River Water Quality in Tāmaki Makaurau / Auckland
2019 Annual Reporting and National Policy Statement for Freshwater Management Current State Assessment

R Ingley and J Groom

February 2021

Technical Report 2021/11

Research and Evaluation Unit | RIMU

Auckland Council
Te Kaunihera o Tāmaki Makaurau

River water quality in Tāmaki Makaurau / Auckland 2019 annual reporting and National Policy Statement for Freshwater Management current state assessment

February 2021 Technical Report 2021/11

R Ingley

J Groom

Research and Evaluation Unit (RIMU)

Auckland Council
Technical Report 2021/11

ISSN 2230-4525 (Print)
ISSN 2230-4533 (Online)

ISBN 978-1-99-100208-2 (Print)
ISBN 978-1-99-100209-9 (PDF)

This report has been peer reviewed by the Peer Review Panel.
Review completed on 5 February 2021 Reviewed by two reviewers
Approved for Auckland Council publication by: Name: Eva McLaren Position: Manager, Research and Evaluation (RIMU)
Name: Jonathan Benge Position: Manager, Water Quality (RIMU)
Date: 5 February 2021

Recommended citation
Ingley, R. and J. Groom (2021). River water quality in Tāmaki Makaurau / Auckland 2019 annual reporting and National Policy Statement for Freshwater Management current state assessment. Auckland Council technical report, TR2021/11

Cover photograph credit
Cascade Stream (Waiheke) photograph by Sheldon Benito

Executive summary

Freshwater environments, including our flowing rivers and streams, wetlands and lakes, are valued by the people of Tāmaki Makaurau / 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).

River water quality is monitored monthly at 36 streams across the Auckland region using a range of physical, chemical, and microbiological variables or attributes, that can be affected by land use activities, point and diffuse source discharges, and land and instream erosion.

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 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 tend to have poor water quality and are affected by the full spectrum of contaminants, while rivers in rural areas were most commonly affected by elevated nitrogen, water temperature, and turbidity. As expected, rivers fed by catchments with a high proportion of native forest cover generally have good water quality.

The current state of river water quality was assessed in relation to the national objectives framework compulsory attributes under the National Policy Statement for Freshwater Management (NPS-FM) 2020 which came into effect on 3 of September 2020, and proposed regional objectives for metal toxicity.

At high concentrations, nitrate and ammonia can be toxic to aquatic fauna. For most of the region, little or no toxicity risk is expected, even for the most sensitive instream species. However, rural streams within the Franklin area failed the national bottom line for nitrate toxicity, and several urban streams failed the national bottom line for ammonia toxicity. Urban streams were also at risk of toxicity effects from zinc contamination. Over a third of our monitored streams were found to have visual clarity levels (measured as turbidity) where moderate to high impacts may be expected for instream fauna, particularly sensitive fish species. Only one stream failed the national bottom line for water clarity.

Faecal contamination of rivers, as indicated by *Escherichia coli,* is a widespread issue across Auckland. The majority of rural and urban monitored river sites were in the E band, or poorest condition under NPS-FM 2020 criteria for *E. coli*. While this has implications for human contact with rivers and streams, this assessment is **not** in relation to identified primary contact sites or the bathing season.

Table of contents

List of figures

List of tables

1.0 Introduction

Auckland's freshwater environments are valued by the people of Auckland. 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 aesthetics, human use, and health of our rivers are influenced by their water quality. River water quality is monitored monthly at 36 streams across the Auckland region using a range of physical, chemical, and microbiological variables or attributes, that can be affected by land use activities, point and diffuse source discharges, and land and instream erosion.

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 Great Barrier Island.

The purpose of this report is to communicate the state of river water quality within the Auckland region for the 2019 calendar year.

This report outlines the following:

- A summary of the variability of individual water quality parameters within and between sites in 2019.
- 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).
- A comparison of relevant water quality parameters against the National Objectives Framework (NOF) river attributes set out in the National Policy

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

Statement for Freshwater Management (NPS-FM 2020), as an assessment of compulsory ecosystem health (water quality) and human health values.

This information 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). This report 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.

1.1 Purpose and objectives

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.
- 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 river 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 river quality issues and their subsequent management.

1.2 Supporting reports

All related reports (past and present) are available on Auckland Council's Knowledge Auckland website: www.knowledgeauckland.org.nz.

Further enquiries or data requests in relation to this or any other reports can be directed to environmentaldata@aucklandcouncil.govt.nz.

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, 2019.

Site name	NZTM X	NZTM Y	Year started	REC Class	Stream order (REC)	Catchment area (ha)
Avondale Stream	1750600	5912264	2012	WW_Low_SS	3	339
Cascades Stream (Waitakere)	1735628	5916378	1986	WW_Low_VA	3	1388
Cascades Stream (Waiheke)	1785942	5923254	2013	WD_Low_HS	1	64
Hoteo River	1735254	5972546	1986	WW_Low_SS	5	26917
Kaukapakapa River	1735833	5944978	2009	WW_Low_SS	1	6157
Kumeu River	1739252	5928781	1993	WW_Low_SS	4	4566
Lucas Creek	1751468	5934510	1993	WD_Low_SS	3	616
Mahurangi River (Forestry)	1747750	5965035	1993	WW_Low_SS	2	490
Mahurangi River (Warkworth)	1748864	5970457	1993	WW_Low_SS	4	4844
Makarau River	1736150	5953126	2009	WW_Low_SS	4	4834
Matakana River	1753500	5976481	1986	WW_Low_SS	4	1385
Ngakoroa Stream	1775164	5881624	1993	WW_Low_VA	3	466
Nukumea Stream	1749411	5951400	2012	WW_Low_SS	2	99
Oakley Creek	1751963	5917636	1994	WW_Low_SS	3	1129
Okura Creek	1751405	5938716	2003	WW_Low_SS	3	553
Omaru Creek	1766268	5916749	2009	WD_Low_SS	2	515
Onetangi Stream	1786243	5926204	2013	WD_Low_HS	2	68
Opanuku Stream	1742086	5915581	1986	WW_Low_SS	3	1566
Otaki Creek	1764306	5907216	1992	WD_Low_SS	2	117
Ōtara Creek (South)	1767422	5907535	1985	WD_Low_VA	3	880
Ōtara Creek (East)	1768335	5908376	1992	WD_Low_SS	3	1828
Oteha River	1751325	5933519	1986	WD_Low_SS	3	1221
Botany Creek	1770686	5913036	1992	WD_Low_SS	3	665
Pakuranga Creek	1769473	5910813	1992	WD_Low_VA	2	216
Papakura Stream (Upper)	1774247	5902648	2012	WW_Low_HS	4	2324
Papakura Stream (Lower)	1771240	5900290	1993	WW_Low_HS	4	4716
Puhinui Stream	1766440	5904295	1994	WD_Low_SS	3	1304
Rangitopuni River	1744450	5932301	1986	WW_Low_SS	5	8366
Riverhead Stream	1737125	5933216	2009	WW_Low_SS	2	410
Vaughan Stream	1755414	5938729	2001	WD_Low_SS	2	239
Wairoa Tributary	1786700	5892817	2009	WW_Low_HS	2	227
Wairoa River	1782682	5901720	1986	WW_Low_HS	5	14885
Waitangi Stream	1754343	5878534	2009	WW_Low_VA	3	1897
Waiwera Stream	1748628	5953665	1986	WW_Low_SS	4	3023
West Hoe Stream	1748314	5950610	2002	WW_Low_SS	2	53
Whangamaire Stream	1763578	5884625	2009	WW_Low_VA	2	814

*WWL = Warm Wet Climate, Low Elevation; WDL = Warm Dry Climate, Low Elevation; WWH = Warm Wet Climate, Hill

Figure 2-1: Location of the 36 river water quality sites monitored in 2019.

(Area shaded in red shows the extent of urban area in 2019 (Hoffman, 2019)

2.2 Catchment land cover

A geospatial assessment of land cover changes over time was carried out for the specific catchment area upstream of each site using the New Zealand Land Cover Database V5.0 (Manaaki Whenua – Landcare Research) (LCDB 5). Land cover classes are a proxy for a wide range of activities or land management practices that ultimately influence water quality (Larned et al., 2019). Land cover in the upstream catchment has been shown to explain more variation in stream contaminant concentrations than land cover in the riparian zone (Larned et al., 2019).

The upstream catchment areas were defined using natural drainage topography and the existing Auckland Council permanent streams network layer.

Catchments upstream of the sites in the river water quality monitoring programme included a range of different land cover types. Detailed land cover types defined by the LCDB 5 were further aggregated into broad level categories (Appendix B). The proportion of land cover type within the upstream catchment of each monitoring site is outlined in Figure 2-2.

The dominant land cover type for each site's upstream catchment was assigned based on the broad land cover categories as of summer 2018/2019 following the approach of Snelder & Biggs 2002 (as applied in Larned et al., 2018). The dominant land cover type is described as 'urban' when urban cover exceeds 15 per cent, and 'rural' when rural cover exceeds 25 per cent. If both urban and rural land cover exceed these thresholds, then 'urban' is considered the dominant land cover. These definitions take into account the disproportionate influence that these land cover categories have on river water quality. If neither of these thresholds are exceeded, then the dominant land cover category is defined by the greatest percentage of land cover type.

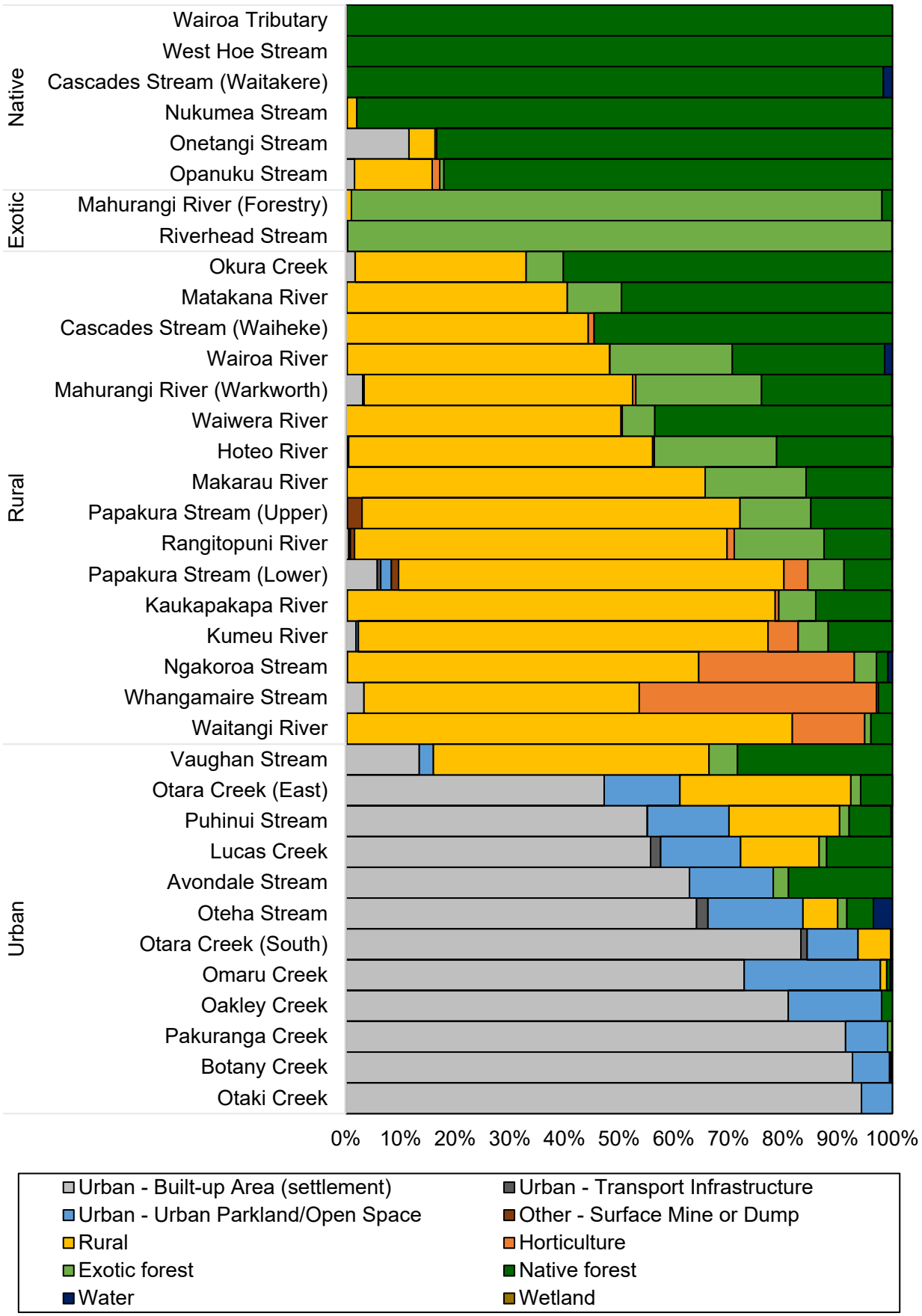


Figure 2-2: Summary of land cover in upstream catchments at 2018/2019 (LCDB5).

2.3 Data collection

The 36 sites are grouped into five runs 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 Appendix A. 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. River water samples were analysed by RJ Hills Laboratories Ltd (Hills), an IANZ accredited laboratory.

The NIWA Hoteo River and Rangitopuni River sites are monitored for the same parameters except for salinity, suspended solids, and copper and zinc. 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. Monitoring at Rangitopuni River is to be discontinued by NIWA and this site has also been monitored by Auckland Council from July 2016. Results of the annual data collected by both NIWA and Auckland Council for 2019, and water quality index scores are presented here, however NPS-FM grading was undertaken for NIWA collected data only as this grading requires a minimum of five years of data.

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. Updated National Environmental Monitoring Standards (NEMS) were released in March 2019 and quality assurance standards are being aligned to NEMS for data collected from January 2020.

The water quality data is stored in Auckland Council's water quality archiving database (KiWQM). The data for the Hoteo River and Rangitopuni River (NIWA) 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.

On some sampling occasions Ōtaki Creek was tidally influenced (as evidenced by high salinity concentrations not consistent with a freshwater environment). As such, on sampling occasions where salinity was greater than 0.5 ppt, it was assumed to be saline influenced. As a consequence of this, all data from the Ōtaki Creek site for two occasions in 2019 (January and October) were removed and not used for analysis.

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.

Values that were less than the detection limit for any water quality parameter are referred to as 'left censored' values. Censored values were replaced by imputed values generated using ROS for the purposes of calculating the five-year state statistics and presentation of the annual data in the form of boxplots. Note that for any site that had greater than 50 per cent of censored data, the annual data is not presented in subsequent boxplots (Larned et al., 2018). The ROS procedure produces estimated values for the censored data that are consistent with the distribution of the uncensored values, and it can accommodate multiple censoring limits (Regression on Order Statistics; Helsel 2012).

For all water quality index calculations, 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, 2006). 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). This will be possible in future reports.

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 2019 calendar year. Basic descriptive statistics are presented as box plots which show variation in the data. Box plots were produced using the software package R package, 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. Outlier values are shown as dots above or below the whiskers. Summary statistics are also provided in supplementary data files.

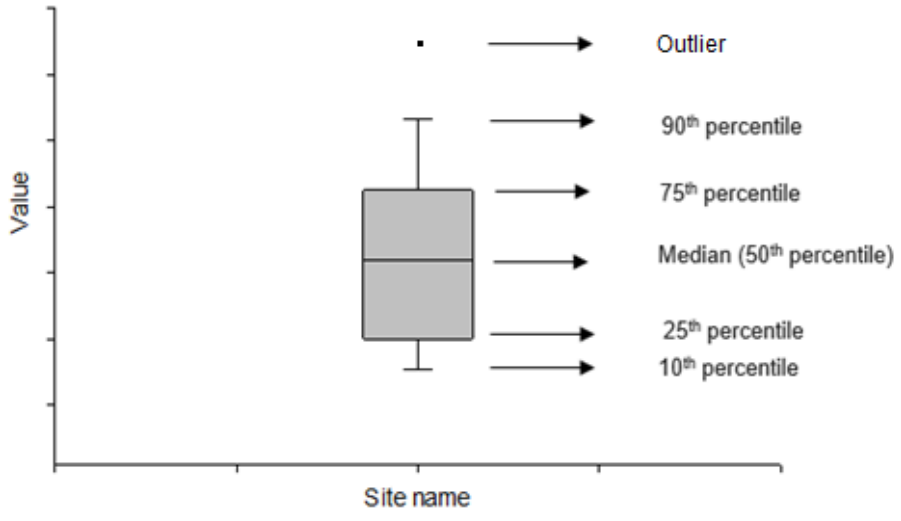


Figure 2-3: The different statistical measures shown within a box plot in this report.

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). The third – level REC class for each site, 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 C for reference.

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 2020).

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 2-2. 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).

Table 2-2: 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.

Score range	WQI Class	Expected narrative outcome
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.

Water quality index guidelines were derived from data observed at four reference sites that represent the best achievable water quality in the Auckland region. 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 2-3). The reference sites were Cascades Stream (Waitākere), Nukumea Stream, Wairoa Tributary and West Hoe Stream.

Rolling three-year monthly median values were used to calculate the 2019 water quality index scores i.e. 2017 to 2019 (Foley, 2018, Appendix D).

Table 2-3: 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
Temperature	17.65	
Nitrate + nitrite nitrogen (mg/L)	0.079	
Ammoniacal nitrogen (mg/L)	0.043	
Turbidity (NTU)	14.0	
Dissolved reactive phosphorus (mg/L)	0.042	

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

The National Policy Statement for Freshwater Management 2020 (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 (MfE, 2020).

The National Objectives Framework (NOF) within the NPS-FM was developed to support councils to set effective freshwater objectives, limits and/or targets. River and stream monitoring information is required in both the objective setting process (to communicate/evidence NPS-FM baseline water quality state (as at 2017) or some more recent state (utilising the most recent data available) and via ongoing assessment of state and to monitor progress towards these river management objectives through time. Councils need to:

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

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 2-4). The '*National Bottom Line'* refers to the minimum state for each attribute that councils must meet or work towards meeting over time (Table 2-5).

The NOF nitrate toxicity assessment is reported here using the proxy total oxidised nitrogen (nitrate + nitrite nitrogen). This assumes the nitrite fraction is almost always a negligible proportion of the total oxidised nitrogen.

The NOF suspended fine sediment guidelines are based on visual clarity and differ between suspended sediment river classes. Sediment classes are based on the third tier of the REC classes. REC classes are shown in Table 2-1. All monitored streams within Auckland fall into suspended sediment classes one and two and most commonly within class two. The NOF suspended fine sediment attribute allows for turbidity measurements to be converted to visual clarity for assessment. This was undertaken with reference to the technical memo prepared by NIWA for the Ministry for the Environment which identified a national regression relationship between site median visual clarity and site median turbidity (Franklin et al., 2020; Franklin et al., 2019). Median turbidity values were natural log transformed and the national regression relationship equation was applied and then transformed via the exponential function as the inverse of the natural logarithm.

National regression equation $$\ln(\mathrm{CLAR}) = 1.21 - 0.72 \ln(\mathrm{TURB})$$

At this time, it is not possible to derive NOF bands for dissolved oxygen from the discrete monthly monitoring undertaken.

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.

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 2-6).

The **2019 current state** is based on data for the five-year period 2015-2019 (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[2]. Current state was determined based on the calculation of the relevant statistical measures, ensuring a minimum of 90 per cent of samples across all site per parameter combinations were required for analysis i.e. a minimum of 54 samples within the five year assessment period rather than extending the period of assessment. Statistics were then compared to the relevant NOF or proposed regional attribute bands.

Table 2-4: NPS-FM National Objectives Framework 2020 attribute bands.
(Red line depicts the national bottom line (NBL) for each attribute, red shading depicts bands failing the NBL)

NOF River Attribute	Ammonia (Ecosystem Health – toxicity)		Nitrate (Ecosystem Health – toxicity)		Suspended fine sediment (Ecosystem Health)	
Metric	**Annual Median**	**Annual Maximum**	**Annual Median**	**Annual 95th %ile**	**Median Class 1**	**Median Class 2**
Unit	**mg NH_4-N/L pH adjusted**		**mg NO_3-N/L**		**Visual clarity (m)**	
A	≤ 0.03	≤ 0.05	≤ 1.0	≤ 1.5	≥ 1.78	≥ 0.93
B	> 0.03 and ≤0.24	> 0.05 and ≤ 0.40	> 1.0 and ≤ 2.4	> 1.5 and ≤ 3.5	< 1.78 and ≥1.55	< 0.93 and ≥0.76
C	> 0.24 and ≤1.30	> 0.40 and ≤2.20	> 2.4 and ≤ 6.9	> 3.5 and ≤ 9.8	< 1.55 and >1.34	< 0.76 and >0.61
D	> 1.30	> 2.20	> 6.9	> 9.8	< 1.34	< 0.61

NOF River Attribute	*Escherichia coli* (Human Contact)			
Metric	**% > 540**	**% > 260**	**Median**	**95th %ile**
Unit	**cfu/100mL**			
A	< 5%	≤ 20%	≤ 130	≤ 540
B	5-10%	20-30%	≤ 130	≤ 1000
C	10-20%	20-34%	≤ 130	≤ 1200
D	20-30%	> 34%	> 130	≤ 1200
E	> 30%	> 50%	> 260	> 1200

[2] '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 2-5: NPS-FM (2020) Action Plan Attribute Bands.

NOF River Attribute	DRP	
Metric	**Median**	**95th %ile**
Unit	**mg/L**	
A	≤ 0.006	≤ 0.021
B	> 0.006 and ≤ 0.01	> 0.021 and ≤0.030
C	>0.01 and ≤0.018	> 0.030 and ≤0.054
D	> 0.018	> 0.054

Table 2-6: Proposed Auckland Attribute Bands for dissolved metal contaminants (Gadd et al., 2019).

NOF River Attribute	Soluble Copper		Soluble Zinc	
Metric	**Annual Median**	**Annual 95th %ile***	**Annual Median**	**Annual 95th %ile***
Unit	**mg/L**		**mg/L**	
A	≤ 0.001	≤ 0.0014	≤ 0.0024	≤ 0.008
B	>0.001 and ≤ 0.0014	>0.0014 and ≤ 0.0018	>0.0024 and ≤ 0.008	>0.008 and ≤ 0.015
C	>0.0014 and ≤ 0.0025	>0.0018 and ≤ 0.0043	>0.008 and ≤ 0.031	>0.015 and ≤ 0.042
D	> 0.0025	> 0.0043	> 0.031	> 0.042

3.0 Results

The percentage of catchment area in urban or pastoral land use has been found to be consistently, positively correlated with contaminant concentrations in freshwater rivers/streams and negatively correlated with ecological health indicators (Snelder et al., 2017; Larned et al., 2019; Gadd et al., 2020). All results are consequently presented divided into dominant land cover categories.

3.1 2019 annual summary

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).

The range of values recorded for each parameter at each site during 2019 were similar to what has been reported for previous years (see Figure 3-1 to Figure 3-8 and supplementary data).

Several anomalous values were recorded in January and February 2019 including:

- Elevated total nitrogen in Ōtara Creek (East) in January (3.6 mg/L), more than double the 98th percentile recorded at this site over the preceding 10 years.
- Elevated total phosphorus at Ngakoroa Stream in February (0.151 mg/L) more than double the 98th percentile recorded at this site over the preceding 10 years.
- Elevated ammoniacal N at Otaki Creek in February and November with both instances more than double the 98th percentile at this site over the preceding 10 years.
- High pH values (>9 pH) recorded in Botany Creek (urban) in February and Hoteo River (rural) in April.

A sewage discharge was observed at Botany Creek in December (S. Benito *pers. comm*.) resulting in extreme outlier values in ammoniacal N, total nitrogen, dissolved reactive phosphorus, total phosphorus, soluble copper and total copper. These values are not shown in subsequent boxplots but are recorded as maximum values in the supplementary data tables.

High concentrations of total oxidised nitrogen (and total nitrogen) were observed at Mahurangi River (Forestry) in 2019 from May to September with the annual median concentration of total oxidised nitrogen more than twice the median value over the past 10 years as well as maximum concentrations more than three times greater than the long term 98th percentile.

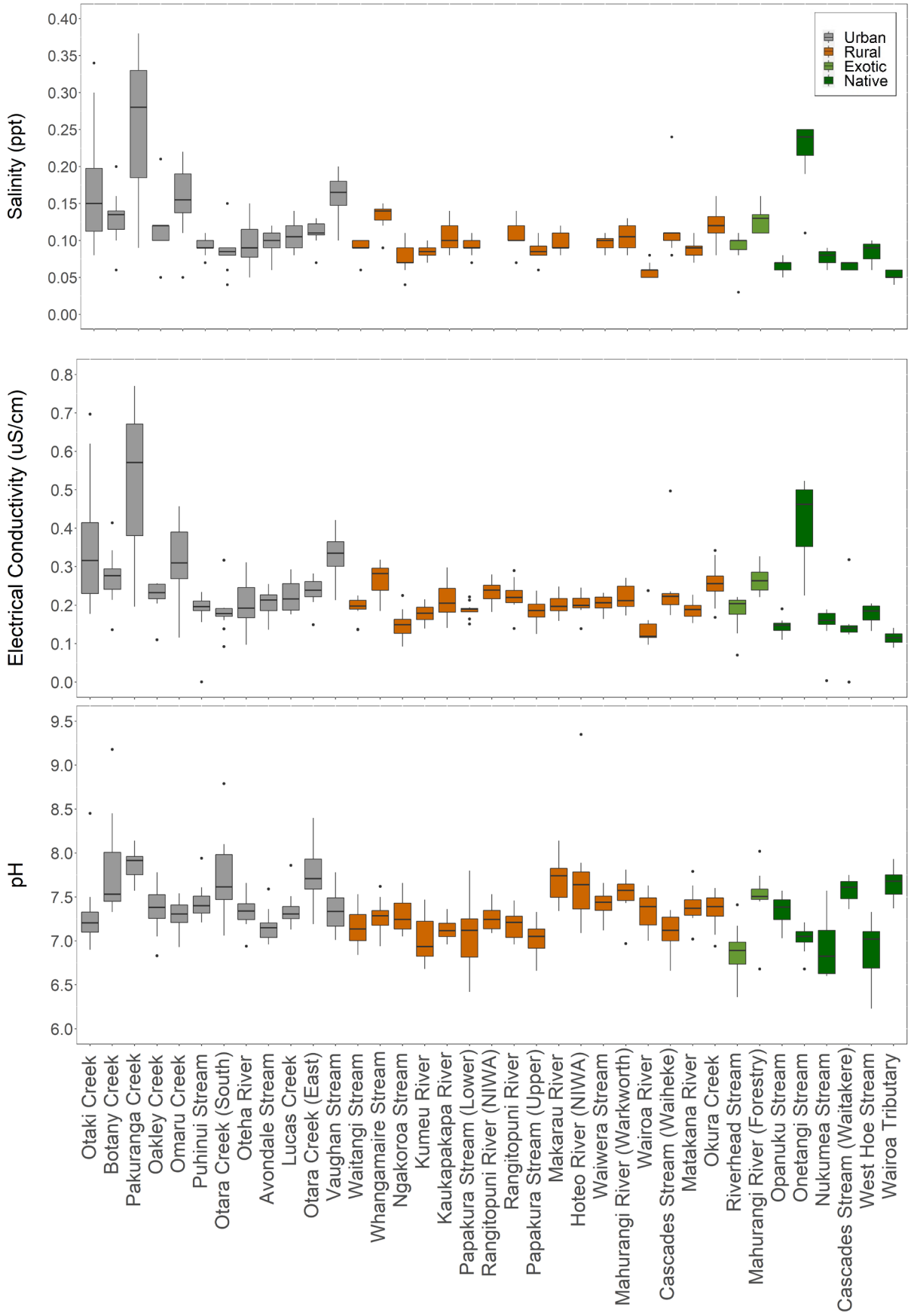


Figure 3-1: Variation in salinity, (ppt) electrical conductivity (µS/cm) salinity (ppt), and pH for river quality data collected from January to December 2019.

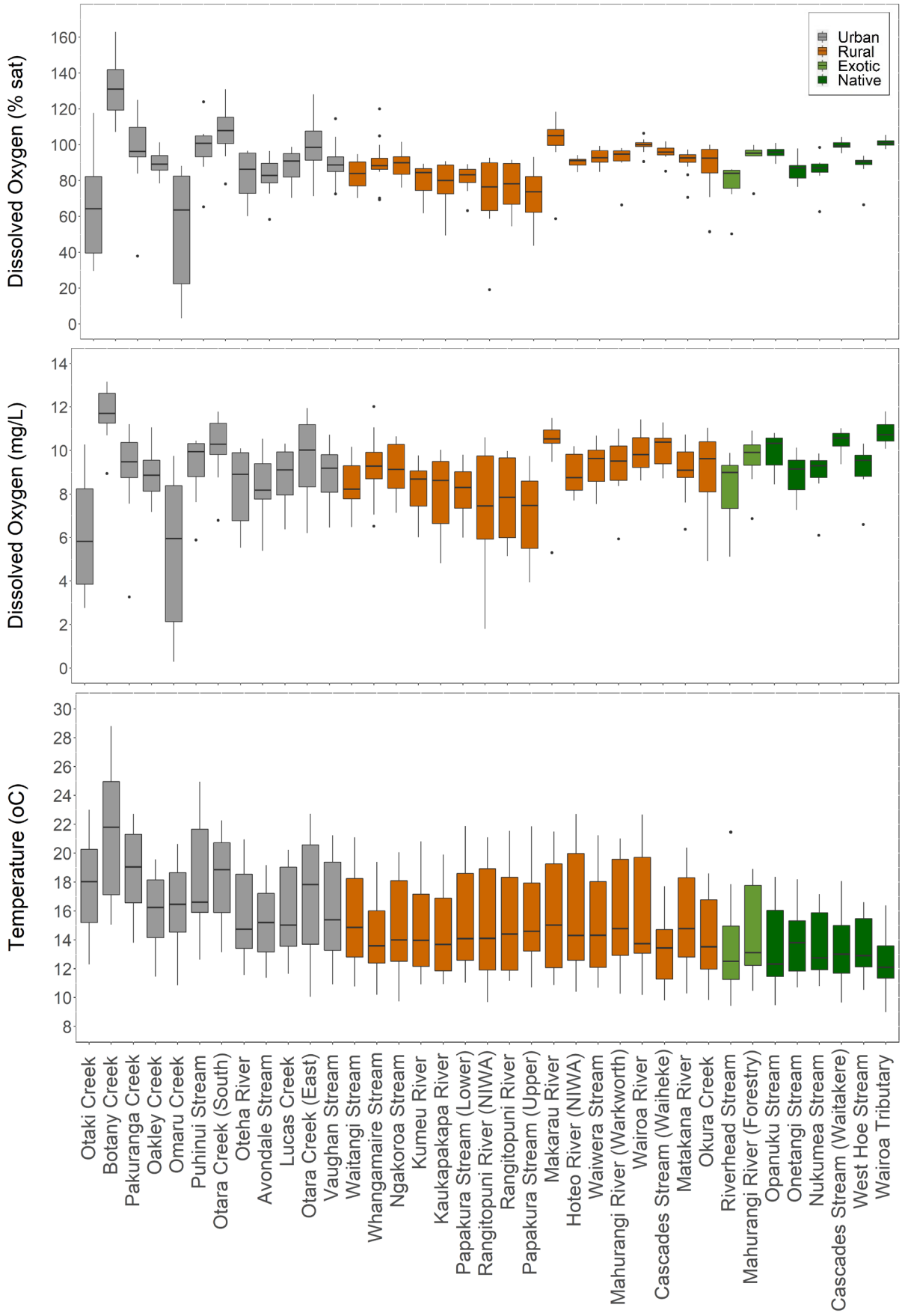


Figure 3-2: Variation in dissolved oxygen as % saturation and concentration (mg/L) and temperature (°C) for river water quality data collected from January to December 2019.

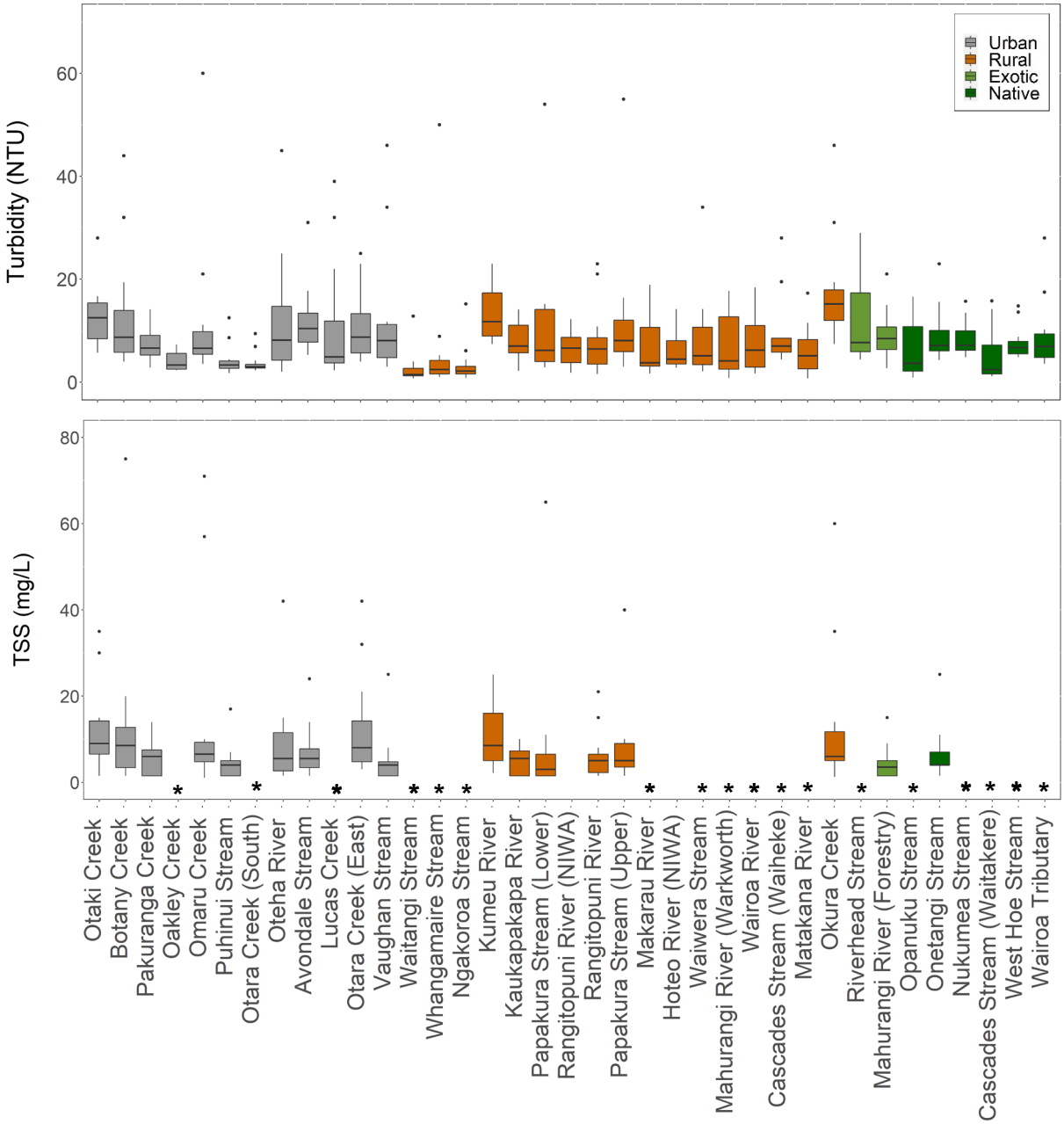


Figure 3-3: Variation in turbidity (NTU) and total suspended solids (mg/L) for river water quality data collected from January to December 2019.[3]

* = >50 per cent of values below detection limit

Three outlier values >60 NTU are not displayed including, Hoteo River (123 NTU), Rangitopuni River (92 NTU), and Okura Creek (75 NTU). These three outliers were recorded in September coinciding with high rainfall.

TSS is not assessed by NIWA for Rangitopuni River or Hoteo River.

[3]Note that TSS values > 20 mg/L were observed at Cascades Stream (Waitakere), Ngakoroa Stream and Whangamaire Stream in August, and over 70 mg/L in March in Whangamaire Stream with evidence of historic flooding at the time of sampling however these are not displayed as the majority of the time levels were below the detection limit (< 3 mg/L).

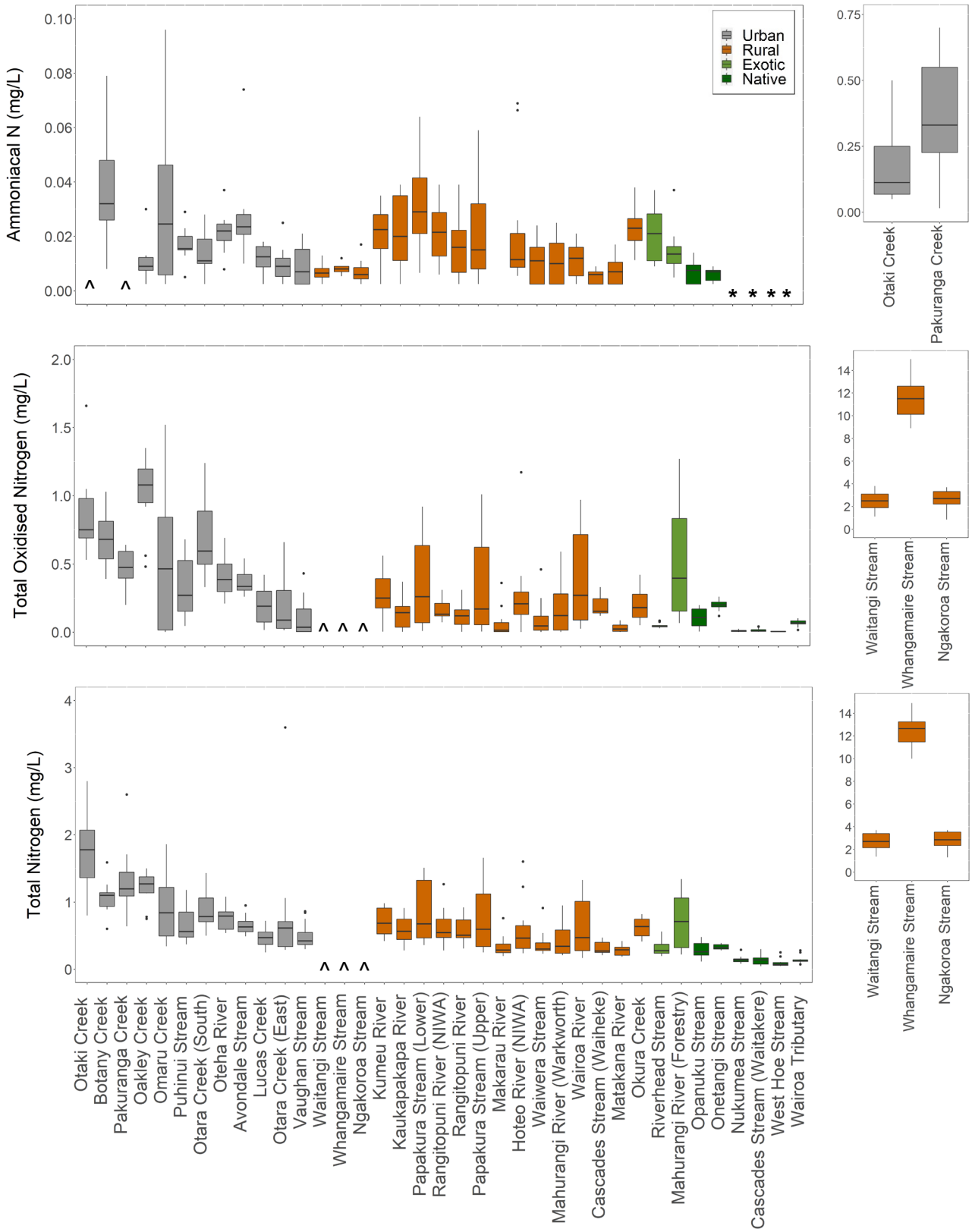


Figure 3-4: Variation in ammoniacal N, total oxidised nitrogen, and total nitrogen for river water quality data collected from January to December 2019.

^ = see inset

* = >50 per cent of values below detection limit

Six outlier values for ammoniacal N >0.1 mg/L are not displayed. See maximum values for Puhinui Stream, Ōtara Creek (East), Oteha River, Papakura Stream Upper and Lower, and Botany Creek in supplementary data tables.
One outlier value for total oxidised nitrogen >2 mg/L is not displayed. See maximum values for Otaki Creek.
One outlier value for total nitrogen is not displayed. See maximum values for Botany Creek.

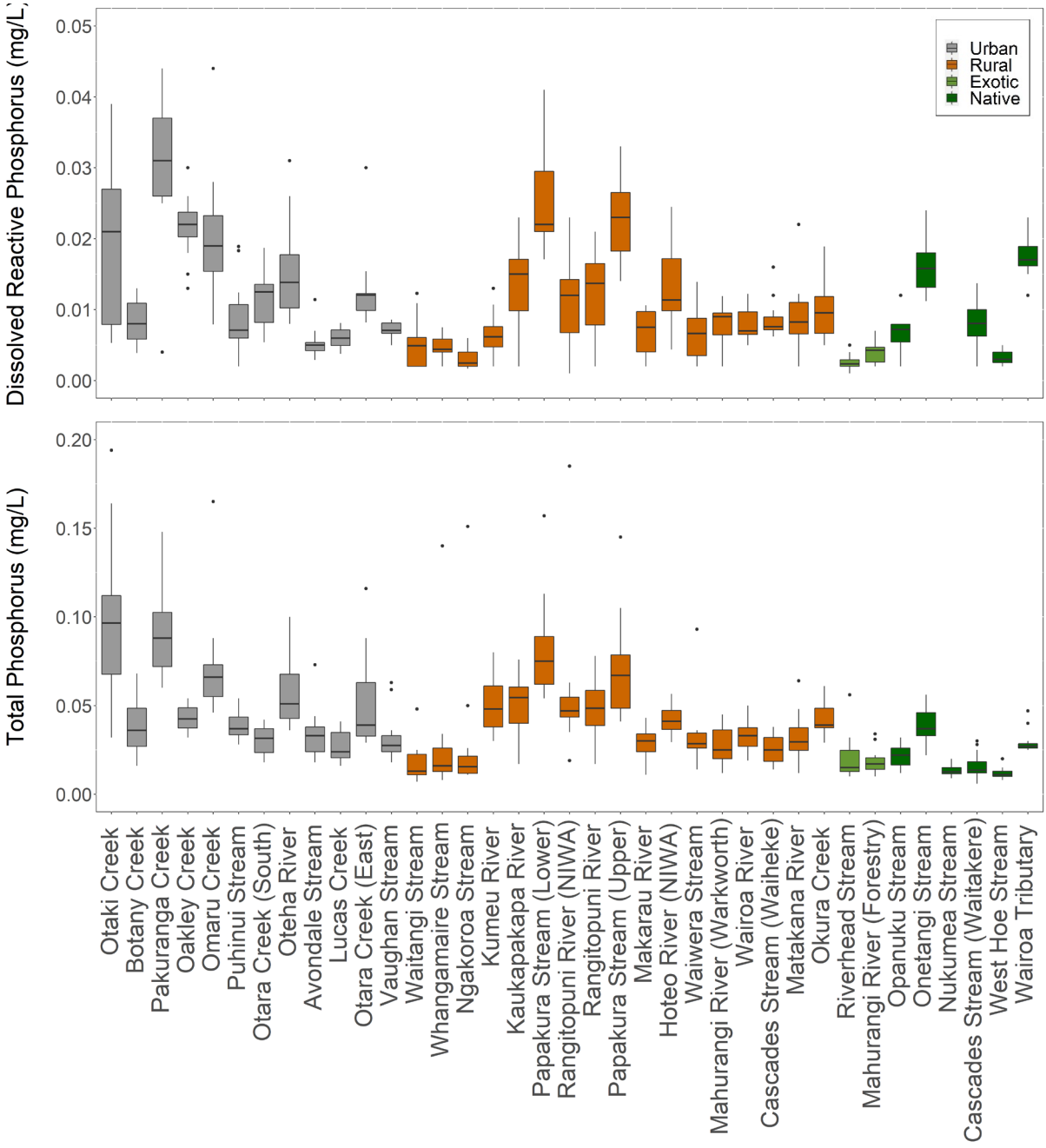


Figure 3-5: Variation in dissolved reactive phosphorus (mg/L) and total phosphorus (mg/L) for river water quality data collected from January to December 2019.

Three outlier values for dissolved reactive phosphorus are not displayed. See maximum values for Botany Creek, Pakuranga Creek, and Papakura Stream (Lower) in supplementary data tables.

Four outlier values for total phosphorus are not displayed. See maximum values for Botany Creek, Pakuranga Creek, Omaru Creek, and Hoteo River in supplementary data tables.

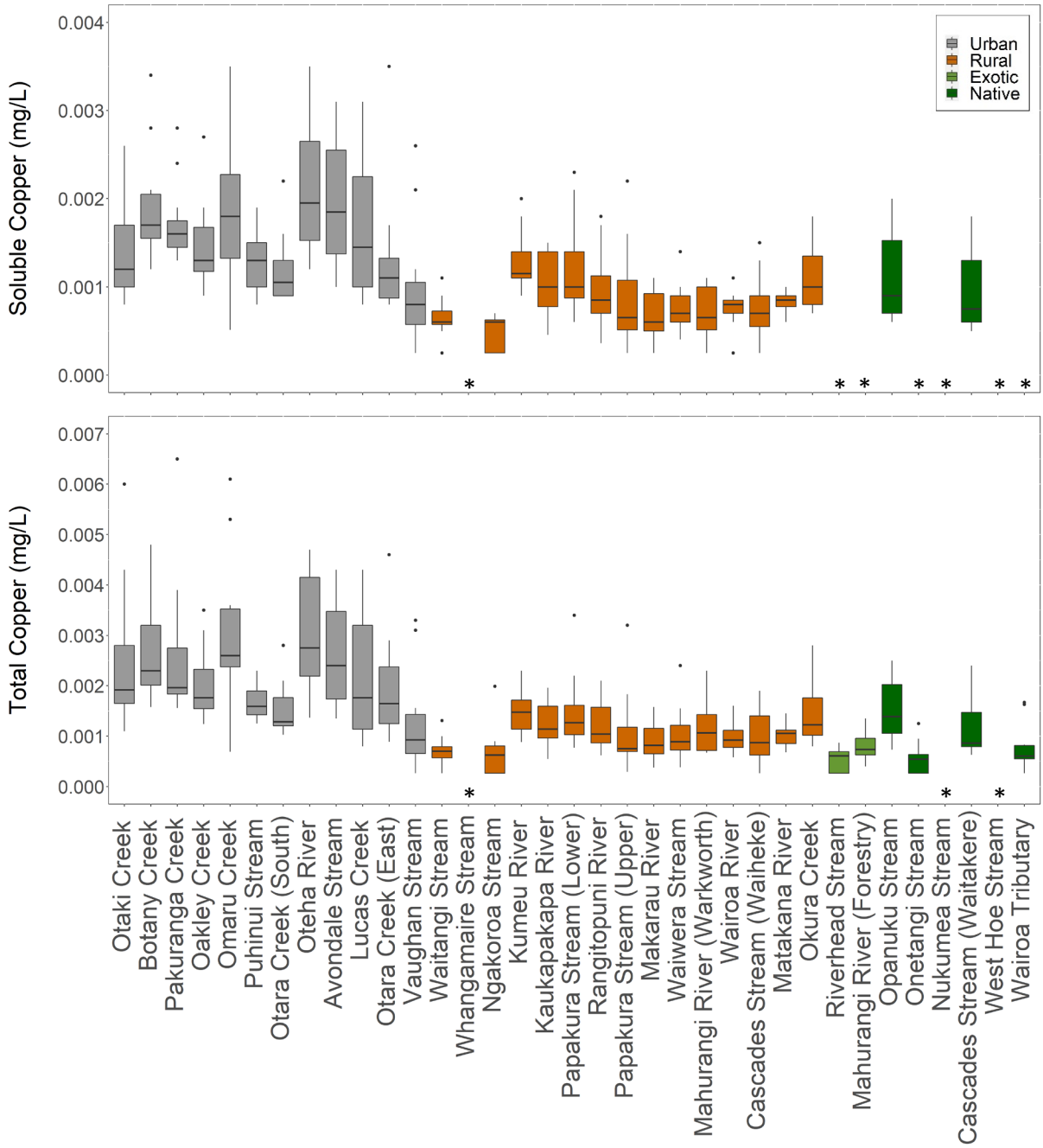


Figure 3-6: Variation in soluble copper (mg/L) and total copper (mg/L) for river water quality data collected from January to December 2019.

* = >50 per cent of values below detection limit

Two outlier values for soluble copper are not displayed. See maximum values for Botany Creek, Pakuranga Creek in supplementary data tables.

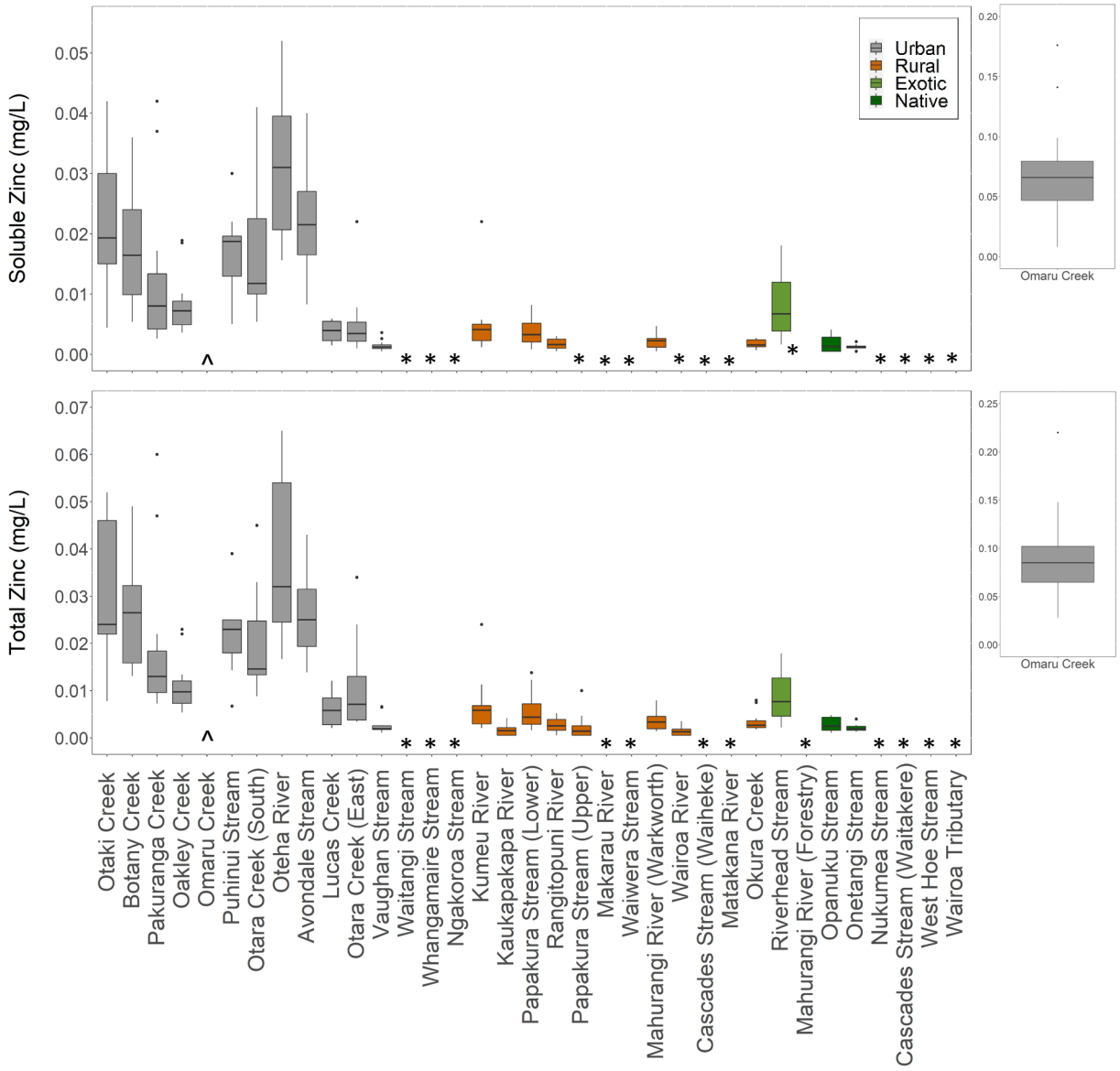


Figure 3-7: Variation in soluble zinc (µg/L) and total zinc (µg/L) for river water quality data collected from January to December 2019.

^ = see inset,

* = >50 per cent of values below detection limit

One outlier value for soluble zinc and for total zinc is not displayed. See maximum values for Otaki Creek in supplementary data tables.

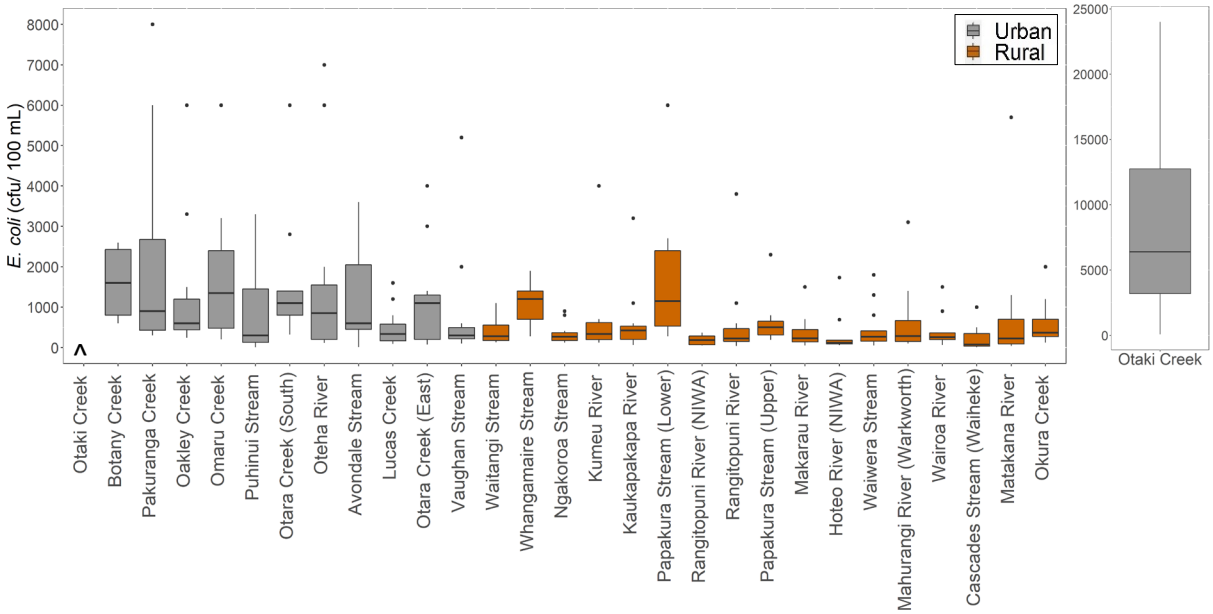


Figure 3-8: Variation in *E. coli* (cfu/100mL) at urban and rural streams for river water quality data collected from January to December 2019.

^ = see inset

Thirteen outlier values >10,000 cfu/100 mL are not displayed across a total of eight sites in urban or rural areas.

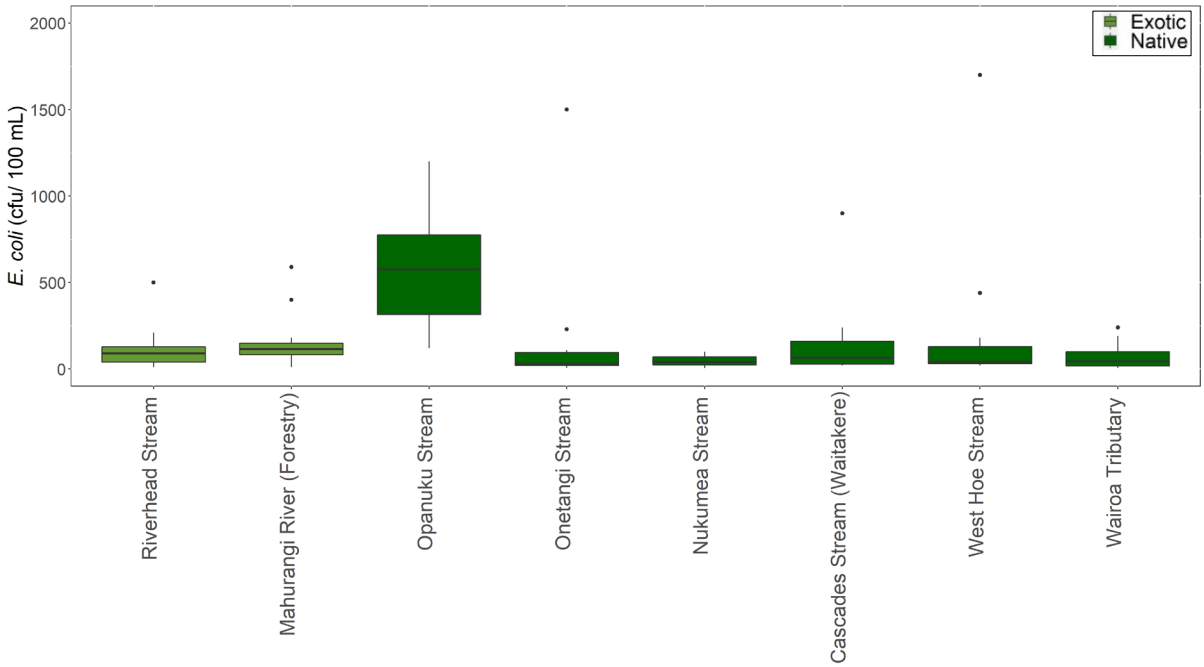


Figure 3-9: Variation in *E. coli* (cfu/100mL) at exotic and native forest streams for river water quality data collected from January to December 2019.

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 2017-2019 have been summarised to derive the 2019 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 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 focus on these exceedances unless otherwise stated.

The frequency of exceedances for each site and parameter are summarised for each land cover class in sections 3.2.2.1 to 3.2.2.3. The maximum frequency per parameter being 12 months within the year.

A low frequency of guideline exceedances (1-3) suggests that the parameter was found to have monthly median concentrations higher than regional reference values, occasionally, such as a seasonal peak. A moderate frequency of guideline exceedances (4-6) suggests that parameter was found to have monthly median concentrations higher than regional reference values for more than one season (more than three months). High (7-9) and very high (10-12) frequencies of exceedances reflect values that are elevated more than half of the time, to most, or all the time.

3.2.1 Regional water quality

In the current assessment period of 2017-2019, more than 60 per cent of monitored sites had water quality that was ‘marginal’ to ‘poor’ and less than 14 per cent of monitored sites had ‘good’ to ‘excellent’ water quality (Figure 3-10 and Figure 3-12). The most common water quality issues affecting monitored sites for the period 2017-2019 were elevated total oxidised nitrogen, water temperature, and either lower or higher dissolved oxygen saturation (Figure 3-11).

There was a greater proportion of streams in the ‘marginal’ water quality class in 2017 to 2019 which appears to be primarily associated with scores fluctuating around the threshold between marginal and poor water quality classes at several urban, and rural

streams (Figure 3-10). Refer to Appendix E for a summary of scores over the past rolling time period. Regionally, there was a higher frequency of guideline exceedances for total oxidised nitrogen, turbidity, and temperature, and a lower frequency of guideline exceedances in ammoniacal nitrogen and dissolved reactive phosphorus over the rolling periods assessed (Figure 3-11).

These indicative findings in relation to changes in water quality over time are generally corroborated by detailed trend analysis undertaken over the past 10 years (see *River water quality state and trends 2010-2019* for further information).

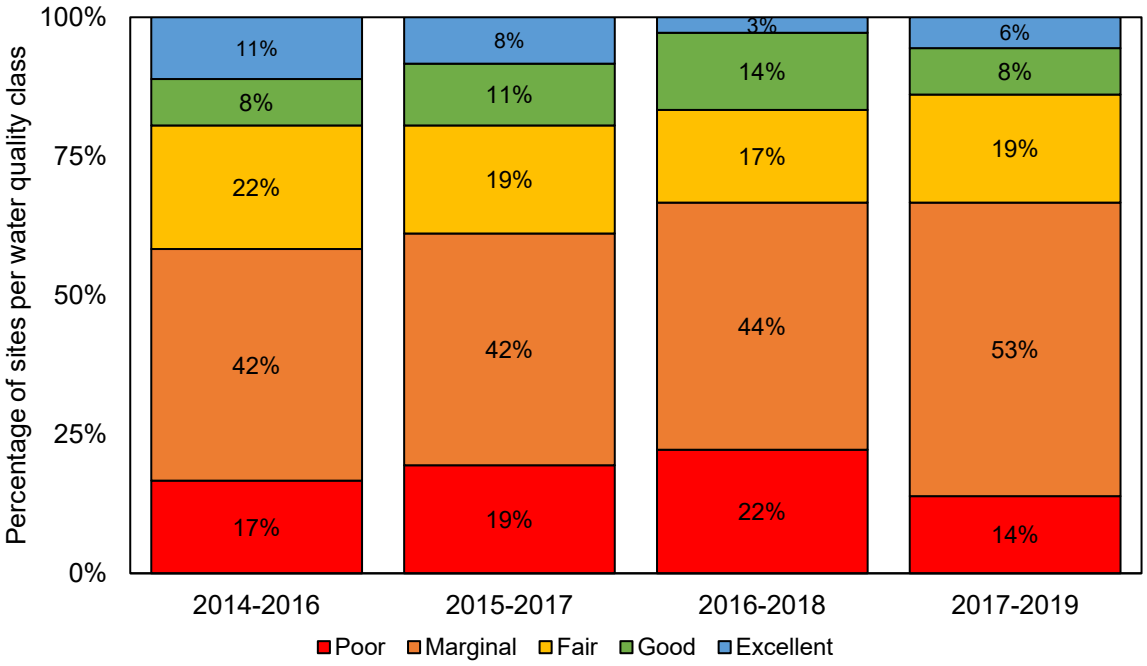


Figure 3-10: Percentage of monitored sites in each water quality index class for each three-year rolling period.

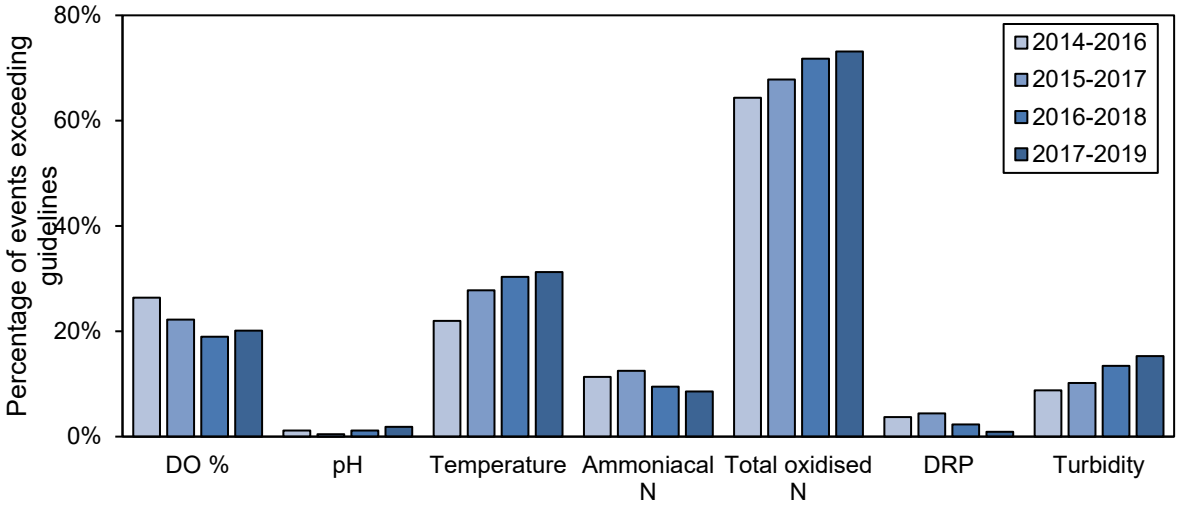


Figure 3-11: Percentage of sampling events that exceeded the relevant water quality guideline for each three-year rolling period.

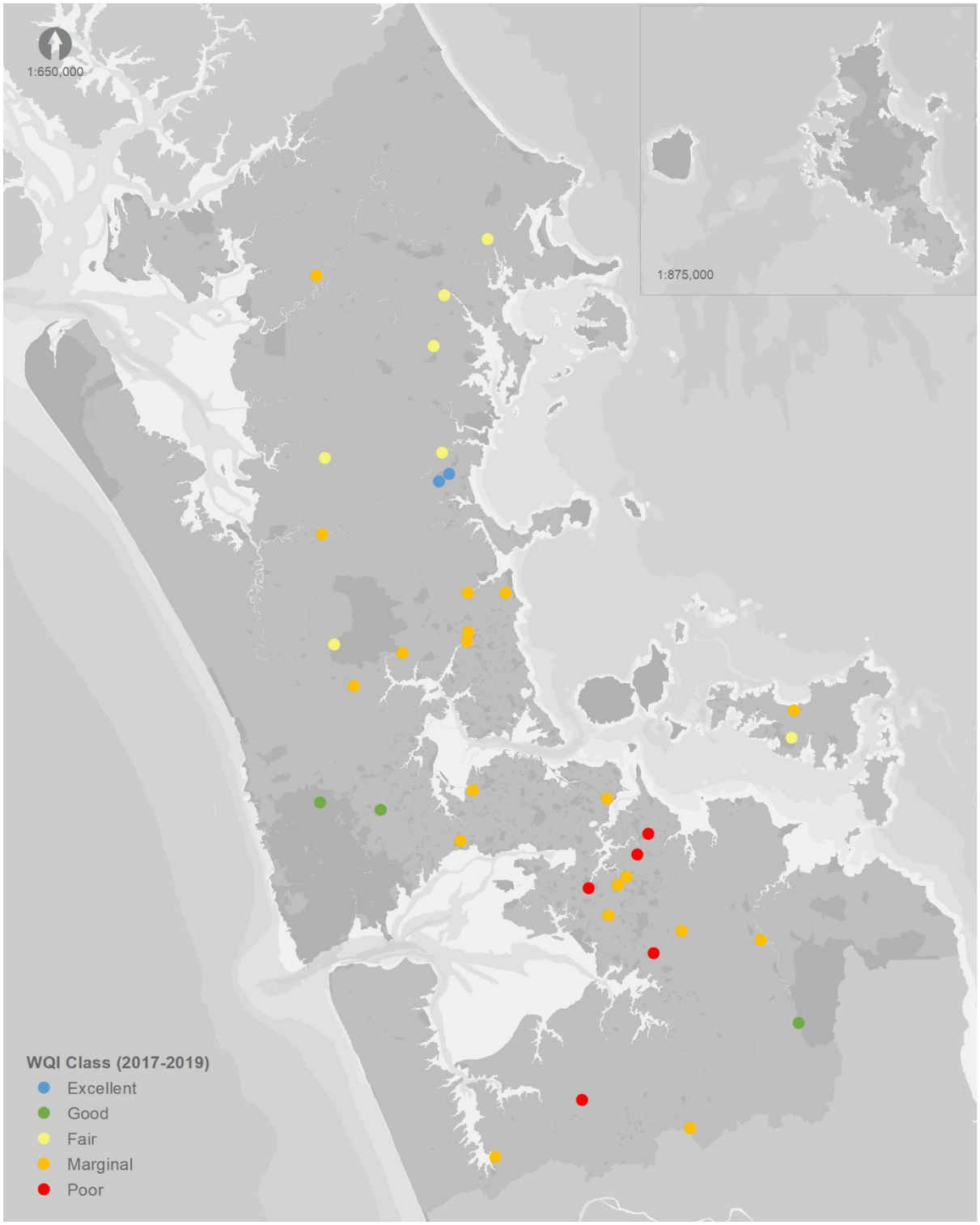


Figure 3-12: Overall water quality index class at Auckland Council river water quality monitoring sites 2017-2019.

3.2.2 Land cover and water quality index

The 2017-2019 water quality index scores are shown for all sites in Figure 3-13 below and the number of times each parameter exceeded the guideline values (bars). Each dominant land cover group is discussed further below, including patterns in individual parameters.

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).

In general, water quality was classed as 'good' to 'excellent' in the native forest sites, 'fair' in the exotic forest site, ranged from 'fair' to 'poor' in the rural sites, and ranged from 'marginal' to 'poor' in the urban sites (Figure 3-13). Onetangi Stream was grouped into the native forest overall land cover category and water quality was assessed as 'marginal' however it is noted that the upstream catchment has 12 per cent cover of urban built up area.

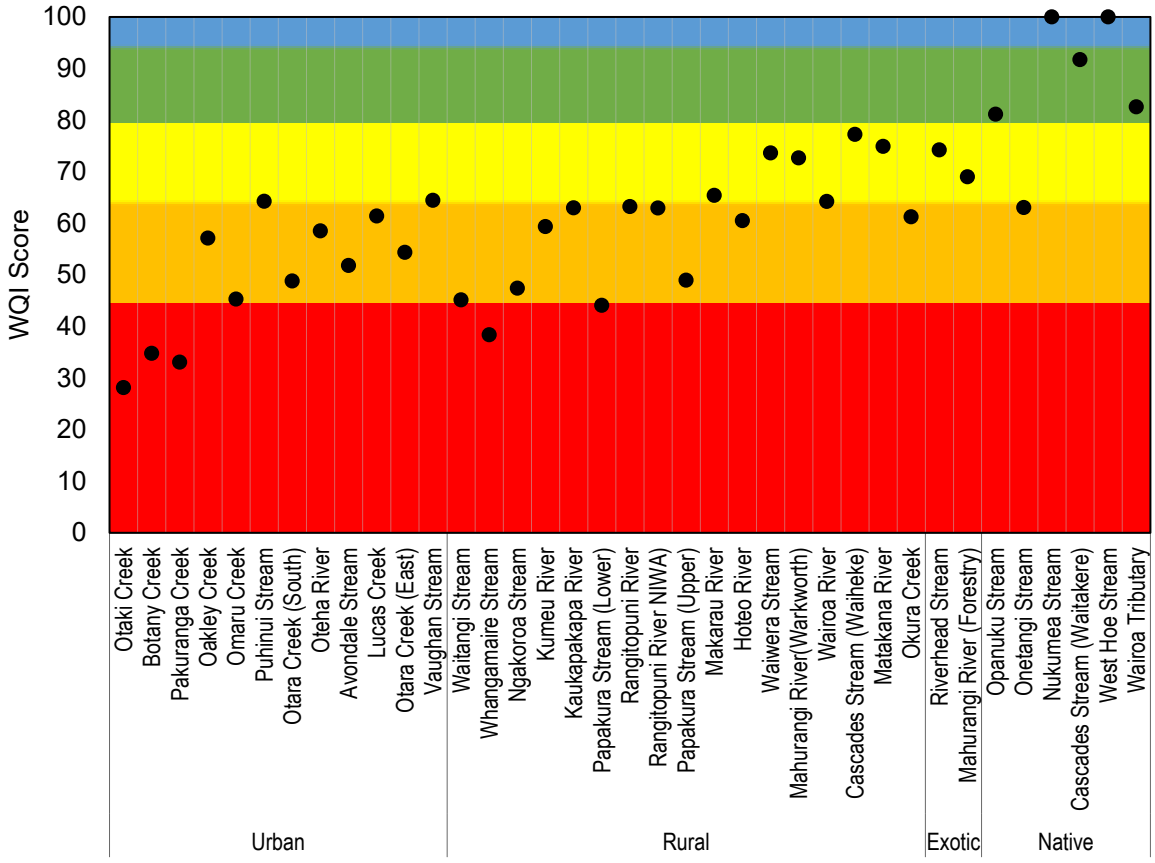


Figure 3-13: Water quality index score for 2017-2019 (median values).
Sites are ordered by highest percentage of urban or rural dominant land cover. Coloured bands indicate excellent (blue) through to poor (red) water quality index classes.

3.2.2.1 Native forest

As expected, water quality was typically within guideline values at the reference site streams (Figure 3-14)).

Nukumea Stream and West Hoe Stream had no guideline exceedances for the 2017-2019 period and were consequently classed as ‘excellent’.

Onetangi Stream and Opanuku Stream have more than 10 per cent of urban or rural land use respectively within the upstream catchments and have higher concentrations of total oxidised nitrogen, and warmer water temperatures.

Wairoa Tributary had five exceedances of the guideline for total oxidised nitrogen in the 2017-2019 period, compared to none during previous reporting (Buckthought et al., 2020). This has resulted in a lower overall water quality index score for this site than in previous years (Appendix E).

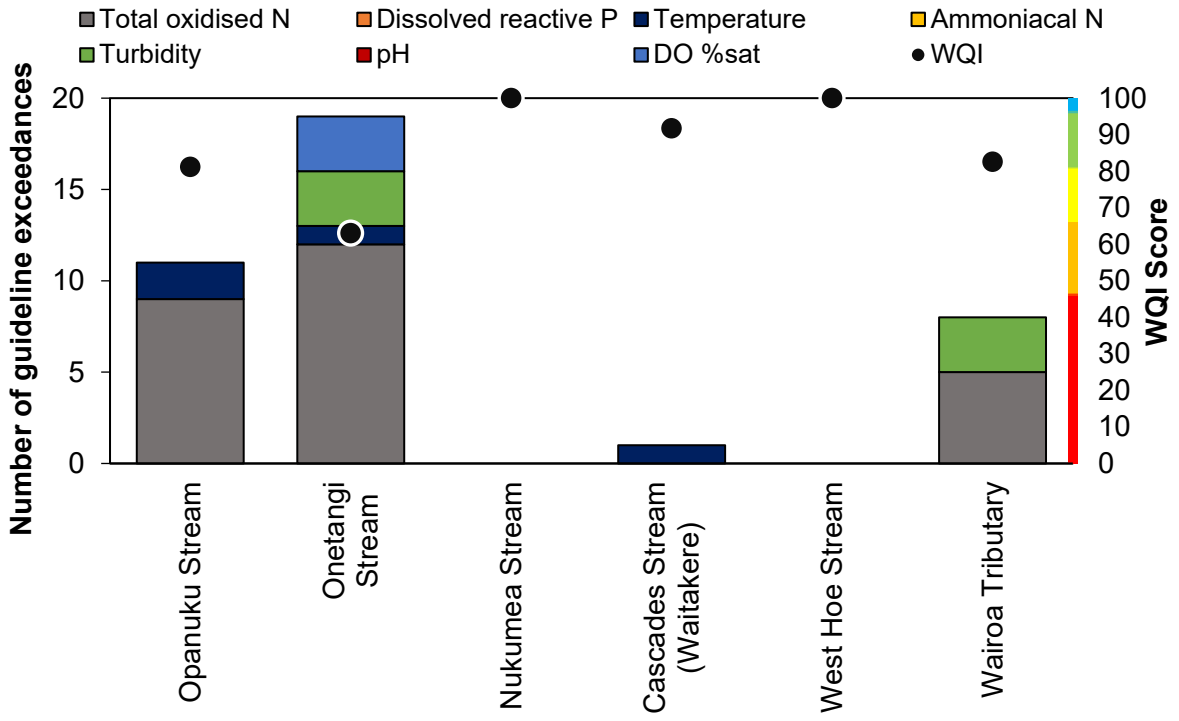


Figure 3-14: Water quality index scores and number of exceedances of the relevant guideline value per site (2017-2019 median values) for native forest sites.
Sites are ordered from lowest to highest percentage of native forest cover in the catchment.

3.2.2.2 Rural and exotic forest

Water quality across sites dominated by rural and exotic forest land cover was mainly ‘fair’ and ‘marginal’, with two sites classed as ‘poor’ (Whangamaire Stream and Papakura Stream (Lower)). Both exotic forest land cover sites were classed as ‘fair’. Elevated total oxidised nitrogen, temperature, and turbidity were the most common issues affecting these rural streams (Figure 3-15a).

All streams in rural and exotic forest catchments exceeded the total oxidised nitrogen guideline at least 50 per cent of the time, except for Makarau River, Matakana River, and Riverhead Stream. Six of the 19 sites exceeded the total oxidised nitrogen guideline 100 per cent of the time (Waitangi Stream, Whangamaire Stream, Ngakoroa Stream, Kumeu River, Rangitopuni River (NIWA) and Mahurangi River (Forestry)). High magnitude exceedances were recorded 100 per cent of the time at Ngakoroa Stream, Whangamaire Stream, and Waitangi Stream, and occasionally at Papakura Stream (Upper) and Wairoa River (not shown in figure).

The temperature guideline was exceeded occasionally to moderately frequently (less than 50 per cent of the time), at all sites except Cascades Stream (Waiheke), which is a well shaded site. Dissolved oxygen guidelines were exceeded occasionally (typically seasonally or less than 25 per cent of the time). Dissolved oxygen was more frequently below guideline values at Papakura Stream (upper). Exceedances for both temperature, and dissolved oxygen occurred in early summer to early autumn (November to April) with high temperatures and low dissolved oxygen affecting the greatest number of sites in January and February.

The turbidity guideline was exceeded at least occasionally at 14 out of the 19 sites, and at Okura Creek the guideline was exceeded 75 per cent of the time. Turbidity was elevated most commonly in winter and spring (June to September).

The ammoniacal nitrogen guideline was exceeded at Papakura Stream, both lower and upper sites, and once at Hoteo River. The dissolved reactive phosphorus guideline was only exceeded once at Papakura Stream (Lower). The pH guidelines were only exceeded once at Makarau River, which has not been observed in previous years (Buckthought et al., 2020).

3.2.2.3 Urban

Water quality was ‘marginal’ to ‘poor’ at all sites dominated by urban land cover. Elevated total oxidised nitrogen, and temperature were the most common issues effecting these urban streams (Figure 3-15b). Streams with ‘poor’ water quality also tended to be impacted by high ammoniacal nitrogen. Urban sites tended to have fewer exceedances of the turbidity guideline than rural sites. Some urban streams also exceeded pH guidelines occasionally.

All streams in urban catchments exceeded the total oxidised nitrogen guideline more than 90 per cent of the time except Ōtara Creek (East) and Vaughan Stream. High magnitude exceedances were recorded moderately frequently at five sites, Botany Creek, Oakley Creek, Ōtaki Creek, Ōtara Creek (South), and Omaru Creek.

Temperature guidelines were exceeded for more than half the year at four of the 12 urban sites in the 2017-2019 period. Temperature guidelines were exceeded most frequently at sites with concrete-lined channels (Botany Creek, Pakuranga Creek and Ōtara Creek South). Urban stormwater and runoff from warm surfaces, such as pavements and roofs, contributes to thermal pollution in streams (Young et al., 2013), however, it is also noted that these sites are generally sampled at midday to early afternoon. It is unsurprising that Botany Creek, with the highest percentage of impervious surfaces in the upstream catchment, consistently exceeds the temperature guideline.

Two urban streams frequently exceeded the guideline for ammoniacal nitrogen at Ōtaki Creek and Pakuranga Creek. Both Ōtaki Creek and Pakuranga Creek also occasionally exceeded the dissolved reactive phosphorus guideline. Pakuranga Creek had consistently higher median ammoniacal nitrogen concentrations than all other monitored sites in the programme (Figure 3-5). The ammoniacal nitrogen guideline was also occasionally exceeded at Botany Creek, Omaru Creek and Avondale Stream.

Dissolved oxygen guidelines were exceeded more than half of the time at three sites – Omaru Creek, Ōtaki Creek and Botany Creek (with exceedances 100 per cent of the time).

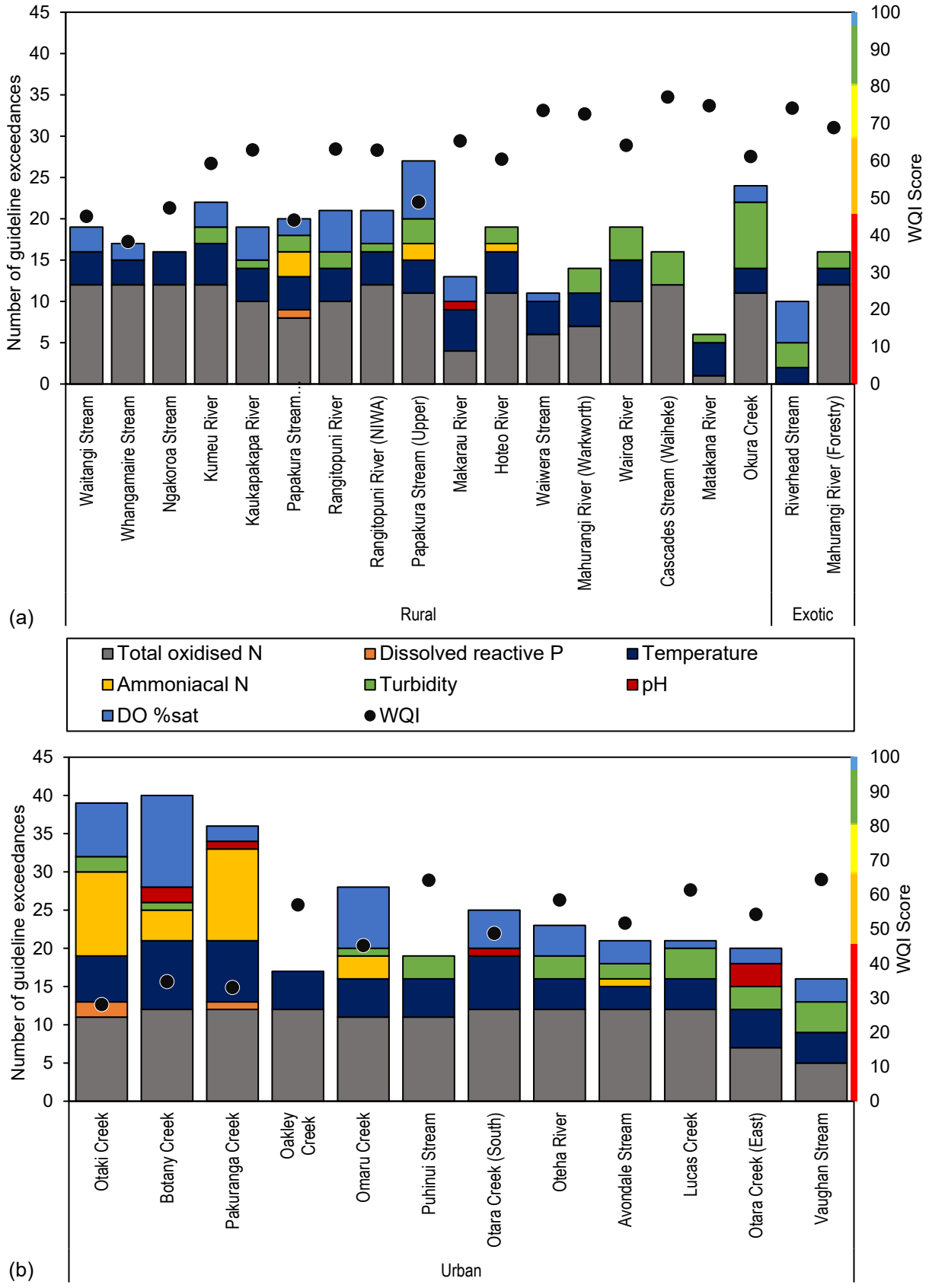


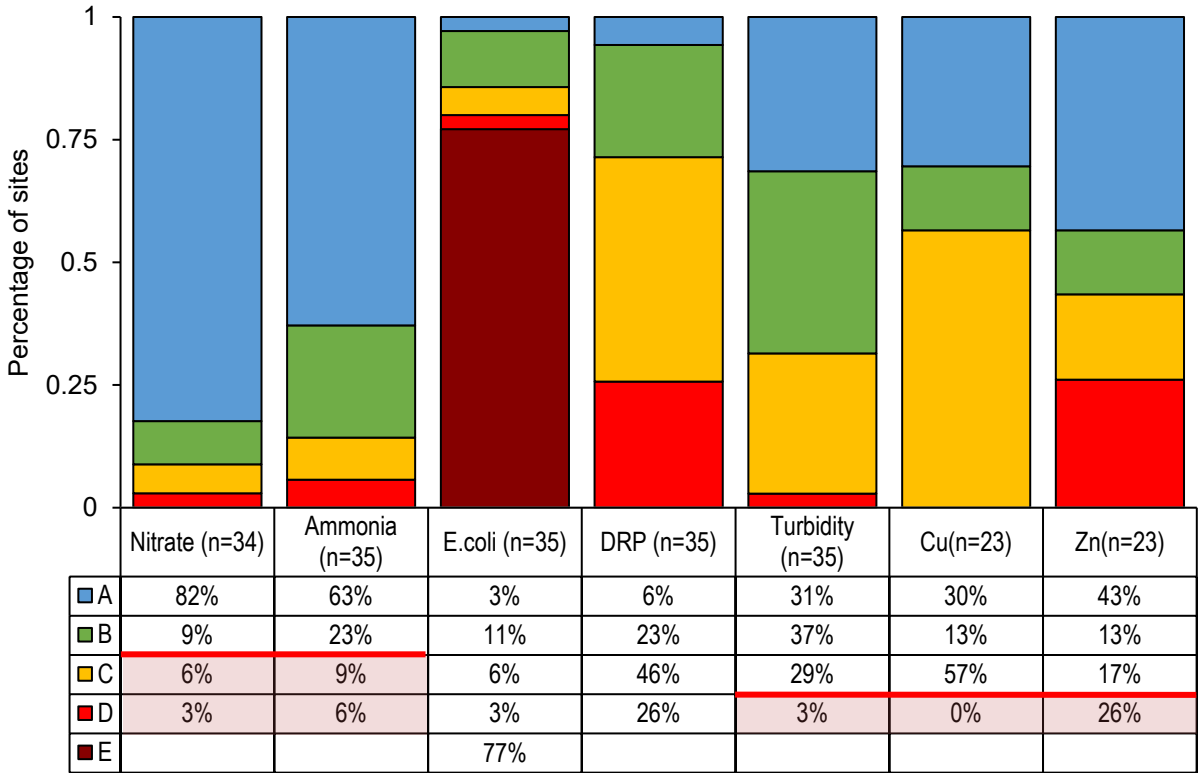
Figure 3-15: Water quality index scores and number of exceedances of the relevant guideline value per site (2017-2019 median values) for (a) rural and exotic forest and (b) urban sites.
Sites are ordered in decreasing percentage of their respective dominant land cover type.

3.3 NPS-FM 2020 National Objectives Framework current state assessment

Data for the five-year period 2015-2019 was assessed against the attribute metrics in the National Objectives Framework (NOF) in the NPS-FM (2020) (see Table 2-4**)** and reported as the relevant band for each monitored stream site for 2019.

The overall bands[4] for each attribute (water quality parameter) and provisional grades for metals (Gadd et al., 2019), are summarised in collectively across the region (Figure 3-16), and per dominant land cover class (Figure 3-17).

The overall band grades per stream site are mapped in Figure 3-18. Bands for the individual metrics per stream site and attribute are reported in table form in Appendix E. The '*National Bottom Line'* refers to the minimum state for each attribute. Grades below the national bottom line mean that there are high concentrations of contaminants, and there are risks of adverse effects on the health of our waterways[5].



	Nitrate (n=34)	Ammonia (n=35)	E.coli (n=35)	DRP (n=35)	Turbidity (n=35)	Cu(n=23)	Zn(n=23)
A	82%	63%	3%	6%	31%	30%	43%
B	9%	23%	11%	23%	37%	13%	13%
C	6%	9%	6%	46%	29%	57%	17%
D	3%	6%	3%	26%	3%	0%	26%
E			77%				

Figure 3-16:Summary of the proportion of all river sites within each overall band assessed against NPS-FM 2020 NOF attributes, and proposed Auckland specific regional attributes (copper and zinc) (2015-2019).
Red line depicts the national bottom line (NBL), or proposed regional bottom line for each attribute, red shading depicts bands failing the bottom line.

[4] The overall band is defined by the lowest (worst) band of the contributing metrics for that attribute state assessment.
[5] Unless existing natural conditions are identified to explain the band grading.

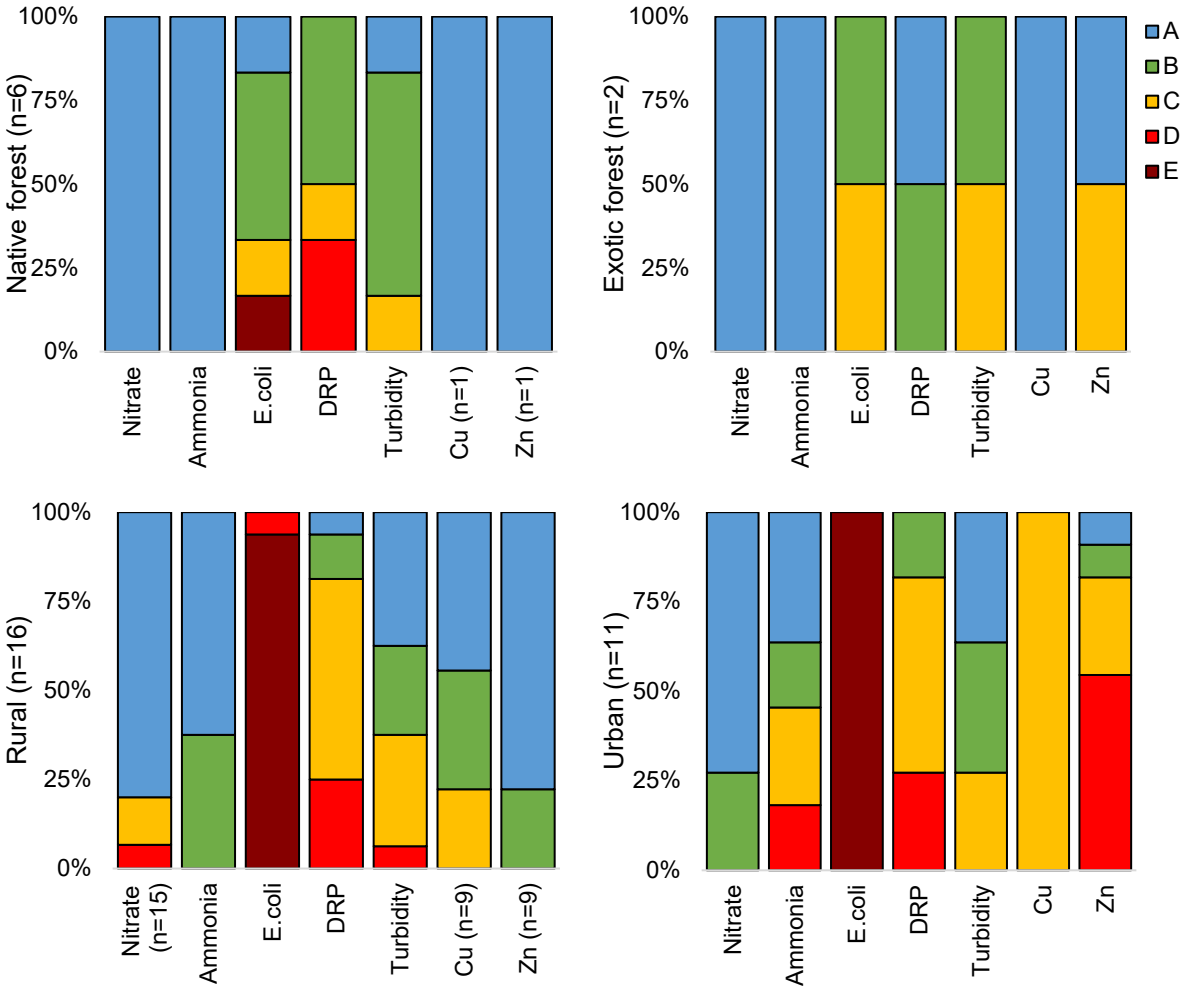


Figure 3-17: Summary of the proportion of sites per dominant land cover class within each overall band across NPS-FM 2020 NOF and proposed Auckland specific water quality attributes (copper and zinc) (2015-2019).

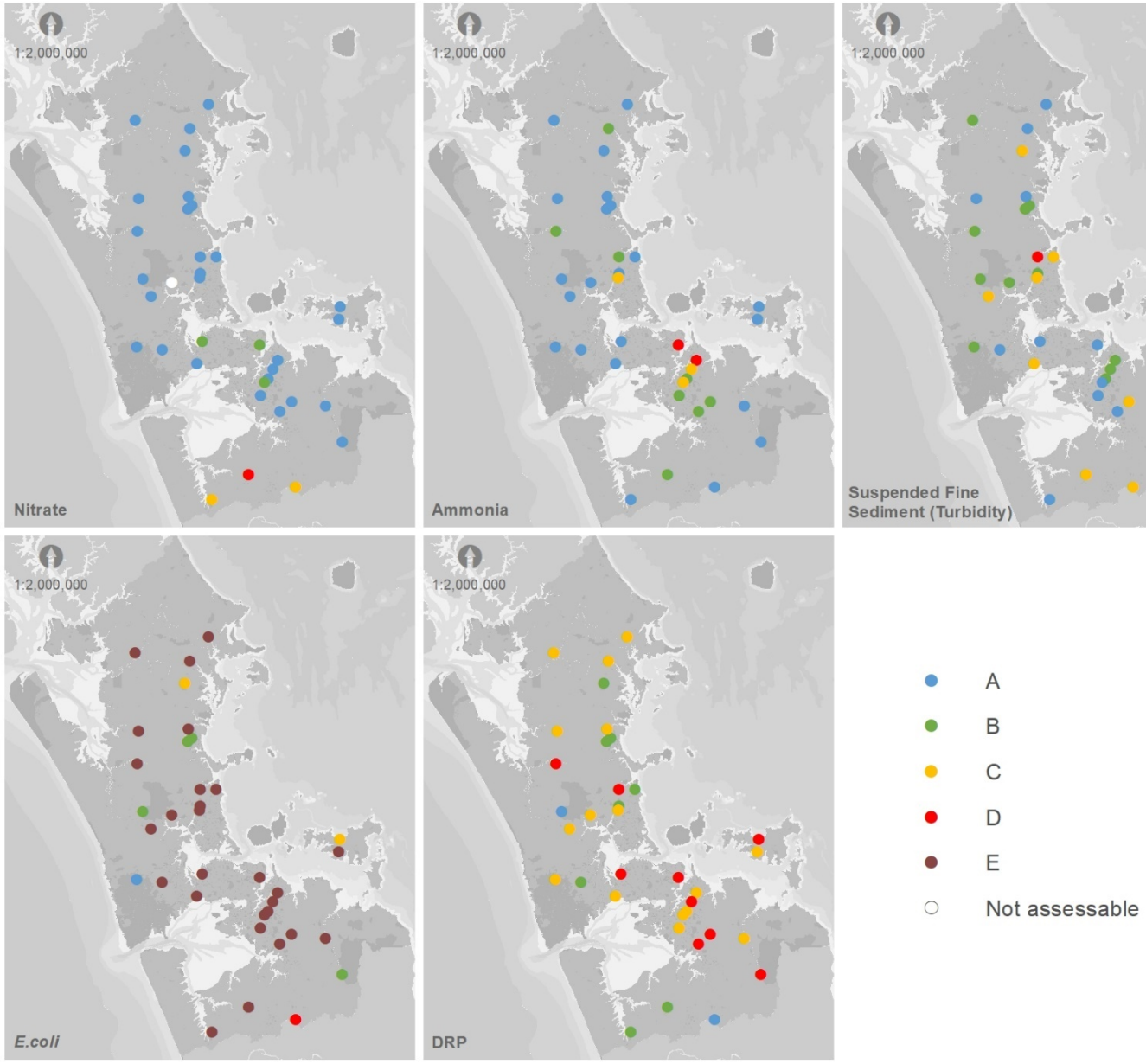


Figure 3-18: Auckland region summary maps of current state (2015-2019) for NPS-FM 2020 overall NOF attribute band per site.

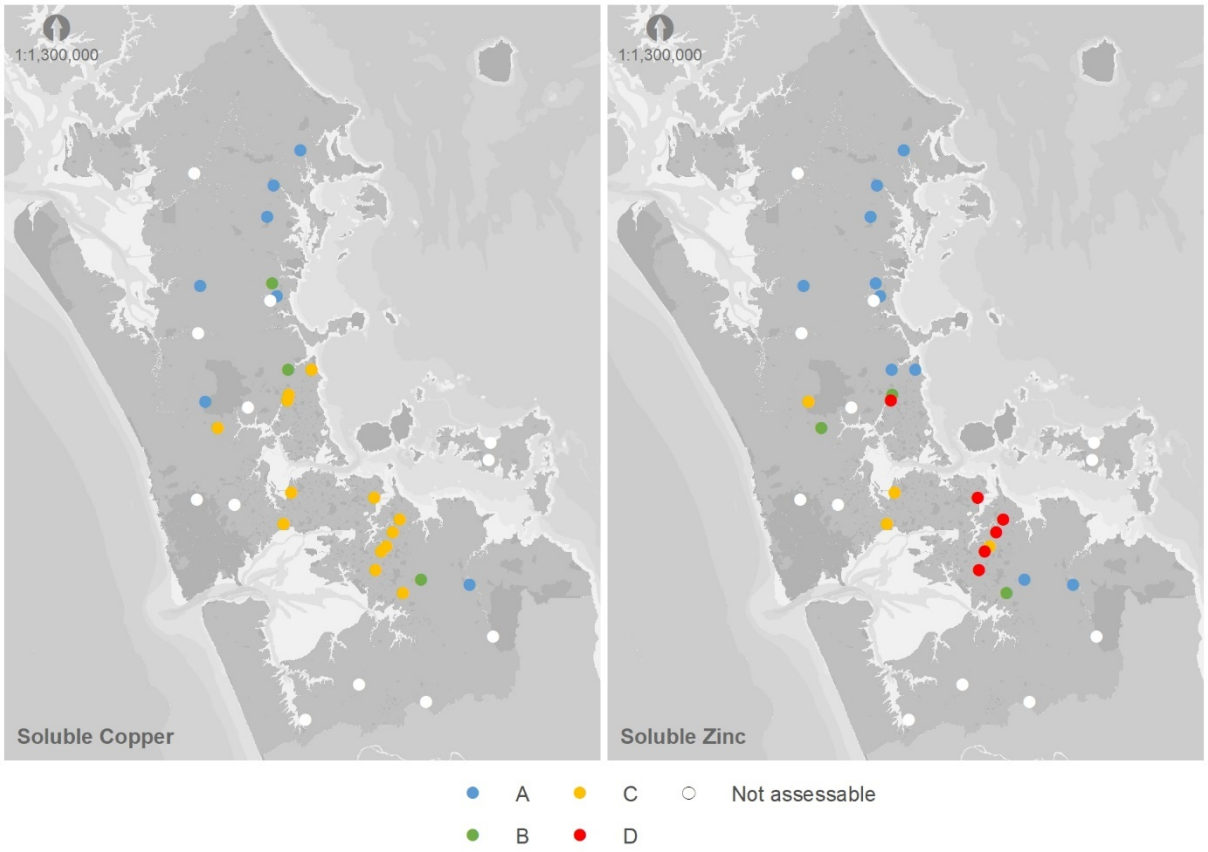


Figure 3-19: Auckland region summary maps of current state (2015-2019) provisional bands for proposed regional copper and zinc guidelines.

3.3.1 Nitrate toxicity

For most of the region, little or no toxicity risk is expected, even for the most sensitive instream species. Over 90 per cent of monitored river water quality sites are above the national bottom line for nitrate toxicity (Figure 3-16).

Three rural sites in the Franklin area (Ngakoroa Stream, Whangamaire Stream and Waitangi Stream) fail the national bottom line for nitrate toxicity (Figure 3-17). 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 thought to be a result of nitrate leaching from intensive horticultural activity in the Franklin area (Meijer et al., 2016). These three sites had the highest proportion of horticultural land cover of all monitored sites (see Figure 2-2 above). Two of the monitored Franklin sites, fall within the C band, where growth effects on 20 per cent of sensitive species (i.e. fish) may be expected, whilst Whangamaire Stream is in the D band, which signals that impacts on the growth of multiple instream species can be expected. The overall ranges the nitrate bands represent have not changed compared to the 2018 analysis, however the National Bottom Line has been revised to sit above the C band within the latest iteration of the

National Objectives Framework (NPS-FM 2020). Central Government have acknowledged the national significance of food production from the Pukekohe (Franklin) area, through a specific nitrate exemption within the NPS-FM 2020. This retained a requirement to better manage instream nitrate concentrations in this area and to demonstrate improvement in water quality but target states may be set below national bottom lines.

Three urban streams are in the B band for nitrate toxicity although only one of these streams, Oakley Creek is within this range for the median attribute as well as the 95th percentile (Appendix F). This suggests that nitrate concentrations are more consistently elevated at this site compared to occasional events.

All other sites within the regional monitoring programme are in the A band for nitrate toxicity, suggesting that this issue is not ubiquitous across the region.

Auckland Council NOF grading for nitrate toxicity has been assessed based on total oxidised nitrogen (nitrate + nitrite nitrogen) assuming that the nitrite fraction is almost always a negligible proportion of the total organic nitrogen. The overall proportions of all dissolved inorganic nitrogen species measured in 2019 were further assessed for streams that failed the national bottom line. Figure 3-20 demonstrates that this assumption is valid, and that nitrite is a negligible factor in the consideration of nitrate toxicity for these sites.

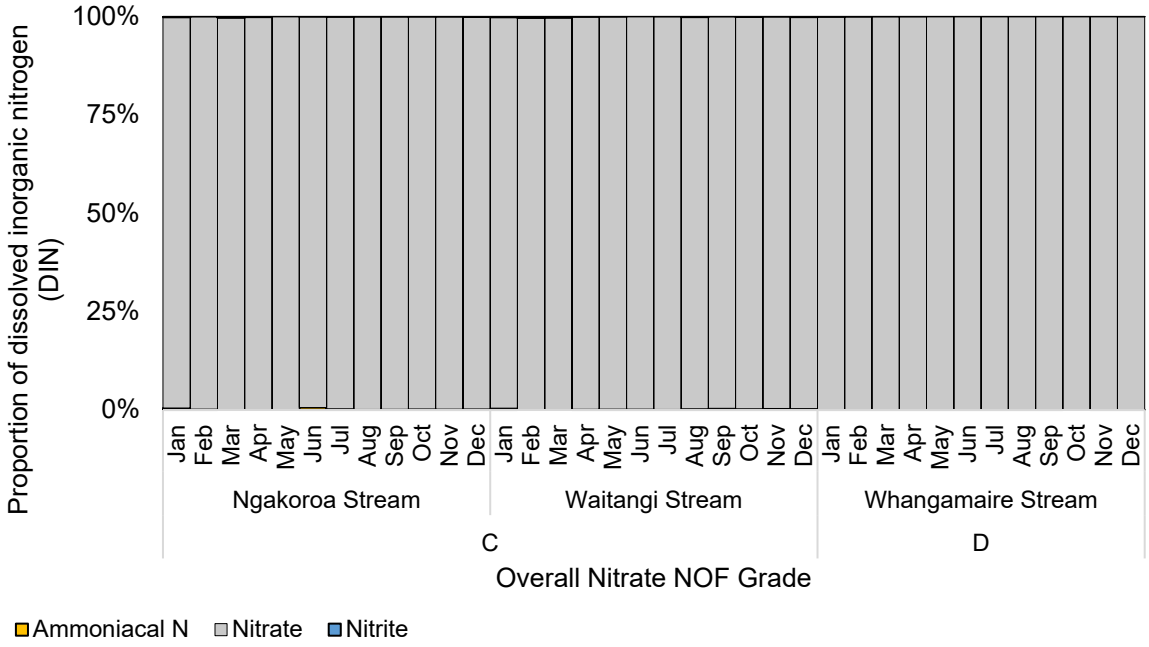


Figure 3-20: Proportion of dissolved inorganic nitrogen species (2019) at sites where nitrate toxicity grades were below the National Bottom Line showing negligible proportions of ammoniacal N or nitrite.

3.3.2 Ammonia toxicity

Regionally, over 80 per cent of sites are above the national bottom line for ammonia toxicity (Figure 3-16). All five streams that failed the national bottom line were in urban areas. Only one stream failed the national bottom line for the median attribute (Pakuranga Creek) with all other streams in the A band for the median attribute, meaning these sites were graded from B to D band based on maximum values that occurred within the five-year assessment period (see Appendix D, Table 6-5). This suggests that infrequent effects of ammonia toxicity occur instream in some years.

The national bottom line changed from below band C to below band B between the NPS-FM 2017 and NPS-FM 2020. Previous assessment in 2018 found only one stream was graded D (Omaru Creek) (Buckthought et al., 2020). This assessment found that Botany Creek was also graded D. This was due to a maximum concentration of 12.4 mg/L recorded in December 2019, associated with a sewage discharge observed during the time of sampling. Due to the way the NPS-FM band assessment is calculated, this site will remain in the D band until 2025 as a result of this single event.

Both ammoniacal nitrogen and nitrite contribute to a greater proportion of the total dissolved inorganic nitrogen fraction at Pakuranga Creek than other monitored sites Figure 3-21. This is indicative of a source of nitrogenous waste (such as wastewater or fertiliser) nearby in the vicinity of the monitoring site.

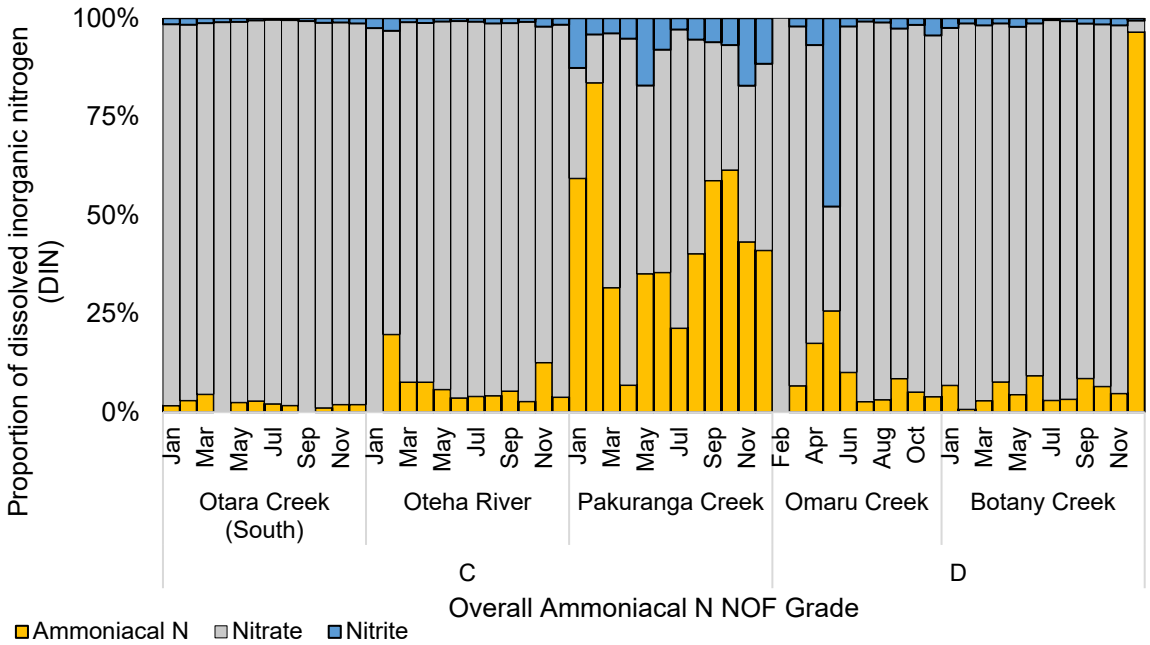


Figure 3-21: Proportion of dissolved inorganic nitrogen species within 2019 at sites where ammonia toxicity grades were below the National Bottom Line.

3.3.3 E. coli

The assessment of *E. coli* as a faecal indicator bacteria undertaken here is **not** in relation to identified primary contact sites or the bathing season. Pollution by faecal contamination is a widespread issue within Auckland across all monitored rural and urban streams (Figure 3-16 and Figure 3-17).

All urban monitored stream sites were in the poorest state band, E, or the poorest state, for all four metrics in terms of human contact values. All rural sites were also in band E, with the exception of Ngakoroa Stream (band D). This is a difference with last year's reporting, where only seven of the rural sites were in the E band (Buckthought et al*.,* 2020). There was more variability across the four metrics for rural streams with two streams in band A for the median attribute (Hoteo River and Cascades Stream (Waiheke)) (see Appendix F).

Native forest reference sites and Riverhead Stream (exotic forest site) were either A or B band for *E. coli* across all four metrics. The native forest sites at Onetangi Stream and Opanuku Stream were graded C and E respectively, presumably reflecting the influence of urban and rural land use within the upstream catchments (Figure 3-17).

3.3.4 Dissolved reactive phosphorus (DRP)

Effects on instream organisms can 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. There is no national bottom line for this attribute.

Less than 30 per cent of monitored streams were in bands A and B for dissolved reactive phosphorus (DRP) indicating that phosphorus levels are elevated within Auckland (Figure 3-16). Three urban, four rural and two native forest sites were within the D band. All other urban sites were assessed to have a C band current state except for Lucas Creek and Vaughan Stream (B band).

The current state of DRP for the four streams with the highest percentage of native forest cover within the upstream catchment ranged from band B (Nukumea Stream and West Hoe Stream) to band D (Wairoa tributary); which suggests that some streams in Auckland may have naturally high dissolved reactive phosphorus levels. Further work is necessary to contextualise the DRP band assessment with regard to what may be considered normal/background DRP concentrations for the region.

The median attribute was typically one band poorer than the 95th percentile attribute for DRP (Appendix F). This suggests that while the base flow state may be elevated, incidents of high concentrations of DRP may be less frequent and at lower levels across Auckland relative to the relationship established at a national level between these metrics.

3.3.5 Suspended fine sediment (turbidity)

This suspended fine sediment attribute differs from the proposed sediment attribute that was previously considered for interim grading of water quality reported for 2016-2018 data (Buckthought et al., 2020). The suspended fine sediment attribute is based on visual clarity and provides for measured turbidity to be converted to clarity (see section 2.5.3). This assessment of suspended fine sediment focuses on the median metric alone (i.e. the state of water clarity 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 also divides streams into specific classes based on the REC class (see Table 2-1). All monitored streams within Auckland fall into suspended sediment classes one and two and most commonly within class two.

Previously, eight streams were assessed as band C or D and these same eight streams are also assessed as bands C or D against the revised guidelines although only one stream, Okura Creek, failed the national bottom line (band D) in the current assessment compared to three streams previously (Buckthought et al., 2020). An additional three streams were also assessed as band C in this assessment including Mahurangi Stream (Forestry), Kumeu River, and Vaughan Stream.

3.3.6 Auckland specific attributes (metals)

3.3.6.1 Copper

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 (Figure 3-17).

Five of the twelve urban streams were in band C across both the median and 95th percentile attributes (Avondale Stream, Omaru Creek, Oteha River, Pakuranga Creek and Botany Creek) (see Appendix D, Table 6-5). Vaughan Stream was overall assessed as band C, due to the 95th percentile band, although the median attribute remained in band A (see Appendix D, Table 6-5). Previous assessment for the 2016-2018 period had graded Vaughan Stream in band B (Buckthought et al., 2020).

Two rural streams were also within band C, namely Kumeu River and Papakura Stream (Lower). These two sites are within band C based on the 95th percentile metric, and band B based on the median metric (see Appendix D, Table 6-5).

The assessment of copper toxicity will change in future reporting with regard to upcoming revision of the ANZ guidelines, including consideration of toxicity modification by dissolved organic carbon (DOC) (Warne et al., 2018).

3.3.6.2 Zinc

Half of the monitored urban sites were below the proposed regional bottom line for dissolved zinc (D band, Figure 3-17). At these sites, toxicity can approach acute levels (i.e. risk of death for sensitive instream species).

All rural streams were within bands A and B, suggesting there would be no or minimal zinc toxicity effects observed. Riverhead Stream (exotic forest) was within band C based on the 95th percentile attribute suggesting there are occasional high concentrations of zinc at this stream (see Appendix D, Table 6-5).

The assessment of zinc toxicity will change in future reporting with regard to upcoming revision of the ANZ guidelines, including consideration of toxicity modification for instream water hardness (Warne et al., 2018).

4.0 Summary

This report provides information on the current state of river water quality in relation to national and regional objectives. The results of the 2019 river water quality data analysis are broadly consistent with previous years' results. The percentage of catchment area in urban or pastoral land use has been found to be consistently, positively correlated with contaminant concentrations in freshwater rivers/streams and negatively correlated with ecological health indicators (Snelder et al., 2017; Larned et al., 2019; Gadd et al., 2020).

Regionally, overall water quality state follows a similar distribution. 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 had good to excellent river water quality based on the overall water quality index scores[6].

Rivers in urban catchments tend to be affected by elevated nutrients (although to a far lesser degree than in some horticulture dominated catchments, namely in the Franklin area), 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.

This report provides a current state assessment of several water quality attributes under the National Policy Statement for Freshwater Management 2020 (MfE, 2020) using data from the five-year period 2015-2019.

At high concentrations, nitrogen and ammonia can be toxic to aquatic fauna. For most of the region, little or no toxicity risk is expected, even for the most sensitive instream species. Three rural sites in the Franklin area (Ngakoroa Stream, Whangamaire Stream and Waitangi Stream) failed the National Bottom Line for nitrate toxicity, and five urban streams failed the national bottom line for ammonia toxicity[7].

Two key metal contaminants were assessed in relation to chronic (long-term exposure) toxicity risk for river fauna. No sites were below the proposed regional bottom line for copper toxicity, however half of the monitored urban sites were below the proposed regional bottom line for zinc toxicity.

The limiting nutrient in rivers potentially driving excessive plant and algal growth, is most commonly phosphorus (McDowell et al., 2009). Less than 30 per cent of monitored streams were in bands A and B for dissolved reactive phosphorus (DRP)

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

[7] The *national bottom line* was revised since the NPS-FM 2017 version that toxicity was assessed against in the 2018 annual river report.

indicating that phosphorus levels are elevated within Auckland, however, none of the four reference sites monitored are in band A, which suggests that phosphorus levels may be naturally elevated within parts of the region, and further interpretation will be required to understand the natural condition state across the region.

Suspended sediment was assessed in accordance with the latest revised NOF framework which provides for monitored turbidity to be converted to visual clarity. Over a third of our monitored streams, including streams in all dominant land cover categories were found to have low water clarity (bands C and D) where moderate to high impacts may be expected for instream fauna, particularly sensitive fish species. Only one stream failed the national bottom line (band D).

Faecal contamination of rivers by *E. coli* is the most geographically widespread issue facing Auckland, with the majority of monitored river sites in the poorest state band. While this has implications for human contact with rivers and streams, this assessment is **not** in relation to identified primary contact sites or the bathing season.

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.

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.

APHA, (2017). 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.

Buckthought, L., Ingley, R. and Grant, C. (2020). Auckland River Water Quality: Annual Report and National Policy Statement for Freshwater Management, Current State Assessment 2018. Auckland Council technical report, TR2020/014.

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.

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.

Franklin, P., Booker, D., Stoffels, R. (2020). Memo: Contract 23184: Task 2 – Turbidity and visual clarity threshold conversion. https://www.mfe.govt.nz/sites/default/files/media/Fresh%20water/technical-report-2-comparison-of-clarity-and-turbidity-bottom-lines.pdf Accessed:17/09/2020.

Franklin, P., Stoffels, R., Clapcott, J., Booker, D., Wagenhoff, A., Hickey, C. (2019). Deriving potential fine sediment attribute thresholds for the National Objectives Framework. Prepared by NIWA for the Ministry for the Environment. Report No. 2019039HN.

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, DP2019/004.

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

Helsel, D.R. (2012). Statistics for Censored Environmental Data Using Minitab and R, 2nd Edition. Statistics in Practice John Wiley & Sons, Inc.

Hoffman, L., (2019). A brief history of Auckland's urban form. Auckland Council. A brief history of Auckland's urban form 2019 - Knowledge Auckland

Ingley, R. (2021). River water quality state and trends in Tāmaki Makaurau / Auckland 2010-2019. State of the environment reporting. Auckland Council technical report, TR2021/07.

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, Larned, S., Houlbrouke, D. J. (2009). Nitrogen and Phosphorus in new Zealand Streams and Rivers: Control and Impact of Eutrophication and the Influence of Land Management. *New Zealand Journal of Marine and freshwater Research* 43(4) 985-995.

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 (2020). National Policy Statement for Freshwater Management 2020. ME1518 https://www.mfe.govt.nz/sites/default/files/media/Fresh%20water/national-policy-statement-for-freshwater-management-2020.pdf

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, TR2010/030.

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.

Warne, M. ST J., Batley G.E., van Dam R. A., Chapman J. C., Fox D. R., Hickey C. W. and Stauber, J. L. (2018). Revised Method for Deriving Australian and New Zealand Water Quality Guideline Values for Toxicants – update of 2015 version. Prepared for the revision of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Governments and Australian state and territory governments, Canberra, 48 pp.

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.

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.

6.0 Acknowledgements

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

We acknowledge the efforts of several Environmental Specialist staff and students from RIMU who contributed to sample collection. Special thanks go to Sheldon Benito for running the 2019 field programme as operational lead and to Vanitha Pradeep and Jade Khin for data management and quality assurance processes.

Thanks to R.J Hill Laboratories for their services in laboratory analysis of the samples and to NIWA for the use of the Hoteo and Rangitopuni River data.

Thank you to Coral Grant (Auckland Council) and to Bill Vant (Waikato Regional Council) for discussion and comments that improved previous versions of this report.

Appendix A Analytical Methods

Table 6-1: Parameters tested in 2019.

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	°C	Field	EXO sonde, thermistor
Conductivity	Conductivity	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 (2017) 2540 D
Turbidity	Turbidity	NTU	Lab	APHA (2017) 2130 B (modified)
Ammoniacal nitrogen	Ammoniacal N	mg N/L	Lab	APHA (2017) 4500-NH3 H
Nitrite	Nitrite	mg N/L	Lab	APHA (2017) 4500- NO3 I (modified)
Nitrate	Nitrate	mg N/L	Lab	Calculation
Total oxidised nitrogen	TON	mg N/L	Lab	APHA (2017) 4500-NO3 I (Modified)
Total nitrogen	Total N	mg N/L	Lab	APHA (2017) 4500-N C, 4500-NO3 I (Modified)
Dissolved reactive phosphorus	DRP	mg P/L	Lab	APHA (2017) 4500-P G (Modified)
Total phosphorus	Total P	mg P/L	Lab	APHA (2017) 4500-P B, E (Modified)
Soluble copper	Soluble Cu	mg/L	Lab	APHA (2017) 3125 B/ USEPA 200.8 (Modified)
Total copper	Total Cu	mg/L	Lab	APHA (2017) 3125 B/ USEPA 200.8 (Modified)
Soluble zinc	Soluble Zn	mg/L	Lab	APHA (2017) 3125 B/ USEPA 200.8 (Modified)
Total zinc	Total Zn	mg/L	Lab	APHA (2017) 3125 B/ USEPA 200.8 (Modified)
Escherichia coli	*E. coli*	cfu/100mL	Lab	APHA (2017) 9222 G
Chlorophyll α[8]	Chl a	g/m^3	Lab	APHA (2017) 10200 H (modified) 23rd ed.
Modifiers				
Dissolved organic carbon	DNPOC	mg/L	Lab	APHA (2017) 5310 C (modified) 23rd ed.
Total hardness (as $CaCO_3$)	Hardness	mg/L	Lab	APHA (2017) 2340 B 23rd ed.

* As per RJ Hill Laboratories Ltd

[8] Only six months of data has been collected and therefore no results for this parameter are presented.

Appendix B Contributing catchment information for monitored sites

Table 6-2: Summary of LCDB Land Cover Classes and Broad Aggregations.

LCDB Land Cover Classes within catchments upstream of river water quality monitoring sites	Aggregated Land Cover Classes	Broad Level Dominant Land Cover
Broadleaved Indigenous Hardwoods	Native forest	Native
Indigenous Forest	Native forest	Native
Manuka and/or Kanuka	Native forest	Native
Deciduous Hardwoods	Exotic forest	Exotic
Exotic Forest	Exotic forest	Exotic
Forest – Harvested	Exotic forest	Exotic
Orchard, Vineyard or Other Perennial Crop	Horticulture	Rural
Short-rotation Cropland	Horticulture	Rural
Gorse and/or Broom	Rural	Rural
High Producing Exotic Grassland	Rural	Rural
Low Producing Grassland	Rural	Rural
Built-up Area (settlement)	Urban	Urban
Transport Infrastructure	Urban – Transport Infrastructure	Urban
Urban Parkland/Open Space	Urban Parkland	Urban
Sand or Gravel	Other	NA
Surface Mine or Dump	Other	NA
Lake or Pond	Water	NA
Mangrove	Water	NA
Flaxland	Wetland	NA
Herbaceous Freshwater Vegetation	Wetland	NA

Appendix C Australia and New Zealand default guideline values

Table 6-3: Australian and NZ 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 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.

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 water quality index (Foley, 2018). This approach uses the water quality results of seven specific water quality parameters to produce four 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:

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

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 water quality index calculation are dissolved oxygen (% saturation), pH, temperature, turbidity, ammoniacal nitrogen, total oxidised nitrogen and dissolved reactive phosphorus.

Guidelines, were derived from the 98th percentile value for each parameter (and the 2nd percentile value for parameters with upper and lower bounds), except for turbidity

which was derived from the 90th percentile, from four Auckland Council reference sites over a static 10-year period from 2007-2016 (as per Foley, 2018): 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.

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 guidelines to determine the relative deviation from natural conditions in Auckland.

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, water quality index scores for the river water quality monitoring programme reported prior to 2018 are not directly comparable.

Appendix E Water quality index summary scores

Table 6-4: River water quality index scores and classes based on rolling three-year median value across 2014 to 2019.
Blue = Excellent, Green = Good, Yellow = Fair, Orange = Marginal, Red = Poor.
Sites in each land cover category are in order of decreasing catchment land cover proportion.

Land cover	Site name	WQI Score (2014-2016)	WQI Score (2015-2017)	WQI Score (2016-2018)	WQI Score (2017-2019)
Urban	Ōtaki Creek	31.6	27.2	27.2	28.1
	Botany Creek	35.9	34.6	40.9	34.8
	Pakuranga Creek	32.4	39.2	33.3	33.1
	Oakley Creek	55.8	56.2	53	57.1
	Omaru Creek	40.5	43.4	46.1	45.3
	Puhinui Stream	65	57.5	49.6	64.2
	Ōtara Creek (South)	50.4	50.4	42.4	48.8
	Oteha River	52	52.4	53	58.5
	Avondale Stream	50.8	58.4	52.1	51.8
	Lucas Creek	62.1	61.8	61.4	61.4
	Ōtara Creek (East)	62.2	62.7	55.2	54.4
	Vaughan Stream	64.1	63.5	64.2	64.5
Rural	Waitangi Stream	48.1	46.1	44.8	45.1
	Whangamaire Stream	34.6	38.4	34.5	38.4
	Ngakoroa Stream	43.9	46.8	47	47.4
	Kumeu River	59.7	51.5	58.7	59.4
	Kaukapakapa River	47.5	46.8	62.7	63
	Papakura Stream (Lower)	51.3	42.9	42.8	44.1
	Rangitopuni River	66.4	63.3	64.3	63.2
	Papakura Stream (Upper)	49.5	40.9	41.1	49
	Makarau River	73.9	81.6	81.6	65.4
	Hoteo River (NIWA)	70.5	70.3	60.9	60.5
	Waiwera Stream	65.4	73	73.5	73.6
	Mahurangi River (Warkworth)	73.5	73.4	72.7	72.7
	Wairoa River	67.2	64.6	63.6	64.2
	Cascades Stream (Waiheke)	81.2	79.4	70.4	77.2
	Matakana River	83.1	83.1	75	74.9
	Okura Creek	45.9	61.6	62.3	61.2
Exotic	Riverhead Stream	65.8	66	66.1	74.2
	Mahurangi River (Forestry)	80.8	72.5	70.9	69
Native	Opanuku Stream	74.3	82.1	80.9	81.1
	Onetangi Stream	71.8	72.4	63.4	63
	Nukumea Stream	100	100	91.7	100
	Cascades Stream (Waitakere)	100	100	100	91.7
	West Hoe Stream	100	100	91.7	100
	Wairoa Tributary	100	91.7	91.7	82.6

Appendix F NPS-FM (2020) and regional attributes current state band reporting by individual metric

Table 6-5: Auckland region current state bands (2015-2019) 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	Copper		Zinc		*E. coli*				Nitrate		NH_4-N		DRP		Turbidity
		Med	95th	Med	95th	Med	95th	>260	>540	Med	95th	Med	Max	Med	95th	Med
Urban	Otaki Creek	I.D	I.D	I.D	I.D	I.D	I.D	I.D	I.D	I.D	I.D	I.D	I.D	I.D	I.D	I.D
	Botany Creek	C	C	C	**D**	**E**	**E**	**E**	**E**	A	A	A	**D**	B	C	B
	Pakuranga Creek	C	C	C	**D**	**E**	**E**	**E**	**E**	A	A	**C**	**C**	**D**	**D**	B
	Oakley Creek	B	C	C	C	**E**	**E**	**E**	**E**	B	B	A	A	**D**	C	A
	Omaru Creek	C	C	**D**	**D**	**E**	**E**	**E**	**E**	A	B	A	**D**	**D**	**D**	A
	Puhinui Stream	B	C	C	**D**	**E**	**E**	**E**	**E**	A	A	A	B	C	B	A
	Ōtara Creek (South)	B	C	C	**D**	**E**	**E**	**E**	**E**	A	B	A	**C**	C	B	A
	Oteha River	C	C	C	**D**	**E**	**E**	**E**	**E**	A	A	A	**C**	C	B	C
	Avondale Stream	C	C	C	C	**E**	**E**	**E**	**E**	A	A	A	A	C	B	C
	Lucas Creek	B	C	B	A	**E**	**E**	**E**	**E**	A	A	A	A	B	A	B
	Ōtara Creek (East)	B	C	B	C	**E**	**E**	**E**	**E**	A	A	A	B	C	B	B
	Vaughan Stream	A	C	A	A	**E**	**E**	**E**	**E**	A	A	A	A	B	B	C
Rural	Waitangi Stream	I.D	I.D	I.D	I.D	**E**	C	**E**	**D**	**C**	**C**	A	A	B	A	A
	Whangamaire Stream	I.D	I.D	I.D	I.D	**E**	**E**	**E**	**E**	**D**	**D**	A	B	B	A	C
	Ngakoroa Stream	I.D	I.D	I.D	I.D	**D**	B	C	B	**C**	**C**	A	A	A	A	C
	Kumeu River	B	C	B	A	**E**	**E**	**E**	**E**	A	A	A	A	C	B	C
	Kaukapakapa River	I.D	I.D	I.D	I.D	**E**	**E**	**E**	**D**	A	A	A	B	**D**	C	B
	Papakura Stream (Lower)	B	C	B	A	**E**	**E**	**E**	**E**	A	A	A	B	**D**	**D**	A
	Rangitopuni River (NIWA)	I.D	I.D	I.D	I.D	**D**	**E**	**D**	C	I.D	I.D	A	A	C	B	B
	Papakura Stream (Upper)	A	B	A	A	**E**	**E**	**E**	**E**	A	A	A	B	**D**	**D**	C

Land cover	Site name	Copper		Zinc		*E. coli*				Nitrate		NH_4-N		DRP		Turbidity
		Med	95th	Med	95th	Med	95th	>260	>540	Med	95th	Med	Max	Med	95th	Med
	Makarau River	A	A	A	A	**D**	**E**	**D**	**D**	A	A	A	A	C	A	A
	Hoteo River (NIWA)	I.D	I.D	I.D	I.D	A	**E**	B	C	A	A	A	A	C	C	B
	Waiwera Stream	A	B	A	A	**D**	**E**	**D**	C	A	A	A	A	C	B	A
	Mahurangi River (Warkworth)	A	A	A	A	**D**	**E**	**D**	**D**	A	A	A	B	C	B	A
	Wairoa River	A	A	A	A	**D**	**E**	**D**	**D**	A	A	A	A	C	B	B
	Cascades Stream (Waiheke)	I.D	I.D	I.D	I.D	A	**E**	B	C	A	A	A	A	C	B	C
	Matakana River	A	A	A	A	**D**	**E**	**D**	C	A	A	A	A	C	B	A
	Okura Creek	A	B	A	A	**E**	**E**	**E**	**E**	A	A	A	B	C	**D**	**D**
Exotic	Riverhead Stream	A	A	B	C	A	B	A	B	A	A	A	A	A	A	B
Exotic	Mahurangi River (Forestry)	A	A	A	A	A	B	B	C	A	A	A	A	B	A	C
Native	Opanuku Stream	I.D	I.D	I.D	I.D	**E**	**E**	**E**	**E**	A	A	A	A	B	A	A
Native	Onetangi Stream	I.D	I.D	I.D	I.D	A	B	A	C	A	A	A	A	**D**	C	C
Native	Nukumea Stream	A	A	A	A	A	B	A	B	A	A	A	A	B	A	B
Native	Cascades Stream (Waitakere)	I.D	I.D	I.D	I.D	A	A	A	A	A	A	A	A	C	B	B
Native	West Hoe Stream	I.D	I.D	I.D	I.D	A	B	A	B	A	A	A	A	B	A	B
Native	Wairoa Tributary	I.D	I.D	I.D	I.D	A	B	A	B	A	A	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**

Auckland Council
Te Kaunihera o Tāmaki Makaurau