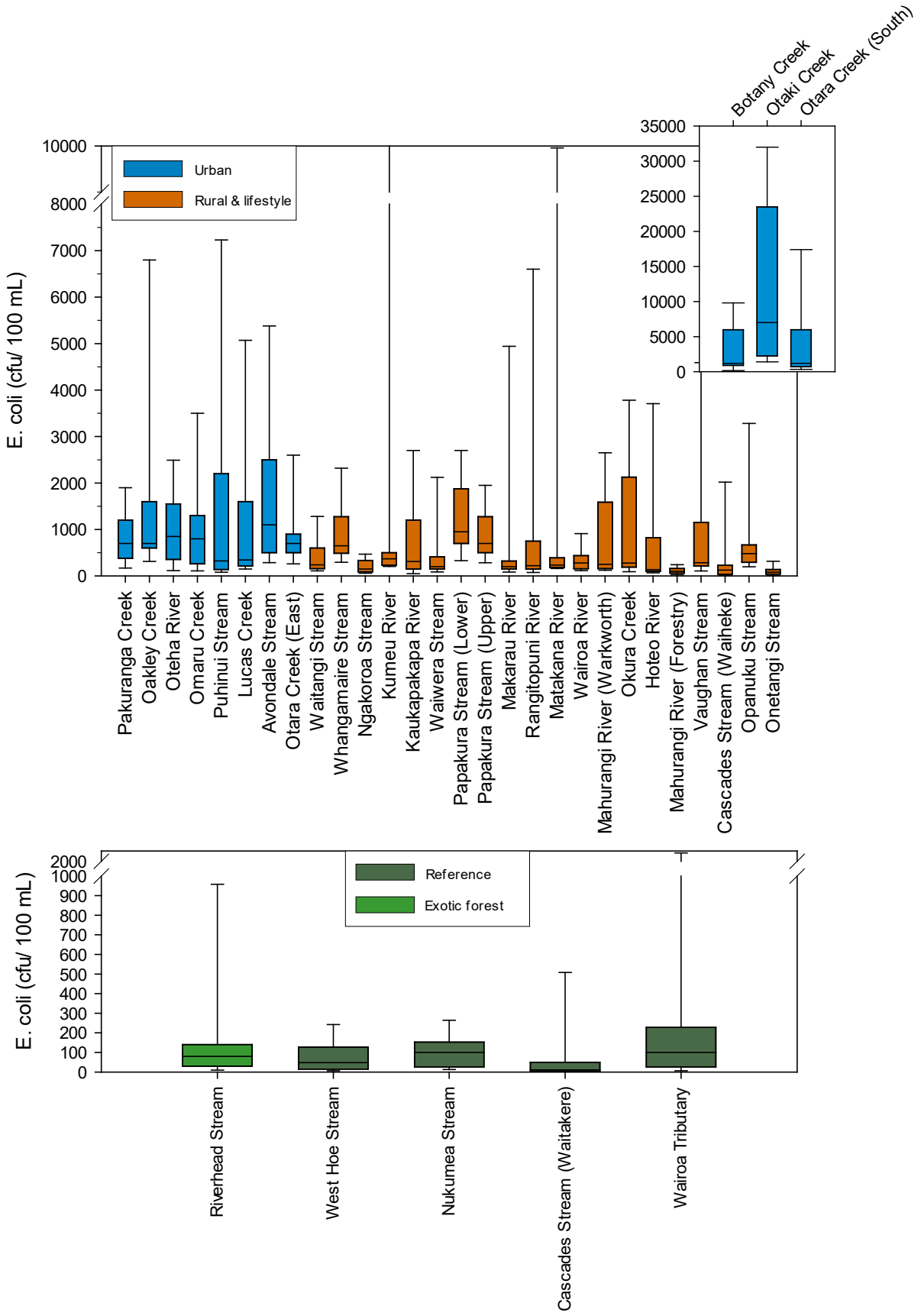

Figure 3-8: Variation in *E. coli* (cfu/100mL) for river water quality data collected from January to December 2018.

3.2 Water quality index

The water quality index represents the deviation from reference, or non-human influenced, conditions as evidenced by monitored reference sites in the Auckland region, rather than indicating whether the water quality is suitable for a particular purpose or activity.

The median of monthly values from 2016-2018 have been summarised to derive the 2018 water quality index. This has been presented as an overview of water quality across the Auckland region (section 3.2.1) and differences between dominant land cover types (section 3.2.2). The water quality index was also calculated for the periods 2014-2016 and 2015-2017 to compare changes in water quality over time.

The water quality index groups the exceedances for each site into three magnitudes (see Appendix D for methodology details): less than 10 times the guideline value; greater than 10 times the guideline value; and greater than 25 times the guideline value. Most exceedances fall within the smallest magnitude of less than 10 times the guideline value and the discussion below focuses on these exceedances unless otherwise stated.

3.2.1 Regional water quality

More than 60 per cent of monitored sites had water quality that was ‘marginal’ to ‘poor’ and less than 20 per cent of monitored sites had ‘good’ to ‘excellent’ water quality (Figure 3-9 and Figure 3-11). The most common water quality issues affecting monitored sites for the period 2016-2018 were elevated total oxidised nitrogen, water temperature, turbidity, and either lower or higher dissolved oxygen saturation (Figure 3-10).

At a regional level, the water quality index appears to be slightly declining over time, shown by a small increase in the percentage of sites in the ‘poor’ class and a decrease in the number of sites in the ‘excellent’ class between the 2014-2016 and 2016-2018 rolling periods (Figure 3-9). Collectively, 15 sites declined by one water quality class, including three of the reference sites, three urban sites and nine rural sites, when compared to the classes calculated for the 2014-2016 period (Table 6-3 in Appendix B). The decline in scores for these 15 sites were primarily driven by an increased frequency of exceedances of turbidity or temperature guidelines and this is reflected in the increasing frequency of exceedances of these parameters over time, as summarised in Figure 3-10.

Minor variation in scores over time can result in sites changing water quality class (as per section 2.6), where a single exceedance results in the class changing from ‘excellent’ to ‘good’. Some variation between these two categories may be expected.

Four sites improved by one water quality class. Movement in scores can also be obscured within a single class. For example, the greatest improvements in water quality score across the region – at Okura Creek, Kaukapakapa River and Waiwera Stream – did not result in a change in water quality class (see Table 6-5 in Appendix C). Improved scores across all seven of these sites were associated with a reduction in the number of different parameters that had exceedances.

A decreasing number of exceedances was observed for dissolved reactive phosphorous (Figure 3-10). This should be treated with caution as a potential step-decline was observed for this parameter coinciding with the change in laboratory providers (see section 2.6). However, regionally, decreasing trends have been observed over the period 2005-2014 (Buckthought and Neale, 2016), and nationally, decreasing concentrations have been observed at the majority of monitored sites across New Zealand (McDowell et al., 2019).

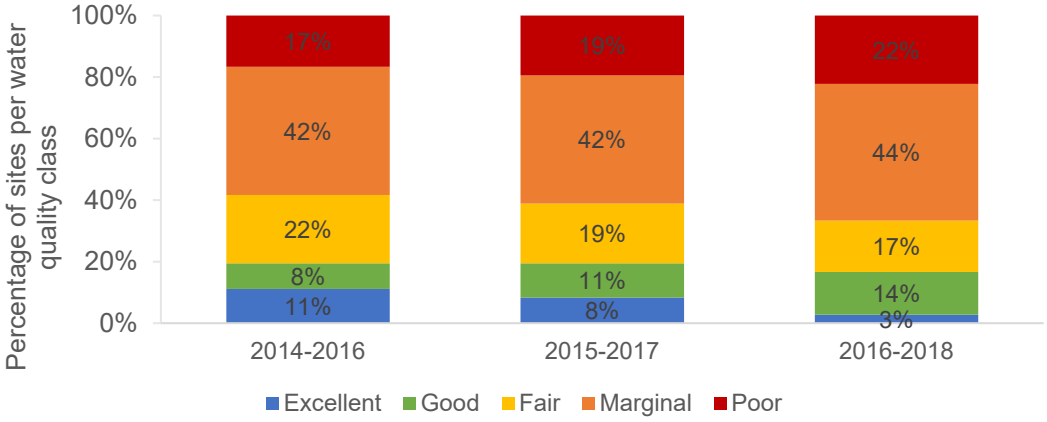

Figure 3-9: Percentage of monitored sites in each water quality index class from 2016-2018 (presented as three-year rolling medians).

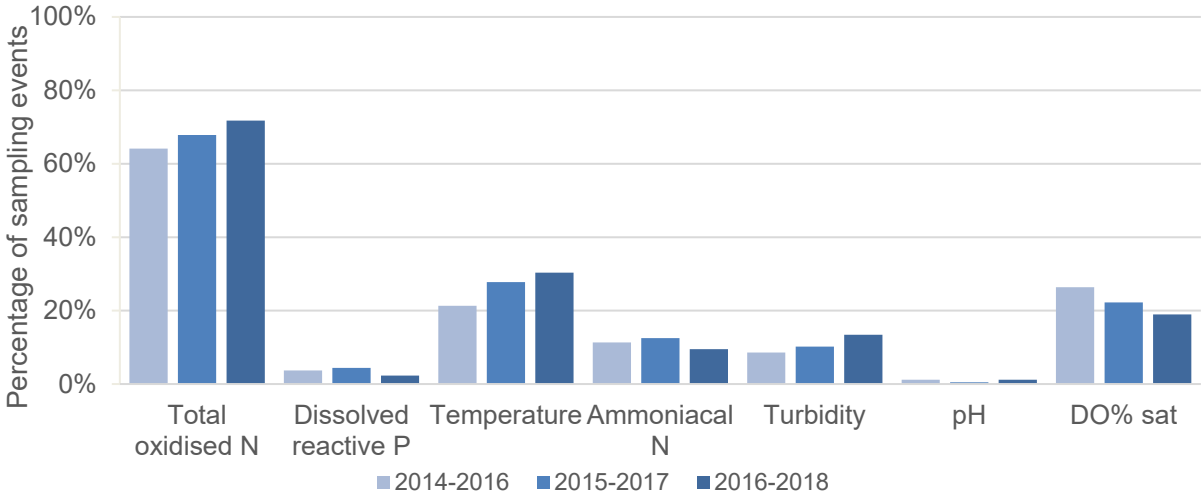

Figure 3-10: Percentage of sampling events that exceeded the relevant water quality guideline (<10x guideline), for each of the seven constituent parameters, for each three-year rolling period.

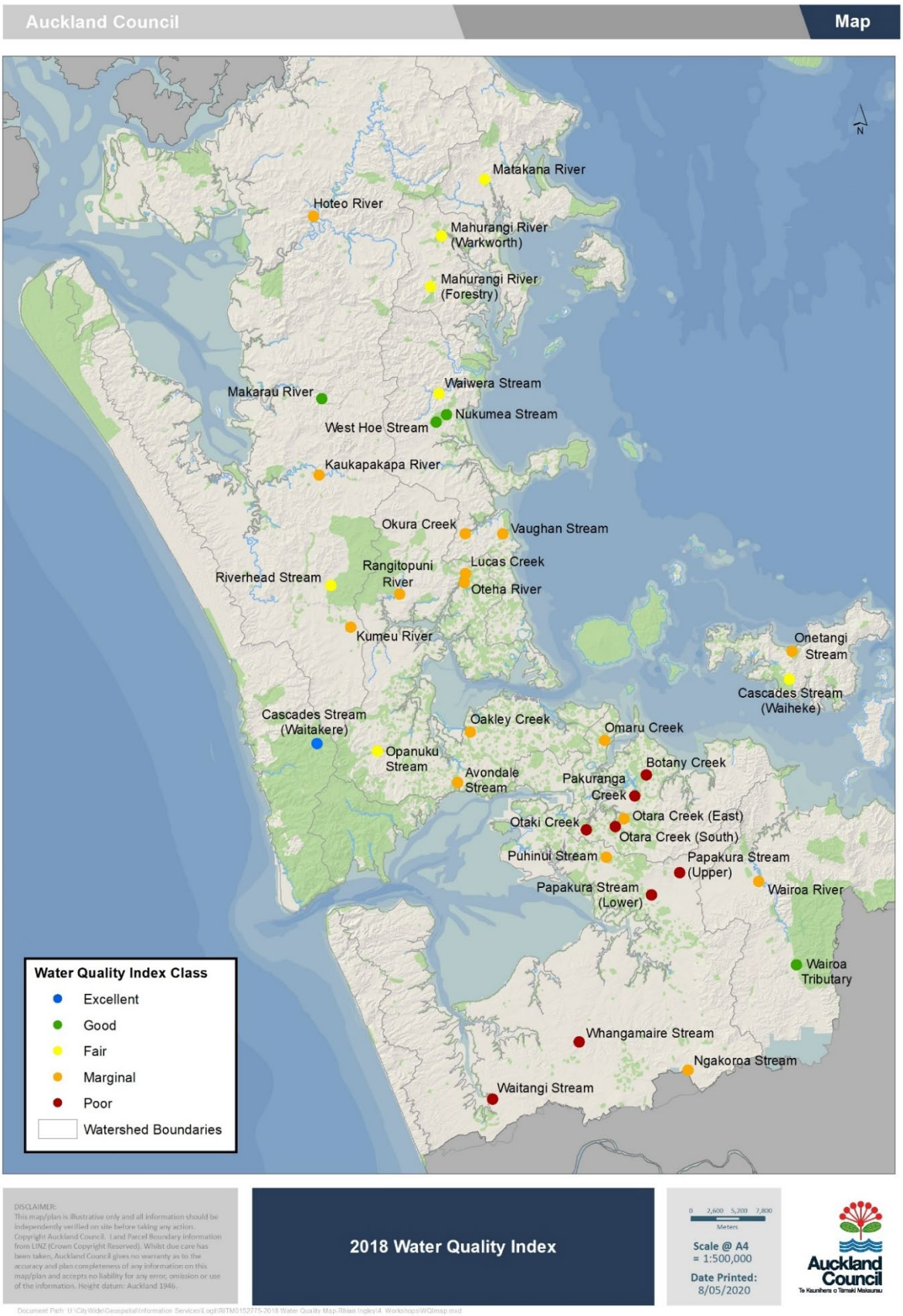

Figure 3-11: Overall water quality index class at Auckland Council river water quality monitoring sites 2016-2018.

3.2.2 Land use and water quality index

The 2016-2018 water quality index scores (circles), and the number of times each parameter exceeded the guideline values (bars), are shown for all sites in Figure 3-12 below. The maximum number of exceedances per parameter in each time period is 12 (for monthly data). Each dominant land use group is discussed further below, including patterns in individual parameters and changes over the past three rolling time periods (2014-2016, 2015-2017, and 2016-2018).

In general, water quality was classed as 'good' to 'excellent' in the native forest sites, 'fair' in the exotic forest site, ranged from 'good' to 'poor' in the rural and lifestyle sites, and ranged from 'marginal' to 'poor' in the urban sites (Figure 3-12).

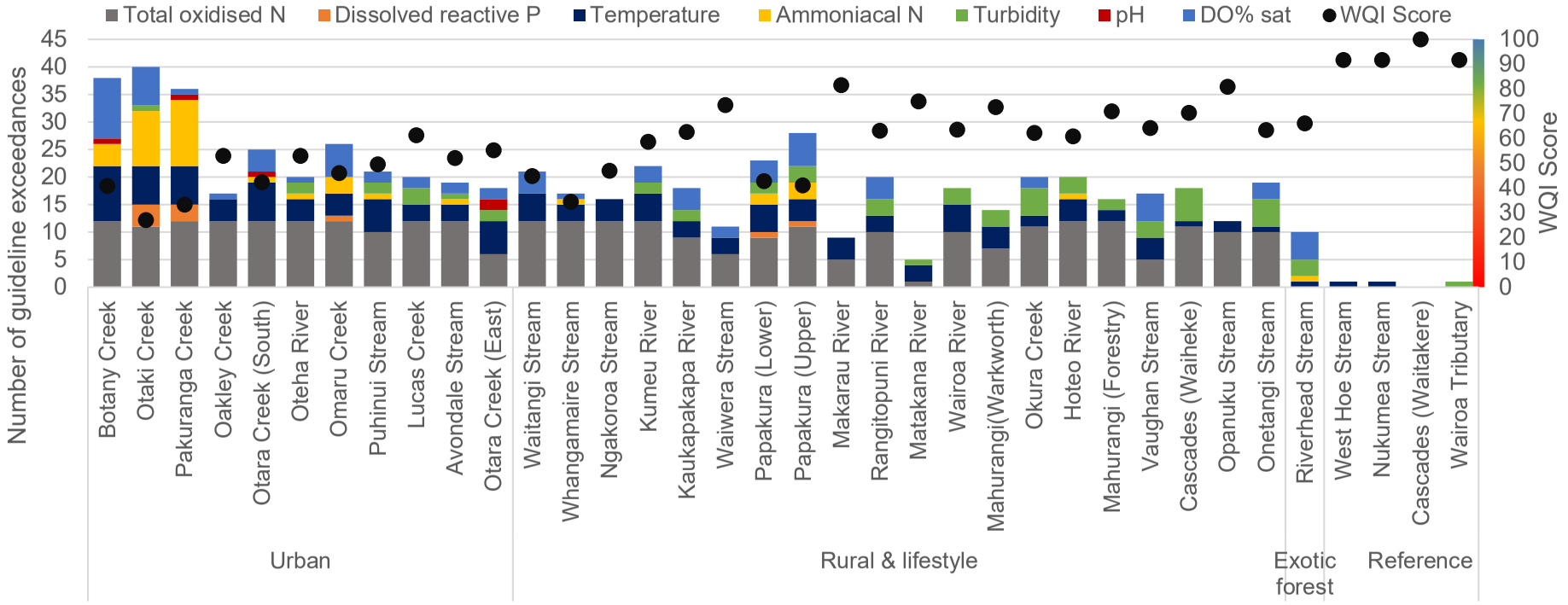

Figure 3-12: Water quality index score (circles) and number of exceedances of the relevant guideline value per site (bars) for 2016-2018 (median values) (sites are ordered by increasing percentage of dominant land cover).

3.2.2.1 Reference sites

As expected, water quality was typically within guideline values at the reference site streams (Figure 3-13). Higher median temperatures in 2016-2018 resulted in two reference sites decreasing water quality class from ‘excellent’ to ‘good’.

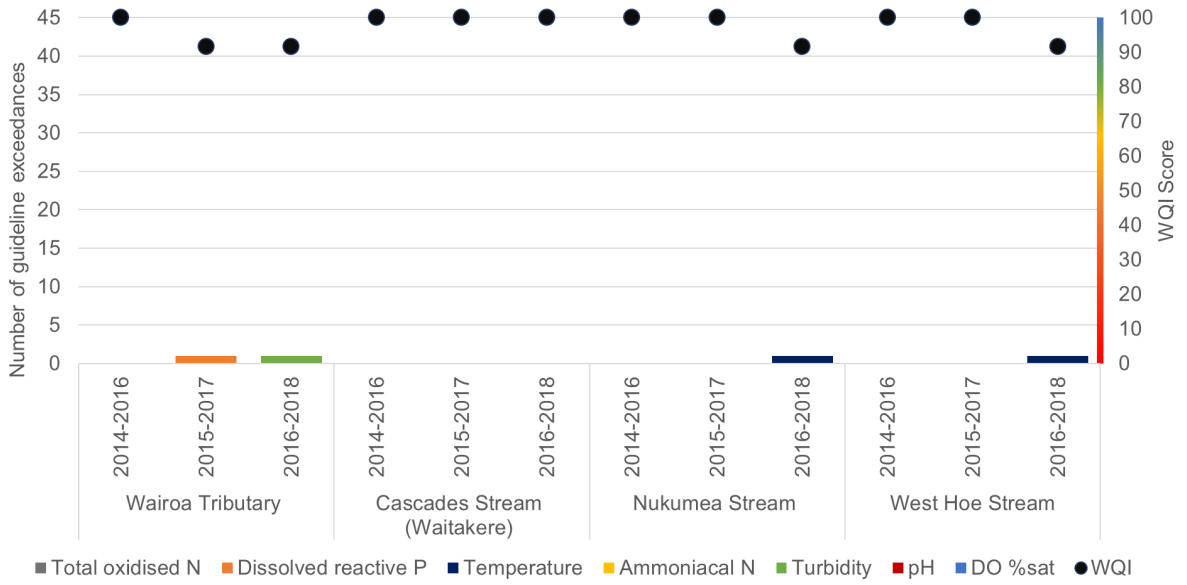

Figure 3-13: Water quality index score (circles) and number of exceedances of the relevant guideline value per site (bars) (2014-2016, 2015-2017 and 2016-2018 median values) for reference sites. Reference sites are ordered from highest to lowest percentage of native forest cover in the catchment.

3.2.2.2 Rural and lifestyle

Water quality was variable across sites dominated by rural and lifestyle land uses ranging from ‘good’ to ‘poor’, however, total oxidised nitrogen (TON) and temperature were the most common issues for all sites (Figure 3-14a). Sites with ‘fair’ water quality also tended to be affected by a low frequency of turbidity exceedances; sites with ‘marginal’ water quality tended to be affected by low dissolved oxygen; whilst sites in the ‘poor’ class were impacted by all of the above plus elevated ammoniacal nitrogen.

All sites exceeded the TON guideline at least 50 per cent of the time, except for Matakana River. The Matakana River site has a mix of rural land uses in its catchment, dominated by sheep and beef grazing, which is similar to a number of other sites, so it is unclear why this site has notably fewer TON exceedances. Fifteen of the 20 rural sites exceeded the TON guideline more than 75 per cent of the time. At Papakura Stream (Upper and Lower) the guideline was occasionally exceeded by more than 10 times, and by more than 25 times at all sampling events in the Ngakoroa Stream and Whangamaire Stream, and at most sampling events in the Waitangi Stream.

The frequency of TON exceedances was stable over time at most sites, however, there were slight increases over time at eight of the 20 sites. The site with the greatest increases in the frequency of TON exceedances was Rangitopuni River. However, this appears to be associated with a potential step increase coinciding with a change in laboratory service provider.

The temperature guideline was exceeded occasionally to moderately frequently at all rural sites across the three rolling time periods. All exceedances occurred in summer to early autumn (December to April). Cascades Stream (Waiheke) is a well shaded site and the temperature guideline was only exceeded in the most recent rolling time period (2016-2018). This is similar to the pattern observed at reference sites.

The turbidity guideline was exceeded moderately frequently at Cascades Stream (Waiheke), Okura Creek and Onetangi Stream in the most recent rolling time period, with a clear increase in the frequency of exceedances over time at these sites. There was a consistently low frequency of exceedances at most other rural sites, however, there has also been a small increase in the frequency of exceedances since the 2014-2016 period at Papakura Stream (Upper and Lower), Mahurangi River (Forestry and Warkworth) and Wairoa River.

Dissolved oxygen exceedances were consistently observed at 11 of the 20 sites. At most of these sites the frequency of exceedances is decreasing over time. It is noted that dissolved oxygen was not monitored prior to June 2016 at Rangitopuni River and the 2014-2016 water quality index score for this site is based on the 2016 results for this variable and not a median over three years (as per the other variables).

The ammoniacal nitrogen guideline was exceeded occasionally at the Papakura Stream (Lower) and moderately frequently at Papakura Stream (Upper). Exceedances at these two sites were typically greater than 10 times the guideline.

The dissolved reactive phosphorus guideline was only exceeded at two rural sites in the 2016-2018 period – at Papakura Stream Upper and Lower. Kaukapakapa Stream had a low frequency of exceedances in the 2014-2016 period and fewer exceedances have been observed over time.

The single exotic forest site, Riverhead Stream, did not have elevated TON concentrations. The ‘fair’ water quality at this site was due to a low frequency of exceedances of the turbidity guideline and a moderate frequency of exceedances of the dissolved oxygen guideline. These were consistent over time. Low pH values also resulted in an exceedance of this guideline on at least one occasion.

3.2.2.3 Urban

Water quality was ‘marginal’ to ‘poor’ at all urban dominated sites. Total oxidised nitrogen (TON) and temperature were the most common issues for all sites. Sites with

‘poor’ water quality also tended to be impacted by high ammoniacal nitrogen and exceedances of dissolved oxygen (higher or lower than guideline). Urban sites tended to have fewer exceedances of the turbidity guideline than rural sites. Unlike the rural sites, urban streams also tended to exceed pH guidelines occasionally. Botany Creek is the only site where pH exceedances were consistently observed over time.

The TON guideline was exceeded more than 80 per cent of the time at all sites, except Ōtara Creek (East). At five sites (Botany Creek, Oakley Creek, Ōtaki Creek, Ōtara Creek (South), Omaru Creek) the TON guideline was exceeded by more than 10 times the guideline moderately frequently, and the guideline was exceeded by more than 25 times at Ōtaki Creek.

Temperature guidelines were exceeded for more than half the year at six of the 11 urban sites in the 2016-2018 period. A slight increase in the frequency of exceedances was observed over the rolling three time periods for most sites, most notably at Ōtaki Creek. Temperature guidelines were exceeded most frequently at sites with concrete-lined channels (Botany Creek, Pakuranga Creek, Ōtara Creek South and Puhinui Stream). Urban stormwater and runoff from warm surfaces, such as pavements and roofs, contributes to thermal pollution in streams. It is unsurprising that Botany Creek, with the highest percentage of impervious surfaces in the upstream catchment, consistently exceeds the temperature guideline (Young et al., 2013).

The ammoniacal nitrogen guideline was frequently exceeded at Ōtaki and Pakuranga Creeks (occasionally greater than 10 times the guideline). The ammoniacal nitrogen guideline was occasionally exceeded at Botany Creek, Ōtara Creek (South), Omaru Creek and Avondale Stream. The consistent nature of these exceedances could suggest wastewater inputs upstream of these sites. Pakuranga Creek had consistently higher median ammoniacal nitrogen concentrations than all other monitored sites in the programme (Figure 3-5). Other forms of nitrogen (TON and total N) were not unusually high at this site, however, total and dissolved phosphorus concentrations were also consistently high compared to other sites in the programme and both Ōtaki Creek and Pakuranga Creek also occasionally exceeded the dissolved reactive phosphorus guideline.

Dissolved oxygen guidelines were exceeded more than half of the time at three sites – Omaru Creek (lower than guideline), Ōtaki Creek (lower than guideline) and Botany Creek (higher than guideline).

Over time the turbidity guideline was exceeded occasionally, but consistently, at Lucas Creek, Oteha River, Ōtara Creek (East) and Ōtaki Creek. A low frequency of exceedances was also observed at Puhinui Stream in the 2016-2018 period.

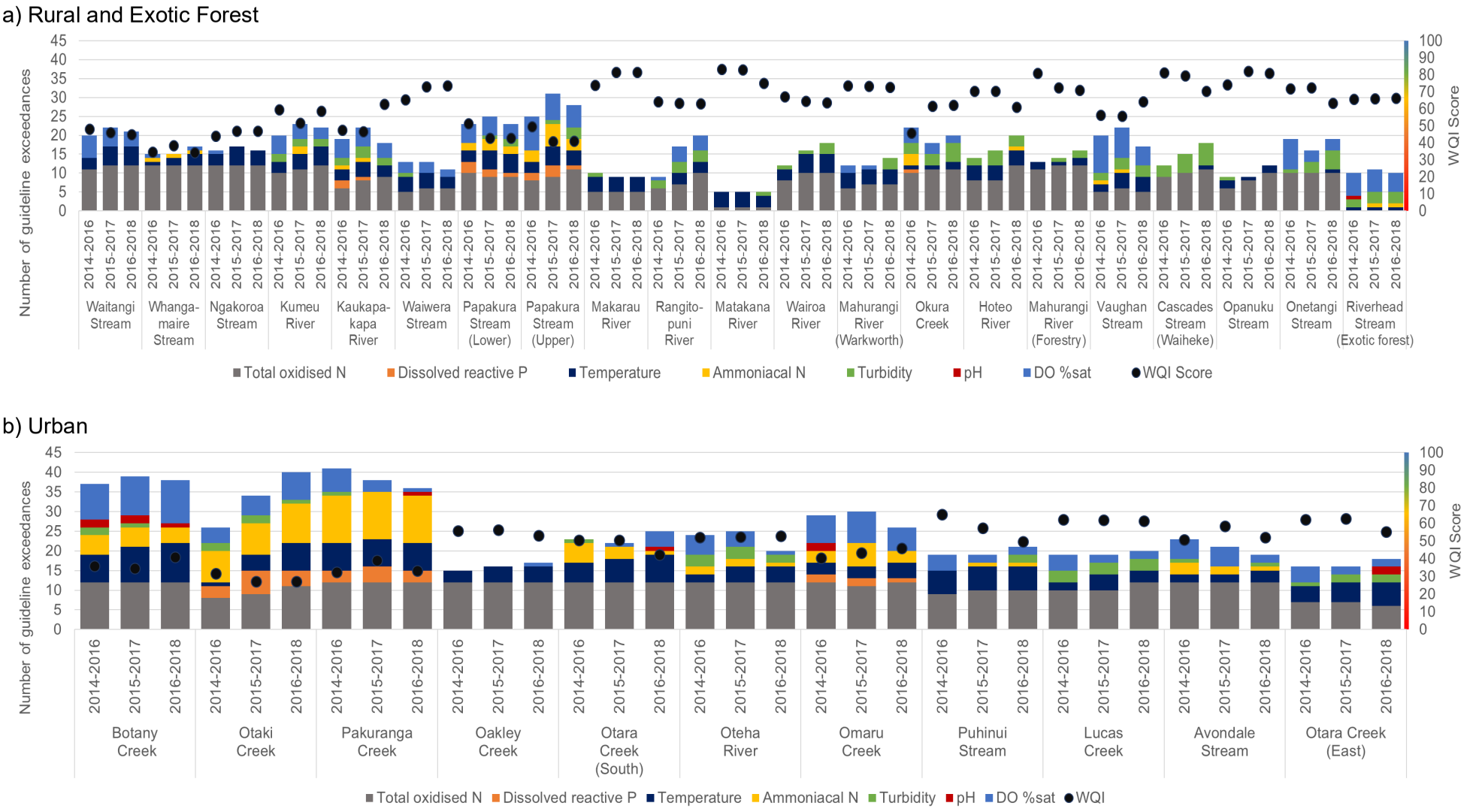

Figure 3-14: Water quality index score (circles) and number of exceedances of the relevant guideline value per site (bars) (2014-2016, 2015-2017 and 2016-2018 median values) for (a) rural and exotic forest and (b) urban sites. Sites are ordered in decreasing percentage of their respective dominant land cover type.

3.3 NPS-FM (2017) current state assessment and additional regional attribute current state assessment

Using a rolling time period assessment approach, data for the five-year period 2014-2018 was assessed against the attribute metrics in the National Objectives Framework (NOF) in the NPS-FM (2017) (see Table 2-6**)** and reported as the relevant band for each monitored stream site for 2018.

The overall bands[7] for each attribute (water quality parameter) per stream site are shown in Table 3-1 below and are also summarised in Figure 3-15 as either being above or below a national bottom line. The bands for individual metrics are reported in table form in Appendix E.

The results are reported in two distinct groups:

- The current national NPS-FM 2017 NOF attributes
- Further proposed attributes, with a preliminary assessment against either
    - Auckland specific guidance, e.g. dissolved copper and zinc; or
    - Recently proposed NPS-FM 2019 NOF numeric attributes dissolved nutrients (N and P)) and suspended fine sediment.

3.3.1 NPS-FM (2017) attributes

The Whangamaire Stream in Franklin is the only monitored stream that fails the national bottom line for nitrate toxicity (Table 3-1). The median value of nitrate at this site was two times the bottom line and the 95th percentile value was just under two times the bottom line. This signals that impacts on the growth of multiple instream species can be expected. The other two monitored Franklin sites, Ngakoroa Stream and Waitangi Stream, fall within the less degraded end of the C band, where growth effects on up to 20 per cent of sensitive species (i.e. fish) may be expected.

All other sites within the regional monitoring programme are in the A or B band for nitrate toxicity[8], suggesting that this issue is localised in spatial extent. For most of the region, little or no toxicity risk is expected, even for the most sensitive instream species. This assessment suggests that ongoing management is required to improve the level of instream nitrate in some streams in the Franklin area.

[7] The overall band is defined by the lowest (worst) band of the contributing metrics for that attribute state assessment.

[8] This contrasts to regional picture for the water quality index reporting on TON exceedances which is more aligned with the NPS-FM reporting presented here for the DIN attribute as these guidelines are set at a lower level to manage for effects of eutrophication rather than instream toxicity effects.

Omaru Creek is the only site that fails the national bottom line for ammonia toxicity (Table 3-1). This is due to the occurrence of pH-adjusted maximum concentrations of 12.3 mg/L in March 2014, and another of 6.3 mg/L in April 2015, which exceed the national bottom line of 2.2 mg/L for ammonia toxicity (Table 2-6). This signals that for a short time, instream ammonia toxicity may have had acute effects (i.e. risk of death) for sensitive species. But also, that these effects have not occurred recently at this site and that, for at least half of the time, the site is very healthy (i.e. the median metric sits in the A band).

All other sites within the regional monitoring programme are within the A or B band for the median metric, suggesting that infrequent effects of ammonia toxicity occur instream under the assessment framework used here (see Appendix D, Table 6-25). High maximum instream ammonia concentrations (C band states) are also reported here for several other streams within predominantly urban catchments (Table 3-1). Pakuranga Creek most frequently, and recently, exceeded the maximum metric. Streams with catchments dominated by rural, exotic or native forest land cover were in an A or B band state for both metrics, suggesting very limited ammonia toxicity effects on instream species (Table 6-25).

Pollution by faecal contamination is a widespread issue across the Auckland region (Table 3-1). All urban monitored stream sites were below the minimum acceptable state (i.e. below band C) for *E. coli* in terms of human health for recreation values[9]. All rural sites were also below the minimum acceptable states, with the exception of Mahurangi River (Forestry) and Onetangi Stream. All the reference sites and the single exotic forest site were either A or B band for *E. coli* across all four metrics.

3.3.2 Auckland specific attributes

3.3.2.1 Copper and zinc

No sites were below the proposed regional bottom line (below C band) for dissolved copper. However, all the monitored urban sites had a current state of C band (Table 3-1). The worst of these urban sites were Avondale Stream, Omaru Creek, Oteha River and Pakuranga Creek, with both assessment metrics in a C band (Appendix D, Table 6-25). Two of the monitored rural streams were also within the C band, namely Kumeu River and Papakura Stream (Lower). Streams within the C band may have toxicity effects occurring regularly for the top 20 per cent of sensitive species. The

[9] The *E. coli* assessment undertaken here is for all currently monitored SoE sites using the NOF attribute (NPS-FM, 2017) and is not for primary contact sites using the metrics described in Appendix 5 (NPS-FM, 2017).

single monitored reference site is assessed as A band, suggesting there would be no copper toxicity effects observed here.

Note that the assessment of copper toxicity will change in future reporting once standardisation for instream dissolved organic carbon (DOC) is possible as per ANZ guidelines updates (Warne et al., 2018).

Just over half of the monitored urban sites were below the proposed regional bottom line for dissolved zinc (D band, Table 3-1). At these sites, the toxicity impact could be acute (i.e. risk of death for sensitive instream species may be approached). The monitored rural sites were all A and B band states, which is similar to the single monitored reference site, suggesting there would be no zinc toxicity effects observed. The single exotic forest site was identified in a C band state, but was not close to the proposed regional bottom line.

Note that the assessment of zinc toxicity will change in future reporting once standardisation for instream water hardness (via $CaCO_3$) is possible as per ANZ guidelines updates (Warne et al., 2018).

3.3.2.2 Proposed attributes – nutrients

Effects on instream organisms can occur at inorganic nitrogen levels far lower than those that cause toxicity effects. The national bottom line for dissolved inorganic nitrogen (DIN, Table 3-1), proposed in the 2019 consultation version of the NPS-FM, is used here as a provisional grading of regional instream DIN. This is an assessment of the effects of excess nitrogen via instream eutrophication effects, as opposed to toxicity effects reported via the nitrate and ammonia attribute assessments.

Under this provisional assessment, four of the 11 urban sites – Ōtaki Creek, Oakley Creek and Ōtara Creek (South) – fall below the proposed national bottom line for DIN (D band). All three rural sites in the Franklin area fall below the proposed national bottom line. This is expected, as these sites concurrently fail or are in the C band of the existing NPS-FM 2017 toxicity bottom lines for nitrate, which is set at a far higher instream concentration.

This suggests that for these streams, instream macroinvertebrates and fish communities may be altered if other factors favouring eutrophication also exist, for example hypoxia. The water quality index suggests that hypoxia may be frequently occurring in Ōtaki, Omaru Creek and Waitangi Stream (see section 3.2.2). For comparison, all reference (native forest) sites and the single exotic forest site were in the A band, suggesting that no effects of DIN enrichment are likely to be observed.

Effects on instream organisms can also occur due to eutrophication effects caused by excessive instream phosphorus, where the bioavailable form is dissolved reactive

phosphorus (DRP). Unlike several forms of nitrogen, phosphorus does not cause toxicity effects in rivers and streams. The proposed NPS-FM 2019 national bottom line for DRP (Table 3-1) is used here as a provisional grading of regional instream DIN.

Four urban, five rural and two reference sites were below the proposed DRP national bottom line (D band). All of the other urban sites were assessed to have a C band current state. Two of the reference sites – Cascades Stream (Waitākere) and Wairoa Tributary – were also below the proposed bottom line for DRP. However, this is not unexpected due to their underlying contributing catchment geology (McGroody et al., 2008). The proposed DRP attribute has a 'natural exclusion' principal that applies to rivers that would be naturally high in dissolved reactive phosphorus due to their underlying parent geology, e.g. North Island streams with tertiary mudstone and volcanic ash (Whitehead, 2018). This 'exclusion principal' will apply to some streams within the Auckland region.

It is important to note that this is a provisional assessment of DIN and DRP and that, in due course, these proposed attributes will not be relevant for many hard-bottom rivers across the region. In these rivers, the periphyton attribute could impose stricter nutrient objectives.

3.3.2.3 Proposed attributes – sediment

This preliminary assessment of suspended fine sediment in monitored streams departs the proposed NPS-FM (2019) attribute band calculations, as it is based on a five year assessment period of NTU turbidity values (see section 2.5.3).

This assessment is focused on the median metric alone (i.e. the state of stream suspended sediment 50 per cent of the time) and does not reflect any assessment of high sediment loads experienced relatively infrequently at any of these monitored sites. This assessment is, in a way, a more refined assessment of suspended sediment in streams than that undertaken by the regional water quality index, as it divides streams into specific classes based on their underlying geology (see Table 2-1 for SSC class definition for each monitored site). The turbidity national bottom line for class 5 streams (REC – WD_Low_SS) is proposed at 13.1 (FNU), which is similar (although not directly comparable) to the regional water quality index guideline of 14 (NTU). Many of the sites in the current monitoring network are in class 5 streams.

Using this modified assessment, three sites (all rural) were below the proposed NPS-FM (2019) suspended fine sediment (turbidity) national bottom line – namely, Ngakoroa Stream, Papakura Steam (Upper) and Okura Creek. Several other urban and rural sites were assessed as C band, but of these, only the Whangamaire Stream site sits near the C/D band boundary.

Table 3-1: Auckland Region NPS-FM current state bands (2014-2018).

Bands in red denote failure of national or interim regional bottom lines, or for *E. coli* minimum acceptable state; orange depicts C band streams which may warrant further consideration in the limit setting process; and green identifies current state that should be maintained. I.D. = Insufficient data for grade calculation.

Sites are ordered in decreasing percentage of their respective dominant land cover type.

Land Cover	AC Site Name	Freshwater Management Unit (watershed)	NPS-FM (2017) attributes			Auckland-specific attributes				
			NO_3-N	NH_4-N	*E. coli*	Cu	Zn	DIN*	DRP**	Sediment
Urban	Botany Creek	Tamaki	A	C	**E**	C	**D**	C	C	A
	*Ōtaki Creek****	*Tamaki*	*B*	*C*	***E***	*C*	***D***	***D***	***D***	*B*
	Pakuranga Creek	Tamaki	A	C	**E**	C	**D**	C	**D**	A
	Oakley Creek	Waitemata	B	A	**E**	C	C	**D**	**D**	A
	Ōtara Creek (South)	Tamaki	B	C	**E**	C	**D**	**D**	C	A
	Oteha River	Waitemata	A	C	**E**	C	**D**	B*	C	C
	Omaru Creek	Tamaki	B	**D**	**E**	C	**D**	**D**	**D**	A
	Puhinui Stream	Manukau Harbour	A	B	**E**	C	**D**	B	C	A
	Lucas Creek	Waitemata	A	B	**E**	C	B	B*	C	B
	Avondale Stream	Waitemata	A	B	**E**	C	C	B	C	C
	Ōtara Creek (East)	Tamaki	A	A	**E**	C	C	B	**C**	B
Rural and lifestyle	Waitangi Stream	Manukau Harbour	C	A	**E**	I.D	I.D	**D***	B	A
	Whangamaire Stream	Manukau Harbour	**D**	B	**E**	I.D	I.D	**D**	C	C
	Ngakoroa Stream	Manukau Harbour	C	A	**D**	I.D	I.D	**D**	B	**D**
	Kumeu River	Kaipara	A	A	**E**	C	B	B	C	B
	Kaukapakapa River	Kaipara	A	B	**E**	I.D	I.D	A	**D**	A
	Waiwera Stream	Hibiscus Coast	A	A	**D**	A	A	A	C	A
	Papakura Stream (Lower)	Manukau Harbour	A	B	**E**	C	B	C	**D**	B
	Papakura Stream (Upper)	Manukau Harbour	A	B	**E**	B	A	C	**D**	**D**

Land Cover	AC Site Name	Freshwater Management Unit (watershed)	NPS-FM (2017) attributes			Auckland-specific attributes				
			NO_3-N	NH_4-N	*E. coli*	Cu	Zn	DIN*	DRP**	Sediment
	Makarau River	Kaipara	A	A	**D**	A	A	A	C	A
	*Rangitopuni River*****	*Waitemata*	*A*	*A*	***D***	*I.D*	*I.D*	*A*	*C*	*A*
	Matakana River	North East	A	A	**D**	A	A	A	C	A
	Wairoa River	Wairoa	A	A	**D**	A	A	B	C	B
	Mahurangi River (Warkworth)	Mahurangi	A	B	**D**	A	A	A	C	A
	Okura Creek	Hibiscus Coast	A	B	**E**	B	A	B	**D**	**D**
	Hoteo River	Kaipara	A	B	**D**	I.D	I.D	B	C	A
	Mahurangi River (Forestry)	Mahurangi	A	A	C	A	A	A*	B	B
	Vaughan Stream	Hibiscus Coast	A	A	**E**	B	A	A	C	B
	Cascades Stream (Waiheke)	Islands	A	A	**D**	I.D	I.D	A	C	C
	Opanuku Stream	Waitemata	A	A	**E**	I.D	I.D	A*	C	A
	Onetangi Stream	Islands	A	A	C	I.D	I.D	A	**D**	C
Exotic forest	Riverhead Stream	Kaipara	A	A	B	A	C	A	B	B
Reference Sites	West Hoe Stream	Hibiscus Coast	A	A	B	I.D	I.D	A	B	A
	Nukumea Stream	Hibiscus Coast	A	A	B	A	A	A	B	A
	Cascades Stream (Waitākere)	West Coast	A	A	A	I.D	I.D	A*	**D**	B
	Wairoa Tributary	Wairoa	A	A	B	I.D	I.D	A	**D**	B

* Denotes hard bottom streams (REC) where the DIN objective may be replaced by a stricter periphyton objective (once periphyton monitoring is established).

** The proposed DRP attribute has a natural exclusion principal that will be applied to rivers with naturally high levels of nutrient enrichment derived from underlying catchment geology.

*** Ōtaki Creek grading is only based on 37 data points over five years (out of a total possible of 60), due to sampling dates being removed because of strong saline influence as per Table 2-3.

**** Current state assessment of Rangitopuni River includes data from three different analytical laboratories (NIWA Hamilton from Jan 2014 to Jun 2016, Watercare Services from Jul 2016 to Jun 2017, and Hill Laboratories from Jul 2017 to Dec 2018).

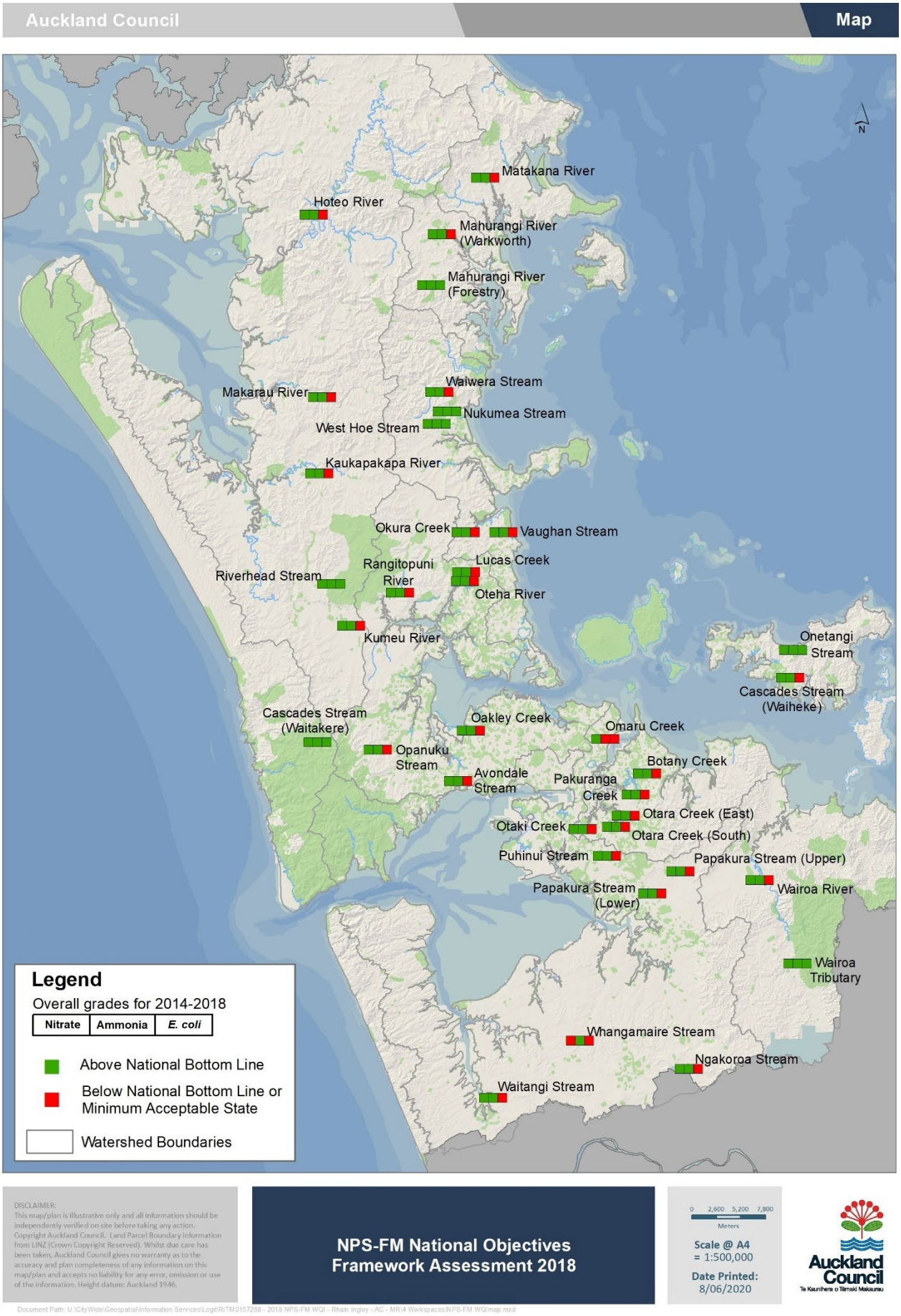

Figure 3-15: Auckland Region NPS-FM NOF current state bands (2014-2018). Both D and E-band fail the minimum acceptable state for *E. coli*, while a D-band fails the national bottom line for nitrate and ammonia toxicity.

4.0 Summary

Water quality has been consistently monitored at approximately one quarter of our currently monitored rivers since 1986, which is before the introduction of the RMA in 1991. The additional sites added across the period covered by the Auckland Council Air, Land and Water Plan 2010, and the Auckland Unitary Plan 2016, make up today's total of 36 monitored rivers and streams. This continuous long-term data collection is important for identifying both the current state and long-term historic trends[10] in river water quality parameters. This supports analysis of changes in the way we utilise land for different activities and discharge contaminants into river receiving environments, and allows a better understanding of human induced change and Auckland Council's associated adaptive management response.

The results of the 2018 river water quality data analysis are broadly consistent with previous years' results. Rivers in urban catchments tend to be affected by elevated nutrients (although to a far lesser degree than in some horticulture dominated catchments), key urban metals (dissolved copper and zinc), temperature, and faecal pathogens. Rivers in rural catchments tend to be affected by elevated nutrients, suspended fine sediments / turbidity and faecal pathogens. These results are reflected in the overall water quality index scores[11] for the 2016-2018 period. Rivers in urban catchments had the poorest scores, rivers in rural catchments typically ranged from 'poor' to 'fair' and, as expected, rivers dominated by native forested catchments (reference sites) had 'good' to 'excellent' river water quality. The water quality index may indicate a slight decline in regional water quality over the three rolling time periods assessed, as there appears to be a slight increase in the number of 'poor' sites and decrease in the number of 'excellent' sites.

Our monitoring also reiterates some site-specific river water quality issues, including:

- high total oxidised nitrogen concentrations in some of the streams (or sections of the streams) in the Franklin area associated with a high proportion of horticultural land use in the contributing catchment and underlying natural volcanic geology
- nutrient and potential wastewater ingress issues in Pakuranga Creek
- higher than expected copper and dissolved reactive phosphorus concentrations in a native forest reference site (Cascades Stream (Waitākere)), which could be occurring naturally due to the underlying geology.

[10] Note that historic water quality trends do not predict future water quality trends unless land use and climate stay constant.

[11] Note that the guidelines used to determine water quality index scores are not regulatory triggers or thresholds.

This report provides a current state assessment of attributes under the National Policy Statement for Freshwater Management (MfE, 2017a) using data from the five-year period 2014-2018. Furthermore, it provides a preliminary assessment for additional regionally significant attributes against proposed guidelines (current at the time this report was written; MfE, 2019). This provides an assessment against nationally derived bands for water quality across a much broader range of stream types, not all of which occur within the Auckland region. The national approach recognises that stream type can influence water quality, with several attributes refined to allow specific stream types to be assessed across smaller groupings, for example, the proposed suspended fine sediment attribute.

Faecal contamination of rivers by *E. coli* is the most geographically widespread issue facing Auckland, with the majority of monitored river sites failing the minimum acceptable state condition. Only one stream (Whangamaire Stream) failed the national bottom line for nitrate toxicity. However, two other sites with moderate proportions of horticultural activity in the catchments and overlying shallow volcanic geology, were assessed to be within the C band, warranting consideration around management to prevent possible future water quality decline. One stream, Omaru Creek, failed the national bottom line for ammonia toxicity, but these issues appear to be of an historic nature (in 2014 and 2015). Five other urban sites were assessed to be within the C band for ammonia toxicity, warranting consideration around management to prevent possible future water quality decline.

All urban river sites had high dissolved copper and zinc concentrations and the preliminary assessment identified that seven of these sites failed the proposed Auckland-specific bottom line for dissolved zinc. A more refined assessment will be undertaken when the required toxicity modifiers can be incorporated.

Several urban and rural river sites also failed the proposed national bottom lines (NPS-FM, 2019) for the additional dissolved organic nitrogen (DIN) and dissolved reactive phosphorus (DRP) nutrient attributes. Notably, two reference sites failed the national bottom line for DRP, which indicates that the underlying geology of the streams and contributing catchments needs to be considered when assessing these attributes. Three sites also failed the proposed suspended sediment national bottom line (measured using turbidity as a proxy).

Auckland Council's river water quality index will be phased out through time as a regional reporting tool and will be replaced by ongoing reporting against future national standards. This will be prescribed by the National Policy Statement for Freshwater Management, with additional parameter reporting as required to provide evidence of regionally significant water quality issues.

5.0 References

Allibone, R., Horrax, J. and Parkyn, S. (2001). Stream classification and instream objectives for Auckland's urban streams. Auckland Regional Council technical report, TR2008/002.

APHA (2012). Standard methods for the examination of water and wastewater, 22nd edition edited by E. W. Rice, R. B. Baird, A. D. Eaton and L. S. Clesceri. American Public Health Association (APHA), American Water Works Association (AWWA) and Water Environment Federation (WEF), Washington, D.C., USA.

Auckland Council (2015). The Health of Auckland's Natural Environment in 2015: Te Oranga o te Taiao o Tāmaki Makaurau. Auckland Council, Auckland. 215 pages.

Auckland Regional Council. (2002). Background concentrations of inorganic elements in soils from the Auckland region. Auckland Regional Council technical publication, TP153, October 2001. Reprinted April 2002.

Australian and New Zealand Governments. (2018). Deriving guideline values for water quality. Australian and New Zealand guidelines for fresh and marine water quality. Canberra (ACT): ANZG and Australian state and territory governments https://www.waterquality.gov.au/anz-guidelines/guideline-values/derive.

Buckthought, L. E. and Neale, M. W. (2016). State of the environment monitoring: river water quality state and trends in Auckland 2005-2014. Auckland Council technical report, TR2016/008.

Canadian Council of Ministers of the Environment (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.

Davies-Colley, R., McBride, G. (2016). Accounting for changes in method in long-term nutrient data. Recommendations based on analysis of paired SoE data from Wellington rivers. Prepared for the Ministry for the Environment. NIWA Client Report No. HAM2016-070.

Foley, M. (2018). Updating the methodology used to calculate the overall water quality score at marine water quality sites in the Auckland region. Auckland Council technical report, TR2018/027.

Gadd, J., Hickey, C. W. (2016a). Guidelines for the protection of aquatic ecosystems, toxicant trigger values: Copper – freshwater. Australian and New Zealand guidelines for fresh and marine water quality. *Draft* September 2016. Council of Australian Governments Standing Council on Environment and Water, Canberra, ACT, Australia.

Gadd, J., Hickey, C. W. (2016b). Guidelines for the protection of aquatic ecosystems, toxicant trigger values: Zinc – freshwater. Australian and New Zealand guidelines for fresh and marine water quality. Draft September 2016. Council of Australian Governments Standing Council on Environment and Water, Canberra, ACT, Australia.

Gadd, J., Snelder, T., Fraser, C. and A. Whitehead (2020). Urban river and stream water quality state and trends 2008-2017. Prepared for the Ministry for the Environment. NIWA Client Report 2018328AK.

Gadd, J., Williamson, B., Mills, G., Hickey, C., Cameron, M., Vigar, N., Buckthought, L., Milne, J. (2019). Developing Auckland-specific ecosystem health attributes for copper and zinc: summary of work to date and identification of future tasks. Auckland Council discussion paper 2019/004.

Griffiths, R. (2016). Recommended Coastal Water Quality Standards for Northland. Northland Regional Council.

Lockie, S. and Neale, M. W. (2013). State of the environment monitoring: river water quality annual report 2012. Auckland Council technical report, TR2013/032.

Lockie, S and Neale, M. W. (2014). State of the environment monitoring: river water quality annual report 2013. Auckland Council technical report, TR2014/032.

Larned, S., Whitehead, A., Fraser, C., Snelder, T., Yang, J. (2018). Water quality state and trends in New Zealand rivers. Analyses of national data ending in 2017. Prepared for the Ministry for the Environment. NIWA Client Report No. 2018341CH.

Larned, S.T., Moores, J., Gadd, J., Baillie, B., Schallenberg (2019). Evidence for the effects of land use on freshwater ecosystems in New Zealand. New Zealand Journal of Marine and Freshwater Research. DOI 10.1080/00288330.2019.1695634.

McBride, G. (2016). National Objectives Framework – Statistical considerations for design and assessment. Prepared for the Ministry for the Environment by National Institute of Water and Atmospheric Research Limited, September 2016 (NIWA client report no: HAM16022, NIWA project number MFE16203).

McDowell, R.W., Hedley, M.J., Pletnyakov, P. Rissmann, C., Catto, W., Patrick W. (2019). Why are median phosphorus concentrations improving in New Zealand streams and rivers?, Journal of the Royal Society of New Zealand, 49:2, 143-170, doi: 10.1080/03036758.2019.1576213.

McGroody, M. E., Baisden, W. T., and L. O. Hedin (2008). Stoichiometry of hydrological C, N, and P losses across climate and geology: An environmental matrix approach across New Zealand primary forests. Global Biogeochemcial Cycles Vol. 22, GB1026, doi:10.1029/2007GB003005.

Meijer, K., Buckthought, L., Curran-Cournane, F., Martindale, M., Prebble, N and Long, L (2016). Elevated nitrate concentrations in Franklin surface and groundwater: a review. Auckland Council technical report, TR2016/015.

Ministry for the Environment (2017a). National Policy Statement for Freshwater Management 2014 (Amended 2017). http://www.mfe.govt.nz/publications/fresh-water/nationalpolicy-statement-freshwater-management-2014-amended-2017.

Ministry for the Environment (2017b). A Guide to Attributes. In Appendix 2 of the National Policy Statement for Freshwater Management 2014 (as amended 2017). Wellington: Ministry for the Environment.

Ministry for the Environment (2018). Australian and New Zealand Guidelines for Fresh and Marine Water Quality. https://www.mfe.govt.nz/publications/fresh-water/australian-and-new-zealand-guidelines-fresh-and-marine-water-quality.

Ministry for the Environment, (2019). Action for Healthy Waterways: A discussion document on national direction for our essential freshwater. September 2019. https://www.mfe.govt.nz/publications/fresh-water/draft-national-policy-statement-freshwater-management.

Neale, M.W. (2010). State of the environment monitoring: river water quality annual report 2009. Auckland Regional Council technical report, 2010/030.

NEMS (2019). National Environmental Monitoring Standards. http://www.nems.org.nz/documents/.

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-T07/218, Wellington.

Scarsbrook, M.R., (2006). State and trends in the National Water Quality Network (1989-2005). NIWA Client Report HAM2006-131 to Ministry for the Environment.

Snelder, T.H., and Biggs, B.J.F. (2002). Multiscale River Environment Classification for water resources management. Journal of the American Water Resources Association, 38(5): 1225-1239. doi:10.1111/j.1752-1688.2002.tb04344.x.

Snelder, T., Biggs, B. and Weatherhead, M. (2010). New Zealand River Environment classification User Guide. Produced for the Ministry for the Environment by the National Institute of Water and Atmospheric Research (NIWA). March 2004 (Updated 2010).

Snelder, T., Larned, S.T., McDowell, R. (2017). Anthropogenic increases of catchment nitrogen and phosphorous loads in New Zealand. New Zealand Journal of Marine and Freshwater Research 52:336-361.

US EPA (1994). US Environmental Protection Agency, Method 200.8 for the "Determination of Trace Metals in Waters and Wastes by Inductively Coupled Plasma – Mass Spectrometry" Revision 5.4.

US EPA (2002). US Environmental Protection Agency, Method 1603: *Escherichia coli* (*E. coli*) in Water by Membrane Filtration Using Modified membrane-Thermotolerant *Escherichia coli* Agar (Modified mTEC).

White, P.A., Moreau, M., Mourot, F., White, J., Johnson, K., and M. Hill, (2019). Groundwater in the Franklin area. GNS Science report 2019/81 prepared for Auckland Council and Waikato Regional Council.

Whitehead, A. (2018). Spatial modelling of river water quality state: Incorporating monitoring data from 2013 to 2017. NIWA Client report 2018360CH prepared for Ministry for the Environment, December 2018. 41 p.

Young D, Afoa E, Meijer K, Wagenhoff A, Utech C (2013). Temperature as a contaminant in streams in the Auckland region, stormwater issues and management options. Prepared by Morphum Environmental Ltd for Auckland Council. Auckland Council technical report, TR2013/044.

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Appendix A Australia and New Zealand Default Guideline Values

Table 6-1: Australian and New Zealand Default Guideline Values (DGV) for physical and chemical parameters in freshwater in New Zealand for the REC classes relevant to Auckland river monitoring sites.

REC Class	Parameter	REC abbreviation	20th %ile DGV*	80th %ile DGV*	Units
Warm Wet Hill	Conductivity	WWH	–	94	µS/cm
Warm Wet Hill	DO % sat	WWH	90	104	% sat
Warm Wet Hill	pH	WWH	7.25	7.8	
Warm Wet Hill	TSS	WWH	–	4.2	mg/L
Warm Wet Hill	Turbidity	WWH	–	2.7	NTU
Warm Wet Hill	Ammoniacal N	WWH	–	0.006	mg/L
Warm Wet Hill	Nitrate	WWH	–	0.036	mg/L
Warm Wet Hill	Total N	WWH	–	0.179	mg/L
Warm Wet Hill	Reactive Phosphorus	WWH	–	0.008	mg/L
Warm Wet Hill	Total P	WWH	–	0.017	mg/L
Warm Wet Low	Conductivity	WWL	–	115	µS/cm
Warm Wet Low	DO % sat	WWL	92	103	% sat
Warm Wet Low	pH	WWL	7.26	7.7	
Warm Wet Low	TSS	WWL	–	8.8	mg/L
Warm Wet Low	Turbidity	WWL	–	5.2	NTU
Warm Wet Low	Ammoniacal N	WWL	–	0.01	mg/L
Warm Wet Low	Nitrate	WWL	–	0.065	mg/L
Warm Wet Low	Total N	WWL	–	0.292	mg/L
Warm Wet Low	Reactive Phosphorus	WWL	–	0.014	mg/L
Warm Wet Low	Total P	WWL	–	0.024	mg/L
Warm Dry Low	Conductivity	WDL	–	86	µS/cm
Warm Dry Low	DO % sat	WDL	82	100	% sat
Warm Dry Low	pH	WDL	7.27	7.8	
Warm Dry Low	TSS	WDL	–	4.6	mg/L
Warm Dry Low	Turbidity	WDL	–	4.2	NTU
Warm Dry Low	Ammoniacal N	WDL	–	0.0017	mg/L
Warm Dry Low	Nitrate	WDL	–	0.195	mg/L
Warm Dry Low	Total N	WDL	–	0.281	mg/L
Warm Dry Low	Reactive Phosphorus	WDL	–	0.007	mg/L
Warm Dry Low	Total P	WDL	–	0.023	mg/L

*The 80th and 20th percentile DGV are the guideline values for which the annual median values of the dataset should not exceed or fall below, respectively.

Table 6-2: Proposed Default Guideline Values (DGV) for copper and zinc in New Zealand

Guideline value type (% species protection)	Copper (μg/L) at DOC 0.5 mg/L	Zinc (μg/L) at pH 8 and hardness 30mg/L as $CaCO_3$
99%	0.35	0.6
95%	1.2	3
90%	2.1	6
80%	4.0	12

Appendix B Contributing catchment information for monitored sites

Table 6-3: Land use classes geospatially assigned to catchments and associated 'nested' land cover for reporting.

Assigned land use class	Nested land use for reporting purposes	Additional aggregation into four land cover categories
1 – Road (VDP ≤ 1,000)	Road	Urban
2 – Road (VDP ≤ 5,000)	Road	Urban
3 – Road (VDP ≤ 20,000)	Road	Urban
4 – Road (VDP ≤ 50,000)	Road	Urban
5 – Road (VDP ≤ 100,000)	Road	Urban
Paved Industrial	Urban	Urban
Paved Rural	Urban	Urban
Paved Open Space	Urban	Urban
Roofs Iron	Urban	Urban
Roofs Other	Urban	Urban
Roofs Tile	Urban	Urban
Mine and bare ground	Urban	Urban
Tourism areas	Urban	Urban
Pervious	Pervious	Pervious
Dairy – Irrigated and dry land pasture	Dairy	Rural and lifestyle
Sheep, beef and deer	Sheep, beef and deer	Rural and lifestyle
Pigs, poultry and other	Pigs, poultry and other	Rural and lifestyle
Exotic Grassland	Grass/shrubland	Rural and lifestyle
Idle/unclassed	Grass/shrubland	Rural and lifestyle
Native grassland and conservation	Grass/shrubland	Rural and lifestyle
Ungrased high producing exotic pasture	Grass/shrubland	Rural and lifestyle
Green houses, flowers and nurseries	Horticulture	Rural and lifestyle
Orchards	Horticulture	Rural and lifestyle
Short-rotation Cropland	Horticulture	Rural and lifestyle
Vegetables	Horticulture	Rural and lifestyle
Lifestyle blocks	Lifestyle	Rural and lifestyle
Native forest	Native forest	Native forest
Exotic forest/plantations	Exotic forest	Exotic forest
Waterbody	Waterbody	N/A
Estuary and Marine	Waterbody	N/A

Table 6-4: Land use breakdown as a percentage of the upstream catchment area for each river water quality monitoring site.

Site	Urban %	Road %	Urban – Pervious %	Water body/ coast %	Lifestyle %	Sheep, Beef & Deer %	Pigs, Poultry, Other %	Dairy %	Horticulture %	Grass/ shrub %	Exotic forest %	Native forest %	Upstream catchment area(km^2)
Botany Creek	40.3	12.1	45.2	0.0	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.65
Ōtaki Creek	38.7	12.8	48.2	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.17
Pakuranga Creek	34.2	16.2	49.2	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.16
Oakley Creek	33.4	10.8	55.5	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.29
Ōtara Creek (South)	30.7	12.5	56.0	0.2	0.5	0.0	0.0	0.0	0.0	0.1	0.0	0.0	8.80
Oteha Stream	30.6	10.7	54.6	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.21
Omaru Creek	29.9	10.5	59.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.15
Puhinui Stream	26.3	9.3	43.2	0.5	1.8	3.6	0.1	0.0	0.0	12.1	0.4	2.7	12.95
Lucas Creek	19.8	10.3	68.8	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	6.16
Avondale Stream	21.9	7.3	70.8	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.39
Ōtara Creek (East)	11.5	4.9	65.1	0.6	6.9	4.3	0.0	0.0	0.0	4.6	0.5	1.5	18.28
Waitangi River	0.1	1.0	2.2	0.2	13.9	35.7	4.4	21.8	12.4	7.7	0.3	0.3	18.97
Whangamaire Stream	0.9	1.4	4.3	0.3	15.2	19.1	6.4	9.5	34.0	8.3	0.0	0.5	8.14
Ngakoroa Stream	0.0	1.3	4.2	1.3	15.3	37.0	2.9	0.0	25.5	11.2	0.7	0.6	4.66
Kumeu River	1.5	1.3	3.5	0.4	34.4	28.5	3.7	2.0	5.8	11.9	2.7	4.3	45.66
Kaukapakapa River	0.1	0.8	2.6	0.7	13.5	42.4	6.1	16.6	0.9	6.4	3.4	6.6	61.57
Waiwera River	0.0	0.5	2.7	0.7	12.3	58.9	0.6	2.3	0.3	6.5	5.6	9.6	30.23
Papakura Stream (Lower)	3.0	1.3	5.7	0.2	12.8	29.6	10.3	11.5	3.3	12.7	7.2	2.3	47.16
Papakura Stream (Upper)	0.7	0.8	2.0	0.3	4.8	33.2	11.2	16.3	0.0	12.3	14.1	4.2	23.24
Makarau River	0.2	0.4	2.8	0.4	3.2	54.3	3.4	1.9	0.0	11.2	19.9	2.3	48.34
Rangitopuni River	0.3	1.3	6.2	0.8	29.8	26.4	1.8	2.1	2.2	11.2	14.7	3.2	83.66
Matakana River	0.0	0.5	2.3	0.1	11.8	45.5	1.3	5.7	0.0	7.2	7.2	18.4	13.85

Site	Urban %	Road %	Urban – Pervious %	Water body/ coast %	Lifestyle %	Sheep, Beef & Deer %	Pigs, Poultry, Other %	Dairy %	Horticulture %	Grass/ shrub %	Exotic forest %	Native forest %	Upstream catchment area(km^2)
Wairoa River	0.1	0.7	2.2	2.0	9.6	46.5	2.2	8.7	0.1	4.2	15.7	8.1	148.85
Mahurangi River (Warkworth)	1.2	0.9	8.1	0.6	7.7	47.2	1.4	0.0	0.9	11.7	11.8	8.6	48.44
Okura Creek	0.2	1.5	3.2	0.1	28.2	7.0	17.6	0.0	6.3	7.9	6.8	21.3	4.90
Mahurangi River (Forestry)	0.0	0.5	0.5	0.0	0.0	62.4	0.0	0.0	0.0	0.5	33.9	2.1	5.53
Hoteo River	0.1	0.5	3.3	0.7	3.0	34.5	0.4	22.9	0.3	5.1	19.7	9.7	269.17
Vaughan Stream	4.3	1.7	93.9	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.39
Cascades Stream (Whakanewha)	0.4	0.7	0.0	0.0	6.5	1.6	0.0	0.0	1.1	41.5	0.0	48.3	0.64
Opanuku Stream	1.6	1.0	4.7	0.6	18.7	12.5	3.1	0.0	2.1	2.0	1.1	52.7	15.66
Onetangi Stream	2.3	1.6	20.9	0.0	1.5	0.2	0.0	0.0	0.0	2.2	0.0	71.4	0.68
Riverhead Forest Stream	0.0	1.0	1.3	0.0	0.1	0.0	0.0	0.0	0.0	0.0	97.6	0.0	4.10
Wairoa Tributary	0.2	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	99.8	2.27
Cascades Stream (Waitākere)	0.0	0.3	1.4	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	95.8	13.88
Nukumea Stream	0.0	0.3	5.0	0.0	16.1	5.5	0.0	0.0	0.0	0.0	0.2	72.9	0.99
West Hoe Stream	0.0	0.0	2.9	0.0	1.7	31.3	0.0	0.0	0.0	0.0	0.0	64.1	0.53

Appendix C River water quality data summary tables

Table 6-5: River water quality index scores and classes updated for 2016-2018 based on rolling three-year median values.
Blue = Excellent, Green = Good, Yellow = Fair, Orange = Marginal, Red = Poor.
Sites in each land use category are in order of decreasing catchment land use proportion.

Land use category	Site name	WQI Score (2014-2016)	WQI Score (2015-2017)	WQI Score (2016-2018)
Urban	Botany Creek	35.9	34.6	40.9
	Ōtaki Creek	31.6	27.2	27.2
	Pakuranga Creek	32.4	39.2	33.3
	Oakley Creek	55.8	56.2	53
	Ōtara Creek (South)	50.4	50.4	42.4
	Oteha River	52	52.4	53
	Omaru Creek	40.5	43.4	46.1
	Puhinui Stream	65	57.5	49.6
	Lucas Creek	62.1	61.8	61.4
	Avondale Stream	50.8	58.4	52.1
	Ōtara Creek (East)	62.2	62.7	55.2
Rural and lifestyle	Waitangi Stream	48.1	46.1	44.8
	Whangamaire Stream	34.6	38.4	34.5
	Ngakoroa Stream	43.9	46.8	47
	Kumeu River	59.7	51.5	58.7
	Kaukapakapa River	47.5	46.8	62.7
	Waiwera Stream	65.4	73	73.5
	Papakura Stream (Lower)	51.3	42.9	42.8
	Papakura Stream (Upper)	49.5	40.9	41.1
	Makarau River	73.9	81.6	81.6
	Rangitopuni River	66.4	63.3	64.3
	Matakana River	83.1	83.1	75
	Wairoa River	67.2	64.6	63.6
	Mahurangi River (Warkworth)	73.5	73.4	72.7
	Okura Creek	45.9	61.6	62.3
	Hoteo River	70.5	70.3	60.9
	Mahurangi River (Forestry)	80.8	72.5	70.9
	Vaughan Stream	64.1	63.5	64.2
	Cascades Stream (Waiheke)	81.2	79.4	70.4
	Opanuku Stream	74.3	82.1	80.9
	Onetangi Stream	71.8	72.4	63.4
Exotic forest	Riverhead Stream	65.8	66	66.1
Reference sites	West Hoe Stream	100	100	91.7
	Nukumea Stream	100	100	91.7
	Cascades Stream (Waitākere)	100	100	100
	Wairoa Tributary	100	91.7	91.7

Table 6-6: Salinity (ppt) river data collected January to December 2018.

	Site	Count	Min	Max	25th%	Median	75th%
Urban	Botany Creek	11	0.12	0.15	0.13	0.13	0.13
	Ōtaki Creek	8	0.12	0.31	0.12	0.14	0.15
	Pakuranga Creek	11	0.07	0.30	0.19	0.21	0.27
	Oakley Creek	11	0.06	0.13	0.10	0.11	0.12
	Ōtara Creek (South)	10	0.06	0.09	0.08	0.08	0.09
	Oteha River	12	0.06	0.13	0.08	0.11	0.12
	Omaru Creek	11	0.08	0.19	0.15	0.16	0.17
	Puhinui Stream	12	0.05	0.10	0.08	0.10	0.10
	Lucas Creek	12	0.06	0.13	0.10	0.11	0.12
	Avondale Stream	11	0.05	0.11	0.10	0.10	0.11
	Ōtara Creek (East)	11	0.09	0.12	0.09	0.10	0.11
Rural & lifestyle	Waitangi Stream	12	0.08	0.10	0.09	0.09	0.10
	Whangamaire Stream	12	0.09	0.15	0.12	0.14	0.14
	Ngakoroa Stream	12	0.06	0.09	0.07	0.07	0.08
	Kumeu River	11	0.05	0.09	0.07	0.08	0.08
	Kaukapakapa River	11	0.08	0.11	0.09	0.09	0.10
	Waiwera Stream	11	0.08	0.10	0.09	0.09	0.10
	Papakura Stream (Lower)	12	0.07	0.10	0.08	0.09	0.10
	Papakura Stream (Upper)	12	0.07	0.10	0.08	0.09	0.09
	Makarau River	11	0.08	0.09	0.08	0.08	0.09
	Rangitopuni River	12	0.06	0.12	0.09	0.10	0.11
	Matakana River	12	0.07	0.10	0.08	0.08	0.09
	Wairoa River	12	0.04	0.06	0.05	0.05	0.06
	Mahurangi River (Warkworth)	12	0.08	0.11	0.08	0.08	0.10
	Okura Creek	12	0.10	0.13	0.11	0.12	0.13
	Hoteo River	NA					
	Mahurangi River (Forestry)	11	0.10	0.12	0.10	0.11	0.11
	Vaughan Stream	12	0.10	0.19	0.13	0.15	0.15
	Cascades Stream (Waiheke)	10	0.09	0.24	0.09	0.10	0.11
	Opanuku Stream	12	0.06	0.07	0.06	0.07	0.07
	Onetangi Stream	10	0.11	0.25	0.20	0.22	0.23
Exotic	Riverhead Stream	11	0.06	0.11	0.10	0.10	0.11
Reference	West Hoe Stream	12	0.07	0.10	0.08	0.09	0.09
	Nukumea Stream	12	0.08	0.09	0.08	0.09	0.09
	Cascades Stream (Waitākere)	11	0.06	0.08	0.06	0.08	0.08
	Wairoa Tributary	12	0.04	0.06	0.05	0.05	0.06

Table 6-7: Electrical conductivity (μS/cm) river data collected January to December 2018.

	Site	Count	Min	Max	25th%	Median	75th%
Urban	Botany Creek	11	0.25	0.31	0.26	0.27	0.28
	Ōtaki Creek	8	0.26	0.63	0.26	0.28	0.32
	Pakuranga Creek	11	0.14	0.61	0.39	0.44	0.55
	Oakley Creek	11	0.12	0.28	0.21	0.23	0.25
	Ōtara Creek (South)	11	0.14	0.19	0.17	0.18	0.19
	Oteha River	12	0.14	0.26	0.18	0.22	0.25
	Omaru Creek	11	0.18	0.39	0.31	0.34	0.36
	Puhinui Stream	12	0.11	0.22	0.17	0.20	0.22
	Lucas Creek	12	0.14	0.27	0.21	0.23	0.25
	Avondale Stream	11	0.11	0.23	0.21	0.22	0.22
	Ōtara Creek (East)	11	0.19	0.26	0.19	0.21	0.24
Rural & lifestyle	Waitangi Stream	12	0.18	0.21	0.19	0.19	0.20
	Whangamaire Stream	12	0.18	0.31	0.25	0.28	0.30
	Ngakoroa Stream	12	0.13	0.19	0.15	0.15	0.18
	Kumeu River	11	0.12	0.19	0.15	0.16	0.17
	Kaukapakapa River	11	0.16	0.23	0.18	0.19	0.21
	Waiwera Stream	11	0.17	0.21	0.19	0.20	0.20
	Papakura Stream (Lower)	12	0.15	0.21	0.18	0.18	0.20
	Papakura Stream (Upper)	12	0.15	0.20	0.17	0.18	0.19
	Makarau River	11	0.16	0.20	0.17	0.18	0.20
	Rangitopuni River	12	0.12	0.26	0.20	0.21	0.22
	Matakana River	12	0.14	0.20	0.16	0.17	0.19
	Wairoa River	12	0.09	0.13	0.10	0.11	0.12
	Mahurangi River (Warkworth)	12	0.16	0.23	0.17	0.18	0.21
	Okura Creek	12	0.22	0.28	0.23	0.25	0.27
	Hoteo River	NA					
	Mahurangi River (Forestry)	11	0.21	0.24	0.21	0.22	0.24
	Vaughan Stream	12	0.22	0.39	0.27	0.30	0.32
	Cascades Stream (Waiheke)	10	0.19	0.49	0.20	0.21	0.23
	Opanuku Stream	12	0.12	0.15	0.13	0.14	0.15
	Onetangi Stream	10	0.22	0.52	0.40	0.45	0.48
Exotic	Riverhead Stream	11	0.13	0.24	0.21	0.22	0.23
Reference	West Hoe Stream	12	0.15	0.20	0.16	0.18	0.19
	Nukumea Stream	12	0.16	0.19	0.17	0.18	0.19
	Cascades Stream (Waitākere)	11	0.13	0.18	0.14	0.17	0.17
	Wairoa Tributary	12	0.09	0.12	0.10	0.11	0.12

Table 6-8: pH river data collected January to December 2018.

	Site	Count	Min	Max	25th%	Median	75th%
Urban	Botany Creek	11	7.61	8.72	7.73	7.93	7.96
	Ōtaki Creek	8	7.00	7.68	7.16	7.49	7.60
	Pakuranga Creek	11	7.58	8.30	7.88	7.96	8.00
	Oakley Creek	11	7.16	7.88	7.33	7.57	7.73
	Ōtara Creek (South)	11	7.30	9.04	7.48	7.67	7.95
	Oteha River	12	7.27	7.84	7.37	7.43	7.59
	Omaru Creek	11	7.03	7.76	7.20	7.45	7.71
	Puhinui Stream	12	6.81	7.95	7.22	7.48	7.72
	Lucas Creek	12	7.31	7.81	7.36	7.44	7.54
	Avondale Stream	11	6.88	7.58	6.96	7.18	7.36
	Ōtara Creek (East)	11	7.30	8.39	7.50	7.93	8.22
Rural & lifestyle	Waitangi Stream	12	6.53	7.68	6.92	7.09	7.64
	Whangamaire Stream	12	6.79	7.71	7.10	7.26	7.62
	Ngakoroa Stream	12	6.70	7.76	7.01	7.28	7.55
	Kumeu River	11	6.65	7.41	6.72	6.89	7.15
	Kaukapakapa River	11	6.76	7.61	6.94	6.97	7.27
	Waiwera Stream	11	6.84	7.81	7.08	7.29	7.45
	Papakura Stream (Lower)	12	6.41	8.26	6.75	7.04	7.36
	Papakura Stream (Upper)	12	6.45	7.50	6.67	6.94	7.38
	Makarau River	11	6.10	8.11	7.28	7.53	7.97
	Rangitopuni River	12	6.87	7.68	7.01	7.15	7.31
	Matakana River	12	7.17	8.04	7.27	7.45	7.77
	Wairoa River	12	6.61	7.68	6.77	7.45	7.61
	Mahurangi River (Warkworth)	12	7.16	7.94	7.40	7.56	7.81
	Okura Creek	12	7.28	7.91	7.35	7.49	7.67
	Hoteo River	11	7.06	7.77	7.27	7.54	7.65
	Mahurangi River (Forestry)	11	7.34	7.99	7.41	7.59	7.77
	Vaughan Stream	12	6.90	7.91	7.14	7.25	7.53
	Cascades Stream (Waiheke)	10	6.94	7.76	7.02	7.15	7.38
	Opanuku Stream	12	6.81	7.86	6.93	7.21	7.49
	Onetangi Stream	10	6.76	7.40	6.79	6.97	7.16
Exotic	Riverhead Stream	11	6.08	7.24	6.17	6.68	6.73
Reference	West Hoe Stream	12	6.67	8.29	6.89	7.16	7.40
	Nukumea Stream	12	6.56	7.54	6.80	6.95	7.22
	Cascades Stream (Waitākere)	11	6.51	8.02	7.45	7.76	7.87
	Wairoa Tributary	12	7.27	8.11	7.39	7.67	8.00

Table 6-9: Dissolved oxygen (% saturation) river data collected January to December 2018.

	Site	Count	Min	Max	25th%	Median	75th%
Urban	Botany Creek	10	108.5	161.8	114.7	127.3	135.1
	Ōtaki Creek	8	61.1	111.0	64.7	77.7	82.9
	Pakuranga Creek	9	79.2	115.3	85.5	90.9	98.3
	Oakley Creek	10	81.0	96.4	92.4	93.9	95.5
	Ōtara Creek (South)	10	95.8	150.5	98.4	102.5	110.9
	Oteha River	12	81.5	99.0	86.7	93.5	96.1
	Omaru Creek	10	51.2	88.9	64.6	82.5	88.4
	Puhinui Stream	12	69.4	113.2	91.7	101.9	109.5
	Lucas Creek	12	82.3	100.2	89.6	94.9	98.0
	Avondale Stream	10	76.3	93.2	85.3	90.0	92.3
	Ōtara Creek (East)	9	83.2	136.6	94.0	95.0	108.6
Rural & lifestyle	Waitangi Stream	12	67.2	104.2	76.5	87.6	95.8
	Whangamaire Stream	12	65.4	110.6	77.2	85.9	97.0
	Ngakoroa Stream	12	78.8	98.8	86.5	89.5	95.3
	Kumeu River	11	78.1	97.1	86.4	90.2	92.3
	Kaukapakapa River	11	71.8	92.5	81.1	89.1	90.3
	Waiwera Stream	11	77.6	99.7	93.8	95.7	96.6
	Papakura Stream (Lower)	12	71.5	95.3	77.5	86.2	89.6
	Papakura Stream (Upper)	12	46.4	88.5	56.4	72.7	85.9
	Makarau River	11	70.3	115.7	97.5	100.0	108.3
	Rangitopuni River	12	66.4	99.4	79.8	89.7	92.6
	Matakana River	12	85.7	98.1	91.1	93.2	95.1
	Wairoa River	12	95.0	104.3	95.5	98.7	102.0
	Mahurangi River (Warkworth)	12	85.2	101.8	91.4	95.9	98.4
	Okura Creek	12	82.3	100.5	94.1	96.3	99.5
	Hoteo River	12	73.7	94.5	84.7	92.6	94.0
	Mahurangi River (Forestry)	11	93.7	100.6	94.3	96.6	98.3
	Vaughan Stream	12	57.4	100.2	65.5	82.8	97.9
	Cascades Stream (Waiheke)	10	87.4	95.4	92.8	93.8	95.2
	Opanuku Stream	12	84.0	103.2	95.4	98.2	98.9
	Onetangi Stream	10	73.9	96.7	79.0	84.7	87.6
Exotic	Riverhead Stream	11	60.0	87.7	69.3	83.5	86.2
Reference	West Hoe Stream	12	88.3	95.3	89.2	90.7	92.7
	Nukumea Stream	12	81.8	90.5	85.5	87.3	89.6
	Cascades Stream (Waitākere)	11	90.2	103.5	98.8	100.3	101.7
	Wairoa Tributary	12	92.3	99.3	96.2	97.7	98.8

Table 6-10: Dissolved oxygen (mg/L) river data collected January to December 2018.

	Site	Count	Min	Max	25th%	Median	75th%
Urban	Botany Creek	10	9.9	13.3	10.8	11.5	12.0
	Ōtaki Creek	8	5.5	10.9	5.8	6.9	8.3
	Pakuranga Creek	9	7.2	9.7	7.9	8.6	9.6
	Oakley Creek	10	7.5	10.1	8.6	9.2	9.8
	Ōtara Creek (South)	10	8.4	12.8	9.4	9.8	10.9
	Oteha River	12	7.6	10.4	8.0	9.4	10.1
	Omaru Creek	10	5.3	9.3	6.3	7.5	8.9
	Puhinui Stream	12	6.4	11.6	9.1	9.7	10.9
	Lucas Creek	12	7.8	10.4	8.4	9.8	10.2
	Avondale Stream	10	7.2	10.0	8.0	8.7	9.6
	Ōtara Creek (East)	9	7.4	11.5	9.1	9.8	10.9
Rural & lifestyle	Waitangi Stream	12	6.1	10.8	7.2	9.0	10.4
	Whangamaire Stream	12	6.1	11.9	7.5	9.6	10.3
	Ngakoroa Stream	12	7.7	11.1	8.0	9.3	10.6
	Kumeu River	11	7.0	10.1	8.4	8.8	9.6
	Kaukapakapa River	11	6.5	10.4	7.3	8.9	9.6
	Waiwera Stream	11	6.9	10.8	8.5	9.9	10.4
	Papakura Stream (Lower)	12	6.6	10.3	7.3	8.5	9.8
	Papakura Stream (Upper)	12	4.2	9.8	5.1	7.1	9.4
	Makarau River	11	6.5	11.1	9.8	10.3	10.9
	Rangitopuni River	12	6.0	10.6	7.7	9.3	9.8
	Matakana River	12	7.5	10.4	8.6	9.6	10.1
	Wairoa River	12	8.2	11.4	9.2	10.0	10.7
	Mahurangi River (Warkworth)	12	7.5	10.8	8.7	9.6	10.6
	Okura Creek	12	7.5	10.7	8.9	10.3	10.6
	Hoteo River	12	6.8	10.5	8.2	9.1	10.1
	Mahurangi River (Forestry)	11	8.7	10.7	9.2	10.4	10.5
	Vaughan Stream	12	5.4	9.9	6.3	8.7	9.5
	Cascades Stream (Waiheke)	10	8.7	10.7	9.1	9.7	10.0
	Opanuku Stream	12	7.7	11.3	9.2	10.4	10.9
	Onetangi Stream	10	6.8	10.6	7.6	8.7	9.5
Exotic	Riverhead Stream	11	5.4	10.0	6.6	8.5	9.5
Reference	West Hoe Stream	12	8.5	10.0	9.0	9.7	9.9
	Nukumea Stream	12	7.8	9.7	8.5	9.3	9.6
	Cascades Stream (Waitākere)	11	8.5	11.3	9.9	10.6	11.1
	Wairoa Tributary	12	8.9	11.9	10.0	10.7	11.0

Table 6-11: Temperature (°C) river data collected January to December 2018.

	Site	Count	Min	Max	25th%	Median	75th%
Urban	Botany Creek	11	15.7	27.2	17.3	21.6	23.6
	Ōtaki Creek	8	15.0	22.0	16.3	19.8	21.6
	Pakuranga Creek	11	15.0	24.0	16.2	19.7	21.4
	Oakley Creek	11	12.9	21.0	13.8	17.6	19.2
	Ōtara Creek (South)	11	14.5	23.4	16.2	19.7	21.5
	Oteha River	12	12.2	21.9	13.2	14.4	17.8
	Omaru Creek	11	13.1	22.2	14.2	18.2	19.9
	Puhinui Stream	12	10.6	25.5	13.3	16.2	20.7
	Lucas Creek	12	11.9	21.0	13.2	14.3	17.9
	Avondale Stream	11	12.1	20.9	12.7	17.3	18.2
	Ōtara Creek (East)	11	12.6	24.0	13.9	18.6	21.2
Rural & lifestyle	Waitangi Stream	12	9.6	22.2	12.6	15.0	19.0
	Whangamaire Stream	12	9.1	18.8	12.0	13.9	17.4
	Ngakoroa Stream	12	7.9	21.3	11.6	13.3	18.0
	Kumeu River	11	11.5	20.5	13.5	15.9	18.0
	Kaukapakapa River	11	10.3	20.7	12.4	15.3	20.0
	Waiwera Stream	11	10.1	21.3	13.0	14.6	20.7
	Papakura Stream (Lower)	12	9.2	21.8	11.9	14.8	18.7
	Papakura Stream (Upper)	12	9.1	22.3	12.1	14.8	18.6
	Makarau River	11	10.3	22.5	13.2	14.8	19.4
	Rangitopuni River	12	10.1	20.4	12.3	15.3	17.5
	Matakana River	12	11.3	21.7	12.3	14.0	17.8
	Wairoa River	12	9.2	23.1	12.1	14.6	18.7
	Mahurangi River (Warkworth)	12	11.0	21.7	12.2	15.0	18.1
	Okura Creek	12	10.4	20.0	12.1	13.3	16.5
	Hoteo River	12	10.4	22.5	12.5	15.4	18.7
	Mahurangi River (Forestry)	11	11.6	19.2	12.0	12.9	16.5
	Vaughan Stream	12	12.3	21.3	13.6	15.1	19.3
	Cascades Stream (Waiheke)	10	10.4	18.5	11.7	13.7	16.4
	Opanuku Stream	12	9.4	19.8	11.7	13.3	17.9
	Onetangi Stream	10	10.7	19.0	11.6	14.0	16.8
Exotic	Riverhead Stream	11	9.5	20.8	11.1	13.9	18.0
Reference	West Hoe Stream	12	11.1	17.9	11.4	12.8	15.1
	Nukumea Stream	12	11.1	18.5	11.5	13.2	15.6
	Cascades Stream (Waitākere)	11	10.4	18.5	11.7	13.1	16.8
	Wairoa Tributary	12	7.3	16.9	10.1	11.1	15.0

Table 6-12: Total suspended solids (mg/L) river data collected January to December 2018.

	Site	Count	Min	Max	25th%	Median	75th%
Urban	Botany Creek	11	1.5	9.0	1.5	4.0	4.0
	Ōtaki Creek	8	1.5	13.0	1.9	4.0	11.3
	Pakuranga Creek	11	1.5	18.0	4.0	5.0	7.0
	Oakley Creek	11	1.5	21.0	1.5	5.0	10.0
	Ōtara Creek (South)	11	1.5	5.0	1.5	1.5	4.0
	Oteha River	12	1.5	31.0	4.0	8.0	14.3
	Omaru Creek	11	1.5	175.0	3.0	5.0	7.0
	Puhinui Stream	12	1.5	193.0	4.3	6.5	12.0
	Lucas Creek	12	1.5	25.0	1.5	4.0	13.3
	Avondale Stream	11	1.5	16.0	4.0	5.0	6.0
	Ōtara Creek (East)	11	5.0	184.0	10.0	21.0	35.0
Rural & lifestyle	Waitangi Stream	12	1.5	3.0	1.5	1.5	1.5
	Whangamaire Stream	12	1.5	8.0	1.5	1.5	2.6
	Ngakoroa Stream	12	1.5	24.0	1.5	1.5	5.8
	Kumeu River	11	4.0	77.0	5.0	8.0	11.0
	Kaukapakapa River	11	3.0	21.0	3.0	7.0	13.0
	Waiwera Stream	11	1.5	12.0	1.5	3.0	7.0
	Papakura Stream (Lower)	12	1.5	17.0	1.9	4.0	7.8
	Papakura Stream (Upper)	12	3.0	21.0	5.3	8.5	11.8
	Makarau River	11	1.5	12.0	1.5	3.0	7.0
	Rangitopuni River	12	1.5	36.0	3.0	4.0	11.0
	Matakana River	12	1.5	47.0	1.5	3.5	6.0
	Wairoa River	12	1.5	21.0	3.3	5.0	13.8
	Mahurangi River (Warkworth)	12	1.5	16.0	1.5	3.5	8.3
	Okura Creek	12	3.0	53.0	5.3	17.5	38.3
	Hoteo River	NA					
	Mahurangi River (Forestry)	12	1.5	26.0	3.3	5.5	14.5
	Vaughan Stream	12	1.5	160.0	7.3	8.5	17.3
	Cascades Stream (Waiheke)	10	1.5	22.0	2.6	5.5	7.3
	Opanuku Stream	12	1.5	4.0	1.5	1.5	1.5
	Onetangi Stream	10	3.0	15.0	4.8	9.0	11.0
Exotic	Riverhead Stream	11	1.5	10.0	1.5	4.0	5.0
Reference	West Hoe Stream	12	1.5	16.0	1.5	1.5	1.5
	Nukumea Stream	12	1.5	4.0	1.5	1.5	1.5
	Cascades Stream (Waitākere)	10	1.5	1.5	1.5	1.5	1.5
	Wairoa Tributary	12	1.5	16.0	1.5	4.0	10.5

Table 6-13: Turbidity (NTU) river data collected January to December 2018.

	Site	Count	Min	Max	25th%	Median	75th%
Urban	Botany Creek	11	4.9	11.7	5.0	6.8	10.8
	Ōtaki Creek	8	4.7	15.2	6.7	8.8	10.9
	Pakuranga Creek	11	5.3	27.0	6.1	7.8	19.9
	Oakley Creek	11	2.8	21.0	5.2	6.6	9.6
	Ōtara Creek (South)	11	2.0	15.1	3.8	5.8	8.2
	Oteha River	12	4.8	40.0	6.3	10.7	23.6
	Omaru Creek	11	2.6	26.0	4.7	6.6	8.2
	Puhinui Stream	12	1.9	70.0	4.1	6.8	16.0
	Lucas Creek	12	3.4	31.0	5.3	9.2	24.2
	Avondale Stream	11	8.0	22.0	9.6	11.3	12.7
	Ōtara Creek (East)	11	3.8	84.0	10.2	22.0	46.0
Rural & lifestyle	Waitangi Stream	12	1.2	9.8	1.4	2.1	4.6
	Whangamaire Stream	12	1.2	11.1	2.0	2.8	3.7
	Ngakoroa Stream	12	1.4	11.7	2.1	4.6	5.7
	Kumeu River	11	7.5	64.0	8.4	10.8	19.0
	Kaukapakapa River	11	4.3	23.0	5.5	9.7	17.4
	Waiwera Stream	11	4.3	25.0	5.0	7.0	13.4
	Papakura Stream (Lower)	12	1.9	32.0	4.0	8.1	14.3
	Papakura Stream (Upper)	12	5.4	36.0	7.8	12.6	14.9
	Makarau River	11	2.5	18.2	3.2	5.9	10.7
	Rangitopuni River	12	4.8	34.0	6.1	9.8	21.3
	Matakana River	12	1.9	62.0	4.0	6.6	8.8
	Wairoa River	12	1.7	29.0	3.9	6.1	17.4
	Mahurangi River (Warkworth)	12	2.8	21.0	4.7	7.7	17.2
	Okura Creek	12	10.1	64.0	13.8	17.3	31.8
	Hoteo River	12	5.4	65.1	6.7	12.7	23.0
	Mahurangi River (Forestry)	12	6.3	46.0	8.1	9.8	18.2
	Vaughan Stream	12	5.9	62.0	7.3	14.0	27.3
	Cascades Stream (Waiheke)	10	6.0	78.0	6.4	21.0	30.5
	Opanuku Stream	12	2.3	19.6	2.8	5.2	11.1
	Onetangi Stream	10	7.1	22.0	10.7	15.9	21.0
Exotic	Riverhead Stream	11	5.4	41.0	6.7	8.0	27.0
Reference	West Hoe Stream	12	4.5	9.3	5.3	6.1	7.8
	Nukumea Stream	12	4.7	11.6	5.7	6.4	7.8
	Cascades Stream (Waitākere)	11	1.6	24.0	2.6	3.8	10.1
	Wairoa Tributary	12	5.9	28.0	6.6	9.1	16.0

Table 6-14: Ammoniacal nitrogen (mg NH_4-N/L) river data collected January to December 2018.

	Site	Count	Min	Max	25th%	Median	75th%
Urban	Botany Creek	11	0.0025	0.1380	0.0100	0.0280	0.0420
	Ōtaki Creek	8	0.0280	0.1100	0.0612	0.0795	0.0930
	Pakuranga Creek	11	0.0380	0.8100	0.2900	0.3500	0.4700
	Oakley Creek	11	0.0025	0.0190	0.0025	0.0070	0.0150
	Ōtara Creek (South)	11	0.0025	0.2300	0.0050	0.0150	0.0330
	Oteha River	12	0.0025	0.0660	0.0025	0.0120	0.0307
	Omaru Creek	11	0.0025	0.2000	0.0100	0.0210	0.0600
	Puhinui Stream	12	0.0025	0.0650	0.0025	0.0170	0.0287
	Lucas Creek	12	0.0025	0.0600	0.0025	0.0043	0.0135
	Avondale Stream	11	0.0025	0.0660	0.0150	0.0200	0.0320
	Ōtara Creek (East)	11	0.0025	0.0550	0.0025	0.0025	0.0300
Rural & lifestyle	Waitangi Stream	12	0.0025	0.0440	0.0025	0.0043	0.0068
	Whangamaire Stream	12	0.0025	0.0280	0.0025	0.0053	0.0110
	Ngakoroa Stream	12	0.0025	0.0180	0.0025	0.0055	0.0142
	Kumeu River	11	0.0025	0.0330	0.0025	0.0150	0.0210
	Kaukapakapa River	11	0.0025	0.0340	0.0120	0.0160	0.0260
	Waiwera Stream	11	0.0025	0.0240	0.0025	0.0110	0.0130
	Papakura Stream (Lower)	12	0.0025	0.0780	0.0025	0.0130	0.0215
	Papakura Stream (Upper)	12	0.0025	0.1000	0.0049	0.0235	0.0555
	Makarau River	11	0.0025	0.0160	0.0025	0.0025	0.0130
	Rangitopuni River	12	0.0025	0.0400	0.0095	0.0175	0.0195
	Matakana River	12	0.0025	0.0300	0.0025	0.0025	0.0025
	Wairoa River	12	0.0025	0.0360	0.0025	0.0070	0.0147
	Mahurangi River (Warkworth)	12	0.0025	0.0190	0.0025	0.0025	0.0122
	Okura Creek	12	0.0025	0.0340	0.0025	0.0120	0.0273
	Hoteo River	12	0.0025	0.0790	0.0140	0.0230	0.0437
	Mahurangi River (Forestry)	12	0.0025	0.0260	0.0025	0.0048	0.0165
	Vaughan Stream	12	0.0025	0.0210	0.0025	0.0025	0.0044
	Cascades Stream (Waiheke)	10	0.0025	0.0190	0.0025	0.0025	0.0046
	Opanuku Stream	12	0.0025	0.0130	0.0025	0.0048	0.0110
	Onetangi Stream	10	0.0025	0.0240	0.0025	0.0048	0.0115
Exotic	Riverhead Stream	11	0.0120	0.0580	0.0150	0.0200	0.0320
Reference	West Hoe Stream	12	0.0025	0.0060	0.0025	0.0025	0.0025
	Nukumea Stream	12	0.0025	0.0050	0.0025	0.0025	0.0025
	Cascades Stream (Waitākere)	11	0.0025	0.0060	0.0025	0.0025	0.0025
	Wairoa Tributary	12	0.0025	0.0060	0.0025	0.0025	0.0025

Table 6-15: Total oxidised nitrogen (mg NO_x-N/L) river data collected January to December 2018.

	Site	Count	Min	Max	25th%	Median	75th%
Urban	Botany Creek	11	0.580	1.600	0.720	0.860	1.250
	Ōtaki Creek	8	1.170	3.100	1.257	1.920	2.550
	Pakuranga Creek	11	0.038	0.810	0.290	0.350	0.470
	Oakley Creek	11	0.760	1.760	0.820	1.100	1.290
	Ōtara Creek (South)	11	0.590	2.300	1.000	1.200	1.520
	Oteha River	12	0.220	0.580	0.253	0.330	0.395
	Omaru Creek	11	0.250	1.790	0.540	0.920	1.350
	Puhinui Stream	12	0.013	0.890	0.203	0.415	0.785
	Lucas Creek	12	0.086	0.550	0.127	0.179	0.337
	Avondale Stream	11	0.280	0.540	0.370	0.420	0.490
	Ōtara Creek (East)	11	0.003	0.760	0.166	0.410	0.550
Rural & lifestyle	Waitangi Stream	12	1.370	4.500	1.830	2.400	3.675
	Whangamaire Stream	12	8.700	15.200	10.200	12.300	13.500
	Ngakoroa Stream	12	1.630	4.900	2.350	3.000	3.875
	Kumeu River	11	0.119	0.700	0.210	0.320	0.460
	Kaukapakapa River	11	0.023	0.450	0.106	0.186	0.340
	Waiwera Stream	11	0.025	0.280	0.041	0.139	0.194
	Papakura Stream (Lower)	12	0.018	1.210	0.040	0.295	0.825
	Papakura Stream (Upper)	12	0.020	1.070	0.065	0.340	0.847
	Makarau River	11	0.001	0.340	0.008	0.097	0.220
	Rangitopuni River	12	0.075	0.370	0.138	0.172	0.227
	Matakana River	12	0.001	0.115	0.008	0.011	0.056
	Wairoa River	12	0.009	1.010	0.143	0.415	0.705
	Mahurangi River (Warkworth)	12	0.030	0.280	0.071	0.176	0.207
	Okura Creek	12	0.110	0.290	0.174	0.198	0.240
	Hoteo River	12	0.131	0.694	0.207	0.334	0.506
	Mahurangi River (Forestry)	12	0.171	0.480	0.197	0.245	0.370
	Vaughan Stream	12	0.003	0.230	0.015	0.076	0.156
	Cascades Stream (Waiheke)	10	0.093	0.198	0.113	0.160	0.191
	Opanuku Stream	12	0.016	0.220	0.076	0.125	0.157
	Onetangi Stream	10	0.137	0.310	0.185	0.225	0.253
Exotic	Riverhead Stream	11	0.020	0.044	0.024	0.037	0.043
Reference	West Hoe Stream	12	0.003	0.013	0.003	0.004	0.006
	Nukumea Stream	12	0.003	0.015	0.005	0.006	0.010
	Cascades Stream (Waitākere)	11	0.002	0.038	0.009	0.013	0.029
	Wairoa Tributary	12	0.039	0.095	0.052	0.081	0.088

Table 6-16: Total nitrogen (mg N/L) river data collected January to December 2018.

	Site	Count	Min	Max	25th%	Median	75th%
Urban	Botany Creek	11	0.930	2.000	1.060	1.240	1.750
	Ōtaki Creek	8	1.450	3.500	1.662	2.290	3.200
	Pakuranga Creek	11	0.038	0.810	0.290	0.350	0.470
	Oakley Creek	11	1.010	2.700	1.190	1.250	1.560
	Ōtara Creek (South)	11	0.820	2.800	1.310	1.420	1.950
	Oteha River	12	0.420	0.920	0.563	0.650	0.762
	Omaru Creek	11	0.470	2.600	0.960	1.270	1.750
	Puhinui Stream	12	0.460	1.470	0.755	0.795	1.135
	Lucas Creek	12	0.290	1.000	0.315	0.515	0.618
	Avondale Stream	11	0.520	0.900	0.560	0.750	0.860
	Ōtara Creek (East)	11	0.330	1.210	0.450	0.860	1.070
Rural & lifestyle	Waitangi Stream	12	1.780	4.400	2.100	2.600	3.675
	Whangamaire Stream	12	7.500	16.000	11.925	12.850	14.350
	Ngakoroa Stream	12	1.990	4.600	2.425	3.000	3.600
	Kumeu River	11	0.570	1.730	0.580	0.740	0.870
	Kaukapakapa River	11	0.470	1.070	0.600	0.680	0.930
	Waiwera Stream	11	0.260	0.690	0.320	0.370	0.490
	Papakura Stream (Lower)	12	0.370	2.100	0.470	0.730	1.298
	Papakura Stream (Upper)	12	0.300	1.720	0.417	0.680	1.247
	Makarau River	11	0.220	0.730	0.270	0.350	0.560
	Rangitopuni River	12	0.490	1.050	0.515	0.680	0.900
	Matakana River	12	0.140	0.690	0.184	0.215	0.255
	Wairoa River	12	0.180	1.460	0.295	0.645	0.938
	Mahurangi River (Warkworth)	12	0.220	0.710	0.270	0.420	0.492
	Okura Creek	12	0.380	0.870	0.445	0.595	0.820
	Hoteo River	12	0.390	1.425	0.542	0.595	0.957
	Mahurangi River (Forestry)	12	0.330	0.670	0.360	0.385	0.435
	Vaughan Stream	12	0.270	0.800	0.320	0.410	0.630
	Cascades Stream (Waiheke)	10	0.220	0.540	0.240	0.345	0.470
	Opanuku Stream	12	0.141	0.640	0.200	0.260	0.362
	Onetangi Stream	10	0.300	0.560	0.345	0.405	0.497
Exotic	Riverhead Stream	11	0.161	0.540	0.189	0.290	0.500
Reference	West Hoe Stream	12	0.041	0.096	0.045	0.065	0.077
	Nukumea Stream	12	0.059	0.162	0.076	0.099	0.124
	Cascades Stream (Waitākere)	11	0.037	0.360	0.043	0.059	0.152
	Wairoa Tributary	12	0.080	0.181	0.113	0.133	0.144

Table 6-17: Dissolved reactive phosphorus (mg P/L) river data collected January to December 2018.

	Site	Count	Min	Max	25th%	Median	75th%
Urban	Botany Creek	11	0.002	0.013	0.002	0.006	0.007
	Ōtaki Creek	8	0.014	0.035	0.015	0.017	0.025
	Pakuranga Creek	11	0.038	0.810	0.290	0.350	0.470
	Oakley Creek	11	0.013	0.033	0.018	0.020	0.023
	Ōtara Creek (South)	11	0.002	0.013	0.004	0.006	0.009
	Oteha River	12	0.004	0.025	0.006	0.007	0.014
	Omaru Creek	11	0.007	0.041	0.014	0.018	0.025
	Puhinui Stream	12	0.002	0.014	0.006	0.008	0.013
	Lucas Creek	12	0.002	0.012	0.003	0.006	0.009
	Avondale Stream	11	0.002	0.011	0.002	0.005	0.006
	Ōtara Creek (East)	11	0.006	0.020	0.008	0.012	0.015
Rural & lifestyle	Waitangi Stream	12	0.002	0.013	0.002	0.004	0.008
	Whangamaire Stream	12	0.002	0.010	0.002	0.005	0.007
	Ngakoroa Stream	12	0.001	0.008	0.002	0.002	0.004
	Kumeu River	10	0.005	0.011	0.005	0.007	0.009
	Kaukapakapa River	10	0.011	0.029	0.014	0.016	0.024
	Waiwera Stream	10	0.002	0.010	0.006	0.007	0.009
	Papakura Stream (Lower)	12	0.006	0.037	0.012	0.019	0.024
	Papakura Stream (Upper)	12	0.011	0.039	0.012	0.019	0.027
	Makarau River	10	0.002	0.016	0.006	0.009	0.012
	Rangitopuni River	11	0.008	0.026	0.009	0.014	0.017
	Matakana River	12	0.002	0.013	0.005	0.007	0.010
	Wairoa River	12	0.002	0.014	0.005	0.007	0.010
	Mahurangi River (Warkworth)	12	0.002	0.014	0.006	0.007	0.011
	Okura Creek	12	0.005	0.018	0.007	0.011	0.014
	Hoteo River	12	0.007	0.033	0.012	0.016	0.027
	Mahurangi River (Forestry)	12	0.002	0.006	0.002	0.002	0.005
	Vaughan Stream	12	0.002	0.016	0.005	0.007	0.010
	Cascades Stream (Waiheke)	10	0.002	0.009	0.005	0.006	0.006
	Opanuku Stream	11	0.002	0.014	0.002	0.006	0.007
	Onetangi Stream	10	0.006	0.022	0.009	0.011	0.017
Exotic	Riverhead Stream	10	0.002	0.007	0.002	0.002	0.005
Reference	West Hoe Stream	12	0.002	0.005	0.002	0.002	0.004
	Nukumea Stream	12	0.002	0.004	0.002	0.002	0.002
	Cascades Stream (Waitākere)	10	0.005	0.017	0.010	0.012	0.013
	Wairoa Tributary	12	0.009	0.019	0.014	0.016	0.018

Table 6-18: Total phosphorus (mg P/L) river data collected January to December 2018.

	Site	Count	Min	Max	25th%	Median	75th%
Urban	Botany Creek	11	0.017	0.037	0.020	0.026	0.036
	Ōtaki Creek	8	0.045	0.093	0.054	0.071	0.090
	Pakuranga Creek	11	0.038	0.810	0.290	0.350	0.470
	Oakley Creek	11	0.026	0.078	0.044	0.055	0.057
	Ōtara Creek (South)	11	0.019	0.044	0.022	0.029	0.034
	Oteha River	12	0.031	0.068	0.037	0.049	0.063
	Omaru Creek	11	0.036	0.118	0.049	0.056	0.068
	Puhinui Stream	12	0.028	0.270	0.032	0.043	0.061
	Lucas Creek	12	0.015	0.066	0.022	0.028	0.041
	Avondale Stream	11	0.020	0.049	0.023	0.029	0.030
	Ōtara Creek (East)	11	0.026	0.199	0.047	0.064	0.078
Rural & lifestyle	Waitangi Stream	12	0.011	0.052	0.012	0.016	0.022
	Whangamaire Stream	12	0.009	0.049	0.012	0.014	0.021
	Ngakoroa Stream	12	0.006	0.037	0.014	0.018	0.020
	Kumeu River	11	0.033	0.152	0.037	0.044	0.055
	Kaukapakapa River	11	0.042	0.100	0.044	0.058	0.068
	Waiwera Stream	11	0.020	0.059	0.022	0.024	0.030
	Papakura Stream (Lower)	12	0.047	0.102	0.055	0.062	0.069
	Papakura Stream (Upper)	12	0.044	0.088	0.054	0.070	0.076
	Makarau River	11	0.018	0.071	0.026	0.027	0.034
	Rangitopuni River	12	0.034	0.093	0.038	0.052	0.066
	Matakana River	12	0.017	0.112	0.022	0.025	0.034
	Wairoa River	12	0.016	0.057	0.027	0.032	0.042
	Mahurangi River (Warkworth)	12	0.018	0.053	0.025	0.028	0.040
	Okura Creek	12	0.022	0.098	0.033	0.049	0.058
	Hoteo River	12	0.040	0.156	0.043	0.049	0.074
	Mahurangi River (Forestry)	12	0.012	0.046	0.016	0.019	0.023
	Vaughan Stream	12	0.025	0.082	0.027	0.038	0.055
	Cascades Stream (Waiheke)	10	0.020	0.042	0.022	0.026	0.036
	Opanuku Stream	12	0.009	0.048	0.011	0.020	0.028
	Onetangi Stream	10	0.027	0.055	0.032	0.042	0.051
Exotic	Riverhead Stream	11	0.008	0.040	0.009	0.015	0.033
Reference	West Hoe Stream	12	0.005	0.019	0.007	0.010	0.012
	Nukumea Stream	12	0.006	0.014	0.006	0.010	0.010
	Cascades Stream (Waitākere)	11	0.016	0.040	0.017	0.018	0.021
	Wairoa Tributary	12	0.019	0.042	0.022	0.026	0.032

Table 6-19: Soluble copper (µg/L) river data collected January to December 2018.

	Site	Count	Min	Max	25th%	Median	75th%
Urban	Botany Creek	11	1.10	3.70	1.30	1.50	1.70
	Ōtaki Creek	8	1.20	3.40	1.23	1.70	2.08
	Pakuranga Creek	11	0.04	0.81	0.29	0.35	0.47
	Oakley Creek	11	1.00	3.70	1.40	2.10	2.50
	Ōtara Creek (South)	11	0.80	2.10	1.10	1.40	1.40
	Oteha River	12	1.30	3.60	1.60	2.25	3.05
	Omaru Creek	11	1.40	5.20	1.70	2.30	3.00
	Puhinui Stream	12	0.90	2.90	1.15	1.50	1.98
	Lucas Creek	12	0.70	2.90	1.23	1.75	2.58
	Avondale Stream	11	1.20	4.10	1.70	2.30	2.50
	Ōtara Creek (East)	11	0.90	2.10	1.20	1.40	1.70
Rural & lifestyle	Waitangi Stream*	7	0.25	1.20	0.25	0.60	0.70
	Whangamaire Stream*	7	0.25	1.10	0.25	0.25	0.25
	Ngakoroa Stream*	7	0.25	0.80	0.25	0.60	0.70
	Kumeu River	11	0.70	3.40	0.80	1.30	1.80
	Kaukapakapa River*	6	0.60	1.60	0.68	0.90	1.53
	Waiwera Stream	11	0.25	1.60	0.50	0.60	0.90
	Papakura Stream (Lower)	12	0.60	2.10	0.85	1.10	1.38
	Papakura Stream (Upper)	12	0.25	1.70	0.60	0.80	1.08
	Makarau River	11	0.25	1.40	0.25	0.90	1.10
	Rangitopuni River*	7	0.70	1.80	0.70	1.00	1.60
	Matakana River	12	0.25	1.20	0.53	0.65	0.98
	Wairoa River	12	0.25	1.30	0.60	0.65	0.88
	Mahurangi River (Warkworth)	12	0.25	1.60	0.50	0.70	0.98
	Okura Creek	12	0.50	1.60	0.70	1.10	1.48
	Hoteo River	NA					
	Mahurangi River (Forestry)	12	0.25	0.70	0.25	0.55	0.60
	Vaughan Stream	12	0.25	1.80	0.63	0.95	1.30
	Cascades Stream (Waiheke)*	5	0.25	1.50	0.48	1.00	1.30
	Opanuku Stream*	7	0.25	1.40	0.25	0.90	1.30
	Onetangi Stream*	5	0.25	1.20	0.25	0.60	1.05
Exotic	Riverhead Stream	11	0.25	1.40	0.25	0.25	0.80
Reference	West Hoe Stream*	7	0.25	0.25	0.25	0.25	0.25
	Nukumea Stream	12	0.25	0.60	0.25	0.25	0.25
	Cascades Stream (Waitākere)*	6	0.25	1.70	0.25	0.80	1.33
	Wairoa Tributary*	7	0.25	0.25	0.25	0.25	0.25

**Sites where metals monitoring was initiated in June 2018.*

Table 6-20: Total copper (µg/L) river data collected January to December 2018.

	Site	Count	Min	Max	25th%	Median	75th%
Urban	Botany Creek	11	1.450	4.400	1.760	1.950	2.300
	Ōtaki Creek	8	1.540	5.100	1.947	2.450	3.000
	Pakuranga Creek	11	0.038	0.810	0.290	0.350	0.470
	Oakley Creek	11	1.290	5.500	2.000	2.600	3.400
	Ōtara Creek (South)	11	1.110	2.500	1.450	1.600	1.920
	Oteha River	12	1.330	5.100	1.970	2.900	4.425
	Omaru Creek	11	1.650	6.400	2.100	3.100	4.500
	Puhinui Stream	12	1.230	27.000	1.487	1.820	2.700
	Lucas Creek	12	0.760	4.500	1.343	2.100	3.375
	Avondale Stream	11	1.440	5.300	2.100	2.800	3.000
	Ōtara Creek (East)	11	1.050	3.000	1.730	2.200	2.500
Rural & lifestyle	Waitangi Stream*	7	0.265	1.360	0.560	0.660	0.800
	Whangamaire Stream*	7	0.265	1.950	0.265	0.265	0.590
	Ngakoroa Stream*	7	0.265	1.230	0.600	0.930	1.050
	Kumeu River	11	0.960	4.900	1.120	1.870	2.100
	Kaukapakapa River*	6	0.900	2.200	0.907	1.085	2.125
	Waiwera Stream	11	0.265	2.200	0.620	0.860	1.140
	Papakura Stream (Lower)	12	0.710	2.800	1.152	1.305	1.625
	Papakura Stream (Upper)	12	0.610	2.700	0.813	0.915	1.452
	Makarau River	11	0.265	2.100	0.560	1.040	1.630
	Rangitopuni River*	7	0.870	2.600	0.930	1.250	2.000
	Matakana River	12	0.580	2.600	0.670	0.860	1.237
	Wairoa River	12	0.600	1.800	0.773	1.040	1.440
	Mahurangi River (Warkworth)	12	0.265	1.920	0.575	0.990	1.270
	Okura Creek	12	0.650	3.100	0.855	1.245	1.925
	Hoteo River	NA					
	Mahurangi River (Forestry)	12	0.265	2.100	0.334	0.730	1.202
	Vaughan Stream	12	0.580	2.900	0.700	1.010	1.657
	Cascades Stream (Waiheke)*	5	0.560	3.400	0.795	1.360	2.690
	Opanuku Stream*	7	0.620	2.200	0.780	1.400	1.870
	Onetangi Stream*	5	0.610	1.510	0.630	0.910	1.310
Exotic	Riverhead Stream	11	0.265	1.840	0.265	0.710	0.950
Reference	West Hoe Stream*	7	0.265	0.265	0.265	0.265	0.265
	Nukumea Stream	12	0.265	1.260	0.265	0.265	0.583
	Cascades Stream (Waitākere)*	6	0.265	2.600	0.471	0.955	2.150
	Wairoa Tributary*	7	0.265	1.540	0.265	0.750	0.780

**Sites where metals monitoring was initiated in June 2018.*

Table 6-21: Soluble zinc (µg/L) river data collected January to December 2018.

	Site	Count	Min	Max	25th%	Median	75th%
Urban	Botany Creek	11	4.80	33.00	5.90	12.20	22.00
	Ōtaki Creek	8	12.70	54.00	17.93	28.00	38.25
	Pakuranga Creek	11	0.04	0.81	0.29	0.35	0.47
	Oakley Creek	11	4.30	17.30	7.80	9.70	14.70
	Ōtara Creek (South)	11	4.90	29.00	15.30	20.00	28.00
	Oteha River	12	21.00	50.00	26.00	30.50	43.50
	Omaru Creek	11	31.00	165.00	33.00	56.00	120.00
	Puhinui Stream	12	7.30	124.00	10.23	15.20	29.03
	Lucas Creek	12	1.80	5.70	2.88	3.85	4.68
	Avondale Stream	11	11.60	32.00	16.40	22.00	30.00
	Ōtara Creek (East)	11	1.20	4.30	1.60	2.20	3.40
Rural & lifestyle	Waitangi Stream*	7	0.50	1.30	0.50	0.50	0.50
	Whangamaire Stream*	7	0.50	2.50	0.50	0.50	0.50
	Ngakoroa Stream*	7	0.50	1.50	0.50	0.50	0.50
	Kumeu River	11	1.70	8.20	3.00	3.80	5.40
	Kaukapakapa River*	6	0.50	1.80	0.88	1.15	1.58
	Waiwera Stream	11	0.50	1.90	0.50	0.50	0.50
	Papakura Stream (Lower)	12	1.60	6.40	2.23	3.05	4.00
	Papakura Stream (Upper)	12	0.50	4.70	0.50	1.15	1.68
	Makarau River	11	0.50	3.50	0.50	0.50	0.50
	Rangitopuni River*	7	1.40	4.10	1.60	1.80	3.80
	Matakana River	12	0.50	3.40	0.50	0.50	1.70
	Wairoa River	12	0.50	1.40	0.50	0.50	0.50
	Mahurangi River (Warkworth)	12	0.50	4.10	1.23	1.60	2.65
	Okura Creek	12	0.50	3.40	1.13	1.35	2.18
	Hoteo River	NA					
	Mahurangi River (Forestry)	12	0.50	0.50	0.50	0.50	0.50
	Vaughan Stream	12	0.50	2.40	0.50	0.80	1.90
	Cascades Stream (Waiheke)*	5	0.50	1.40	0.50	0.50	0.95
	Opanuku Stream*	7	0.50	2.30	1.10	1.90	2.30
	Onetangi Stream*	6	0.00	2.10	1.05	1.85	2.03
Exotic	Riverhead Stream	11	5.70	24.00	7.10	12.00	18.20
Reference	West Hoe Stream*	7	0.50	1.10	0.50	0.50	0.50
	Nukumea Stream	12	0.50	1.10	0.50	0.50	0.50
	Cascades Stream (Waitākere)*	6	0.50	0.50	0.50	0.50	0.50
	Wairoa Tributary*	7	0.50	0.50	0.50	0.50	0.50

**Sites where metals monitoring was initiated in June 2018.*

Table 6-22: Total zinc (µg/L) river data collected January to December 2018.

	Site	Count	Min	Max	25th%	Median	75th%
Urban	Botany Creek	11	9.80	45.00	13.50	17.00	25.00
	Ōtaki Creek	8	19.50	69.00	29.25	32.00	45.00
	Pakuranga Creek	11	0.04	0.81	0.29	0.35	0.47
	Oakley Creek	11	5.90	27.00	11.70	15.50	23.00
	Ōtara Creek (South)	11	9.80	36.00	17.20	25.00	34.00
	Oteha River	12	24.00	64.00	34.00	43.50	58.50
	Omaru Creek	11	37.00	181.00	38.00	73.00	141.00
	Puhinui Stream	12	10.40	410.00	14.83	21.50	34.75
	Lucas Creek	12	3.50	15.20	4.35	5.20	9.33
	Avondale Stream	11	14.00	41.00	24.00	26.00	37.00
	Ōtara Creek (East)	11	2.80	11.60	5.10	6.20	8.70
Rural & lifestyle	Waitangi Stream*	7	0.55	1.80	0.55	0.55	1.20
	Whangamaire Stream*	7	0.55	3.90	0.55	1.30	2.40
	Ngakoroa Stream*	7	0.55	1.80	0.55	0.55	1.50
	Kumeu River	11	2.80	11.90	3.70	5.40	8.90
	Kaukapakapa River*	6	1.50	3.50	1.80	2.35	2.75
	Waiwera Stream	11	0.55	2.00	0.55	0.55	1.40
	Papakura Stream (Lower)	12	2.20	10.30	3.80	4.70	6.63
	Papakura Stream (Upper)	12	1.10	8.40	1.63	2.25	3.28
	Makarau River	11	0.55	5.30	0.55	0.55	1.90
	Rangitopuni River*	7	2.40	6.40	3.00	3.20	4.90
	Matakana River	12	0.55	5.10	0.55	0.98	2.93
	Wairoa River	12	0.55	4.00	0.55	1.25	2.50
	Mahurangi River (Warkworth)	12	1.30	6.20	2.23	3.10	4.28
	Okura Creek	12	1.80	12.70	2.15	3.10	4.65
	Hoteo River	NA					
	Mahurangi River (Forestry)	12	0.55	4.40	0.69	1.40	2.18
	Vaughan Stream	12	0.55	6.20	1.40	1.75	3.83
	Cascades Stream (Waiheke)*	5	0.55	3.10	0.55	1.50	2.55
	Opanuku Stream*	7	1.30	4.80	1.60	3.50	3.60
	Onetangi Stream*	5	2.00	3.40	2.20	2.70	3.35
Exotic	Riverhead Stream	11	7.60	28.00	8.40	12.70	19.40
Reference	West Hoe Stream*	7	0.55	1.60	0.55	1.10	1.40
	Nukumea Stream	12	0.55	2.10	0.55	0.83	1.58
	Cascades Stream (Waitākere)*	6	0.55	1.60	0.55	0.55	1.30
	Wairoa Tributary*	7	0.55	2.00	0.55	0.55	1.90

**Sites where metals monitoring was initiated in June 2018.*

Table 6-23: *E. coli* (cfu/100 mL) river data collected January to December 2018

	Site	Count	Min	Max	25th%	Median	75th%
Urban	Botany Creek	11	60	10000	900	1200	6000
	Ōtaki Creek	8	1400	32000	2250	7000	23500
	Pakuranga Creek	11	150	1900	380	700	1200
	Oakley Creek	11	290	8000	600	700	1600
	Ōtara Creek (South)	11	300	18000	700	1200	6000
	Oteha River	12	70	2700	355	850	1550
	Omaru Creek	11	90	4000	260	800	1300
	Puhinui Stream	12	60	9000	140	325	2200
	Lucas Creek	12	140	6000	215	345	1600
	Avondale Stream	11	260	6000	500	1100	2500
	Ōtara Creek (East)	11	200	3000	500	700	900
Rural & lifestyle	Waitangi Stream	12	100	1400	158	240	603
	Whangamaire Stream	12	290	2500	488	650	1275
	Ngakoroa Stream	12	50	500	88	150	335
	Kumeu River	11	200	28000	230	370	500
	Kaukapakapa River	11	27	3000	150	310	1200
	Waiwera Stream	11	80	2400	150	200	410
	Papakura Stream (Lower)	12	320	3000	700	950	1875
	Papakura Stream (Upper)	12	250	2100	500	700	1275
	Makarau River	11	80	6000	150	200	320
	Rangitopuni River	12	70	9000	148	220	750
	Matakana River	12	150	14000	183	235	390
	Wairoa River	12	100	1000	155	280	438
	Mahurangi River (Warkworth)	12	120	2800	158	250	1588
	Okura Creek	12	60	3900	190	275	2125
	Hoteo River	11	61	4352	99	135	823
	Mahurangi River (Forestry)	12	22	260	60	100	160
	Vaughan Stream	12	80	6000	213	285	1150
	Cascades Stream (Waiheke)	10	10	2200	35	125	228
	Opanuku Stream	12	160	4000	293	480	668
	Onetangi Stream	10	5	330	39	80	138
Exotic	Riverhead Stream	11	5	1100	30	80	140
Reference	West Hoe Stream	12	5	290	15	48	128
	Nukumea Stream	12	10	300	26	100	153
	Cascades Stream (Waitākere)	11	2	600	5	11	50
	Wairoa Tributary	12	5	3000	26	100	228

Appendix D Water quality index methodology

The water quality index (WQI) is used to simplify how we communicate the state or changes of complex water quality data by incorporating multiple factors (parameters) into a single number or score.

The water quality index used in this report is largely based on that developed by the Canadian Council of Ministers for the Environment (CCME) (2001) with some modifications to ensure the method aligns with the Auckland Council Marine WQI (Foley, 2018). This approach uses the water quality results of seven specific water quality parameters to produce five water quality indices, from which a water quality class is then assigned. It should be noted that temporal bias may exist in these samples due to the nature of the sampling runs and that exceedances or otherwise may occur based on the time of day a site is consistently sampled.

The water quality indices include:

- Scope – the percentage of parameters that failed to meet the guideline 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 guideline during the time period under consideration (the lower this index, the better).
- Magnitude – the amount by which failed tests exceeded the guideline (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.

The seven parameters included in the 2018 WQI calculation are dissolved oxygen (% saturation), pH, temperature, turbidity, ammoniacal nitrogen, total oxidised nitrogen and dissolved reactive phosphorus.

Baseline objective values, or guidelines, were derived from the 98th percentile value for each parameter (and the 2nd percentile value for parameters with upper and lower

bounds) from five Auckland Council reference sites over a static 10-year period from 2007-2016 (as per Foley, 2018):

- (Cascades Stream (Waitākere) (2)
- Nukumea Stream (13)
- Wairoa Tributary (31) and
- West Hoe Stream (35)

These reference sites represent the best achievable water quality in un-impacted environments in Auckland. The rest of the water quality data were tested against these thresholds to determine the relative deviation from natural conditions in Auckland. A water quality class is then assigned to each site based on the score and meaning outline in Table 6-24 below:

Table 6-24: Water quality index categories and scoring ranges used by Auckland Council (and recommended by CCME) for the period from 2007-2016.

Score range	WQI Class	Meaning
95-100	Excellent	Water quality is protected with a virtual absence of threat or impairment; conditions very close to natural or pristine levels. These index values can only be obtained if all measurements are within guidelines virtually all the time.
80-94	Good	Water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels or water quality guidelines.
65-79	Fair	Water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels or water quality guidelines.
45-64	Marginal	Water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels or water quality guidelines.
0-44	Poor	Water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels or water quality guidelines.

Appendix E NPS-FM and regional attributes current state band reporting by individual metric

Table 6-25: Auckland region current state bands (2014-2018) broken down per metric by attribute. Note the lowest band represents the overall band for each attribute. Bands in red denote national bottom line failure. I.D = Insufficient data to calculate grade.

Land Cover	Site Name	NPS-FM (2017) attributes								Proposed Auckland-specific attributes								
		NO_3-N		NH_4-N		*E. coli*				Copper		Zinc		DIN		DRP		Turbidity
		Med	95th	Med	Max	>540	>260	Med	95th	Med	95th	Med	95th	Med	95th	Med	95th	Med
Urban	Botany Creek	A	A	A	C	E	E	E	E	B	C	C	D	C	C	C	C	A
	Ōtaki Creek	B	B	B	C	E	E	E	E	B	C	C	D	C	D	D	D	B
	Pakuranga Creek	A	A	B	C	E	E	E	E	C	C	C	D	C	C	D	D	A
	Oakley Creek	B	B	A	A	E	E	E	E	B	C	C	C	D	B	D	C	A
	Ōtara Creek (South)	A	B	A	C	E	E	E	E	A	C	C	D	C	D	C	B	A
	Oteha River	A	A	A	C	E	E	E	E	C	C	C	D	B	B	C	B	C
	Omaru Creek	A	B	A	D	E	E	E	E	C	C	D	D	C	D	D	D	A
	Puhinui Stream	A	A	A	B	D	E	E	E	B	C	C	D	B	B	C	B	A
	Lucas Creek	A	A	A	B	E	E	E	E	B	C	B	B	B	B	C	A	B
	Avondale Stream	A	A	A	B	E	E	E	E	C	C	C	C	B	B	C	B	C
	Ōtara Creek (East)	A	A	A	A	E	E	E	E	A	C	B	C	B	B	C	B	B
Rural and lifestyle	Waitangi Stream	C	C	A	A	C	E	E	C	I.D	I.D	I.D	I.D	D	D	B	A	A
	Whangamaire Stream	D	D	A	B	E	E	E	E	I.D	I.D	I.D	I.D	D	D	C	A	C
	Ngakoroa Stream	C	C	A	A	B	B	D	B	I.D	I.D	I.D	I.D	D	D	B	A	D
	Kumeu River	A	A	A	A	E	E	E	E	B	C	B	A	B	B	C	B	B
	Kaukapakapa River	A	A	A	B	D	E	E	E	I.D	I.D	I.D	I.D	A	A	D	C	A
	Waiwera Stream	A	A	A	A	C	D	D	D	A	A	A	A	A	A	C	B	A
	Papakura Stream (Lower)	A	A	A	B	E	E	E	E	A	C	B	A	B	C	D	D	B

Land Cover	Site Name	NPS-FM (2017) attributes								Proposed Auckland-specific attributes								
		NO_3-N		NH_4-N		*E. coli*				Copper		Zinc		DIN		DRP		Turbidity
		Med	95th	Med	Max	>540	>260	Med	95th	Med	95th	Med	95th	Med	95th	Med	95th	Med
	Papakura Stream (Upper)	A	A	A	B	E	E	E	E	A	B	A	A	B	C	D	D	D
	Makarau River	A	A	A	A	C	D	D	D	A	A	A	A	A	A	C	A	A
	Rangitopuni River	A	A	A	A	C	D	D	D	I.D	I.D	I.D	I.D	A	A	C	B	A
	Matakana River	A	A	A	A	C	C	D	D	A	A	A	A	A	A	C	B	A
	Wairoa River	A	A	A	A	C	D	D	D	A	A	A	A	B	B	C	B	B
	Mahurangi River (Warkworth)	A	A	A	B	D	C	D	D	A	A	A	A	A	A	C	B	A
	Okura Creek	A	A	A	B	E	E	E	E	A	B	A	A	A	B	C	D	D
	Hoteo River	A	A	A	B	C	B	A	D	I.D	I.D	I.D	I.D	B	B	C	C	A
	Mahurangi River (Forestry)	A	A	A	A	C	B	A	C	A	A	A	A	A	A	B	A	B
	Vaughan Stream	A	A	A	A	E	E	E	E	A	B	A	A	A	A	C	B	B
	Cascades Stream (Waiheke)	A	A	A	A	C	A	A	D	I.D	I.D	I.D	I.D	A	A	C	B	C
	Opanuku Stream	A	A	A	A	E	E	E	E	I.D	I.D	I.D	I.D	A	A	C	A	A
	Onetangi Stream	A	A	A	A	C	A	A	B	I.D	I.D	I.D	I.D	A	A	D	C	C
Exotic forest	Riverhead Stream	A	A	A	A	B	A	A	B	A	A	B	C	A	A	B	A	B
Reference Sites	West Hoe Stream	A	A	A	A	B	A	A	B	I.D	I.D	I.D	I.D	A	A	B	A	A
	Nukumea Stream	A	A	A	A	A	A	A	B	A	A	A	A	A	A	B	A	A
	Cascades Stream (Waitākere)	A	A	A	A	A	A	A	A	I.D	I.D	I.D	I.D	A	A	D	B	B
	Wairoa tributary	A	A	A	A	B	A	A	B	I.D	I.D	I.D	I.D	A	A	D	C	B

Find out more: phone 09 301 0101, email rimu@aucklandcouncil.govt.nz or visit aucklandcouncil.govt.nz **and knowledgeauckland.org.nz**

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